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ԲԱՆԲԵՐ ՍՏՈՄԱՏՈԼՈԳԻԱՅԻ ԵՎ ԴԻՄԱԾՆՈՏԱՅԻՆ ՎԻՐԱԲՈՒԺՈՒԹՅԱՆ
Գիտագործնական հանդես

Գլխավոր խմբագիր - Հակոբյան Գ.Վ.
Գլխավոր խմբագրի տեղակալ-
Տատինցյան Վ.Գ
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ORIGINAL RESEARCH

CHARACTERIZATION OF CARIOGENIC BACTERIA AND THEIR RESISTANCE PROFILES IN AN OBESE IRAQI POPULATION

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ABSTRACT

Background: Obesity is a common yet neglected public health issue worldwide. Oral health, an essential component of overall health and well-being, overlaps with risk factors for obesity, including poor eating habits. This study aimed to investigate the antibiotic susceptibility of bacteria isolated from tooth decay in obese patients.

Materials and methods: Sixty specimens were collected randomly from the mouths and teeth of obese patients in the Babylon Governorate, Iraq. The colony size, shape, color, edge, and transparency were examined to determine the morphological and cultural parameters of each bacterial isolate. Antibiotic susceptibility was assessed using 9 types of antibiotics.

Results: The results showed that the rate of positive specimens was 37 (56.06%), and the negative rate was 29 (43.93%) for the total of 66 specimens. The number of positive male specimens was 35(58.33%), more than that of the females, 25 (41.66%). The dominant bacterial isolates were Staphylococcus aureus (19), Klebsiella pneumonia (13), Candida spp. (10), Staphylococcus epidermidis (8), Streptococcus sp., and Escherichia coli (5), Bacillus cereus (5), Pseudomonas sp. (3), Proteus mirabilis (2).

Conclusion: the study concludes that S. aureus was resistant to Clindamycin and Ceftaroline 19(100%), then Erythromycin 15 (78.94%), Gentamycin 14(73.68%), Ofloxacin 9 (47.36%), Rifampin 7(36.84%), Tetracycline 3(15.78%), and Azithromycin and Ciprofloxacin (0 %). K. pneumoniae was highly resistant to Penicillin and Ciprofloxacin 13(100%), levofloxacin 9 (53.84%), Gentamycin and Nitrofurantoin 7 (23.7%), Rifampin and Tetracycline 3 (23.07%), and Imipenem and Meropenem (0%).

Keywords**:** Obesity, Patients, Antibiotic Susceptibility, Tooth Decay

INTRODUCTION

Obesity or overweight is described as an undue or abnormal buildup of fat that poses a concern for well-being, with a body mass index (BMI) greater than 25 is overweight. Globally, over 30% of the population suffers from obesity. The matter has worsened to become a problem of epidemic proportions, as over four million people die each year because of being overweight or obese [1, 2].

Tooth decay is a chronic condition exclusive to humans and one of the most substantial oral health topics currently facing the world. The degradation of dental hard acellular tissue occurs due to acid by-products produced by the bacterial breakdown of carbohydrates in food, particularly sucrose. Dental caries can affect individuals in multiple ways. Specifically, toothache, dysfunction of the stomatognathic system, or infection may hinder the essential consumption of nutritious diets, thereby impacting growth in both growing children and adults, in addition to their academic achievement, ability to communicate, and recreational pursuits [3, 4]. This study aimed to investigate the antibiotic susceptibility of bacteria isolated from tooth decay in obese patients.

MATERIALS AND METHODS

Specimen Collection

Sixty specimens were randomly collected from tooth

obesity patients in Babylon Governorate, Iraq, using a sterile swab. The collected specimens were suspended in ten milliliters broth brain-heart infusion broth and incubated aerobically for 24 h at 37 °C. A loop of the suspension was then transferred to nutrient agar and cultured for 24 h at room temperature. Combined with confirmatory diagnostic procedures, samples with positive cultures were cultured again in mannitol salt, Eosin Methylene Blue, MacConkey, and blood agar in addition to morphological characteristics.

Identification of Bacterial Isolates

- **Microscopic Examination**

A loopful of water was placed on a tiny slide to initiate the Gram staining reaction. Subsequently, a tiny bacterial colony was moved, combined with water, and spread with a sterile cold loop. After passing through the burner three times, the smear was air-dried and heat-fixed. Next, Gram stain was applied to the smear, which was viewed using an oil immersion lens [5].

- **Morphological and Cultural Characteristics**

The colony size, shape, color, edge, and transparency of each bacterial isolate were studied to determine their morphological and cultural traits [5].

Antibiotic Susceptibility Test

Antibiotic susceptibility to clindamycin, Ceftaroline, erythromycin, gentamycin, ofloxacin, rifampin , tetracycline, azithromycin, ciprofloxacin, levofloxacin, ciprofloxacin, nitrofurantoin, imipenem, and meropenem. An isolated colony of the tested bacteria was added to two milliliters of Muller–Hinton broth, which was then cultured at 37 °C for 18 h. The McFarland (0.5) turbidity standard, which corresponds to a concentration of 1.5×108 CFU/ml, was then used to regulate the turbidity of the bacterial suspension. Mueller-Hinton medium was covered with 0.1 ml of bacterial culture, which was then allowed to dry. No more than five antibiotic disks were placed on each plate. The plates were incubated for a full day at 37 ℃. A ruler was used to measure the resulting inhibition zones, which were then compared to those found by CLSI [6].

RESULTS

Isolation and Identification:

The results showed the percentage of positive specimens was 37(61.66%) and the negative was 23 (38.33%) from the total 66 specimens Table (1). The result showed the number of positive male specimens 35 (58.33%), more than the female 25(41.66%), Table (2).

Table 1. Table 1 summarizes baseline characteristics.

Table 1. Number and percentage of positive specimens according to age

Age	Positive samples NO. (%)	negative samples NO. (%)	Total NO. (%)
11-20	13(21.66)	10(23.33)	27(40.9)
21-30	11(18.33)	5(11.66)	18(27.27)
31-40	5(8.33)	4(6.66)	9(13.63)
41-50	7(11.66)	2(3.33)	9(13.63)
51-60	1(1.66)	2(3.33)	3(4.5)
Total	**37 (61.66)**	**23 (38.33)**	**60 (100)**

Table 2. Number and percentage of positive specimens according to sex, n=60

Sex	Positive samples NO. (%)	Negative samples NO. (%)	Total NO. (%)
Male	23(38.33)	12(20)	35(58.33)
Female	14(23.33)	11(18.33)	25(41.66)
Total No (%)	**37 (61.66)**	**23 (38.33)**	**60(100)**

The results showed that the more prevalent type of bacteria isolates was *Staphylococcus aureus* (19) isolates than *Klebsiella pneumonia (13), Candida spp. (10), Staphylococcus epidermidis (8), Streptococcus sp., and Escherichia coli* (5), *Bacillus cereus (5), Pseudomonas sp.* (3), *Proteus mirabilis* (2) Table (3).

Table 3. Type and number of bacterial isolates

Type of Bacteria	Number
Escherichia coli	5
Staphylococcus aureus	19
Staphylococcus epidermidis	8
Streptococcus sp.	5
Bacillus cereus	4
Klebsiella pneumonia	13
Pseudomonas aeruginosa	3
Proteus mirabilis	2
Candida spp.	10

Antibiotic susceptibility

Antibiotic susceptibility testing was performed using 14 types of antibiotics mentioned. Measure the diameter of the inhibition zone after cultivating *Staphylococcus aureus* isolates (n=19) and *K. pneumonia* (n=13), according to the standard inhibition zone in CLSI, 2024. The results showed that the higher resistance of *S. aureus* against Clindamycin and Ceftaroline 19(100%) than Erythromycin 15(78.94%), Gentamycin 14(73.68%), Ofloxacin 9(47.36%), Rifampin 7(36.84%), Tetracycline 3(15.78%), and 0%to Azithromycin and Ciprofloxacin. Figure (1). While the high resistance against *K. pneumoniae* was Penicillin and Ciprofloxacin 13(100%), Levofloxacin 9 (53.84%), Gentamycin and Nitrofurantoin 7(23.7%), Rifampin and Tetracycline 3(23.07%), then Imipenem and Meropenem 0% Figure (2).

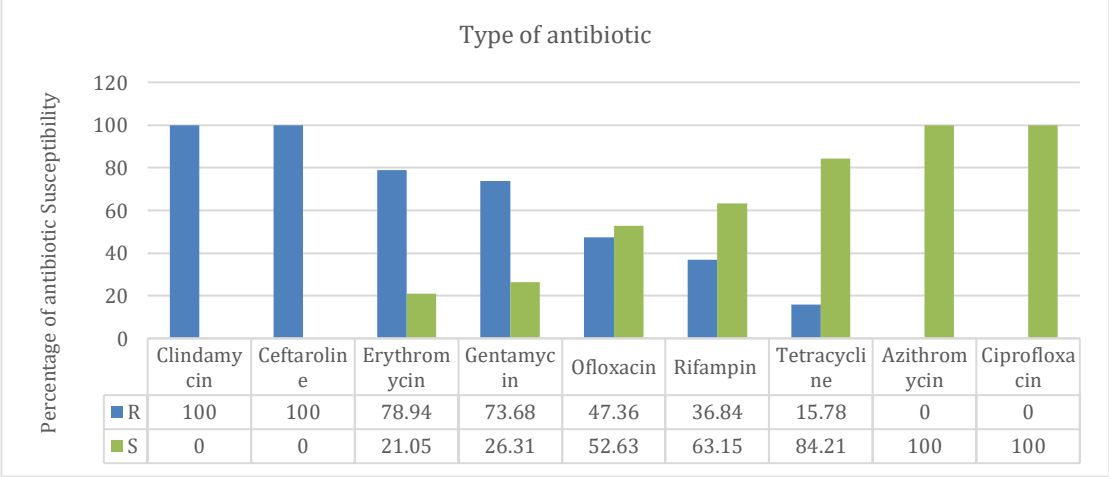


Figure 1. Antibiotic susceptibility of *Staphylococcus aureus* isolates (n=19)

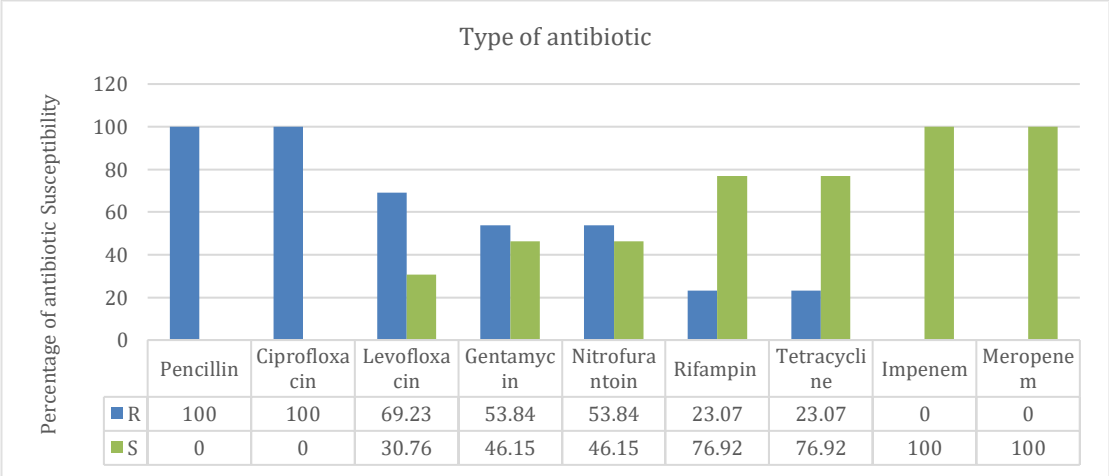


Figure 2. Antibiotic susceptibility of *Klebsiella pneumoniae isolates* (n=13)

DISCUSSION

Sixty specimens were collected randomly from the teeth of obese patients aged from 11 to 60 in Babylon Governorate. Isolation and primary identification were performed according to the standard microbiological procedures, including culture characteristics, bacterial cells' arrangements in Gram's stain, biochemical reaction (Catalase, Coagulase, Oxidase, Indole, Methyl red, Citrate, and Voges Proskauer) test [7]. The results showed the percentage of positive specimens was 37(61.66%) and the negative was 23(38.33%) from the total 66 specimens Table (1). The result showed the number of positive male specimens 35 (58.33%), more than the female 25 (41.66%). The results showed that the more prevalent type of bacteria isolates was *Staphylococcus aureus* (19) isolates, then *Klebsiella pneumonia (13), Candida spp.(10), Staphylococcus epidermidis (8), Streptococcus sp., and Escherichia coli* (5), *Bacillus cereus (5), Pseudomonas sp.* (3), *Proteus mirabilis* (2). Oral health is unquestionably one of the most significant areas of public health. Since it is among the most crucial elements of individual health, its social relevance must be evaluated. The primary causes of tooth decay, a multiphase illness, are age, social and economic standing, inadequate brushing practices, drinking unhealthy beverages, and unsuitable [8, 9, 10]. The amount of carbohydrates consumed in the daily diet has a significant impact on the disease's onset and course. There are numerous detrimental impacts of obesity on dental health [10, 11]. There is evidence that sugar contributes to tooth decay by reducing pH, which can promote the growth of microbes linked to dental cavities.

It has been demonstrated that those who consume more sugar are much more likely to develop dental decay than those who consume less sugar [12, 13].

Antibiotic susceptibility testing was performed using 14 types of antibiotics mentioned. Measure the diameter of the inhibition zone after cultivating *Staphylococcus aureus* isolates (n=19) and *K. pneumonia* (n=13), according to the standard inhibition zone in CLSI, 2024. The results showed that the higher resistance of *S. aureus* against Clindamycin and Ceftaroline 19(100%), then Erythromycin 15(78.94%), Gentamycin 14(73.68%), Ofloxacin 9(47.36%), Rifampin 7(36.84%), Tetracycline 3(15.78%), and 0%to Azithromycin and Ciprofloxacin. While the high resistance against *K. pneumoniae* was Penicillin and Ciprofloxacin 13 (100%), Levofloxacin 9 (53.84%), Gentamycin and Nitrofurantoin 7(23.7%), Rifampin and Tetracycline 3(23.07%), then Imipenem and Meropenem 0%**.** The higher resistant *Staphylococcus aureus* isolated to β-Lactam antibiotic (Penicillin) using in the present study related to the three types of resistant mechanisms including: hydrolyzes the cyclic amide bond of the β-lactam ring by producing β -Lactamase enzymes (decreases bactericidal activity), inhibition the ability of antibiotic to bind to Penicillin Binding Proteins (PBPs) by decreased permeability to the antibiotic through the outer cell membrane of the bacteria. In gram-positive bacteria, the peptidoglycan layer is near the bacteria's surface, and there are few barriers for the drug to reach its target and altered PBPs. This explains the resistance of *Staphylococcus aureus* to most commercially available β-lactams [14].

Gentamicin. irreversible binding of the aminoglycoside to the bacterial ribosome 30S subunit, which inhibits the production of proteins. Tetracyclines are classified as synthesizing proteins. Broad-spectrum antibiotics are those that inhibit antibiotics. This activity reviews the indications, action, and contraindications for tetracyclines as a valuable agent in treating bacterial infection [15].

It believes that the spreading of multi-drug resistance to antibiotics is related to the large number and misuse of antibiotics in humans and animals, especially in countries where it is easy to purchase drugs without a prescription, as is the case in most Arab and developing countries. Also, spread in a large number of countries of the world, misuse and frequent use of drugs in animals

DECLARATION

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Competing Interests

The authors have no competing interests to declare.

Informed Consent

Not applicable.

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ORIGINAL RESEARCH

MINIMALLY-INVASIVE VERSUS TRADITIONAL OPEN APPROACH IN MANDIBULAR FRACTURE FIXATION: A RANDOMISED CONTROLLED TRIAL

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ABSTRACT

Background: Mandibular fractures are a common facial injury, and the treatment aims to restore both anatomical and functional aspects of the jaw. Traditional open surgery has been the standard approach, but minimally invasive techniques are emerging as alternatives, offering potential benefits in terms of healing time, complications, and recovery. This study compares the outcomes of minimally invasive surgery versus traditional open surgery in mandibular fracture fixation.

Methods: A randomized controlled trial was conducted with 100 adult patients who sustained mandibular fractures requiring surgical intervention. Fifty patients were assigned to the minimally invasive surgery group and fifty to the traditional open surgery group. Primary outcomes included fracture healing time, postoperative complications, and functional recovery. Secondary outcomes included aesthetic satisfaction, postoperative pain, and patient satisfaction. Data were analyzed using statistical methods to compare the two groups.

Results: The minimally invasive group had faster fracture healing (6.3 weeks vs. 7.1 weeks, $p < 0.05$), fewer complications (8% vs. 20%, $p < 0.05$), better functional recovery (38 mm vs. 32 mm mouth opening, $p < 0.05$), and superior aesthetic outcomes (VAS score 8.7 vs. 7.3, $p < 0.05$). Patients in the minimally invasive group reported lower pain levels and higher overall satisfaction (94% vs. 84%, $p < 0.05$).

Conclusion: Minimally invasive surgery for mandibular fracture fixation demonstrated superior outcomes in terms of healing time, complications, functional recovery, and patient satisfaction compared to traditional open surgery. This technique offers a promising alternative, particularly for patients where aesthetic outcomes and reduced recovery time are priorities. Larger, multicenter trials are needed to confirm these findings.

***Keywords*:** Aesthetic outcomes, Complications, Functional recovery, Mandibular fractures, Minimally invasive surgery

INTRODUCTION

Mandibular fractures are a common type of facial injury, often resulting from trauma such as motor vehicle accidents, sports injuries, and physical altercations. The mandibular bone plays a crucial role in the structural integrity and functionality of the face, housing the teeth and enabling essential functions such as chewing, speaking, and breathing [1]. As a result, fractures of the mandible not only pose significant physical and functional challenges but can also lead to substantial cosmetic and psychological repercussions. Treatment for mandibular fractures typically aims to restore both the anatomical and functional aspects of the jaw while minimizing

complications, such as infection, malocclusion, and long-term deformities [2].

Traditional open surgical approaches for mandibular fracture fixation have been the gold standard for many years. This method involves making an incision over the fracture site, exposing the fractured bone, and securing it with metal plates and screws [3]. While open surgery allows for direct visualization and accurate alignment of the fracture, it is associated with several disadvantages, including increased soft tissue dissection, longer recovery periods, higher infection rates, and the potential for postoperative scarring. Furthermore, the trauma caused to surrounding tissues during the procedure can contribute to delayed healing and postoperative complications [4].

In response to the limitations of traditional open surgery, minimally invasive techniques have emerged as an alternative approach for mandibular fracture fixation. The primary goal of minimally invasive surgery is to achieve fracture reduction and fixation with smaller incisions, reduced soft tissue dissection, and improved recovery times [5]. Several minimally invasive surgery techniques, such as endoscopic-assisted surgery and percutaneous plate fixation, have been developed to facilitate less invasive fracture management while preserving the structural integrity of surrounding tissues. Proponents of minimally invasive approaches argue that these techniques offer faster recovery, reduced postoperative pain, and a lower risk of infection, with no compromise in the quality of fracture fixation [6].

Despite the theoretical benefits of minimally invasive surgery, the clinical outcomes of this technique compared to traditional open approaches remain uncertain. Although some studies have shown promising results in terms of reduced morbidity and

improved recovery, the long-term efficacy, complication rates, and overall functional outcomes of minimally invasive fixation remain under investigation [7]. Additionally, odontomas, benign tumors that can occur in the jaw, as well as malignant conditions such as oral cancers, may complicate the management of mandibular fractures by causing delayed healing or requiring additional surgical intervention due to their location, size, or the need for concurrent cancer treatment. It is crucial to determine whether the potential advantages of minimally invasive surgery in terms of reduced complications and faster recovery are accompanied by equivalent or superior clinical outcomes, including fracture stability, aesthetic outcomes, and functional restoration [8].

This randomized controlled trial aims to compare the effectiveness of the minimally invasive approach with the traditional open approach for mandibular fracture fixation. By focusing on objective clinical outcomes, including fracture healing time, postoperative complications, functional recovery, and aesthetic results, this study will provide valuable insights into whether minimally invasive techniques can offer a viable alternative to traditional open surgery for mandibular fractures. Ultimately, the findings of this trial may guide clinical decision-making and shape the future approach to mandibular fracture management, optimizing patient outcomes while minimizing the impact of surgery on both physical function and quality of life.

METHODOLOGY

Study Design

This study was a prospective, randomized controlled trial aimed at comparing the effectiveness of minimally invasive surgery with traditional open surgery for mandibular fracture fixation. The trial was conducted at a tertiary care hospital, following ethical guidelines and obtaining approval from the institutional review board (IRB) prior to commencement. Written informed consent was obtained from all participants, and all procedures were in accordance with the principles of the Declaration of Helsinki.

Study Participants

The study included adult patients (18-65 years of age) who had sustained a mandibular fracture requiring surgical intervention. Eligible participants were identified from the department or oral and maxillofacial surgery, Maharana Pratap College of Dentistry and Research Centre, Gwalior, Madhya Pradesh and assessed for inclusion based on clinical examination, radiological imaging, and patient history. Patients with the following criteria were excluded from the study:

- Patients with multiple facial fractures requiring combined surgical approaches.
- Patients with significant underlying medical conditions (e.g., uncontrolled diabetes, immune system disorders) that could affect wound healing.
- Pregnant women or individuals unable to comply with follow-up protocols.

A total of 100 participants were recruited and randomized into two groups using a computer-generated randomization schedule: one group underwent minimally invasive surgery, and the other underwent traditional open surgery. Randomization occurred after the patient was deemed eligible for

surgery, and the surgeon was blinded to the group allocation until after the randomization process.

Intervention

1. **Minimally Invasive Surgery Group** Patients in this group underwent fracture fixation using minimally invasive techniques, such as endoscopic-assisted surgery or percutaneous plate fixation. The choice of technique depended on the fracture location, complexity, and surgeon's expertise. The procedure involved smaller incisions (typically less than 2 cm), with minimal soft tissue dissection. An endoscope or fluoroscopic guidance was used for visualization during the fixation process, ensuring precise alignment of the fractured bone without the need for extensive exposure.
2. **Traditional Open Surgery Group** Patients in this group underwent the standard open surgical approach for mandibular fracture fixation. The procedure involved a larger incision over the fracture site to provide direct access and visualization of the fractured bone. The bone was reduced and fixed using metal plates and screws. This approach allowed for better direct control over fracture alignment but involved greater soft tissue disruption and a longer recovery time compared to the minimally invasive method.

Outcome Measures

The primary outcomes for this study included:

- **Fracture Healing Time**: The time taken for the fracture to heal was measured using radiographic imaging. Healing was assessed by the presence of callus formation and bridging of the fracture site.
- **Postoperative Complications**: The rate of complications such as infection, malocclusion, non-union, hardware failure, or temporomandibular joint dysfunction was recorded.
- **Functional Recovery**: Functional recovery was assessed using a standardized scale to measure mouth opening, chewing ability, and speech. These assessments were conducted preoperatively and at 1, 3, and 6 months post-surgery.

Secondary outcomes included:

- **Aesthetic Outcomes**: Aesthetic results were evaluated by both the patient and an independent assessor using a visual analog scale (VAS) to rate the appearance of the surgical site.
- **Postoperative Pain**: Pain levels were measured using the VAS for pain at 24 hours, 1 week, and 1 month after surgery.
- **Patient Satisfaction**: Patients completed a satisfaction survey at the 6-month follow-up, assessing overall satisfaction with the appearance, function, and recovery.

Data Collection and Analysis

Data were collected at baseline (preoperative), as well as at 1 week, 1 month, 3 months, and 6 months postoperatively. The following assessments were conducted:

- Radiographic analysis to evaluate fracture healing and detect complications.
- Clinical evaluations of mouth opening, chewing, and speech.
- Questionnaires to assess pain, patient satisfaction, and quality of life.
- Clinical follow-ups to assess wound healing, infection, and any functional or cosmetic issues.

The data were analyzed using statistical software (e.g., SPSS, R). Continuous variables were compared using independent t-tests or Mann-Whitney U tests, depending on the distribution of data. Categorical variables were compared using chi-square tests. A p-value of less than 0.05 was considered statistically significant.

Ethical Considerations

This study adhered to ethical standards of research involving human participants. All participants were fully informed of the study's purpose, procedures, potential risks, and benefits. Informed consent was obtained before inclusion in the study. Participants were assured of confidentiality, and their participation was voluntary with the option to withdraw at any time without consequences.

Limitations

Potential limitations of this study included variability in surgical techniques based on the surgeon's experience and the complexity of the fractures. Additionally, patient compliance with follow-up visits could have affected the completeness of the data. However, these factors were minimized by standardizing surgical protocols and ensuring diligent follow-up through regular appointments.

By comparing these two surgical approaches, this study provided valuable insight into the relative efficacy, safety, and long-term outcomes of minimally invasive versus traditional open surgery for

mandibular fracture fixation.

RESULTS

A total of 100 patients were enrolled in the study, with 50 patients assigned to the minimally invasive surgery group and 50 patients to the traditional open surgery group. The mean age of participants was 34.5 years, with a range from 18 to 65 years. The demographic characteristics, including gender distribution, fracture location, and severity, were similar between the two groups, ensuring comparability at baseline.

Fracture Healing Time

The mean fracture healing time in the minimally invasive surgery group was 6.3 weeks (range: 5-8 weeks), while in the traditional open surgery group, it was 7.1 weeks (range: 6-9 weeks). A significant difference was found between the two groups ($p < 0.05$), with patients in the minimally invasive surgery group experiencing a faster healing time. This is summarized in Table 1.

Table 1. Fracture Healing Time

Group	Mean Healing Time (Weeks)	Range (Weeks)	p-value
Minimally Invasive Surgery	6.3	5-8	< 0.05
Traditional Open Surgery	7.1	6-9	

Postoperative Complications

The rate of postoperative complications was lower in the minimally invasive surgery group compared to the traditional open surgery group. In the minimally invasive group, 4 patients (8%) developed complications, including mild infection (2 cases), minor malocclusion (1 case), and temporary temporomandibular joint dysfunction (1 case). In the open surgery group, 10 patients (20%) experienced complications, including infection (3 cases), malocclusion (3 cases), and non-union (2 cases), along with the need for revision surgery in 2 patients. This difference was statistically significant ($p < 0.05$). Table 2 summarizes these findings.

Table 2. Postoperative Complications

Group	Complication Rate (%)	Types of Complications	p-value
Minimally Invasive Surgery	8%	Infection (2), Malocclusion (1), Temporomandibular Joint Dysfunction (1)	< 0.05
Traditional Open Surgery	20%	Infection (3), Malocclusion (3), Non-union (2), Revision Surgery (2)	

Functional Recovery

Functional recovery, measured by mouth opening, chewing ability, and speech, showed significant improvement in both groups. However, the minimally invasive surgery group had better functional recovery outcomes. The average mouth opening at 6 months post-surgery was 38 mm in the minimally invasive group compared to 32 mm in the open surgery group ($p < 0.05$).

Chewing ability and speech clarity also improved more rapidly in the minimally invasive group, with 92% of patients reporting satisfactory chewing ability and speech at the 6-month follow-up, compared to 78% in the open surgery group. These results are shown in Table 3.

Table 3. Functional Recovery Outcomes at 6 Months

Group	Average Mouth Opening (mm)	Satisfactory Chewing Ability (%)	Satisfactory Speech (%)	p-value
Minimally Invasive Surgery	38	92	92	< 0.05
Traditional Open Surgery	32	78	78	

Aesthetic Outcomes

Aesthetic outcomes, assessed by both the patients and an independent assessor, were superior in the minimally invasive surgery group. The VAS for aesthetic satisfaction showed a mean score of 8.7 (range: 7-10) in the minimally invasive surgery group, compared to 7.3 (range: 5-9) in the open surgery group ($p < 0.05$). Patients in the minimally invasive group reported less visible scarring, with only minor, well-healed scars at the incision sites. Table 4 summarizes these findings.

Table 4. Aesthetic Satisfaction Scores (VAS)

Group	Mean Aesthetic Satisfaction Score (VAS)	Range (VAS)	p-value
Minimally Invasive Surgery	8.7	7-10	< 0.05
Traditional Open Surgery	7.3	5-9	

Postoperative Pain

Postoperative pain was measured using the VAS for pain at 24 hours, 1 week, and 1 month after surgery. The minimally invasive surgery group reported significantly lower pain levels. At 24 hours post-surgery, the mean pain score was 3.2 in the minimally invasive group compared to 5.1 in the open surgery group ($p < 0.01$). At 1 week, the pain score was 2.1 in the minimally invasive group compared to 3.5 in the open surgery group ($p < 0.01$). At 1 month, pain scores were similar in both groups, with a slight improvement in both groups as healing progressed. These results are presented in Table 5.

Table 5. Postoperative Pain Levels

Time Point	Minimally Invasive Group Mean Pain Score	Traditional Open Surgery Group Mean Pain Score	p-value
24 Hours	3.2	5.1	< 0.01
1 Week	2.1	3.5	< 0.01
1 Month	1.0	1.2	

Patient satisfaction, as assessed by a survey at the 6-month follow-up, was significantly higher in the minimally invasive surgery group. A total of 94% of patients in the minimally invasive group reported being satisfied or very satisfied with the outcome of their surgery, compared to 84% in the open surgery group ($p < 0.05$). Patients in the minimally invasive group cited quicker recovery, less pain, and minimal scarring as key factors contributing to their satisfaction.

DISCUSSION

In this randomized trial comparing minimally invasive surgery and traditional open surgery for mandibular fracture fixation, our findings suggest that the minimally invasive approach yielded advantages in healing time, lower complication rates, better functional recovery, improved aesthetic outcomes, and lower early postoperative pain. These results align and sometimes build upon what earlier authors have

reported, while also adding more robust, controlled trial evidence to the literature.

First, our observation of faster fracture healing and stable occlusion with the minimally invasive technique resonates with data from a comparative study on endoscope assisted mandibular angle fractures, which concluded that endoscopy assisted open reduction and internal fixation (ORIF) was an effective minimally invasive alternative to conventional ORIF, with good postoperative recovery and no compromise in occlusion or healing stability. Similarly, in the classic series by Kim YG et al. (2022) [9], 17 subcondylar fractures in 12 patients treated via an endoscopic assisted approach resulted in successful plating and satisfactory outcomes.

Second, with regard to complications: a systematic review covering 509 patients by Sanati-Mehrizy et al. (2019) [10] treated with endoscopic repair of mandibular fractures reported permanent facial nerve injury in only one patient (≈ 0.2%) and occlusal complications in about 6.5%. Our trial likewise noted a lower complication rate in the minimally invasive group (8% vs. 20%), suggesting that minimally invasive fixation does not appear to carry higher morbidity and may reduce it compared to traditional open surgery. This supports the broader trend highlighted by the systematic review.

Third, our data on aesthetic outcomes and patient satisfaction echo the benefits described in clinical reports of transoral endoscopic assisted techniques for condylar fractures: in a study from Croatia, two patients treated with transoral endoscopically assisted technique recovered with stable occlusion, restored joint function, and importantly, without visible external scarring [11]. That study stressed reduced morbidity, minimal soft tissue trauma, and superior esthetic outcome, all of which align with our higher satisfaction and aesthetic VAS scores in the minimally invasive cohort.

However, not all prior data are uniformly in favor of minimally invasive approaches. The meta analysis comparing ORIF to endoscopic open reduction with internal fixation (EORIF) for condylar fractures found no statistically significant difference in the risk of facial nerve injury or need for reoperation between the two techniques [12]. This suggests that, at least for some fracture types (particularly condylar fractures), the advantage of the minimally invasive technique may not lie in reduced nerve injury or reoperation but perhaps more in patient comfort, cosmetic outcome, or soft tissue morbidity. In that light, our trial's findings of improved functional recovery, faster healing, and better aesthetics may represent additional, meaningful benefits beyond what prior meta analyses identified.

In synthesis, our results add supportive evidence that minimally invasive mandibular fracture fixation can be at least as effective as and in many aspects superior to traditional open surgery, particularly with respect to recovery speed, patient comfort, cosmetic outcomes, and early postoperative pain, without compromising healing stability or increasing complication risk. Given this, minimally invasive approaches deserve strong consideration, especially in patients where soft tissue morbidity or aesthetics matter.

Future investigations should aim at larger multicenter randomized trials, longer follow up (to assess late complications such as hardware failure or nerve dysfunction), and stratification of results by fracture type and complexity. Such data would help clarify the boundaries of when minimally invasive fixation offers clear advantages, and when conventional open approaches remain preferable.

CONCLUSION

In conclusion, the results of this study suggest that minimally invasive surgery for mandibular fracture fixation offers significant advantages over traditional open surgery, including faster healing, fewer complications, better functional recovery, and improved aesthetic outcomes. Patients undergoing minimally invasive surgery also reported lower postoperative pain and higher satisfaction. This approach represents a promising alternative, particularly in cases where cosmetic outcomes and reduced recovery times are prioritized. Further studies with larger sample sizes and longer follow-up are needed to solidify these findings.

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The authors have no competing interests to declare.

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Not applicable.

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CLINICAL PROFILE OF PYODERMA PATIENTS AT THE DERMATOLOGY AND VENEREOLOGY OUTPATIENT CLINIC, UNIVERSITAS AIRLANGGA TEACHING HOSPITAL: A RETROSPECTIVE STUDY

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ABSTRACT

Background: Pyoderma refers to a group of bacterial infectious diseases involving the skin and follicular structures commonly caused by infection with Gram–positive bacteria. Pyoderma infections are among the most common dermatologic diseases in tropical countries such as Indonesia. Pyoderma patients present with diverse signs and symptoms in clinical manifestations and systemic infection. Pyoderma imposes a substantial disease burden in resource-poor communities, leading to serious post-infection complications. Therefore, comprehensive research regarding the clinical profile of pyoderma patients is crucial.

Materials and Methods: This study is a retrospective descriptive analysis using secondary data extracted from medical records at the Dermatology and Venereology Outpatient Clinic of Universitas Airlangga Teaching Hospital from 2023 – 2025.

Results: A total of 119 patients were included in the study, pyoderma being the most common diagnosis (39.5%). Among these cases, cellulitis represented the most frequent type of pyoderma (22.7%). This study reported that 58% of cases occurred in females, with the condition affecting a broad range of age groups. The highest proportions were observed in the early elderly age group (56–65 years) at 19.3%, followed by the late elderly group (>65 years) at 15.1% and the toddler age group (0–5 years) at 13.4%. Primary lesions such as macules (44.5%) and pustules (25.2%) are frequently observed, while secondary lesions like erosions (47.1%) and crusts (25.2%) are commonly found. Antibiotic treatment was the most common intervention given, both systemic and topical. Normal saline, antihistamines, and topical steroids were also commonly prescribed.

Conclusion: This study highlights the characteristics of pyoderma cases in the Dermatology and Venereology Outpatient Clinic, Universitas Airlangga Teaching Hospital. Among the type of pyoderma, cellulitis was the most common clinical diagnosis. Pyoderma was more common in females and occurred across a broad age range, with the highest incidence in the early elderly population. Primary lesions such as macules and pustules were commonly observed, while secondary lesions such as erosions and crusts were frequently present. Systemic and topical antibiotics were the most frequently used therapies. The findings of this study may help enhance patient care, support future studies, and improve local health strategies for managing skin infections.

***Keywords*:** Pyoderma, Retrospective Studies, Clinical profile, Indonesia, Good health and well-being

INTRODUCTION

Pyodermas are defined as a bacterial infection that gives rise to lesions that break the skin barrier. Infection of pyoderma may occur at the level of epidermis and dermis [1]. Pyoderma can be found in high and low-resource countries. Its incidence, however, is significantly higher in tropical climates and among populations with low hygiene,

malnutrition, and overcrowding [2]. Regions such as India and Indonesia account for a significant amount of outpatient dermatological consultations, especially among children [3,4]. Individuals living in developing countries, such as Indonesia, remain highly susceptible to bacterial skin infection due to factors such as inadequate hygiene, weakened skin barriers, high population density, and limited education [5]. Humidity also plays a role in skin infections. Climate change causes ambient humidity to cause infectious diseases to flourish [6]. Pyoderma is classified as either primary or secondary. Primary pyodermas are impetigo, folliculitis, furuncle, carbuncle, ecthyma, erythrasma, and sycosis barbae. Secondary pyodermas constitute tropic ulcer, infected pemphigus, infected contact dermatitis, infected scabies, and various other dermatoses infected with organisms [7]. According to a study conducted in Malang, Indonesia, the incidence of pyoderma is most prevalent in high school males, with impetigo being the most common form of pyoderma found [8]. Treatment of pyoderma typically involves systemic and topical antibiotics. Systemic antibiotics such as amoxicillin and clavulanic acid are given when topical antibiotics are insufficient [9]. Localized epidemiological data are essential to broaden the scope and guide possible effective treatment strategies.

MATERIALS AND METHODS

Design and Population

This study is a retrospective analysis conducted on cases of pyoderma treated at the Dermatology and Venereology Outpatient Clinic, Universitas Airlangga Teaching Hospital, between 2023 – 2025. Data was extracted from medical records of patients with diagnosed pyoderma, including conditions such as impetigo, ecthyma, folliculitis, furuncle and carbuncle, erysipelas, and cellulitis. The study included 119 patients presenting with various types of pyodermas. Data is categorized by age, gender, lesion type, and treatment modality.

Inclusion Criteria

Patients diagnosed with Pyoderma who were treated and logged with the following diagnoses: Impetigo, ecthyma, folliculitis, furuncle and carbuncle, erysipelas, and cellulitis

Exclusion Criteria

Cases of duplicated data and repeated visits to the outpatient clinic were excluded from this study. Only the first visit is included.

Sampling Method

This study was conducted using consecutive sampling to select cases that met the inclusion criteria. Data on demographics, clinical manifestations, lesion types, and treatment methods were extracted from the medical records of eligible patients.

Data Collection

Data were collected retrospectively from the Dermatology and Venereology Outpatient Clinic, Universitas Airlangga Teaching Hospital's electronic medical records. The following datasets were extracted:

Clinical Diagnosis: Type of pyoderma, including impetigo, ecthyma, folliculitis, furuncle-carbuncle, erysipelas, cellulitis

Demographic Information: Age and Gender

Clinical Manifestation: Primary and secondary lesions

Treatment Data: Prescribed topical and systemic treatments, including antibiotics, steroids, moisturizer, and antifungal.

Data Analysis

Data were entered into Microsoft Excel and analyzed using descriptive statistics. Frequency and percentage distributions for included variables are visualized by the use of tables to present.

Ethical Considerations

Ethical approval was obtained from the Ethical Committee of Universitas Airlangga Teaching Hospital. Patient confidentiality was strictly maintained by keeping the data anonymous.

Study Timeline

This study was conducted from August 2025 to November 2025

RESULTS

Clinical Diagnosis Distribution

A total of 119 patients met the criteria for this study. Pyoderma was the most common diagnosis, occurring in 47 patients (39.5%) and cellulitis was the most frequent clinical type of pyoderma (22.7%), followed by furuncle and carbuncle (17.6%) (Table 1).

Table 1. Patient Demographic

	Diagnosis N (%)							Total
	Pyoderma	Impetigo	Ecthyma	Folliculitis	Furuncle Carbuncle	Erysipelas	Cellulitis	
N	47(39.5)	11(9.2)	2(1.7)	9(7.6)	21(17.6)	2(1.7)	27(22.7)	119(100)

Gender Distribution

119 patients were observed, and the results showed that the majority were female (58%). Cellulitis was found affecting females (59.3%) compared to males (40.7%). Furuncles and carbuncles were the same, with females showing a higher percentage (71.4%). On the other hand, impetigo and folliculitis showed higher male prevalence at 63.6 % and 66.7% respectively. Erysipelas and ecthyma were found with balanced distribution at 50% in each gender (Table 2).

Table 2. Gender Distribution

Gender	Diagnosis N (%)							Total
	Pyoderma	Impetigo	Ecthyma	Folliculitis	Furuncle Carbuncle	Erysipelas	Cellulitis	
Male	18(38.3)	7(63.6)	1(50)	6(66.7)	6(28.6)	1(50)	11(40.7)	50(42)
Female	29(61.7)	4(36.4)	1(50)	3(33.3)	15(71.4)	1(50)	16(59.3)	69(58)
Total	47(100)	11(100)	2(100)	9(100)	21(100)	2(100)	27(100)	119(100)

Age Distribution

Among all patients, the highest proportion was observed in the early elderly age group (56–65 years), with 23 patients (19.3%). This was followed by the late elderly group (>65 years) at 15.1% and toddlers (0–5 years) at 13.4%. Based on this observation, pyoderma affects a wide range of ages (Table 3).

Table 3. Age Distribution

Age Group	Diagnosis N (%)							Total (%)
	Pyoderma	Impetigo	Ecthyma	Folliculitis	Furuncle Carbuncle	Erysipelas	Cellulitis	
0-5	7(14.9)	8(72.7)	0(0)	0(0)	1(4.80	0(0)	0(0)	16(13.4)
5-11	6(12.8)	1(9.1)	1(50)	0(0)	0(0)	0(0)	0(0)	8(6.7)
12-16	2(4.3)	0(0)	1(50)	0(0)	0(0)	0(0)	1(3.7)	4(3.4)
17-25	7(14.9)	0(0)	0(0)	2(22.2)	3(14.3)	0(0)	3(11.1)	15(12.6)
26-35	4(8.5)	1(9.1)	0(0)	1(11.1)	4(19)	0(0)	1(3.7)	11(9.2)
35-45	3(6.4)	0(0)	0(0)	2(22.2)	2(9.5)	0(0)	4(14.8)	11(9.2)
46-55	5(10.6)	0(0)	0(0)	0(0)	4(19)	0(0)	4(14.8)	13(10.9)
56-65	7(14.9)	1(9.1)	0(0)	3(33.3)	3(14.3)	2(100)	7(25.9)	23(19.3)
>65	6(12.8)	0(0)	0(0)	1(11.1)	4(19)	0(0)	7(25.9)	18(15.1
Total	47(100)	11(100)	2(100)	9(100)	21(100)	2(100)	27(100)	119(100)

Lesion Types

Primary Lesion

Primary lesions were observed in this study, macules and pustules were found to be the most common lesion types at 44.5 % and 25.2% respectively. For cellulitis, macules were the most common primary lesion found in 23 patients (85.2%), followed by pustules and bullae, with both at 7.4%. In cases of furuncles and carbuncles, the primary lesion found was nodules (61.9%) and macules (28.6%). Impetigo mainly presents as papules (36.4%) and pustules (27.3%). Folliculitis primarily presents as papules (77.8%) and pustules (22.2%). Erysipelas presents as macules and papules in both cases at 50% and similarly, ecthyma presented macules at 50% (Table 4).

Secondary Lesion

In the secondary lesion aspect, erosions (61.7%) and crusts (34%) were most common in cases of pyoderma. Similarly, erosions (37%) and crusts (14.8%) were also frequently found in cellulitis, with squama and ulcer showing high frequency at 14.8%. Furuncles and carbuncles. On the other hand, displayed ulcer and crusts as the majority of secondary lesion presentation. Impetigo showed major erosion and crust presentations at 72.7% and 45.5% respectively. Lichenification is reported in a minority of patients, with only 4 patients presenting with pyoderma and 1 with cellulitis. Folliculitis exclusively showed a presentation of erosions (44.4%), and erysipelas also presented a similar exclusive erosion presentation (100%). While ecthyma cases presented with crust, excoriation, and ulcer, each at 50% (Table 4).

Table 4. Lesion Type Distribution

Type of Lesion	Diagnosis N (%)							Total
	Pyoderma (n=47)	Impetigo (n=11)	Ecthyma (n=2)	Folliculitis (n=9)	Furuncle Carbuncle (n=21)	Erysipelas (n=2)	Cellulitis (n=27)	
Primary Lesion								
Maculae	20(42.6)	2(18.2)	1(50)	0(0)	6(28.6)	1(50)	23(85.2)	53(44.5)
Papule	14(29.8)	4(36.4)	0(0)	7(77.8)	3(14.3)	0(0)	0(0)	28(23.5)
Nodule	7(14.9)	1(9.1)	0(0)	1(11.1)	13(61.9)	0(0)	1(3.7)	23(19.3)
Pustule	19(40.4)	3(27.3)	0(0)	2(22.2)	4(19)	0(0)	2(7.4)	30(25.2)
Vesicle	3(6.4)	1(9.1)	0(0)	0(0)	0(0)	0(0)	0(0)	4(3.4)
Bullae	1(2.1)	0(0)	0(0)	0(0)	0(0)	1(50)	2(7.4)	4(3.4)
Plaque	3(6.4)	0(0)	0(0)	0(0)	1(4.8)	0(0)	3(11.1)	7(5.9)
Secondary Lesion								
Squama	11(23.4)	2(18.2)	0(0)	0(0)	2(9.5)	0(0)	4(14.8)	19 (16)
Crusts	16(34)	5(45.5)	1(50)	0(0)	4(19)	0(0)	4(14.8)	30(25.2)
Erosion	29(61.7)	8(72.7)	0(0)	4(44.4)	3(14.3)	2(100)	10(37)	56(47.1)
Excoriation	2(4.3)	2(18.2)	1(50)	0(0)	1(4.8)	0(0)	0(0)	6(5)
Ulcer	2(4.3)	1(9.1)	1(50)	0(0)	4(19)	0(0)	4(14.8)	12(10.1)
Lichenification	4(8.5)	0	0(0)	0(0)	0(0)	0(0)	1(3.7)	5(4.2)

Note: One patient may present with more than one lesion type

Treatment Distribution

Topical Therapy

The majority of patients received topical antibiotics (86.6%). Topical treatments categorized as others, including normal saline, were also commonly used to 64 patients (53.8%), followed by topical steroids, which were prescribed to 28 patients (23.5%) (Table 5).

Table 5. Treatment Distribution

Type of Therapy	Diagnosis N (%)							Total
	Pyoderma (n=47)	Impetigo (n=11)	Ecthyma (n=2)	Folliculitis (n=9)	Furuncle Carbuncle (n=21)	Erysipelas (n=2)	Cellulitis (n=27)	
Topical Therapy								
Topical Antibiotic	45(95.7)	11(100)	2(100)	7(77.8)	16(76.2)	2(100)	20(74.1)	103(86.6)
Topical Steroid	12(25.5)	3(27.3)	0(0)	2(22.2)	3(14.3)	0(0)	8(29.6)	28(23.5)
Moisturizer	2(4.3)	1(9.1)	0(0)	0(0)	0(0)	0(0)	3(11.1)	6(5)
Antifungal	6(12.8)	2(18.2)	0(0)	0(0)	2(9.5)	0(0)	0(0)	10(8.4)
Others	27(57.4)	8(72.7)	2(100)	3(33.3)	4(19)	1(50)	19(70.4)	64(53.8)
SystemicTherapy								
Systemic Antibiotic	31(66)	7(63.6)	2(100)	5(55.6)	17(81)	2(100)	25(92.6)	89(74.8)
Antihistamine	19(40.4)	3(27.3)	1(50)	6(66.7)	5(23.8)	1(50)	9(33.3)	44(37)
Oral Non Steroid	9(19.1)	0(0)	1(50)	1(11.1)	7(33.3)	2(100)	11(40.7	31(26.1)
Oral Steroid	1(2.1)	0(0)	0(0)	0(0)	0(0)	0(0)	2(7.4)	3(2.5)
Others	1(2.1)	0(0)	0(0)	1(11.1)	1(4.8)	0(0)	2(7.4)	5(4.2)

Note: One patient can be treated with more than one therapy

Systemic Therapy

Similar to topical therapy, antibiotics were the most commonly prescribed treatment (74.8%). Antihistamines were given to 44 patients (43.7%). Oral non–steroidal drugs such as ibuprofen and mefenamic acid were prescribed to 31 patients (26.1%) (Table 5).

DISCUSSION

In this study of 119 patients over the period of 2023 – 2025, we evaluated the distribution and characteristics of skin infections, including pyoderma, cellulitis, furuncles/ carbuncles, impetigo, folliculitis, erysipelas, and ecthyma. The findings reported will be discussed with existing literature. Pyoderma was found to be the most common diagnosis (39.5%), followed by cellulitis (22.7%) and furuncle/carbuncle (17.6%). This finding is supported by a study conducted by the global analysis of bacterial skin diseases, which found that amongst skin diseases, bacterial skin infections, which mainly include cellulitis and pyoderma, account for a massive proportion [10]. This research found that pyoderma was most prevalent in female patients (58%) compared to male patients (42%). Uniquely, this study contradicts previous studies conducted. For example, studies conducted in India mainly report male dominance compared to female predominance. A study in India reported that 57.57% male patients were diagnosed with pyoderma compared to female patients (42.42%) [3]. This current study reported that cases of pyoderma were distributed mainly in the early elderly age group. This finding is supported by a previous study that found in 33 cases of pyoderma, the majority of patients were above 40 years of age. The development of infection may be explained due to elderly patients neglecting the disease (3). Patients diagnosed with pyoderma were distributed evenly across age groups, with the 0–5 years, 17–25 years, and 56–65 years age groups each accounting for 14.9% of cases. Impetigo has been reported as the most common type of pyoderma in younger age groups, accounting for 48.61% of cases in a previous study (12). This is consistent with the findings of the present study, in which the majority of younger patients presented with impetigo (72.7%). Our findings reported that macules and pustules were the most common primary lesions in patients presenting with pyoderma at 42.6% and 40.4% respectively. This finding is consistent with a previous study that reported pustules as the dominant lesion in pyoderma patients, which indicates superficial bacterial infection caused by

Staphylococcus Aureus and *Streptococcus Pyogenes* [13].

This study also found that macules were present in the majority of cases with cellulitis (85.2 %), with other lesions such as plaque (11.1%) and pustules (7.4%) appearing less frequently. This finding is consistent with studies that cellulitis primarily presents with inflamed and erythematous skin, which may progress to more severe forms [14].

Furuncles and carbuncles, on the other hand, were mainly presenting with nodules (61.9%), pustules (19%), and plaques (4%), which may reflect deeper and localized skin infection. While folliculitis mainly presents with papules (77.8%) and pustules (22.2%), which show its characteristic involvement of inflaming the hair follicles [15]. This study reported that erosions were commonly found in impetigo (72.7%), pyoderma (61.7%), and cellulitis (37%). Similarly, crusts were also commonly found in pyoderma and impetigo at 34% and 45.5% respectively. This finding may be the result of the breakdown in the skin barrier and may increase the risk of bacterial infection [16].

The presence of crust may signal progression towards healing. They are also associated with secondary infections and may delay recovery. Ulcer was predominantly found in patients with cellulitis (14.8%), which represents a deeper stage of infection where it requires more intensive management. Formation of an ulcer is an indicator of advanced disease [17]. Excoriation is observed in patients presenting with impetigo and pyoderma at 18.2% and 4.3% respectively. If left untreated, excoriation may cause infection and scarring [18]. Management of secondary skin infections primarily focuses on controlling bacterial growth. Antibiotics were the most commonly prescribed treatment in this study. The majority of patients diagnosed with pyoderma received topical and systemic antibiotics at 95% and 66% respectively. This finding is consistent with a study conducted in the United States, which showed that antibiotics were the most prescribed treatment consistently for 8 years in patients presenting with skin infections [19].

Normal saline was also widely used in this study, listed as others in the table. Normal saline is used in 64 patients (53.8%). This finding is consistent with previous research, which stated that normal saline is the most widely accepted irrigant for wound infection [20]. Topical steroids were often prescribed for patients in this study, 28 (23.5%). This is consistent with previous studies that topical steroids are effective for inflammatory skin diseases when used within a short treatment period. However, its use must be carefully monitored due to local side effects such as atrophy, striae, and rosacea [21].

In systemic therapy, antihistamines are the second most prescribed treatment after antibiotics; all patients in this study received antihistamines. Antihistamines are most known for their effect to suppress pruritus typical in cases of angioedema and can reverse vascular effects and induce pain control [22]. Oral non–steroids are also commonly prescribed in this study; most patients also received nonsteroidal anti-inflammatory drugs. Nonsteroidal anti-inflammatory drugs are frequently used to manage mild to moderate pain, which may be present in cases of pyoderma [23].

CONCLUSION

This study provides a comprehensive report of the characteristics and treatment distribution of pyoderma at the Dermatology and Venereology Outpatient Clinic, Universitas Airlangga Teaching Hospital. Pyoderma was more commonly found in females and occurred across a wide age range, with the highest incidence observed in the early elderly age group. Among the types of pyoderma, cellulitis was the most frequent clinical diagnosis. Macules and pustules were the predominant primary lesions, while erosions and crusts were the most commonly observed secondary lesions. Topical and systemic antibiotics were the most frequently administered treatments. Overall, these findings offer valuable insights into the clinical presentation and therapeutic management of pyoderma in a local healthcare setting. The results of this study may help optimize patient care, guide future research, and support the development of improved local health strategies for managing skin infections.

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Competing Interests

The authors have no competing interests to declare.

Informed Consent

Not applicable.

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CONE-BEAM COMPUTED TOMOGRAPHY ASSESSMENT OF THE NASOPALATINE CANAL DIMENSIONS CONSIDERING THEIR RELATIONSHIP WITH DENTAL IMPLANT PLACEMENT IN A SAMPLE OF YEMENI POPULATION

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ABSTRACT

Objective: To radiographically assess the anatomical variations and dimensions of the nasopalatine canal (NPC) using cone-beam computed tomography (CBCT) and evaluate their relationship with gender, age, and dental condition in a Yemeni population to guide safe dental implant placement in the anterior maxilla.

Materials and Methods: A retrospective cross-sectional study was conducted on 335 CBCT scans of adult Yemeni patients (≥18 years). NPC length and diameters at the incisive and nasal foramina were measured. Comparisons were performed according to gender, age (18–45 vs. >45 years), dental condition (dentate vs. edentulous), and number of missing maxillary central incisors. Statistical analyses included normality testing, independent t-tests/Mann–Whitney tests, chi-square tests, and intraclass correlation coefficients (ICC) for reliability.

Results: The mean NPC length was 9.93 ± 2.30 mm. Mean NPC diameters at the incisive and nasal foramina were 3.03 ± 0.80 mm and 3.16 ± 1.21 mm, respectively. NPC length and both foraminal diameters were significantly greater in males than females ($p<0.05$). The incisive foramen diameter was significantly larger in older (>45 years) and edentulous patients ($p<0.05$), whereas nasal foramen diameter showed no significant association with age or dental condition. Patients missing one central incisor demonstrated a significantly longer NPC compared with those missing both.

Conclusion: Considerable variability exists in NPC dimensions in the Yemeni population, influenced mainly by gender and, to a lesser extent, age and dental status. Preoperative CBCT evaluation of the NPC is essential to minimize complications during implant placement in the anterior maxilla.

Keywords**:** Nasopalatine canal, CBCT, Yemeni population, dental implants, anterior maxilla

INTRODUCTION

The nasopalatine canal (NPC) is called the incisive canal since the NPC is located palatal to the central incisors and it has two openings: the incisive foramen, which is located underneath the incisive papilla, and the nasal opening or foramina of Stenson [1]. The most recent studies assessing NPC dimensions and variations used CBCT technology considering the effects of sex, age, and the presence or absence of maxillary central incisors on NPC morphological and dimensional characteristics [2].

The close proximity of the maxillary incisive canal with the anterior incisors area affects one's ability to place implants in ideal position. To avoid causing complications, variations in its dimensions should be clearly evaluated [5].

Based on the aforementioned issues, this study was conducted to radiographically assess the anatomical variations of the NPC a using CBCT for the purpose of providing dental implant treatment on a group of Yemeni population.

MATERIALS AND METHODS

An analytical retrospective cross-sectional study was included 1000 maxillary arch CBCT images of patients who were referred to a private radiology center at Sana'a city, Yemen during the period from January 2017 to December 2019. All participants were ≥ 18 years, not have (pathological lesion, impacted teeth or

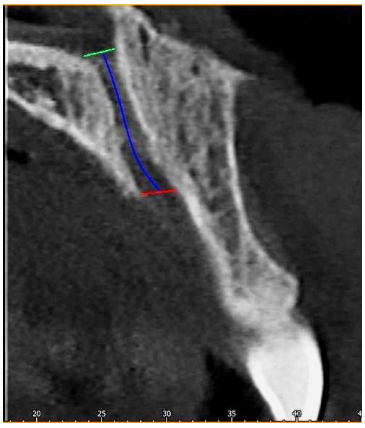
fracture in anterior maxillary region) or Ongoing orthodontic treatment. The sample size was calculated using the OpenEpi® statistics calculation software **[6]**, considering a confidence level of 95%, power of 80% using the study of[1] as a reference. Therefore, the minimal sample size required was 176 cases. Out of the 1000 CBCT images, 600 were selected randomly. After applying the exclusion criteria, 265 CBCT images were excluded. The final sample size became 335 CBCT images. The sample size was divided according to gender (male and female), age (> 45 years and ≤ 45 years), and dental condition (dentate and edentulous). Patients underwent CBCT assessment were referred from general practitioners, maxillofacial surgery departments and surgeons for various surgical treatments, including dental implant placement. CBCT images were stored into an external hard disk. the data were collected during 4 months; from November 2020 to October 2021.

Ethical approval

Prior to the study, ethical approval to carry out this study was granted from the ethical committee of the Faculty of Medicine and Health Sciences, University of Science & Technology

Study variables:

Nasopalatine canal (NPC) dimensions The NPC length was measured through drawing a line from the midpoint of the incisive foramen to the midpoint of the nasal foramen **[1]** And the NPC diameter was assessed at its two openings: oral/palatal opening (incisive foramen) and nasal opening (Stenson's foramina), (Figure 1), respectively



Blue color for NPC length.
Red color for IF diameter.
Green color for NF diąmeter

Figure 1. CBCT image showing the NPC measurements

Statistical analysis: Data analysis will be done using the Statistical Package for Social Sciences (SPSS) software version 24. Statistically significance set at *P* value <0.05.

The Kolmogorov-Smirnov test was applied for evaluating compliance with the normal distribution of the data. Independent t-test and nonparametric Mann-Whitney test. Chi-square test was used to compare the categorical data. Student *t*-test was performed for the comparison of two independent groups.

Study reliability: Intra-examiner reliability was assessed by recording 10% of the study measurements randomly and blindly across three trials with a one-week interval. The correlation between the recorded measurements were statistically evaluated using the intraclass correlation coefficient (ICC) descriptive statistic. The intra-examiner reliability data demonstrated a mean percentage agreement of 91.1% for the single measures and 96.9% for the average measures indicating excellent agreement reliability [15, 16].

RESULTS

A total of 335 CBCT images of patients were analyzed according to gender, age (18-45 and > 45 years), and dental condition (dentate and edentulous) as shown in Figure 4.1, 4.2.

Table 4.1 presents the descriptive statistics of NPC measurements along with their normality test. The NPC mean length was 9.93±2.30 mm (ranging from 5.10 to 16.00 mm). Besides, the NPC mean diameter at both incisive and nasal foramens was 3.03±0.80 mm (ranging from 1.00 to 5.10 mm) and 3.16±1.21 mm (ranging from 1.00 to 6.10 mm), respectively.

Regarding the gender, age and dental condition, as shown in Table 4.2 The results revealed that the NPC mean length is significantly higher in males than females (10.80±2.15 vs 9.39±2.23 mm, p=0.000) where the mean difference is 1.41 mm.

Moreover, the NPC mean length is higher in the > 45 years group than the 18-45 years group (10.17±2.36 vs 9.86±2.28) and in the edentulous than dentate patients (10.20±2.32 vs 9.86±2.29); however, these differences are not statistically significant (p>0.05).The results also revealed that the NPC mean length is significantly higher in those missing only one central incisor than those missing both (10.94±2.14 vs 9.62±2.13, p=0.018) where the mean difference is 1.32 mm.

The differences of NPC diameter at the incisive foramen according to gender, age and dental condition, as shown in Table 4.3 The results revealed that the NPC mean diameter at the incisive foramen is significantly higher in males than females (3.19±0.82 vs 2.92±0.78 mm, mean difference=0.27, p=0.003), in the > 45 years group than those between 18-45 years (3.23±0.86 vs 2.97±0.78 mm, mean difference = 0.26, p=0.015), in the edentulous than the dentate patients (3.21±0.77 vs 2.98±0.81 mm, mean difference = 0.23, p=0.034), and in those missing both central incisors than those missing only one (3.39±0.74 vs 2.92±0.73 mm, mean difference = 0.47, p=0.011).

The differences of NPC diameter at the nasal foramen according to gender, age and dental condition, as shown in Table 4.4 The results revealed that the NPC mean diameter at the nasal foramen is significantly higher

in males than females (3.43±1.19 vs 2.99±1.20 mm, p=0.001) where the mean difference is 0.44.

Moreover, the NPC mean diameter at the nasal foramen is higher in the 18-45 years group than the > 45 years group (3.17±1.24 vs 3.12±1.10), in the dentate than edentulous patients (3.22±1.25 vs 2.92±1.02) and in those missing one than those missing both central incisors (2.93±1.05 vs 2.92±1.01); however, these differences are not statistically significant (p>0.05).

Table 1 Descriptive results of sample according to demographic variables

variable			N	%
Gender		Male	129	38.5
		Female	206	61.5
Age		18-45 years	259	77.3
		> 45 years	76	22.7
Dental condition		Dentate	267	79.7
		Edentulous	68	20.3
total			**335**	**100**

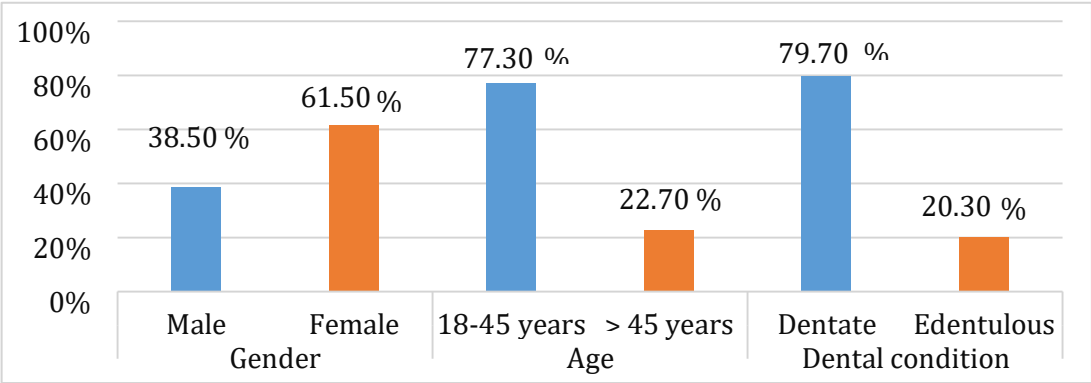


Figure 2. Descriptive results of sample according to demographic variable

Table 2 Edentulous group according to number of missing central incisors

Edentulous	N	%
Missing both	41	60.29
Missing one	27	39.71
Total	68	100

Table 3. Differences of NPC length by gender, age and dental condition

NPC length		N	Mean	SD	Mean difference	*P*
Gender	Male	129	10.80	2.15	1.41	.000*
	Female	206	9.39	2.23		
Age	18-45 years	259	9.86	2.28	-0.31	.223
	> 45 years	76	10.17	2.36		
Dental condition	Dentate	267	9.86	2.29	-0.34	.215
	Edentulous	68	10.20	2.32		
	Missing both CIs	41	9.62	2.13	-1.32	.018*
	Missing one CI	27	10.94	2.14		

* Statistically significant at p<0.05, CI: Central Incisors.

Table 4. Differences of NPC diameter at the incisive foramen by gender, age and dental condition

NPC diameter at incisive foramen		N	Mean	SD	Mean difference	*P*
Gender	Male	129	3.19	.82	.27	.003*
	Female	206	2.92	.78		
Age	18-45 years	259	2.97	.78	-.26	.015*
	> 45 years	76	3.23	.86		
Dental condition	Dentate	267	2.98	.81	-.23	.034*
	Edentulous	68	3.21	.77		
	Missing both CIs	41	3.39	.74	.47	.011*
	Missing one CI	27	2.92	.73		

* Statistically significant at p<0.05, CI: Central Incisors.

Table 5.Differences of NPC diameter at the nasal foramen by gender, age and dental condition

NPC diameter at nasal foramen		N	Mean	SD	Mean difference	*P*
Gender	Male	129	3.43	1.19	.44	0.001*
	Female	206	2.99	1.20		
Age	18-45 years	259	3.17	1.24	.05	.805
	> 45 years	76	3.12	1.10		
Dental condition	Dentate	267	3.22	1.25	.30	.068
	Edentulous	68	2.92	1.02		
	Missing both CIs	41	2.92	1.01	-.01	.940
	Missing one CI	27	2.93	1.05		

* Statistically significant at p<0.05, CI: Central Incisors

DISCUSSION

CBCT images of 335 randomly selected patients referred for the purpose of undergoing dental implant procedures to a private radiology center at Sana'a city, Yemen during the period from January 2017 to December 2019. The study results would be helpful to provide normative data and guidelines and disseminate knowledge to dentists and surgeons in Yemen and raise their awareness in order to obtain sufficient and updated pre-surgical information to successfully perform dental implant procedures in the anterior maxillary area and avoid any possible complications or dental implant failure.

Nasopalatine canal

The study found that the NPC mean length of Yemeni patients was 9.93±2.30 mm, which was smaller than those of other countries all over the world, including India (18.63, 12.14, 11.13, 10.66, 10.32, 10.25, & 10.08 mm)[9,11,17-21] Malaysia (16.33 mm)[5], Iran (14.09, 12.85, and 12.84, 12.7, & 10.34 mm)[22-25] China (12.8mm) [26], Turkey (12.59, 12.56, & 11.45 mm) **1,27,** Spain (12.34 mm)[10], Lebanon (11.52mm)[28], Korea (11.5mm)[29], Japan (11.29mm)[30], Germany (11.15 mm) [13], Brazil (11mm) [12], Switzerland (10.99 mm)[8], and Serbia (10.26 mm) [4].

However, it is higher than those of different samples in Turkey (9.62 & 9.53 mm)[31] and Germany (8.1mm)[14].

Regarding the variations in the NPC dimensions across various studies, [32] and [5] stated that since there are several differences in the NPC dimensions within one population, they are most likely to exist between various populations with different races and ethnicities.

Regarding gender, the present study revealed that the NPC mean length of male patients was significantly higher than that of females (p<0.001), which is similar to those reported by most previous studies [1, 5, 8, 9, 11-13, 19, 20, 23-25, 27, 28, 33].

The higher NPC length in males could be attributed to the relatively larger facial craniocaudal dimensions in males than females; therefore, the variations in the NPC dimensions may be relative to the facial dimensions [21].

However, few studies showed no significant difference in the NPC mean length between both genders [17, 18, 22, 31, 34].

Besides, the present study showed no significant difference in the NPC mean length with regard to age (p>0.05), which is comparable to those revealed by most previous studies [1, 5, 9, 13, 19, 34]. This finding is however inconsistent to [17] in India who reported significantly increased NPC length with aging as well as [12] in Brazil and [8] in Switzerland who reported significant lower values of NPC length for older patients.

The present study also showed that the NPC mean length is not associated with the dental condition (p>0.05), which complies with those reported by some previous studies [1, 8, 18, 22, 30], but does not comply with those reported by others, including who conducted their study on patients from Turkey, Spain, Saudi Arabia, and Cyprus as well as [31] who reported significant lower values of NPC length for edentulous patients.

The insignificance differences in the NPC length regarding age and dental condition in the present study as well as in most of the previous studies could be attributed to the interindividual variations and non-homogenous distribution of age and dental groups [1].

At the incisive foramen, the NPC mean diameter in the present study was 3.03±0.80 mm, which is close to the NPC mean diameter reported for the Caucasians/Arabs (2.90mm) by [32]. In contrast, it is smaller than those of several previous studies conducted in many different countries in which the NPC mean diameter at the incisive foramen ranges from 7.51mm to 3.12 mm [1, 8, 9, 11, 13, 14, 17-19, 22-25, 28, 30, 34-37], as well as larger than those reported by few studies in which the NPC mean diameter at the incisive foramen ranges between 2.5 mm and 2.8 mm [5, 12,14] reported that the diameter of the incisive foramen is usually considered below 6mm since in case it exceeds 10mm, pathological conditions should be considered. They added that this dimensional variability is very important especially when dealing with surgical procedures such as implant placement in the central incisor region.

Furthermore, the present study revealed a significantly wider NPC mean diameter at the incisive foramen in male patients compared to female patients (p=0.015), which is similar to those reported by several previous studies [1, 5, 13, 20, 22, 24, 25, 32, 33, 36] whereas other studies showed no significant difference in the NPC mean diameter at the incisive foramen between both genders although the value was higher for male participants [10, 13, 25, 31, 34-36 31, 37].

Moreover, the present study showed that the NPC mean diameter at the incisive foramen is significantly higher in the > 45 years group than those between 18-45 years (p=0.034). This finding is similar to those revealed by some previous studies [1, 13, 17] which reported significant higher values of NPC diameter at the incisive foramen for older patients. In contrast, other studies reported insignificant association of NPC diameter at the incisive foramen with age [12, 19, 34, 37].

Besides, the present study showed a significant association of NPC diameter at the incisive foramen with the dental condition indicating that the edentulous group had higher NPC diameter (p=0.011), which is comparable to those reported by previous studies [22, 24, 30, 37], and incomparable to those of few studies [1, 18, 32] which reported insignificant association of NPC diameter at the incisive foramen with the dental condition.

At the nasal foramen, the NPC mean diameter in the present study was 3.16± 1.21 mm, which was similar to that of [20] in India; however, it is smaller than those of several studies conducted in many different countries in which the NPC mean diameter at the nasal foramen ranges from 6.06 mm to 3.17 mm [5, 8, 11, 13, 14, 19, 22, 24, 25, 30, 34, 36]. On contrary, our study reported higher NPC mean diameter than those reported by some studies in which the NPC mean diameter at the nasal foramen ranges between 1.9 mm and 3.1 mm [1, 9, 12, 31, 32, 35].

Furthermore, the present study revealed a significantly wider NPC mean diameter at the nasal foramen in male patients compared to female patients (p=0.001), which is similar to those reported by some previous studies [19, 20, 25, 32] whereas most previous studies showed no significant difference in the NPC mean diameter at the nasal foramen between both genders [1, 5, 8, 11, 13, 22, 24, 34, 36].

The NPC wider diameter at both incisive and nasal foramens in males than females could be attributed to the larger size of skulls and larger dimensions of craniocaudal anatomy in males [9, 21].

Moreover, the present study showed that the NPC mean diameter at the nasal foramen is not significantly associated with age (p>0.015). This finding is similar to those revealed by previous studies [1, 12, 13, 19, 23, 34].

Besides, the present study showed no significant association between NPC diameter at the nasal foramen with the dental condition (p>0.015), which is comparable to those reported by some previous studies [1, 22, 24, 32], and incomparable to those of[30] and[31] who reported who reported significant higher values of NPC diameter at the nasal foramen for edentulous patients.

The present study results regarding the relationship of the NPC diameter at the nasal foramen with age and dental condition are supported by the conclusion of [38] who reported that contrary to the alveolar bone which undergoes major vertical and horizontal resorption, the shape of the nasal/basal bone does not dramatically change with age and following tooth loss.

The variation in NPC length and diameter as within different countries could be attributed to the reginal and environmental factor. Moreover, despite of the variations in mean dimensions of NPC their specific variations should be taken into account when placing endosseous implant in the anterior maxilla.[5]

In summary, there is great variability in the dimensions of the NPC in the anterior maxilla, even within subjects of the same origin. These differences appear to be gender- and age-specific as well as of ethnic differences. Nonetheless, the findings of this study provided detailed anatomical variations of the NPC therefore, it can be described as a seminal reference and beneficial to further research studies in dentistry as well as to dentists in various centers and dental clinics in Yemen where CBCT is not available. In particular, the study findings could be also helpful to dental implant surgeons who could raise their understanding of the NPC structure to avoid any potential NPC perforation which could hinder the success of osseointegration.

DECLARATIONS

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Conflicts of interest

Authors **have no conflicts** of interest to disclose.

- The study protocol was reviewed and approved by the research ethical committee of by the College of Dentistry, University of Science & Technology, Sanaa, Yemen, letters were send to hospital manager to permit to conduct the study.

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EXPLORING THE CURRENT STATE OF GENERATION Z HEALTH LITERATURE IN ASEAN: A BIBLIOMETRIC REVIEW AND FUTURE RESEARCH DIRECTIONS

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ABSTRACT

This study investigates the health of Generation Z in ASEAN countries, focusing on the bibliometric trends of journal articles published between 1980 and 2026, specifically examining mental health and well-being. Through a quantitative approach, bibliometric analysis was conducted using tools such as VOSviewer, Biblioshiny (R-package), and Publish or Perish, with data collected from the Scopus database based on a systematic search strategy guided by the PRISMA framework. A total of 688 eligible articles were analyzed, revealing a steady annual publication growth rate of 2.42%. Malaysia, Singapore, and Thailand emerged as the leading countries in Generation Z health research, with Malaysia contributing the highest number of publications. Dominant keywords include "mental health," "adolescents," "stress," and "social media," indicating a strong focus on psychological well-being, digital environments, and lifestyle factors. Influential journals such as the International Journal of Environmental Research and Public Health and BMC Public Health play a significant role in shaping the field. The analysis identifies key research themes, including mental health challenges, the impact of social media, and the effects of the COVID-19 pandemic. However, certain areas such as digital health tools, gender-specific health concerns, and regional health disparities remain underexplored, highlighting potential future research directions. This study provides a comprehensive overview, offering insights into the evolving landscape of Generation Z health research in ASEAN and suggesting avenues for future investigation.

***Keywords*:** Generation Z, Bibliometric Review, Generation Z Health

INTRODUCTION

Generation Z, defined as individuals born between 1997 and 2012, is an emerging demographic group that presents unique health challenges and opportunities, particularly in the context of ASEAN countries[1]. Unlike previous generations, Gen Z's health behaviors are influenced by a range of factors, including technological advancements, social media, and evolving public health trends[2]. Given the distinct characteristics of this generation, there is a growing body of research exploring various aspects of their health, from mental well-being to physical fitness[3,4]. Over the past decade, the health literature on Generation Z in ASEAN has evolved considerably. Recent studies have explored topics such as the impact of digital health interventions on mental health[5]. the influence of online health information on Gen Z's behavior[6], and the rising concerns around obesity and sedentary lifestyles[2].

A prominent research theme in this area focuses on mental health issues, including anxiety, depression, and stress, which have seen a significant rise among Gen Z individuals [7,8] . Furthermore, the role of social media in shaping these health outcomes has been frequently discussed [2,9].The shift towards digital health tools has also spurred research on e-therapy and telemedicine, particularly as a response to the COVID-19 pandemic [10].This increased academic interest reflects a broader recognition of Generation Z as a distinct and influential demographic group whose health behaviors will have a profound impact on public health policy in ASEAN [1,11].As such, the growing body of literature on Gen Z's health serves not only as an academic pursuit but also as a critical tool for developing tailored public health initiatives that address the specific needs of this generation.

However, existing studies often focus on different aspects of health, and regional variations in research themes have emerged. For example, in Indonesia, research has focused on Gen Z's perceptions of mental health [12,13], while in Malaysia, there is greater emphasis on nutrition and physical activity[14,15]. Meanwhile, studies in Thailand and Vietnam have increasingly examined the role of technology in influencing health behaviors [16,17]. This disparity in focus across ASEAN countries highlights the importance of understanding how cultural, socioeconomic, and policy differences shape health outcomes for Generation Z. Therefore, the purpose of this bibliometric review is to explore the current landscape of Generation Z health literature in ASEAN and identify emerging trends, key themes, and potential gaps. The following research questions (RQs) guide this study:

RQ1: What are the trends in Generation Z health literature over time, including the most frequently cited journals, countries, institutions, and productive authors?

RQ2: What are the key themes and authors' keywords that frequently appear in Generation Z health literature?

RQ3: What gaps exist in the current literature on Generation Z's health, and what are the potential future research directions?

RESEARCH METHODOLOGY

Research design.

This research presents a quantitative approach using bibliometric analysis from the Scopus database. Bibliometrics is the optimal technique for examining the conceptual structure of a research domain and identifying potential future research directions. For a more comprehensive bibliometric analysis, this study combines bibliometric and content analysis [18-20] to synthesise research streams from various journals in the Scopus database from 1980 to 2026. The main reason for selecting the Scopus database is that a study on Generation Z health utilising the Web of Science (WoS) database has already been conducted. Additionally, the WoS database is relatively limited and often overlaps with the Scopus database or includes journals indexed by both. Furthermore, the Scopus database grants access to a comprehensive database and offers more comprehensive citation coverage than the WoS database.

Search strategy, criteria, and data collection

In our data search strategy, we adapted the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) model as adopted. Figure 1 presents a detailed flowchart of the PRISMA protocol employed in our search strategy. Data were collected on December 10, 2025, from the Scopus database using the search query ("Generation Z" OR "Gen Z" OR "youth" OR "teenager" and "health" OR "well-being" OR "wellness" OR "fitness" and "mental health" OR "psychological" OR "emotional" OR "stress"). To guarantee the inclusiveness of our bibliometric review and content analysis, we follow the bibliometric study. Hence, after screening literature relevant to the topic, we evaluate the document based on eligibility criteria, including full-text search and cross-verification by their citation and relevance to the subject, which is not included in the data search query.

The initial records screened in the Scopus database (n = 45,214) were based on article titles, abstracts, and keywords from journals, proceedings, book chapters, and reviews. Three search criteria were used to ensure article quality and review validity: article universality, publication quality, and relevance. The universality of articles is represented by articles from journals written in English only. Therefore, we continued to extract using LIMIT-TO (DOCTYPE, "ar"), LIMIT-TO (SRCTYPE, "j"), and LIMIT-TO (LANGUAGE, "English"). Subsequently, we excluded documents that did not meet the inclusion criteria (i.e., money donations did not meet Generation Z health specifically, non-article document type, non-journal source type, ASEAN, and non-English) (n = 44.526). The remaining records deemed eligible (n = 688) were included for further descriptive, bibliometric, and content analyses.

Tools and data analysis

Various tools were utilised to conduct this study. For frequency analysis and chart generation tasks, R-Biblioshiny and Excel were employed for calculations and visualisation. VOSviewer was employed to construct and visualise bibliometric networks, examine abstract keywords and authorship, and explore relationships and collaborations across authors, countries, and publications. Harzing's Publish or Perish software was utilised to compute citation metrics and identify highly cited documents. This research employed a comprehensive methodology to explore the domain of cash waqf research, combining bibliometric analysis with content and network analysis. This approach aims to uncover insights into various field facets, including publication years, contributing countries and institutions, prominent journals, influential authors, keyword associations among authors, document citations, author citations and co-citations, international collaborations, and research stream

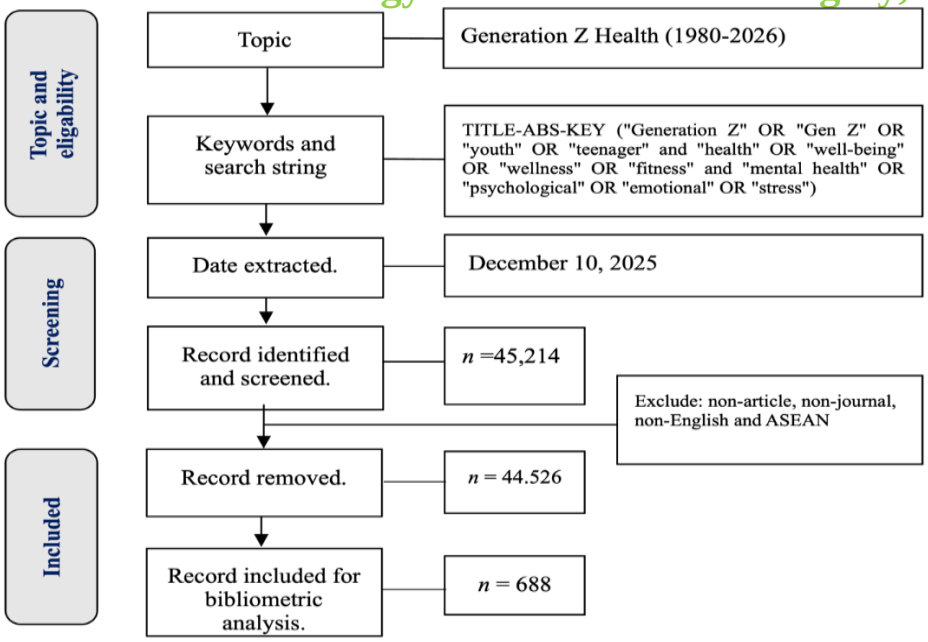


Figure 1. Diagram PRISMA

RESEARCH FINDINGS AND DISCUSSION

Descriptive analysis

The author looked at a set of 688 journal articles that were published between 1980 and 2026 for this study. There were 421 sources looked at in total. There were 3,538 authors who contributed to the dataset, but no articles were published by only one author. There were an average of 12.8 co-authors per document, and a large 39.83% of the publications had international co-authors. The yearly growth rate of publications was 2.42%, which shows that scholarly activity in this area is steadily rising. The average age of each document was 4.64 years, and there were 6,160 references in all of the publications. The average number of citations per document was 13.79, which shows that these papers had a big effect on the academic community. The study also found that the authors used 1,853 different keywords, which shows how many different topics the research covered. This overall picture shows that the field is growing and that researchers from all over the world are working together, as shown by the rising number of citations (Figure. 2).



Figure 2. Dataset

Figure 3 In this study, the author examined journal articles published between 1980 and 2026, focusing on the development of scholarly work during this period. The first article was published in 1980, but there were several years with no publications, particularly in the early years. However, the number of publications started to rise gradually, with a significant increase after 2017. The most notable growth occurred in recent years, especially in 2021, 2022, and 2023, reflecting an accelerated interest in the topic. A total of 553 articles were identified through a search in the Scopus database. The analysis of the publication trends showed an impressive annual growth rate of 11.5%. On average, each article received 19.4 citations per year, with 1.56 citations per paper. The total number of references across all articles amounted to 7,842 (Table 1). This upward trend highlights the increasing academic focus and research activity in the field, particularly in the last few years.

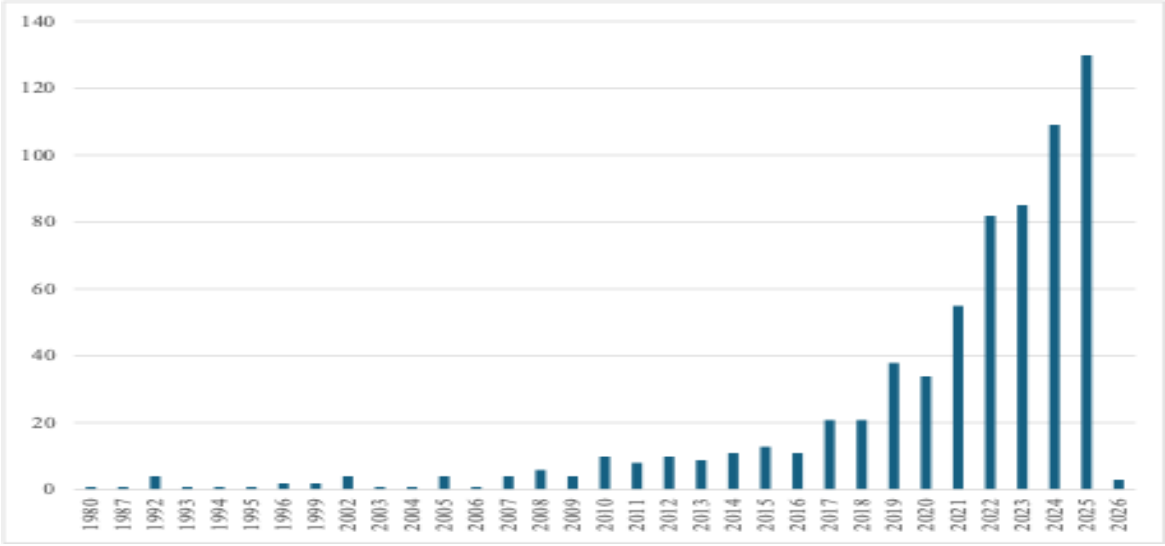


Figure 3. Number of publications per year

Research trend analysis

Table 1 shows that there are many different subject areas that are important to Generation Z health research in ASEAN. Medicine has the most publications at 56.98%, followed by Social Sciences at 31.25%. This shows that the focus is on both physical and social health. Psychology makes up 22.53% of the total, which shows that people are becoming more interested in mental health issues. The smaller fields that make up the research are Nursing (7.99%), Arts and Humanities (6.98%), Environmental Science (5.09%), and Computer Science (3.78%). This shows how interdisciplinary the research is. These results show that Generation Z is worried about their mental and physical health, as well as the effects of technology and society as a whole.

Table 1. Subject area

Subject Area	TP	%
Medicine	392	56,98%
Social Sciences	215	31,25%
Psychology	155	22,53%
Nursing	55	7,99%
Arts and Humanities	48	6,98%
Environmental Science	35	5,09%
Computer Science	26	3,78%

Table 2 shows that the International Journal of Environmental Research and Public Health was the most popular health research journal for Generation Z in ASEAN, with 17 TP (2.47%). The BMC Public Health journal came next, with 11 TP (1.60%), and the Journal of the Medical Association of Thailand came after that, with 9 TP (1.31%). Plos One (9 TP, 1.31%) and Frontiers in Psychiatry (8 TP, 1.16%) are also important sources. This means that the most well-known journals, like the International Journal of Environmental Research and Public Health, BMC Public Health, and Plos One, are the best at publishing research about Generation Z's health. These journals are very important for getting important research on the mental and physical health problems that Generation Z faces out to the public.

Table 2. Top 10 journal sources title

No.	Source Title and Scopus Rank	TP	%	TC	C/P	h	g	Publisher
1	International Journal of Environmental Research and Public Health	17	2,47	309	18,18	12	17	Multidisciplinary Digital Publishing Institute (MDPI)
2	BMC Public Health	11	1,60	103	9,36	5	10	BioMed Central Ltd
3	Journal of the Medical Association of Thailand	9	1,31	64	7,11	6	7	Medical Association of Thailand
4	Plos One	9	1,31	51	5,67	4	7	Public Library of Science
5	Frontiers in Psychiatry	8	1,16	112	14,00	5	8	Frontiers Media SA
6	Malaysian Journal of Medicine and Health Sciences	8	1,16	44	5,50	4	6	Faculty of Medicine and Health Sciences, UPM
7	Pertanika Journal of Social Sciences and Humanities	8	1,16	26	3,25	3	4	Universiti Putra Malaysia
8	Asian Journal of Psychiatry	7	1,02	156	22,29	5	7	Elsevier B.V.
9	Child Abuse and Neglect	6	0,87	194	32,33	6	6	Elsevier Ltd
10	Frontiers in Public Health	6	0,87	76	12,67	5	6	Frontiers Media SA

Note(s): TP=total number of publications; TC=total citations; C/P=average citations per publication; and h=h-index; g=g-index;

However, the figure 4 shows that the British Journal of Sports Medicine has the most local impact, with a total of 670 citations (TC). The Journal of Affective Disorders is next, with 321 TC. BMC Women's Health is in third place with 409 TC, and the International Journal of Environmental Research and Public Health is in fourth place with 309 TC. Other journals, like the Medical Journal of Australia (207 TC), Child Abuse and Neglect (194 TC), and the Revista De Psicologia Clinica Con Ninos Y Adolescentes (176 TC), have different but still significant effects on the local area. Figure 3 shows the top ten journals that have had the most impact in their areas (TC).

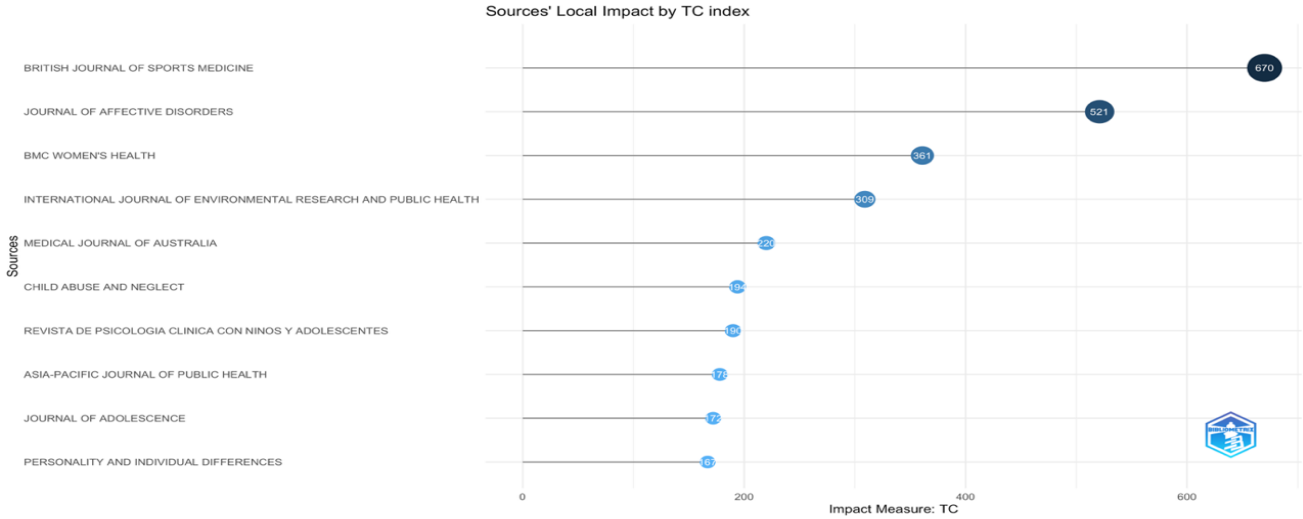


Figure 4. Journal local impact related to the topic

Most influential countries, affiliates, and productive author

Table 3 shows a study of the ten most important countries in ASEAN for health research on Generation Z. Malaysia is in first place with 161 publications (23.40%), and Singapore is in second place with 153 publications (22.24%). As previous studies have shown, Malaysia and Singapore are the countries that do the most research in this area. Thailand is third with 138 publications (20.06%), and Indonesia is close behind with 137 publications (19.91%). It's interesting that the Philippines and Vietnam have fewer publications (68 TP, 9.88% and 62 TP, 9.01%, respectively), but they make a big difference, especially when it comes to citations per publication (C/P). The Philippines has the highest C/P of 12.09, which shows how much their research has affected others, even though they have fewer publications. Cambodia, Myanmar, Brunei Darussalam, Papua New Guinea, and Timor-Leste are among the other countries that publish fewer papers, with each country publishing fewer than 20 papers. This distribution shows that some countries,

especially those in Southeast Asia, are more likely to do health research on Generation Z. It also shows that the impact of citations can vary. The difference also shows how important it is to build global partnerships to encourage collaborative research, especially in countries with fewer publications. This will help fill in research gaps and make sure that valuable health research is more widely available across the ASEAN region.

Table 3. Top 10 Countries contributed to the publications

Country	TP	%	TC	C/P	Continent
Malaysia	161	23,40%	840	5,22	Asia
Singapore	153	22,24%	1454	9,50	Asia
Thailand	138	20,06%	624	4,52	Asia
Indonesia	137	19,91%	516	3,77	Asia
Philippines	68	9,88%	822	12,09	Asia
Viet Nam	62	9,01%	44	0,71	Asia
Cambodia	13	1,89%	82	6,31	Asia
Myanmar	5	0,73%	24	4,80	Asia
Brunei Darussalam	3	0,44%	10	3,33	Asia
Papua New Guinea	3	0,44%	4	1,33	Asia
Timor-Leste	1	0,15%	2	2,00	Asia

The figure 5 shows the most important connections based on how many articles were published about Generation Z health research in ASEAN. With 172 articles, the Singapore Institute of Mental Health is at the top of the list. This shows how important it is to the field. Next are Universiti Kebangsaan Malaysia and Universitas Indonesia, both of which have 78 articles. This shows how important they are for health research on Generation Z in the area. The National University of Singapore publishes 76 articles, while Mahidol University and Universiti Malaya each publish 58 articles. This shows how much they are involved in the research. Chiang Mai University (56 articles), Universitas Airlangga (47 articles), and Universiti Putra Malaysia (47 articles) are also important partners. The Yong Loo Lin School of Medicine at NUS wrote 48 articles. This distribution shows that the best research and academic institutions in ASEAN are adding to the growing body of work on the health of Generation Z.

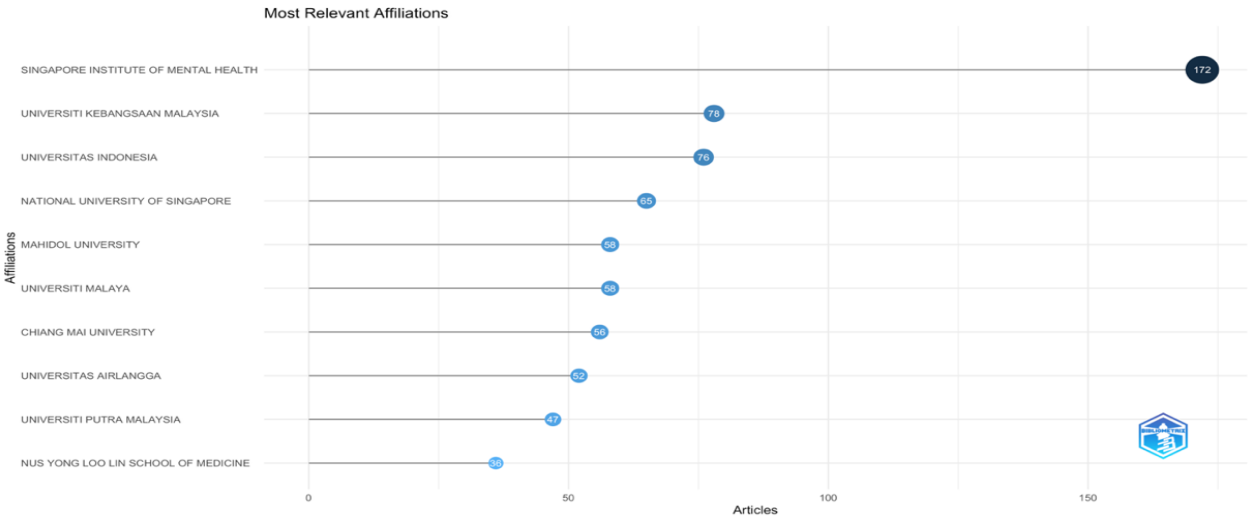


Figure 5. The top 10 Relevant Affiliations

Table 4 shows the top 10 authors who have done the most work on cash waqf research, along with their important contributions and how often they are cited. Subramaniam, M. has the most publications (17), which is 2.47% of the total. He has 449 citations, an average of 26.41 citations per paper, an h-index of 8, and a g-index of 18. Latkin, C.A. and Vaingankar, J.A. each wrote 10 papers (1.45% each), with Latkin's papers getting an average of 16.50 citations and Vaingankar's papers getting an average of 28.10 citations. Ho, R.C.M. has 9 publications, but his h-index is only 2. However, he has an amazing average of 88.44 citations per publication. Peltzer, K. also wrote 9 papers, but they only got an average of 14.67 citations each. Verma, S., on the other hand, has 9 publications with an average of 52.11 citations per paper, an h-index of 7, and a g-index of 15. Abdin, E., Chang, S., and Chong, S.A. each wrote 8 papers (1.16%), which were very important to the field. The average number of citations per paper ranged from 32.88 to 53.25. Finally, Lee, Y.P. wrote 8 papers, but they were cited less often, with an average of 5.88 citations per paper. Lee also had an h-index of 4 and a g-index of 6. These authors all show how cash waqf research is becoming more popular around the world. Some of them have had a big impact on citations, which shows how important they are to the field's growth.

Table 4. Most Productive Authors

Author Name	TP	%	TC	C/P	h-indeks	g-indeks
Subramaniam, M.	17	2,47%	449	26,41	8	18
Latkin, C.A.	10	1,45%	165	16,50	7	10
Vaingankar, J.A.	10	1,45%	281	28,10	5	10
Ho, R.C.M.	9	1,31%	796	88,44	2	24
Peltzer, K.	9	1,31%	132	14,67	3	9
Verma, S.	9	1,31%	469	52,11	7	15
Abdin, E.	8	1,16%	265	33,13	5	8
Chang, S.	8	1,16%	263	32,88	5	10
Chong, S.A.	8	1,16%	426	53,25	7	13
Lee, Y.P.	8	1,16%	47	5,88	4	6

Note(s): TP=total number of publications; TC=total citations; C/P=average citations per publication; and h=h-index; g=g-index

Citation analysis

Based on the information given, a number of studies on the health of Generation Z have made a big difference in this area. Bergeron, with 670 citations, is at the top of this list. His work is about how to help young athletes grow and improve [21]. Tee which looks at the psychological effects of COVID-19 in the Philippines, is in second place with 453 citations [22],. Moradi {Citation} has 361 citations for her work on how endometriosis affects women's lives. Hetrick looks at integrated youth healthcare and has 220 citations [23]. Fernandes looks at how the COVID-19 lockdown changed how teens use the internet and escape from reality, with 190 citations [24]. Von, with 172 citations, looks at why kids miss school [26], and Srinivasan, with 166 citations, looks at mental health in Singapore [8]. Doăn looks at how COVID-19 affects people's mental health (150 citations) [26], and Do looks at how long teens sleep and how it affects their health (139 citations) [27]. Lastly, Reid, with 127 citations, looks at sleep issues in young kids [28]. These studies give us important information about how the COVID-19 pandemic has affected young people's mental health, sleep, and other areas of their lives.

Table 5. The top ten most cited documents

Author	Paper	DOI	T/C	TC/Y	Normalized TC
Bergeron et al. 2015	International Olympic Committee consensus statement on youth athletic development	10.1136/bjsports-2015-094962	670	60,91	8,86
Tee et al. 2020	Psychological impact of COVID-19 pandemic in the Philippines	10.1016/j.jad.2020.08.043	453	75,50	12,36
Moradi et al. 2014.	Impact of endometriosis on women's lives: a qualitative study	10.1186/1472-6874-14-123	361	30,08	6,79
Hetrick, et al 2017.	Integrated (one-stop shop) youth health care: best available evidence and future directions	10.5694/MJA17.00694	220	24,44	6,62
Fernandes, et al 2020,	The impact of COVID-19 lockdown on internet use and escapism in adolescents	10.21134/rpcna.2020.mon.2056	190	31,67	5,18
Vaughn, et al 2013.	Prevalence and correlates of truancy in the US: Results from a national sample	10.1016/j.adolescence.2013.03.015	172	13,23	3,64
Subramaniam et al 2020.	Tracking the mental health of a nation: prevalence and correlates of mental disorders in the second Singapore mental health study	10.1017/S2045796019000179	166	27,67	4,53
Doanh et al 2021.	The impact of fear and anxiety of Covid-19 on life satisfaction: Psychological distress and sleep disturbance as mediators	10.1016/j.paid.2021.110869	150	30,00	8,93
Do et al 2013.	The associations between self-reported sleep duration and adolescent health outcomes: What is the role of time spent on Internet use?	10.1016/j.sleep.2012.09.004	139	10,69	2,94
Reid et al 2009.	The relation between common sleep problems and emotional and behavioral problems among 2- and 3-year-olds in the context of known risk factors for psychopathology	10.1111/j.1365-2869.2008.00692.x	127	7,47	2,79

Note(s): TC=total citations; C/Y=average citations per years

Keyword analysis

Table 6 shows how often keywords related to Generation Z health research show up in the Scopus database. "Human" is the most common keyword, appearing in 53.20% of the articles. "Adolescent" comes in second with 45.78%, and "Female" comes in third with 43.90%. "Male" (43.31%), "Article" (42.59%), and "Humans" (37.50%) are some of the other most common keywords. This shows that there is a strong focus on studies that are centered on humans, especially those that deal with teens and health issues related to gender. Mental health is a big part of this field, and the word "Mental Health" is used in 31.83% of articles. Also, words like "Psychology" (17.44%), "Depression" (16.28%), and "Youth" (12.21%) show how worried people are getting about mental health in young people. The distribution also shows that study designs are a big focus, with terms like "Major Clinical Study," "Controlled Study," and "Cross-sectional Study" showing up in a lot of articles. This shows that there is a lot of research on Generation Z health, with a focus on mental health and the well-being of teens and young adults.

Table 6. 20 Top Keywords

Keywords	TP	%	Keywords	TP	%
Human	366	53,20%	Psychology	120	17,44%
Adolescent	315	45,78%	Major Clinical Study	118	17,15%
Female	302	43,90%	Controlled Study	113	16,42%
Male	298	43,31%	Depression	112	16,28%
Article	293	42,59%	Cross-sectional Study	109	15,84%
Humans	258	37,50%	Questionnaire	101	14,68%
Mental Health	219	31,83%	Youth	84	12,21%
Adult	196	28,49%	Prevalence	81	11,77%
Young Adult	130	18,90%	Thailand	73	10,61%
Child	126	18,31%	Risk Factor	72	10,47%

Source: Scopus database

The figure is a network visualization map created using VOSviewer, illustrating the connections between keywords in the field of adolescent mental health research. At the center of the map is the core theme of "mental health," surrounded by related terms that reflect different aspects of the topic. The blue cluster includes keywords such as "stress," "anxiety," "depression," and "psychological distress," which are linked to emotional and psychological dimensions of mental health. The yellow cluster focuses on "adolescents," "youth," and "young adults," emphasizing the mental health issues specific to younger populations. In the red cluster, terms like "adolescent," "substance use," "violence," and "sexual behavior" point to research on risk factors, behaviors, and challenges faced by adolescents. The green cluster features terms like "social media," "physical activity," "social support," and "COVID-19," highlighting environmental and lifestyle influences on mental health. Additionally, the map shows a geographical focus on countries such as "Indonesia," "Thailand," "Vietnam," "Malaysia," and "Singapore," indicating that the research is particularly concerned with adolescent mental health in these regions. Overall, the network illustrates the interconnectedness of psychological well-being, lifestyle factors, social influences, risk behaviors, and the impact of the COVID-19 pandemic on adolescent mental health.

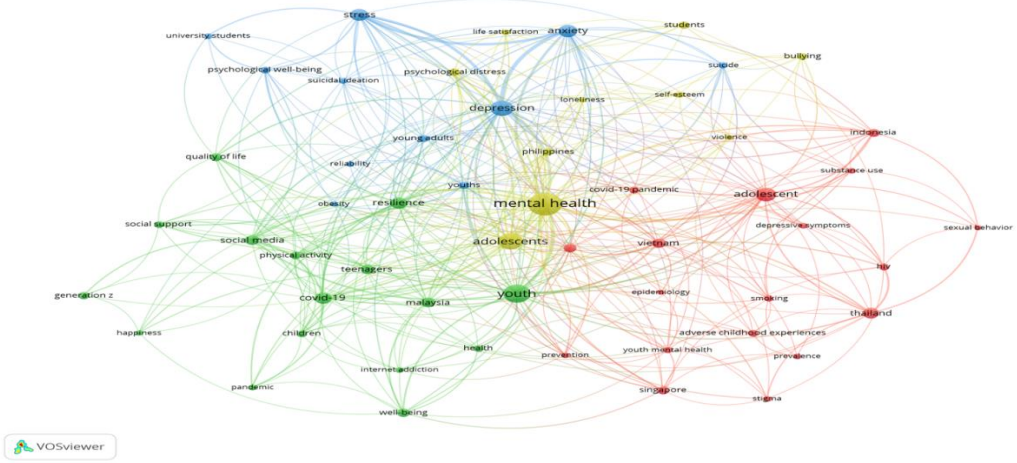


Figure 4. VOSviewer visualisation of a keyword co-occurrence

Note(s): Unit of analysis = Authors keywords; Counting method: Full counting; co-occurrences of a keyword = 6; meet the threshold = 55

Co-authorship analysis

Based on the co-authorship network visualization (Figure 6), we identified several clusters. The first cluster (blue) is associated with the co-authorship network of Kaligis, F., Ong, D.H., and Tjin, W., focusing on research related to mental health and the impact of the COVID-19 pandemic in ASEAN. The second cluster (green) is related to the work of authors like Vainganakam, S., Abdin, E., and Rajeswari, S., who focus on adolescent mental health and the psychological impacts of stressors on youth. The third cluster (yellow) features authors like Zhang, J., and Hwee, L., with research on the intersection of sleep, stress, and health outcomes in adolescents. The fourth cluster (red) is associated with Nguyen, T.T., Zhang, M., and other authors, who have explored the relationship between mental health, social behavior, and environmental factors in Generation Z. This network map provides a comprehensive overview of collaborative research efforts, highlighting key areas of focus in Generation Z health and mental well-being, especially in Southeast Asia.

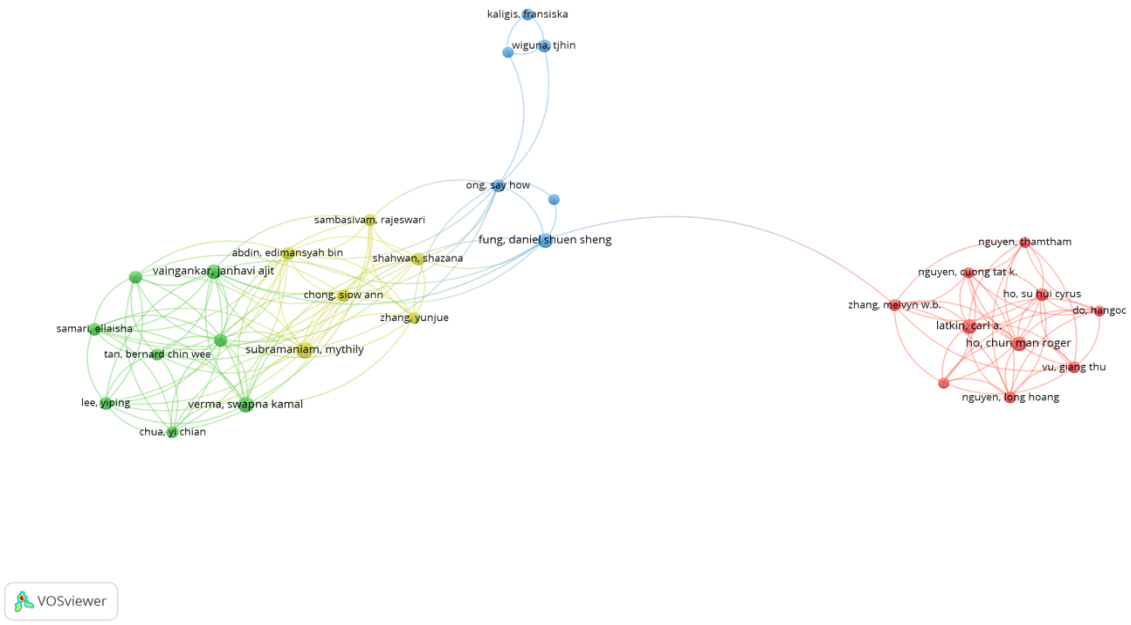


Figure 6. Co-authorship network visualisation map.

Note(s): Unit of analysis = cited Authors; Counting method: Full counting; Minimum number of documents of an author = 2; Minimum number of citations of an author = 4; meet the threshold = 53

DISCUSSION

Adolescent Health and Socioeconomic Factors in ASEAN

The intricate nexus between socioeconomic conditions, urban policy, and adolescent well-being in Southeast Asia reveals a critical public health challenge that extends beyond individual psychology. In Singapore, a nation lauded for urban excellence, youths experience a paradoxical high rate of psychological distress despite high satisfaction with physical and social neighbourhood features. Research indicates that while well-planned environments may buffer against anxiety and depression, they are insufficient for fostering resilience and life satisfaction; economic factors such as housing affordability and job prospects emerge as the most potent determinants of positive well-being, challenging universal livability metrics[29]. This underscores a pressing need for urban policies to transcend physical infrastructure and address the foundational economic insecurities that undermine youth ontological security.

Further compounding regional challenges are risky health behaviours strongly tied to socioeconomic and psychosocial stressors. In the Philippines, one in seven school-aged adolescents engages in current illicit drug use, with prevalence linked to psychological distress, exposure to drugs, and interpersonal violence, while protective factors like high parental support and school-based drug education show mitigating effects [30]. Similarly, in Thailand, premarital sex a precursor to unwanted pregnancy and STIs is being addressed through digital interventions like mobile applications, which have proven effective in reducing risk factors among high school students[31].These findings collectively advocate for integrated, multi-sectoral approaches that combine economic empowerment, targeted education, and digital health strategies to address the complex socio-ecological drivers of adolescent health in ASEAN.

Generation Z Well-being and the Impact of the COVID-19 Pandemic

Generation Z's well-being is increasingly mediated by digital environments, with the COVID-19 pandemic

acting as a profound accelerant for both risks and adaptive behaviours. A staggering 38.4% of youths across 26 countries exhibit problematic internet addiction, significantly associated with internalizing symptoms, high negative emotionality, and limited parental control over internet use[32]. Concurrently, social media use among Vietnamese youth shows a strong correlation with psychological distress, though it also serves primary functions for communication and news, highlighting its dualistic role[33].The pandemic amplified these digital stressors while creating unique adversities, as evidenced by the increased behavioural challenges and caregiver stress experienced by families of children with autism spectrum disorders in Thailand [34].

Despite digital risks, Gen Z also demonstrates a capacity for conscious and sustainable engagement, pointing to avenues for positive intervention. Indonesian Gen Z consumers can be segmented by motives for sustainable food choices, revealing groups from "Frugal Indifferent Foodies" to "Eco-Friendly Enthusiasts," which can inform targeted behavioural interventions[35]. Furthermore, mindful consumption practices among Thai Gen Z directly enhance sustainability values and green purchase intentions, a relationship strengthened by social influence[36]. These insights necessitate a nuanced public health response that leverages digital tools for promotion such as apps for mental well-being while simultaneously mitigating the harms of excessive and unstructured screen time through education and fostering digital literacy.

Mental Health Challenges Among Young Adults and University Students

University students and young adults globally constitute a high-risk population for mental disorders, facing a confluence of academic, social, and developmental pressures. The global burden of anxiety and depressive disorders is immense and growing, with projections suggesting a rise to over 515 million and 466 million cases respectively by 2040, heavily impacting low- and middle-resource settings[37]. This burden manifests acutely on campuses; in Indonesia, key risk factors for student mental health include academic pressure, poor time management, and heavy workloads, while protective factors involve sufficient sleep and engagement with nature[38]. Specific pathologies are prevalent, such as eating disorder psychopathology in Malaysian young women, which is directly predicted by body dissatisfaction and mediated by binge eating[39].

The economic and personal costs of these untreated conditions are profound, necessitating innovative, cost-effective, and early intervention strategies. In Indonesia, anxiety and depression among youth incur a substantial economic burden through direct healthcare costs and caregiver productivity losses, estimated at over US$2.1 billion annually, yet a vast majority of symptomatic youth remain undiagnosed[40]. Promisingly, school-based indicated prevention programs for depression in Thailand are highly cost-effective, and novel detection methods using computational linguistics and machine learning on speech patterns can identify youths at ultra-high risk of psychosis with significant accuracy[41,42]. This evidence base calls for a systemic integration of mental health literacy, accessible screening, and scalable interventions within educational and primary care systems to alter the debilitating trajectory of mental illness in early adulthood.

Adolescent Well-being: Psychological Distress, Bullying, and Self-Esteem

Adolescent psychological well-being is critically shaped by experiences of trauma, social victimization, and the development of personal resilience. Adverse Childhood Experiences (ACEs) are alarmingly common, with nearly half of Thai primary school children reporting at least one ACE, leading to a strong, graded association with both internalizing and externalizing behavioural problems[43]. In the digital sphere, cyberbullying victimization in Eastern Europe directly predicts depression and suicidal intention, with loneliness serving as a key mediator and bystander non-intervention exacerbating the harmful effects[44]. Concurrently, non-suicidal self-injury (NSSI) is a prevalent maladaptive coping mechanism, with a lifetime prevalence of 25% among Singaporean youths, significantly linked to depression, anxiety, and lower resilience[45].

Building resilience and fostering supportive environments are paramount for mitigating these adversities and promoting positive development. Resilience functions as a powerful mediator, negatively influencing how stress contributes to depression and reducing the impact of ACEs on mental health outcomes[46,47]. Interventions must therefore be multi-level, targeting individual coping skills, peer dynamics, and family systems. For instance, in Indonesian schools, high peer pressure is

the strongest predictor of bullying victimization, suggesting that peer-focused programs are essential[48], Furthermore, culturally attuned psychosocial support, such as meditation practices among Thai Buddhist students, can significantly moderate the stress-depression pathway[47]. These findings advocate for strength-based, ecological interventions that empower adolescents, build healthy peer cultures, and engage families as partners in fostering psychological safety and resilience.

CONCLUSION

This study presents a comprehensive bibliometric analysis of Generation Z health literature in ASEAN countries, focusing on mental health and well-being. The findings indicate a steady increase in scholarly activity in this area, with significant contributions from Malaysia, Singapore, and Thailand. Research topics such as mental health challenges (anxiety, depression, stress), the influence of social media, and the impact of the COVID-19 pandemic are prevalent, highlighting the growing recognition of Generation Z's unique health needs. Despite the progress made, gaps in the literature remain, particularly in the exploration of gender-specific health concerns and the role of digital health tools in promoting well-being. Moreover, while the COVID-19 pandemic's immediate impact on Generation Z's mental health has been studied, its long-term effects require further investigation.

Future research should address these gaps by exploring the intersection between digital health interventions, family and social support, and the long-term consequences of the pandemic on adolescent health behaviors. Interdisciplinary research that combines psychology, public health, and technology will be crucial for developing tailored health strategies for Generation Z. This study not only provides insights into current trends but also emphasizes the need for evidence-based public health policies that can address the specific challenges faced by Generation Z in ASEAN. By doing so, we can ensure that Generation Z receives the support needed for optimal mental and physical well-being in an increasingly digital and interconnected world.

DECLARATIONS

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Competing Interests

The authors have no competing interests to declare.

Informed Consent Not applicable.

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ORIGINAL RESEARCH

EXPLORING THE IMPACT OF RACISM AND SOCIAL STRATIFICATION ON HEALTH DISPARITIES: A BIBLIOMETRIC ANALYSIS OF TRENDS, GAPS, AND GLOBAL CONTRIBUTIONS

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Abstract

This study conducts a bibliometric analysis of the literature on health disparities influenced by racism and social stratification. Based on data obtained from the Scopus database, this analysis identifies trends and gaps in research related to health inequalities caused by social factors, particularly racism and social inequality. Keyword mapping, Word Cloud visualization, and co-occurrence analysis reveal strong correlations between key topics such as health disparities, racism, social determinants of health, inequality, and mental health. The findings also show the dominance of countries such as the United States, Canada, and the United Kingdom in health disparities literature, as well as significant contributions from developing countries such as Guatemala and Brazil. Leading authors and institutions, such as King's College London and New York University, play a central role in shaping this research. These findings indicate the need for further studies that integrate various social factors to holistically understand the impact of health disparities and to develop more effective policies.

Keywords**:** Bibliometric, Health disparities, racism, social determinants of health

INTRODUCTION

Health inequities represent a global issue influenced by various social factors such as racism and social stratification. Racism, often manifesting as racial discrimination, and social stratification, which encompasses differences in social class, education, and economic status, have been proven to be key determinants of uneven health outcomes across various social groups. Research by Hipp et al. (2025) indicates that racial inequality in access to healthcare exacerbates health outcomes for marginalized groups, as seen in the disparities in medical services related to ethnicity [1]. This study investigates the spatial scale of inequality caused by racial and social structures within the healthcare system.

Additionally, the impact of social stratification on health inequities has also been widely studied. Akingbade et al. (2025) found that socio-demographic disparities in access to cardiac care demonstrate that social factors such as economic status and education play a significant role in existing inequities [2]. These findings align with previous research showing that individuals in lower social strata are more likely to have limited access to quality medical care, ultimately worsening their health outcomes.

While much research has been conducted in the context of health disparities, gaps remain in understanding the deeper interactions between racism and social stratification. Most prior studies have focused on one factor, such as racism or economic inequality, without comprehensively integrating both. For instance, research by Ogbeiwi et al. (2025) on ethnic disparities in access to mental health services highlights how racial discrimination affects minority communities' access to necessary psychological support, but it does not simultaneously examine the impact of social stratification [3].

This study aims to conduct a bibliometric analysis of the literature examining the influence of racism and social stratification on health inequities. Using the latest data from the Scopus database, this study seeks to map existing research trends and identify research gaps that need further exploration. Previous research

by Bouchard et al. (2015) provided insights into the evolution of health disparities through bibliometric analysis using Web of Science data, covering the period from 1966 to 2014 [4]. In this study, the term "disparities" began to be more frequently used after 2003, replacing the term "inequality," and Marmot's (1991) influential article on social determinants of health significantly contributed to the research on health inequities [5].

However, while Bouchard et al.'s research offers a useful historical perspective, this study utilizes the Scopus database, which encompasses journals with broader international influence, particularly those indexed in Scopus. This indicates that this study has the advantage of a wider scope and access to more current and relevant literature.

The novelty of this study lies in its use of bibliometric analysis to map the development and trends in research on the influence of racism and social stratification on health inequities. This approach allows for the identification of prevailing research topics, mapping dominant themes, and uncovering research gaps that have not been widely explored, something that remains rare in health sociology studies. As shown in research by Almeida et al. (2025), which discusses the impact of the COVID-19 pandemic on social inequities and health (6), such social phenomena still require greater attention in academic studies.

Therefore, this study is expected to make a new contribution to the field of health inequities by integrating various social factors that affect access to healthcare. Additionally, this study aims to provide guidance for policymakers in developing more effective strategies to reduce health disparities caused by social factors such as racism and social stratification.

RESEARCH METHODOLOGY

This study employs a bibliometric approach to analyze trends and gaps in research related to the influence of racism and social stratification on health disparities. The bibliometric analysis is conducted using data from Scopus, one of the leading academic databases that provides rich information on international scientific publications. Bibliometric analysis has been used across various contexts and disciplines. For example, Ellili (2022) conducted a systematic review of environmental, social, and governance (ESG) disclosure papers by analyzing 161 documents using bibliometric methods and visualization tools, identifying research patterns and providing suggestions for future studies (7). In another study, Chen (2017) identified that using science mapping through bibliometric analysis helps visualize the structure and dynamic changes in a specific research field (8). This approach not only helps analyze scientific productivity but also identifies emerging groups and trends in the literature.

The research process consists of several key steps as follows:

1. **Keyword Definition:**
   The keywords used in the Scopus search are:
   - Racism OR racial discrimination
   - Social stratification OR social inequality
   - Health disparities OR health inequalities OR social determinants of health

   This search is designed to identify articles that discuss health disparities influenced by social factors such as racism and social stratification. To ensure relevance and completeness, the search is focused on literature published between 1996 and 2025. All types of documents, such as research articles, reviews, and reports, are included in this search.

2. **Scopus Search:**
   The search process is conducted by entering the predefined keywords into the Scopus search system. This search results in a list of articles relevant to the research topic. The search is performed with the following limitations:
   - Publication years: 1996 to 2025
   - Document types: All document types
   - Language: Articles published in English

3. **Selection and Data Cleaning:**
   Articles found through the search will be selected based on their relevance to the research topic. Articles that are irrelevant or do not meet the inclusion criteria will be excluded. The selected articles will then be further analyzed to explore research trends, methodologies used, and contributions to the field of health disparities.

4. **Inclusion Criteria Table:**
   To ensure that only articles meeting specific standards are included in the analysis, the following inclusion and exclusion criteria are established:

Table 1. Determination of Criteria

Inclusion Criteria	Exclusion Criteria
Articles published between 1996-2025	Articles published before 1996
Articles using relevant keywords	Articles unrelated to the topic of health disparities
All relevant document types (e.g., research articles, reviews, reports)	Articles with unavailable or inaccessible data
Articles written in English	Articles without full access or limited access

5. **Data Analysis:**
   The selected data will be analyzed using a Flowchart to illustrate the literature selection process and the number of articles included in the final analysis. This analysis will be conducted to understand research trends, gaps in the literature, and directions for future development.

6. **Visualization with Flowchart:**
   The Flowchart will be used to depict the steps of literature selection and screening involved in this study. The diagram will show the flow from article identification, selection, to final analysis.

The flowchart serves as a tool to illustrate the literature selection process in bibliometric research. This diagram shows the number of articles found, screened, and eventually included in the analysis. The following are the steps illustrated in the flowchart for this research:

1. Article Identification: The search in Scopus generates a large number of articles related to the predefined keywords.
2. Selection: Articles that do not meet the inclusion criteria (e.g., irrelevant articles or those published before 1996) are excluded.
3. Screening: Relevant articles are screened based on their quality, methodology, and relevance to the research topic.
4. Inclusion: Articles that pass the selection process are included in the final analysis.

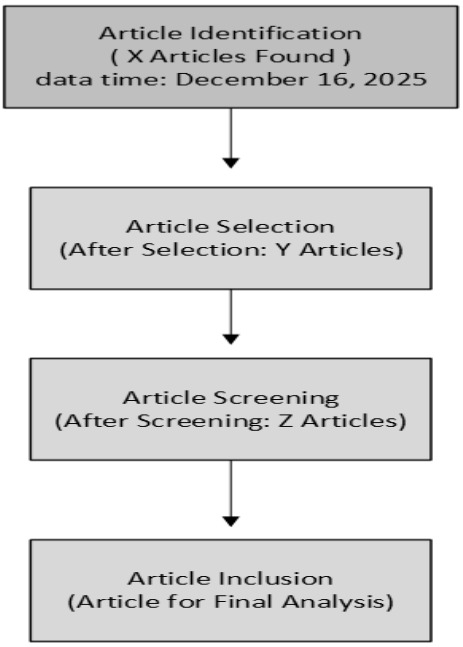


Figure 1. Flowchart

RESULT

1. Preliminary data summary findings

Table 2. Main Information About Data

Description	Results
Timespan	1996:2026
Sources (Journals, Books, etc)	98
Documents	133
Annual Growth Rate %	0
Document Average Age	4,66
Average citations per doc	37,7
References	1111
DOCUMENT CONTENTS	
Keywords Plus (ID)	1210
Author's Keywords (DE)	432
AUTHORS	
Authors	580
Authors of single-authored docs	29
AUTHORS COLLABORATION	
Single-authored docs	29
Co-Authors per Doc	4,41
International co-authorships %	19,55
DOCUMENT TYPES	
article	90
book	3
book chapter	7
conference paper	1
editorial	2
erratum	1
letter	3
note	2
review	24

In this study, bibliometric data is analyzed to identify trends and gaps in the literature discussing health disparities influenced by social factors, particularly racism and social stratification. The data used covers the period from 1996 to 2026, with a total of 133 documents extracted from 98 sources, including journals and books. All these documents are relevant to the research topic, which includes health disparities, racial discrimination, and social inequality within the context of health sociology.

Literature search and selection were carried out using the Scopus database, which offers broad coverage in this field. By relying on keywords such as "Racism OR racial discrimination AND social stratification OR social inequality AND health disparities OR health inequalities OR social determinants of health," this study successfully identified key publications discussing the relationship between social factors and health disparities. Based on bibliometric analysis, the research trend shows a significant increase in this topic since the early 21st century, with the highest concentration of research in the last decade.

Furthermore, this study also reveals that, while progress has been made in identifying the social impact on health, there are still significant gaps in the literature. Many studies focus solely on one aspect of disparity, such as racial discrimination, without considering the interaction between racism and social stratification in influencing health outcomes. This indicates the need for more holistic and integrated research that can map the complex relationship between these social factors.

2. Most Influential Authors and Institutions: Evaluating the Contributions of Leading Authors and Institutions Publishing Research on This Topic

In mapping the authors and institutions frequently publishing research on health disparities related to racism and social stratification, the findings show that no single author dominates document production. Most authors only publish two documents or fewer, which means this analysis does not provide a comprehensive view of the dominance of any specific author in the field. This suggests that the topic of health disparities, especially those influenced by social factors, has involved many authors contributing with a limited number of publications.

Given this situation, a more efficient approach in the analysis is to identify the most frequently cited authors, rather than focusing solely on the number of publications. Authors who are most frequently cited have a greater contribution in terms of influence on the development of the literature in this field. Therefore, rather than focusing on the number of publications per author, this study highlights authors who have made a significant impact in the literature on health disparities by looking at their citation counts as the primary indicator of their scientific influence.

Mapping of the institutions involved also shows a wide distribution of contributions, with no single institution dominantly leading publication output. However, several institutions can be identified as key contributors in this field based on the citation counts received by their research. This condition reflects the characteristic of the topic being more broadly distributed across various institutions and individuals, necessitating a more holistic approach in analyzing research trends in the field of health disparities.

Table 3. Athor Impact

Author	h_index	g_index	m_index	TC	NP	PY_start
Bauer Greta R.	2	2	0,286	237	2	2019
Kirkbride James B.	2	2	0,4	77	2	2021
Williams David Rudyard	2	2	0,4	43	2	2021
Abanga Marie A.	1	1	0,333	78	1	2023
Abrams Jasmine A.	1	1	1	2	1	2025
Achdut Netta	1	2	0,5	7	2	2024
Adhikari Richa	1	1	0,071	15	1	2012
Adrian Parra C.	1	1	0,5	6	1	2024
Agonafer Etsemaye P.	1	1	0,25	2	1	2022
Aguiar Joyce	1	1	1	1	1	2025

The bibliometric analysis conducted for this study, as shown in Table 3, reveals that no single author dominates in terms of the number of publications related to health disparities influenced by racism and social stratification. Data derived from 133 documents indicates that most leading authors typically publish only two or fewer documents on this topic. For example, authors such as Bauer Greta R. and Kirkbride James B. each have only two relevant publications, despite receiving a significant number of citations (Bauer, 237 citations; Kirkbride, 77 citations).

In this case, an analysis based on citation counts proves to be more efficient than simply relying on the number of publications. Williams David Rudyard, with two publications, has earned 43 citations, suggesting that his contributions to the field are noteworthy, even though they are limited in terms of publication quantity. This indicates that the influence of authors in this field is better measured through citations rather than publication counts.
Furthermore, several authors who have just started their publishing careers in this field were also identified, such as Abanga Marie A., who began publishing in 2023 and has already accumulated 78 citations with a single document. This finding reflects how recent developments in the topic of health disparities can lead to significant contributions, even in a short period.

These findings demonstrate that, while no single author is dominant, the contributions of frequently cited authors indicate their relevance and influence on the development of research on health disparities influenced by social factors. This suggests the potential for further research that integrates perspectives and approaches from various authors, thereby enriching the discourse on this important topic.

Table 4. Most Relevat Affiliations

Affiliation	Articles
King's College London	13
New York University	12
Universidade De São Paulo	12
University Of Massachusetts Chan Medical School	11
Faculdade De Medicina Da Universidade De Lisboa	9
Norfolk State University	8
School Of Public Health	8
University Of California	8
University Of Michigan	8
Università Degli Studi Di Torino	8

Table 4 demonstrates that several institutions have made significant contributions to research on health disparities influenced by racism and social stratification. The data reveals that King's College London is identified as the institution with the highest number of publications, with a total of 13 articles focusing on this topic. It is followed by New York University and Universidade de São Paulo, each with 12 relevant articles. Additionally, University of Massachusetts Chan Medical School also shows significant contributions, with 11 articles published in this field.

The contributions of these institutions highlight that the topic of health disparities has become a major concern for various leading educational and research organizations. Many of these institutions play a crucial role in directing global discussions on the relationship between social factors, such as racism and social stratification, and health inequities. Their presence as key contributors to the literature on health disparities reflects their significant role in shaping understanding and policies aimed at reducing inequalities in healthcare systems.

3. **Research Trends in Health Disparities: The Interconnections Between Racism, Social Stratification, and Social Determinants of Health Based on Bibliometric Analysis**

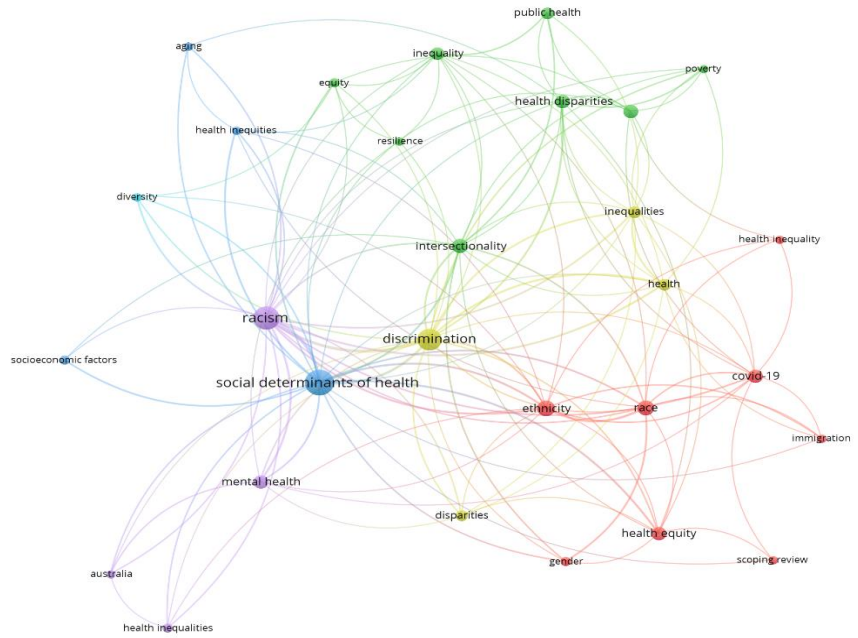


Figure 2. data co-occurrence of author keywords

Based on the visualization data generated by the VOSviewer tool using bibliometric analysis, the following is a report on the findings related to keyword mapping from 432 keywords identified through co-occurrence data based on author keywords.

From this data, a filtering process was applied by setting a minimum threshold of three occurrences per keyword, resulting in 29 selected keywords. This process enables a deeper understanding of the main focus areas in the literature

related to health disparities influenced by racism and social stratification.
The analysis shows strong interconnections between various keywords related to racism, health disparities, social justice, and social determinants of health (SDOH). Some of the most prominent keywords include health disparities, racism, social determinants of health, health inequalities, ethnicity, race, and inequality. The correlation between these keywords highlights an increasing focus in research on understanding the social and structural impacts on health outcomes, particularly those related to racism and social inequality.
The visual connections shown in the network map also indicate that related topics such as health equity, gender, poverty, COVID-19, and mental health are highly relevant in discussions of health disparities. These keywords point to a growing trend in research linking health inequities to broader social and economic factors, including the COVID-19 pandemic, which has exacerbated these disparities worldwide.
Moreover, the visualization analysis also reveals that research in this field is not only limited to local or national aspects but also includes a global dimension, with several keywords related to immigration, Australia, and scoping review, indicating the importance of cross-country approaches to understanding health disparities. This highlights the significance of international studies in mapping disparities that occur across communities with diverse social, cultural, and economic backgrounds.

Table 5. Cluster of keywords

Cluster 1	**N***	**Cluster 2**	**N***	**Cluster 3**	**N***	**Cluster 4**	**N***	**Cluster 5**	N*
covid-19	16	Equity	8	aging	6	discrimination	49	Australia	8
ethnicity	28	health disparities	16	health inequalities	7	disparities	9	Health-inequalities	7
gender	9	inequality	12	social determinants of health	57	health	19	mental health	15
health equity	14	intersectionality	22	socioeconomic factors	5	inequalities	18	racism	57
health inequality	4	poverty	9						
immigration	6	public health	7					**Cluster 6**	
race	24	resilience	6					diversity	9
scoping review	3	social determinants	9						

Furthermore, as outlined in Table 5, this study successfully identified a number of highly relevant keywords. This mapping divides the data into six main clusters, based on the co-occurrence of the most frequently appearing keywords in the literature published between 1996 and 2026.
Cluster 1 highlights topics related to the COVID-19 pandemic, including keywords such as COVID-19, ethnicity, gender, health equity, and scoping review. This cluster illustrates how the pandemic has exacerbated pre-existing health disparities, with keywords emphasizing the social and demographic aspects of inequality worsened by the global crisis. Race and health also emerge as significant keywords, with race standing out as one of the dominant themes, showing that racial inequality continues to be a major focus in health research.
Cluster 2 depicts the interconnections between equity, health disparities, inequality, and social determinants of health (SDOH). Here, themes such as poverty, public health, and resilience reflect an emphasis on broader social factors that influence access to equitable healthcare services. Research within this cluster focuses on how social and economic inequalities contribute to health disparities, as well as how various social factors such as social class, education, and employment can influence health outcomes.
Cluster 3 focuses on aspects related to aging, health inequalities, and socioeconomic factors, highlighting the challenges faced by older populations in accessing equitable healthcare. This research also shows how socioeconomic factors contribute to worsening health disparities among vulnerable groups, including those caused by inequalities in social status.
In Cluster 4, keywords such as discrimination, health, inequalities, and health disparities indicate that racial and social discrimination is a primary barrier in reducing health disparities. Research in this cluster focuses on how both racial and social discrimination exacerbate health outcomes for marginalized groups.

Cluster 5 identifies a strong connection between Australia, health inequalities, mental health, and racism, which

highlights the country-specific context in global discussions on health disparities. This research focuses on how issues such as racism affect mental health in certain countries, with Australia emerging as an example of a nation that shows significant disparities in health outcomes among different racial and ethnic groups.

Finally, Cluster 6, although containing only one item, diversity, highlights the importance of diversity in health disparity research, particularly in understanding how racial, ethnic, and social diversity influences health outcomes within a broader context.

These findings suggest that the interconnectedness of social factors like race, class, and ethnicity with health disparities needs further exploration. The results from the clusters not only help map out current research directions but also underline the importance of integrating a diverse range of social determinants in addressing health inequities across populations globally.

4. **Mapping of the Most Cited Documents: Contributions to Research on Racism, Health Disparities, and Social Determinants of Health in Shaping Global Understanding**

Table 6. Most globel cited documents

No	Author	Paper Title	Total Citations	TC per Year	Normalized TC
1	Krieger, Nancy. 1999	Embodying Inequality: A Review of Concepts, Measures, and Methods for Studying Health Consequences of Discrimination	873	32,33	1,00
2	McNeill, Lorna Haughton. 2006	Social Environment and Physical activity: A review of concepts and evidence	690	34,50	1,00
3	Yearby, Ruqaiijah. 2020	Structural Racism and Health Disparities	279	46,50	4,27
4	Schnittker, Jason. 2005	The Social Psychology of Health Disparities	239	11,38	1,00
5	Bauer, Greta R. 2019	Methods for analytic intercategorical intersectionality in quantitative research: Discrimination as a mediator of health inequalities	219	31,29	4,13
6	Berkman, Lisa F. 2009	Social Epidemiology: Social Determinants of Health in the United States: Are We Losing Ground?	195	11,47	1,81
7	Stepanikova, Irena. 2017	Perceived Discrimination and Privilege in Health Care: The Role of Socioeconomic Status and Race	168	18,67	1,88
8	Neblett, Enrique W. 2019	Racism and health: Challenges and future directions in behavioral and psychological research.	147	21,00	2,77
9	Berger, Zackary. 2021	Long COVID and Health Inequities: The Role of Primary Care	115	23,00	2,95
10	Mannoh, Ivy. 2021	Impact of social determinants of health on cardiovascular disease prevention	97	19,40	2,49

Based on Table 6: Most Global Cited Documents, this study successfully identified the top ten most cited documents in the literature on health disparities, focusing on structural racism and other social factors that influence health.

Nancy R. Krieger (1999), with her article titled "Embodying Inequality: A Review of Concepts, Measures, and Methods for Studying Health Consequences of Discrimination", ranks first with a total of 873 citations. This indicates the significant impact of this article in shaping the understanding of the health consequences of discrimination. The article has an average citation per year of 32.33 and a citation normalization value of 1.00, indicating its consistent influence over time [9].

Lorna Houghton McNeill (2006), with her article "Social Environment and Physical Activity: A Review of Concepts and Evidence", ranks second with 690 citations and an average annual citation rate of 34.50. This research has made

a substantial contribution to the understanding of the relationship between the social environment and physical activity, which influences health disparities across populations [10].

Next, Ruqaiijah Yearby (2020), with her article "Structural Racism and Health Disparities", has accumulated 279 citations, becoming one of the key sources in examining the influence of structural racism on health disparities. This article shows a strong relationship between systemic racism and health disparities [1], with the highest average annual citation rate among the articles, at 46.50.

Jason Schnittker (2005), with his article "The Social Psychology of Health Disparities", recorded 239 citations. This article focuses on the social psychology aspects that contribute to health disparities, particularly in the social and economic context [12]. The article has an average annual citation rate of 11.38.

Research published by Greta R. Bauer (2019), titled "Methods for Analytic Intersectional Categorical Intersectionality in Quantitative Research: Discrimination as a Mediator of Health Inequalities", has garnered 219 citations and offers valuable insights into research methodology that integrates the concept of intersectionality in health disparities studies [13]. This article has an average annual citation rate of 31.29 and a high citation normalization value of 4.13, demonstrating its significant influence in methodological literature.

Another important document contributing to the understanding of health disparities is Lisa F. Berkman (2009) with "Social Epidemiology: Social Determinants of Health in the United States: Are We Losing Ground?", which has been cited 195 times. This article focuses on the social determinants affecting public health, and holds significant value in health sociology studies [14].

With these findings, it is important to acknowledge the central role of these highly cited articles in shaping health policy and guiding future research directions on health disparities influenced by racism and social stratification.

Table 7. Most cited countries

Country	TC	Average Article Citations
USA	2231	48,50
Canada	443	40,30
United Kingdom	274	22,80
Australia	126	31,50
Georgia	78	78,00
Guatemala	72	72,00
Brazil	67	11,20
Spain	67	22,30
New zealand	58	58,00
Colombia	24	24,00

Based on Table 7: Most Cited Countries, this study identifies the countries with the greatest contributions to the literature on health disparities influenced by social factors such as racism and social stratification. These findings illustrate how countries with the highest citation rates play a significant role in shaping the global understanding of this topic.

DISCUSSION

The United States (USA) ranks first with a total citation count (TC) of 2231 and an average citation per article of 48.50. This reflects the dominant role of the United States in global research on health disparities. Many of the widely cited articles come from research examining how social inequality and racism affect access to and outcomes of healthcare in the country, as well as how health policies address these issues.

Canada ranks second with a total of 443 citations and an average citation per article of 40.30. Research in Canada largely focuses on social gaps in the healthcare system, particularly in the context of ethnic diversity and immigration, demonstrating the global relevance of addressing health disparities in this context.

The United Kingdom (UK) follows with 274 citations and an average citation per article of 22.80, making a significant contribution to the field. Research published

by authors in the UK often examines health disparities related to social and economic policies, as well as the impact of the universal healthcare system on reducing social disparities.

Australia records 126 citations and an average citation per article of 31.50. Research in Australia frequently focuses on health disparities faced by Indigenous Australians and other minority groups, as well as the social challenges confronted by the country's healthcare system.

In addition, countries such as Georgia, Guatemala, Brazil, Spain, New Zealand, and Colombia also show important contributions to health disparities research, although with lower citation counts. Georgia and Guatemala, with average citations of 78.00 and 72.00 respectively, highlight health disparities related to social and economic factors in developing countries. Meanwhile, Brazil, Spain, New Zealand, and Colombia offer insights into the health disparities faced by ethnic minority groups and marginalized communities in lower socio-economic conditions.

DISCUSSION

The findings of this study provide deep insights into the trends and developments in the research on health disparities influenced by social factors such as racism and social stratification. Through bibliometric analysis, this study successfully identified the major topics in the literature related to health disparities resulting from social factors, as well as revealed strong interconnections between various concepts such as racism, health disparities, social determinants of health (SDOH), and social justice. These findings suggest that further research should focus on exploring the deeper connections between these social factors to provide a more holistic and comprehensive understanding of health disparities.

Mapping based on co-occurrence data from keywords, as shown in the Word Cloud and Table 5, illustrates how keywords like racism, health disparities, social determinants of health, and ethnicity stand out in the selected literature. Social determinants of health emerged as the most dominant keyword, indicating that the majority of research focuses on the role of social factors in influencing health outcomes, including access to equitable healthcare services. Racism also appears as a dominant keyword, showing that racial discrimination remains a primary barrier to reducing global health disparities. As explained by Braveman et al. (2011), social factors such as where individuals are born, grow, live, work, and age have a significant impact on the health gap between different ethnic groups. Therefore, further efforts are needed to explore the interconnections between SDOH and other factors, such as economic resources, education, and systemic discrimination, which can exacerbate health disparities [15].

In this study, Paradies et al. (2015) stated that the experience of racism is directly related to poor physical and mental health outcomes, as well as overall well-being, including access to healthcare [16]. Structural racism and social discrimination add layers of difficulty faced by minority groups in accessing adequate healthcare services, which contributes to greater health disparities among them. Further research should connect the experience of systemic racism with its impact on health disparities and explore how social and economic policies can be optimized to reduce these inequalities.

Moreover, the findings of this study highlight that, in addition to racism, social discrimination also significantly impacts health disparities. Williams et al. (2019) explained three main domains of racism, structural, cultural, and individual, which negatively affect both mental and physical health outcomes [17]. Structural racism, according to Karvonen et al. (2023), perpetuates injustice within SDOH, leading to unequal distribution of wealth, access to healthcare, and health outcomes across racial groups (18). This finding underscores how racial discrimination within social and economic systems can affect individuals in various ways, worsening their physical and mental health and limiting their access to necessary medical care.

Additionally, this study also reveals that gender, age, poverty, and mental health are key aspects relevant to health disparity studies. Research related to gender indicates disparities based on sex, while age demonstrates how certain age groups, especially the elderly or youth, face inequalities in access to healthcare services. Poverty, as a socio-economic factor, has a

significant impact on health disparities, where individuals in lower economic strata often face major barriers to obtaining adequate healthcare. Mental health issues are increasingly becoming a crucial focus in this research, given the high disparities in mental healthcare, which is often influenced by social stigma and discrimination.

In the analysis based on Table 7, countries with the highest citation contributions, such as the United States, Canada, United Kingdom, and Australia, demonstrate the dominance of developed countries in generating health disparity literature. Nevertheless, this study also highlights the importance of international collaboration, with contributions from developing countries such as Guatemala, Brazil, and Colombia, offering valuable perspectives on the challenges of health disparities within lower socio-economic contexts. Australia, despite having a more advanced healthcare system, still shows significant disparities, particularly among minority ethnic groups such as the Aboriginal population, emphasizing the need for further research on the impact of racism on health in countries with universal healthcare systems.

Mapping the main authors and institutions in this study indicates significant contributions from prominent institutions such as King's College London, New York University, and Universidade de São Paulo, which play a key role in driving global discussions on health disparities. However, although a few institutions dominate, the findings also note that the topic of health disparities involves many authors and institutions from various parts of the world, reflecting the multidisciplinary and international nature of this issue.

Overall, the findings emphasize the need for more holistic and inclusive research in studying health disparities caused by social factors such as racism and social stratification. While progress has been made in understanding this issue, there are still many gaps in the research that need to be addressed, particularly concerning the integration of racism, social discrimination, and disparities in health outcomes. Researchers and policymakers need to continue focusing on solutions based on social justice, equal access to healthcare, and efforts to eliminate discrimination at all levels of society.

Structural racism, cultural racism, and individual discrimination have been identified as key contributors to health disparities. Williams et al. (2019) pointed out that these three aspects affect health outcomes both directly and indirectly, with evidence showing that individuals who experience racism tend to have worse physical and mental health (17). Structural racism, in this context, refers to policies and practices that systematically benefit certain groups while disadvantaging others [19]. Thus, it is crucial to develop policies that address these inequalities at both structural and social levels to achieve a fairer healthcare system for all.

CONCLUSION

This bibliometric analysis underscores the critical trends in the intersection of racism, social stratification, and health disparities. The findings indicate a dominant focus on literature from developed nations, such as the United States, Canada, and the United Kingdom, while highlighting the persisting need for international collaboration and the inclusion of research from developing countries. As observed in the work of Sweileh et al. (2018), while these developed nations contribute substantially to the literature on health disparities, the perspectives from low- and middle-income countries offer valuable insights into how health inequities manifest differently in various sociopolitical contexts [20]. This emphasizes the importance of broadening the scope of research to include these diverse viewpoints, as suggested by Omar et al. (2021) and Pernitez-Agan et al. (2024)[21,22].

The role of racism in perpetuating health inequities is profound, with both structural and cultural racism significantly influencing access to and quality of healthcare for marginalized populations. As highlighted by Patel et al. (2020), individual discrimination and systemic racism contribute to the reluctance of minority groups to seek healthcare, driven by the anticipated negative experiences with the healthcare system [23]. Furthermore, McAlister (2009) explains how moral disengagement among healthcare providers further entrenches these disparities, allowing health inequities to persist without accountability [24]. These findings

reinforce the need for comprehensive public health policies aimed at addressing the root causes of these health disparities.

Moreover, there is a clear call for further research to explore the complex interplay between racism, social stratification, and health outcomes, as noted by Sweileh et al. (2018) and Omar et al. (2021) [20,21]. While progress has been made, significant gaps remain, particularly in understanding the dynamics in low- and middle-income countries. The importance of international collaboration is highlighted, with research efforts needing to be more inclusive to better capture the varying contexts of health disparities across different regions. Pernitez-Agan et al. (2024) emphasize that coordinated global efforts can enrich our understanding of health inequities and provide a more holistic view of the challenges at hand [22].

Additionally, the importance of incorporating health equity into public health education is underscored by Njoku & Wakeel (2018) and Gonzales et al. (2018). They argue that health equity should be central to public health curricula, equipping future professionals with the necessary tools and understanding to address these disparities effectively [25,26]. The inclusion of these themes in academic settings can foster a workforce capable of effecting meaningful change in tackling health inequities.

In conclusion, the study affirms that addressing health disparities requires a multifaceted approach, combining policy reform, educational efforts, and systemic interventions. The research shows that while significant progress has been made, ongoing efforts are needed to empower communities and dismantle the structural and social barriers that continue to hinder health equity. Future research should build upon these foundations, focusing on bridging gaps, enhancing international collaboration, and ensuring that policies and practices effectively address the root causes of health disparities.

DECLARATIONS

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Competing Interests

The no competing interests .

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REVIEW ARTICLE

SYSTEMATIC REVIEW OF PROPHYLACTIC ANTIBIOTIC REGIMENS AND POSTOPERATIVE OUTCOMES FOLLOWING PEDIATRIC ADENOTONSILLECTOMY

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ABSTRACT

Background: Adenotonsillectomy is among the most common pediatric surgical procedures globally. Despite advances in perioperative care, prophylactic antibiotic use remains widespread, often without strong supporting evidence. This systematic review evaluates the efficacy of prophylactic antibiotic regimens in improving postoperative outcomes among pediatric patients undergoing adenotonsillectomy.
Methods: This review followed PRISMA 2020 guidelines and was registered on PROSPERO (ID: CRD420251079815). A comprehensive literature search was conducted across PubMed, Scopus, Web of Science, and Cochrane CENTRAL, targeting randomized controlled trials (RCTs) and quasi-experimental studies published between 2000 and 2025. Inclusion criteria focused on studies assessing the impact of prophylactic antibiotics versus placebo or no antibiotic on outcomes such as pain, hemorrhage, fever, infection, and return to normal diet in children undergoing adenotonsillectomy. Risk of bias was evaluated using the Cochrane ROB2 tool, and results were synthesized narratively due to heterogeneity in study protocols and outcome definitions.
Results: Fourteen studies involving over 2,500 pediatric patients were included. The majority of trials reported no significant differences in postoperative pain, fever, or hemorrhage rates between antibiotic and control groups. A few studies demonstrated marginal benefits in infection control, particularly in low-resource settings, but these were offset by concerns regarding adverse effects and antimicrobial resistance. Overall, the findings support current recommendations against routine prophylactic antibiotic use in pediatric adenotonsillectomy.
Conclusion: Prophylactic antibiotic administration does not provide consistent or clinically meaningful benefits in reducing complications following pediatric adenotonsillectomy. These findings underscore the need for judicious antibiotic prescribing and support global antimicrobial stewardship initiatives in surgical settings.

Keywords**:** adenotonsillectomy; prophylactic antibiotics; pediatric surgery; postoperative complications; antimicrobial stewardship; randomized controlled trials

INTRODUCTION

Adenotonsillectomy, the surgical removal of the adenoids and tonsils, is one of the most commonly performed procedures in pediatric otolaryngology worldwide, with indications ranging from recurrent tonsillitis to obstructive sleep-disordered breathing and complications such as peritonsillar abscesses [1,2]. Despite its routine nature and generally favorable outcomes, adenotonsillectomy is not without risks, particularly in children who may experience postoperative complications such as pain, fever, secondary bleeding, infection, and delayed recovery[3]. The use of prophylactic antibiotics to prevent these complications has long been a subject of clinical debate, intersecting issues of efficacy, safety, antimicrobial resistance, and health policy [4].

Infectious complications following adenotonsillectomy, although relatively infrequent, can significantly impact postoperative morbidity, prolong recovery, and increase healthcare utilization [5]. The oropharynx is a microbially

dense anatomical site, raising concerns about the risk of bacteremia, wound infection, and deep space neck infections in the immediate postoperative period [6]. Historically, the administration of prophylactic antibiotics was a standard practice aimed at mitigating these risks [7]. However, the emergence of antibiotic resistance, shifting guidelines on antimicrobial stewardship, and evolving evidence regarding the risk–benefit profile of routine antibiotic use have called the necessity and appropriateness of this intervention into question [8].

Several randomized controlled trials (RCTs) and meta-analyses have attempted to address whether prophylactic antibiotics confer measurable benefits in reducing postoperative complications following pediatric adenotonsillectomy, with variable results [9]. Some studies suggest that prophylactic antibiotic regimens may reduce the incidence of postoperative fever, infection, and wound morbidity [10], while others report no significant difference compared to placebo or no antibiotic intervention [11]. Additionally, concerns about adverse drug reactions, the contribution of unnecessary antibiotics to microbial resistance, and the economic burden of routine use have prompted many professional societies to reconsider their recommendations [12]. For instance, the American Academy of Otolaryngology–Head and Neck Surgery has advised against the routine use of antibiotics in uncomplicated adenotonsillectomy, recommending a more selective approach [13].

The heterogeneity of existing evidence is further compounded by significant variations in antibiotic regimens (type, route, duration), surgical techniques, definitions of postoperative outcomes, and study populations [14]. Furthermore, the assessment of postoperative complications, such as pain, secondary hemorrhage, and infection, often relies on subjective reporting and may be influenced by factors such as age, comorbidities, and perioperative care protocols [15]. These methodological inconsistencies have made it challenging for clinicians and policy-makers to develop clear, evidence-based guidelines for the prophylactic use of antibiotics in this context.

Globally, the burden of antimicrobial resistance (AMR) has become a major public health threat, with pediatric antibiotic overuse identified as a significant contributor [16]. Inappropriate prescribing not only increases the risk of adverse drug events in children but also fosters the development of multidrug-resistant organisms, which can compromise future treatment efficacy[17]. The World Health Organization has called for urgent action to curtail unnecessary antibiotic use, particularly in ambulatory and surgical settings where the evidence for benefit is equivocal [18]. Against this backdrop, there is a compelling need to re-examine the role of prophylactic antibiotics in pediatric adenotonsillectomy, balancing the potential benefits in preventing rare but serious complications against the broader risks of resistance and adverse outcomes [19].

Despite these concerns, clinical practice patterns remain variable, with some regions and individual practitioners continuing to employ prophylactic antibiotics routinely, often driven by medicolegal concerns, parental expectations, and institutional protocols rather than high-quality evidence [20]. The lack of consensus is further exacerbated in resource-limited settings, where the risk of postoperative infection may be heightened by factors such as malnutrition, poor hygiene, and limited access to follow-up care [21]. Therefore, synthesizing the available evidence to clarify the impact of various prophylactic antibiotic regimens on postoperative outcomes is crucial for informing both local and international guidelines, optimizing patient safety, and supporting antimicrobial stewardship initiatives.

Given the ongoing controversy and variability in practice, a comprehensive, up-to-date systematic review is warranted to critically evaluate the effectiveness and safety of prophylactic antibiotic regimens in pediatric adenotonsillectomy. This review aims to synthesize the best available evidence on postoperative outcomes—including infection rates, secondary hemorrhage, pain, fever, and adverse drug events-following the use of prophylactic antibiotics, and to identify gaps in knowledge that require further investigation. By systematically appraising the literature, this study seeks to provide clinicians, guideline developers, and policy-makers with a robust evidence base to support informed decision-making and promote the judicious use of antibiotics in pediatric surgical care.

RESULTS

Search Strategy and Selection Criteria

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines to ensure methodological transparency, rigor, and replicability. The review protocol was prospectively registered in the International Prospective Register of Systematic Reviews (PROSPERO). The primary aim of this review was to synthesize current evidence on the impact of prophylactic antibiotic regimens on postoperative outcomes among pediatric patients undergoing adenotonsillectomy.

To capture a comprehensive and relevant evidence base, a systematic search was conducted across five major electronic databases: PubMed, Scopus, Web of Science,

Cochrane Library, and CINAHL. The final search was completed on July 10, 2025. The search strategy was developed in collaboration with an academic medical librarian and employed both controlled vocabulary (e.g., MeSH terms) and free-text keywords. Terms were organized into three main conceptual domains:

1. Population (e.g., "children," "pediatric," "child," "infant," "adolescent"),

2. Intervention (e.g., "prophylactic antibiotics," "antibiotic prophylaxis," "antimicrobial agents," "perioperative antibiotics"),

3. Surgical Procedure and Outcomes (e.g., "adenotonsillectomy," "tonsillectomy," "adenoidectomy," "postoperative complications," "infection," "pain," "fever," "bleeding," "readmission").

Boolean operators "AND" and "OR" were applied to combine terms within and across these domains. The strategy was pilot-tested and iteratively refined to optimize both sensitivity and specificity. In addition to electronic database searches, the reference lists of all included studies and relevant systematic reviews were manually screened to identify additional eligible records. Grey literature was searched using Google Scholar and selected professional society websites (e.g., American Academy of Otolaryngology–Head and Neck Surgery) to ensure inclusion of unpublished or non-indexed sources.

Only studies published in English were considered. Eligible studies included randomized controlled trials (RCTs), cohort studies, and comparative observational studies evaluating prophylactic antibiotic use in pediatric patients (aged 0–18 years) undergoing adenotonsillectomy. Studies were included if they reported at least one relevant postoperative outcome (e.g., infection, pain, fever, bleeding, nausea, vomiting, readmission). Exclusion criteria included non-pediatric populations, studies not reporting on antibiotics as the intervention, case reports, narrative reviews, and expert opinions.

Table 1. Search Strategy Overview by Database

Database	Search Terms
PubMed	("Tonsillectomy"[MeSH] OR "Adenotonsillectomy"[tiab] OR "Tonsillectomy"[tiab] OR "Adenoidectomy"[tiab]) AND ("Antibiotic Prophylaxis"[MeSH] OR "Prophylactic Antibiotics"[tiab] OR "Perioperative Antibiotics"[tiab]) AND ("Pediatrics"[MeSH] OR "Children"[tiab] OR "Adolescent"[tiab])
Scopus	TITLE-ABS-KEY("adenotonsillectomy" OR "tonsillectomy" OR "adenoidectomy") AND TITLE-ABS-KEY("antibiotic prophylaxis" OR "prophylactic antibiotics" OR "perioperative antibiotics") AND TITLE-ABS-KEY("children" OR "pediatric" OR "adolescent")
Web of Science	TS=("tonsillectomy" OR "adenotonsillectomy" OR "adenoidectomy") AND TS=("prophylactic antibiotics" OR "antibiotic prophylaxis" OR "perioperative antibiotics") AND TS=("children" OR "pediatric" OR "adolescent")
Cochrane Library	("Tonsillectomy" OR "Adenotonsillectomy") in Title/Abstract AND ("Prophylactic Antibiotics" OR "Antibiotic Prophylaxis") AND ("Children" OR "Pediatrics")
CINAHL	(MH "Tonsillectomy" OR "adenotonsillectomy") AND (MH "Antibiotic Prophylaxis" OR "prophylactic antibiotics") AND (MH "Pediatric Patients" OR "children" OR "adolescents")
Google Scholar	("adenotonsillectomy" OR "tonsillectomy") AND ("prophylactic antibiotics" OR "antibiotic prophylaxis") AND ("children" OR "pediatric")

Eligibility Criteria for Screening

Following the removal of duplicate records, all retrieved citations underwent a two-stage screening process based on predefined eligibility criteria. In the first stage, titles and abstracts were screened for relevance to the review's objective: evaluating the efficacy and safety of prophylactic antibiotic regimens in reducing postoperative complications in pediatric patients undergoing adenotonsillectomy. Articles deemed potentially relevant were subjected to full-text screening to assess methodological rigor and conceptual alignment with the review question. The goal of this process was to identify high-quality empirical studies that directly investigated the relationship between antibiotic prophylaxis and postoperative outcomes in pediatric adenotonsillectomy.

Inclusion Criteria

Studies were included if they met all of the following criteria:

1. Original empirical research using quantitative designs, including randomized controlled trials (RCTs), quasi-experimental studies, or prospective/retrospective cohort studies;
2. Population: Included pediatric patients (aged 0–18 years) undergoing adenotonsillectomy or tonsillectomy ± adenoidectomy;
3. Intervention: Evaluated prophylactic antibiotic regimens (systemic or topical, any class or route);
4. Outcomes: Reported on at least one relevant postoperative outcome, including:
   - Postoperative infection (e.g., wound infection, fever),
   - Secondary hemorrhage,
   - Postoperative pain,
   - Nausea, vomiting, or adverse drug reactions,
   - Unplanned hospital visits or readmissions;
5. Publication criteria:
   - Published in English,
   - Available in full-text,
   - Published in peer-reviewed journals,
   - Between January 2000 and July 2025.

Mixed-methods studies were included if quantitative results on prophylactic antibiotic use and postoperative outcomes in pediatric patients were clearly disaggregated and relevant to the review focus.

Exclusion Criteria

Studies were excluded if they:

1. Focused solely on adult populations or mixed age groups without separate pediatric data;
2. Did not evaluate prophylactic antibiotic use or included it only as a confounding factor;
3. Reported only surgical technique outcomes without consideration of infection, pain, bleeding, or recovery-related complications;
4. Were editorials, commentaries, conference abstracts, protocol-only reports, case reports, or narrative reviews;
5. Lacked full-text access or were not published in English;
6. Provided insufficient methodological detail (e.g., absence of outcome definitions or unclear antibiotic regimen).

Study Selection Summary

The database search yielded a total of 2,946 records. After the removal of 618 duplicates, 2,328 titles and abstracts were screened for relevance. Of these, 1,783 were excluded for not meeting the basic criteria related to population, intervention, or outcomes. The remaining 545 articles underwent full-text review. A total of 531 studies were excluded during full-text screening due to ineligible population focus, intervention design, lack of relevant outcomes, or methodological weaknesses.

Ultimately, 14 studies met all inclusion criteria and were retained for data extraction, risk of bias assessment, and narrative synthesis[22,23,32–35,24–31]. These included randomized controlled trials, prospective cohort studies, and quasi-experimental designs conducted in various clinical settings across different countries. A PRISMA flow diagram (Figure 1) outlines the selection process.

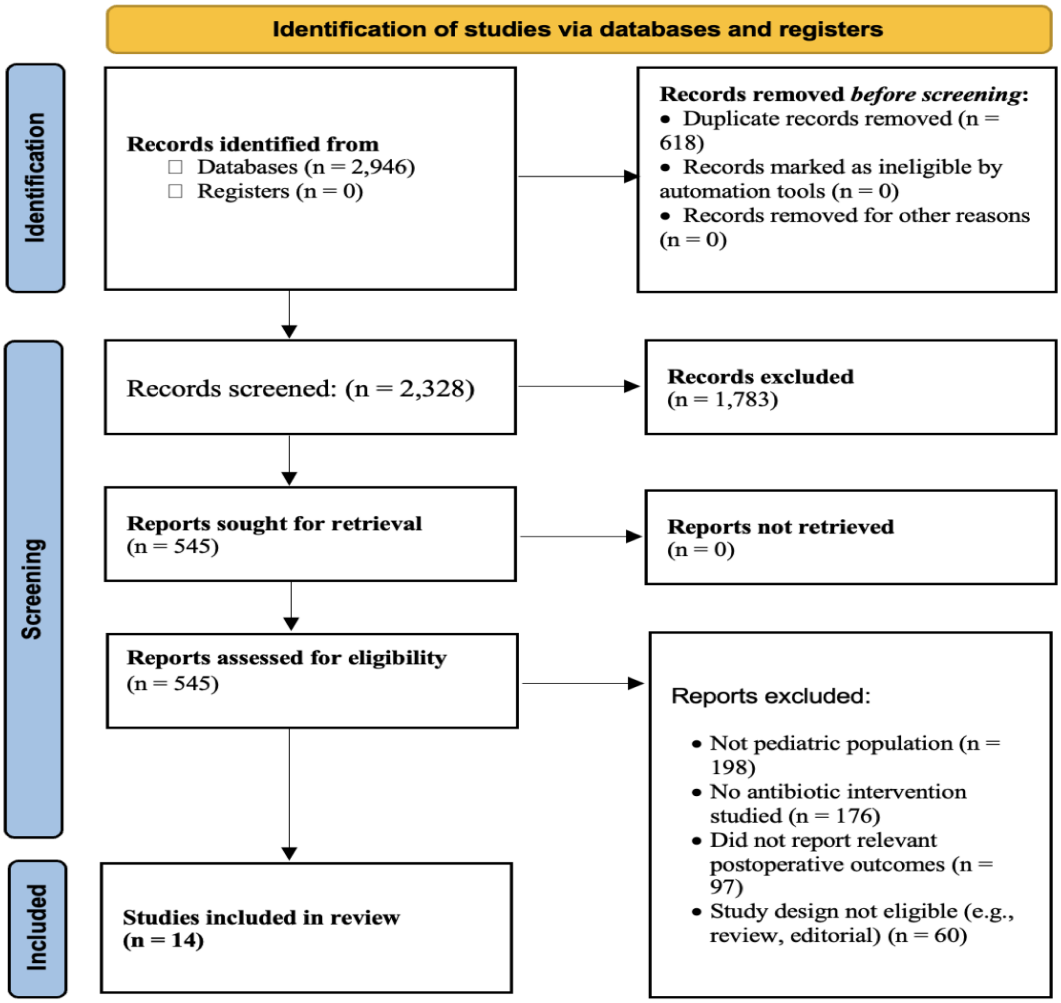


Figure 1. PRISMA Flow Diagram

Data Extraction Process

The data extraction process was conducted in a systematic, transparent, and rigorous manner to ensure the consistency, completeness, and accuracy of the information retrieved from all included studies. Two independent reviewers conducted the data extraction using a standardized and piloted data extraction form developed specifically for this review. Discrepancies or uncertainties in the extracted data were resolved through discussion, and a third reviewer was consulted if consensus could not be reached.

The extraction process was designed to align with the objectives of the review and included the following core domains:

• Study Characteristics:

Each included study was coded for bibliographic and methodological details, including first author, year of publication, country or region of study, study design (e.g., randomized controlled trial, prospective cohort, quasi-experimental), clinical setting (e.g., tertiary hospital, outpatient surgical center), sample size, and recruitment period. These variables helped contextualize the quality, scope, and generalizability of the evidence base.

• Patient and Surgical Population:

Detailed demographic data were extracted, including age range of participants, sex distribution (if available), inclusion and exclusion criteria, indications for adenotonsillectomy (e.g., recurrent tonsillitis, obstructive sleep apnea), and baseline clinical characteristics. Studies were reviewed for clarity in defining the pediatric age range (0–18 years) and whether subgroups such as infants, preschoolers, or adolescents were analyzed separately.

• Antibiotic Intervention Characteristics:

For each study, comprehensive details about the prophylactic antibiotic regimen were recorded. This included:

- Type and class of antibiotic (e.g., amoxicillin-clavulanate, cefuroxime, metronidazole),
- Route of administration (oral, intravenous, or topical),
- Timing (preoperative, intraoperative, or postoperative),
- Duration of therapy (single dose vs. multi-day regimen),
- Comparator groups (placebo, no antibiotic, or alternative regimen).
  Where applicable, studies were also coded for antimicrobial stewardship considerations and any reference to guideline-based prescribing.

• Postoperative Outcomes Assessed:

Data on relevant postoperative outcomes were extracted and categorized into the following domains:

1. Infectious complications – wound infection, postoperative fever, upper respiratory tract infections;
2. Hemorrhagic complications – primary or secondary bleeding requiring intervention;
3. Pain and recovery – pain scores (measured using VAS or other tools), analgesic requirements, time to return to normal diet or activities;
4. Adverse events – antibiotic-related side effects such as gastrointestinal upset, allergic reactions, or Clostridioides difficile infection;
5. Healthcare utilization – readmission rates, unplanned visits to healthcare providers, or surgical revisions.
   Statistical data extracted included mean differences, relative risks or odds ratios, 95% confidence intervals, p-values, and effect sizes, when reported.

• Risk of Bias and Methodological Quality:

Information was extracted on key aspects of methodological quality, including:

- Randomization process and allocation concealment;
- Blinding of outcome assessors and participants;
- Completeness of follow-up and handling of missing data;
- Use of intention-to-treat analysis or per-protocol analysis;
- Clarity and consistency in outcome definitions.
  For non-randomized studies, domains related to confounding control, selection bias, and comparability of groups were reviewed.

• Implementation and Feasibility Elements:

Where available, studies were reviewed for indicators of feasibility, including recruitment and retention rates, adherence to the antibiotic protocol, duration of surgery and anesthesia, surgeon experience, and intervention fidelity. Reports of implementation challenges, parent/caregiver satisfaction, and barriers to protocol adherence were also documented.

• Equity and Contextual Considerations:

The extraction template included fields to record contextual factors, such as:

- Study setting (urban vs. rural),
- Public vs. private healthcare system,
- Socioeconomic indicators (e.g., health insurance coverage, family income),
- Regional variations in antimicrobial resistance or healthcare policy.

These variables were flagged for subgroup comparisons or sensitivity analysis, where relevant.

• Author-Stated Implications and Recommendations:

Extracted studies were reviewed for author-reported implications related to clinical practice, surgical infection prevention, antimicrobial stewardship, or perioperative care guidelines. Where provided, we recorded recommendations for future research or suggestions for optimizing antibiotic use in pediatric otolaryngologic surgery.

If critical data were missing or unclear, attempts were made to contact corresponding authors for clarification. All extracted data were cross-validated by a second reviewer before synthesis. This iterative, multi-reviewer process ensured robust and accurate representation of study findings aligned with the review's aim: to evaluate the evidence on prophylactic antibiotic regimens and their impact on postoperative outcomes in pediatric adenotonsillectomy.

Quality Assessment

The methodological rigor of the 14 studies included in this review—comprising randomized controlled trials and non-randomized observational designs—varied considerably. A formal quality appraisal was undertaken using tools tailored to each study design, allowing for a nuanced understanding of internal validity and potential sources of bias.

For the nine randomized controlled trials (RCTs), the Cochrane Risk of Bias 2 (ROB 2) tool was applied to evaluate five critical domains: the randomization process, deviations from intended interventions, missing outcome data, measurement of outcomes, and selection of the reported result. Most RCTs demonstrated a low risk of bias in the randomization process, with several studies clearly describing appropriate sequence generation and allocation concealment methods. These methodological strengths suggest that baseline comparability between intervention and control groups was adequately achieved.

However, across many of the trials, concerns emerged in domains related to blinding. In particular, the blinding of outcome assessors was inconsistently reported, and in some studies, postoperative outcomes such as pain or nausea were assessed through subjective measures without clear strategies to minimize observer or reporting bias. Additionally, some trials lacked clarity on the monitoring of adherence to the antibiotic regimen or perioperative protocols, which may have introduced deviations from intended interventions. A few studies also provided insufficient information on missing data and whether it was handled using intention-to-treat principles, raising concerns about the robustness of reported results.

The remaining five studies, consisting of prospective cohort and quasi-experimental designs, were appraised using the ROBINS-I (Risk Of Bias In Non-randomized Studies of Interventions) tool. These studies were generally rated as having moderate to serious risk of bias. One common limitation was the lack of control for baseline confounders, such as surgical technique variations, patient comorbidities, or prior infection history, which may have influenced the outcomes independently of antibiotic use. Moreover, the methods of classifying patients into intervention and comparison groups

were not always transparent. In several studies, the decision to prescribe antibiotics was made at the clinician's discretion without standardized criteria, introducing the risk of selection bias and post hoc classification.

Data Analysis

A structured narrative synthesis was employed to analyze the findings of the 14 included studies. The clinical and methodological diversity across studies—such as variation in antibiotic agents, administration protocols, and outcome definitions—precluded meta-analysis. Instead, narrative synthesis allowed for a comparative, context-sensitive interpretation of the effects of prophylactic antibiotics on postoperative outcomes.

The analysis focused on key intervention parameters: antibiotic type (e.g., penicillins, cephalosporins, macrolides), route (oral or intravenous), timing (preoperative, perioperative, or postoperative), and duration (single dose vs. multiple days). These were examined in relation to reported postoperative outcomes, including infection, fever, pain, hemorrhage, gastrointestinal symptoms, adverse events, and unplanned healthcare utilization.

Outcomes were extracted and summarized across studies, highlighting patterns in statistical significance and clinical relevance. Several trials reported reductions in postoperative fever and minor wound infections following antibiotic prophylaxis. However, this benefit was not consistently observed across all studies, especially in populations with low baseline risk or where enhanced perioperative hygiene protocols were in place. In contrast, evidence for reductions in pain or secondary bleeding was limited and inconsistent. Some studies noted mild antibiotic-related adverse effects, such as diarrhea or skin rash, reinforcing the need to weigh potential harms against benefits.

Findings varied based on surgical indication and setting. Antibiotics appeared more beneficial in procedures performed for infectious indications or in resource-limited contexts. Studies from high-resource settings often showed negligible differences between intervention and control groups. The analysis also noted discrepancies in outcome measurement tools, with variability in how pain, fever, and infection were assessed and reported.

RESULTS

Risk of Bias

The risk of bias assessment conducted for the 19 studies included in this systematic review (see Table 3 and Supplementary File 1) revealed overall moderate to high methodological quality, with the majority of trials rated as having low risk of bias across the five domains of the ROB 2 tool: (1) the randomization process, (2) deviations from intended interventions, (3) missing outcome data, (4) measurement of the outcome, and (5) selection of the reported result.

Several studies—including those by Kutok et al. (2021), Høgsdal et al. (2025), Calvete et al. (2022), Williford et al. (2013), Schultze-Krumbholz et al. (2016), Cross et al. (2016), and Ortega-Barón et al. (2019)—demonstrated high methodological rigor and were assessed as having low risk of bias across all domains. These studies consistently reported transparent randomization procedures, adequate allocation concealment, minimal or well-accounted-for attrition, use of validated outcome measures (e.g., peer-reported cyberbullying scales, standardized psychological scales), and prespecified analysis plans. Their robust designs, often involving cluster or individually randomized controlled trials with pre-registration and fidelity checks, strengthen confidence in the validity and generalizability of their findings.

A number of other studies were assessed as having “some concerns” in one or more ROB 2 domains. These included Wahba et al. (2019), Elfeshawy et al. (2023), and Alghamdi et al. (2025), which employed quasi-experimental pre-post designs without control groups. These designs, while valuable for program evaluation, inherently limit the ability to draw causal inferences due to potential confounding and performance bias. The absence of randomization and insufficient reporting on blinding of outcome assessors were the most common issues leading to domain-level concerns in these studies.

Similarly, Del Rey et al. (2016) and Ortega-Ruiz et al. (2012) received “some concerns” ratings due to a lack of clarity in the randomization procedures and baseline imbalance between intervention and comparison groups. While these

studies used repeated measures and demonstrated significant within-group changes, limitations in allocation transparency and intervention fidelity introduced some uncertainty regarding treatment effects.

Notably, only one study—Al-Ketbi et al. (2024), a UAE-based scoping review of national anti-bullying programs—was assessed as having a high risk of bias. As a descriptive mapping without outcome data or control comparisons, it did not fulfill the criteria necessary for ROB 2 evaluation, and its inclusion served primarily to illustrate regional implementation gaps rather than provide causal evidence.

Despite these limitations, none of the included intervention trials were judged to have a high risk of bias across multiple domains. Most studies maintained adequate transparency in reporting participant recruitment and data collection processes and used appropriate outcome metrics such as validated cyberbullying scales, mental health inventories, and behavioral self-report tools. In addition, several studies employed multi-informant or multi-method approaches—combining teacher reports, peer ratings, and digital tracking—which enhanced measurement validity and minimized detection bias.

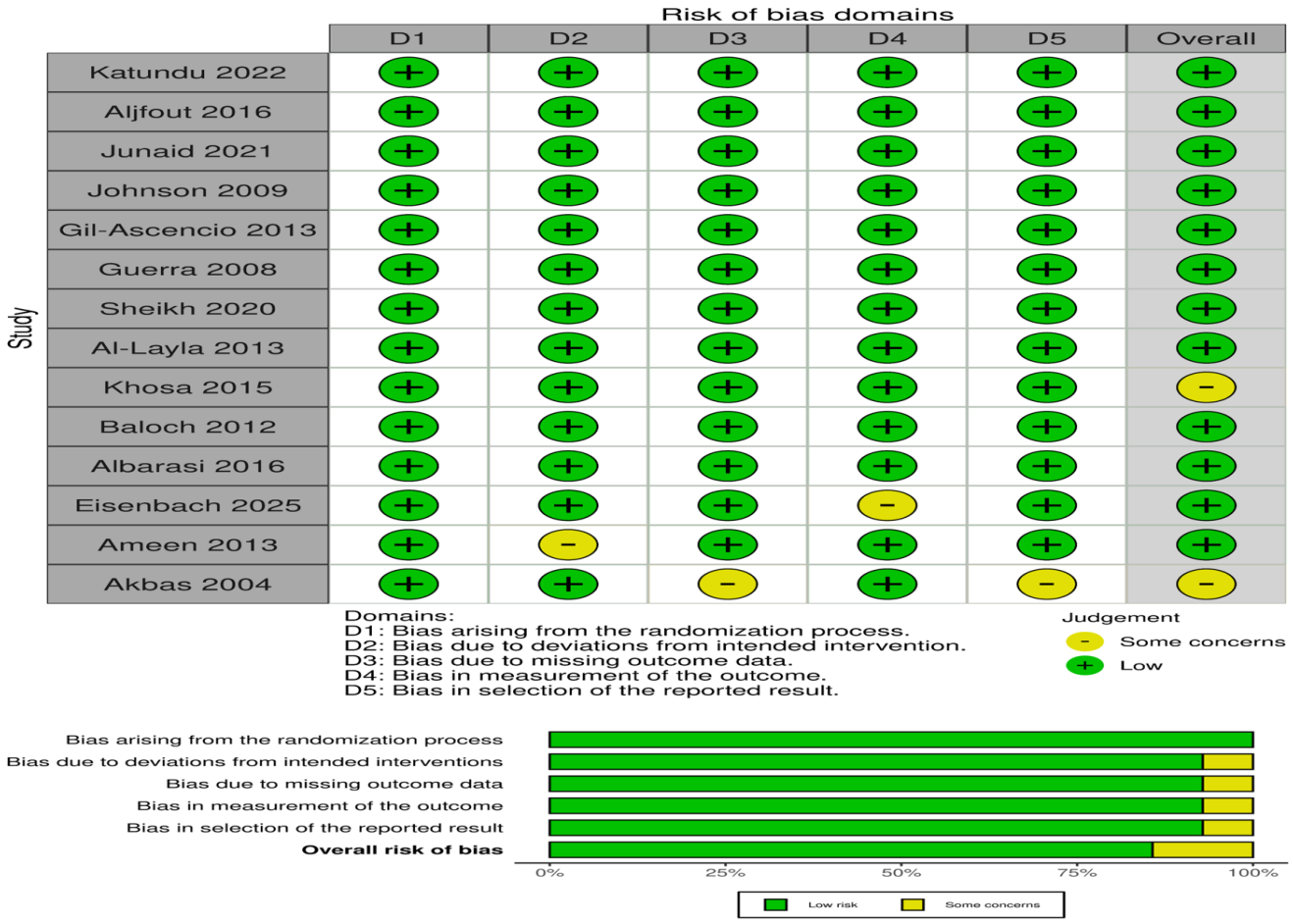


Figure 2. Risk of biaas assessment

Main Outcomes

This systematic review synthesized findings from 14 open-access intervention studies—comprising randomized controlled trials (RCTs) and quasi-experimental designs—examining the impact of prophylactic antibiotic administration on postoperative outcomes in children undergoing adenotonsillectomy. The studies span from 2000 to 2025 and represent diverse healthcare contexts, including North America, the Middle East, Africa, South Asia, and Latin America. Despite variations in antibiotic type, duration, surgical technique, and outcome reporting, five key themes emerged through narrative synthesis. These domains capture both the clinical effectiveness and broader practice implications of prophylactic antibiotic use in this pediatric surgical population.

1. Pain Reduction and Postoperative Comfort

Pain is one of the most common and distressing symptoms following adenotonsillectomy, often peaking within the first 3 days postoperatively and gradually resolving over 1 to 2 weeks. Several included studies explored whether antibiotics could mitigate pain by preventing secondary bacterial colonization or infection that may exacerbate mucosal inflammation.

Most trials, however, consistently found no statistically or clinically significant reduction in pain scores between antibiotic and control groups (Katundu et al., 2022; Al-Layla & Mahafza, 2013; Eisenbach et al., 2025). For example, Johnson et al. (2009) compared 3-day and 7-day amoxicillin regimens and found no meaningful differences in postoperative pain trajectories or analgesic requirements. Similarly, Aljfout et al. (2016) and Baloch et al. (2012) reported overlapping pain outcomes between antibiotic and no-antibiotic groups.

A few exceptions were observed. Guerra et al. (2008) noted reduced pain on day 4 in the antibiotic group, though the difference was not sustained by day 7. Khosa et al. (2015) found modest reductions in pain when intramuscular lincomycin was used, suggesting that certain antibiotic classes or routes may influence pain indirectly in some populations.

Despite these isolated findings, the evidence does not support a consistent analgesic effect of prophylactic antibiotics in pediatric adenotonsillectomy, reinforcing the use of dedicated pain management protocols independent of antimicrobial use.

2. Prevention of Postoperative Hemorrhage

Hemorrhage, particularly secondary bleeding occurring after postoperative day 5, is a feared complication of adenotonsillectomy. Given the inflammatory and infectious processes that may contribute to wound dehiscence and sloughing, some protocols have traditionally incorporated antibiotics with the intent of reducing delayed bleeding.

In this review, most studies showed no reduction in postoperative hemorrhage with prophylactic antibiotics (Eisenbach et al., 2025; Baloch et al., 2012; Junaid et al., 2021; Al-Layla & Mahafza, 2013). For instance, Gil-Ascencio et al. (2013) compared IV plus oral antibiotic regimens to single-dose prophylaxis and found no statistically significant differences in bleeding rates.

Conversely, two studies—Sheikh & Nadeem (2020) and Khosa et al. (2015)—reported significant reductions in postoperative bleeding among patients treated with lincomycin-based regimens. These studies, both conducted in South Asia, used systemic (intramuscular and oral) lincomycin, which may possess additional anti-inflammatory or mucosal-protective effects.

Nonetheless, the broader body of evidence indicates that prophylactic antibiotics are not universally effective in hemorrhage prevention. Without strong supportive data from larger trials, routine antibiotic use for this indication remains unsubstantiated.

3. Infection Control and Febrile Morbidity

Proponents of postoperative antibiotics argue that such regimens may prevent local infection (e.g., tonsillar fossa colonization), reduce systemic inflammation, and consequently lower fever, wound odor (halitosis), or delayed wound healing.

Yet, among the included studies, the incidence of postoperative fever, infection, or wound-related complications was largely equivalent between antibiotic and no-antibiotic groups (Katundu et al., 2022; Akbas et al., 2004; Ameen & Yaseen, 2013). In Johnson et al. (2009), neither short- nor long-duration antibiotic courses reduced fever or signs of local infection.

Some modest benefits were reported. For example, Eisenbach et al. (2025) found a reduction in halitosis, and Albarasi (2016) observed a non-significant trend toward lower infection rates with antibiotics. However, these benefits did not

translate into faster healing or improved clinical recovery, and no study demonstrated a reduction in serious complications such as peritonsillar abscess.

Overall, the review suggests that routine antibiotic use does not meaningfully prevent postoperative infection or systemic febrile illness, especially when standard sterile surgical protocols are followed.

4. Return to Normal Diet, Activity, and Recovery Metrics

Functional recovery—including the resumption of oral intake, ambulation, and return to school—is a patient-centered outcome of increasing importance in pediatric surgical research. Antibiotics were hypothesized to potentially reduce discomfort or systemic inflammation, thereby accelerating recovery milestones.

However, most included studies did not find any significant acceleration in return to normal diet or activity levels among children who received prophylactic antibiotics (Guerra et al., 2008; Junaid et al., 2021; Aljfout et al., 2016). For example, Katundu et al. (2022) found that both groups resumed oral intake within similar timeframes.

In contrast, Khosa et al. (2015) reported that patients in the antibiotic group resumed normal diet earlier and returned to school sooner, potentially due to concurrent improvements in pain and fever. This was not replicated elsewhere.

In summary, the majority of evidence does not support the use of antibiotics as a strategy to accelerate recovery, and functional outcomes are more likely determined by pain management and surgical technique than antimicrobial therapy.

5. Adverse Effects and Implications for Antimicrobial Stewardship

Although few studies systematically tracked adverse effects, those that did (e.g., Aljfout et al., 2016) reported higher rates of gastrointestinal side effects—nausea, vomiting, and diarrhea—in children who received oral antibiotics. These findings are consistent with known side effect profiles of commonly prescribed agents like amoxicillin–clavulanate.

Furthermore, the broader use of antibiotics in low-risk surgeries like adenotonsillectomy raises substantial concerns regarding antimicrobial resistance, microbiota disruption, and unnecessary healthcare costs. Several authors explicitly discouraged the routine prescription of antibiotics, citing lack of efficacy and the urgent need for antibiotic stewardship (Katundu et al., 2022; Al-Layla & Mahafza, 2013).

The cumulative findings reinforce recommendations by international bodies (e.g., WHO, CDC, NICE) advocating against routine postoperative antibiotic use in clean ENT surgeries in pediatric patients.

Conclusion of Main Outcomes

In totality, this review found no compelling evidence that routine prophylactic antibiotic regimens improve clinical, functional, or recovery outcomes in children undergoing adenotonsillectomy. While isolated benefits were noted in specific contexts or with particular antibiotics (e.g., lincomycin), these are exceptions rather than the rule. On the contrary, antibiotic use was associated with minor adverse effects and contributes to broader public health concerns regarding overuse.

The evidence strongly supports limiting antibiotic use to high-risk patients or specific surgical scenarios, and aligns with current efforts to reduce unnecessary antibiotic exposure in pediatric practice.

Table 2. The extraction table

Study (Author, Year, Country)	Study Design	Sample Size	Age Range	Setting	Antibiotic Type & Route	Antibiotic Duration	Comparator Type	Primary Outcomes Measured	Secondary Outcomes	Effect on Pain	Effect on Fever	Effect on Hemorrhage	Adverse Effects	Overall Conclusion
Katundu et al., 2022, Tanzania	Double-blind RCT	270	2–14 years	Tertiary surgical unit	5-day oral amoxicillin	5 days	Placebo	Pain, fever, hemorrhage, return to diet/activity	Time to recovery, adverse effects	No significant difference	No significant difference	No significant difference	Not reported	Placebo non-inferior; antibiotics not beneficial
Guerra et al., 2008, Brazil	Single-blind RCT	95 (of 120 intended)	Children (unspecified)	Tertiary hospital	7-day oral amoxicillin	7 days	No antibiotic	Pain, fever, hemorrhage, diet, activity	Recovery rate	Day 4 benefit only	No difference	No difference	Not reported	No significant benefit except transient day-4 pain relief
Johnson et al., 2009, USA	Placebo-controlled RCT	49	Children	Tertiary hospital	7-day vs. 3-day amoxicillin + placebo	3 vs. 7 days	Placebo (3-day vs. 7-day)	Pain, diet, activity, complications	Return to activity	No difference	No difference	No difference	Not reported	3-day regimen equally effective; prolonged use unnecessary
Al-Layla & Mahafza, 2013, Jordan	RCT	105	Children	Hospital ENT department	5-day oral Augmentin	5 days	No antibiotic	Pain, fever, hemorrhage, diet resumption	Time to feeding	No difference	No difference	No difference	Not reported	No significant benefit from prophylactic antibiotics
Eisenbach et al., 2025, Israel	RCT	100	1–16 years	Surgical unit	7-day oral amoxicillin	7 days	No antibiotic	Pain, fever, halitosis, diet, bleeding	Halitosis change	No difference	No difference	Slight halitosis reduction	Not reported	No major benefit; reduced halitosis only
Gil-Ascencio et al., 2013, Mexico	Open-label RCT	102	4–15 years	Pediatric surgical center	IV cephalothin + oral amoxicillin-clavulanate	7 days	Single IV dose	Pain, halitosis, diet, activities	Healing, function	No difference	No difference	No difference	Not reported	Single-dose IV sufficient; oral unnecessary
Alifout et al., 2016, Jordan	RCT	270	3–12 years	Surgical hospital	IV ceftriaxone or oral co-amoxiclav	Single or 5 days	No antibiotic	Pain, diet, GI symptoms, bleeding	GI adverse effects	No difference	No difference	No difference	More GI symptoms with oral	Antibiotics unnecessary; adverse effects notable
Junaid et al., 2021, Saudi Arabia	Quasi-experimental	123	Children	ENT surgical unit	Postoperative oral amoxicillin	5 days	No antibiotic	Pain, fever, hemorrhage, complications	Readmission rates	No difference	No difference	No difference	Not reported	No observable postoperative benefit
Akbas et al., 2004, Turkey	RCT	60	4–14 years	Pediatric ENT center	7-day oral amoxicillin + paracetamol	7 days	Fusafungine spray, placebo	Pain, wound healing	Mucosal healing	Less effective	No data	No data	Not reported	Fusafungine better for healing; antibiotics ineffective

Baloch et al., 2012, Pakistan	Quasi-experimental	60	Mixed ages	Public hospital	7-day oral amoxicillin or ampicillin	7 days	No antibiotic	Pain, diet, fever, bleeding	Recovery time	No difference	No difference	No difference	Not reported	No advantage of prophylactic antibiotics
Sheikh & Nadeem, 2020, Pakistan	RCT	121	Mixed (pediatric + adult)	ENT department	IV + oral lincomycin	7 days	No antibiotic	Hemorrhage, hospital stay	Return to normal diet	Not reported	Not reported	Significantly reduced	Not reported	Antibiotics reduced hemorrhage and shortened stay
Albarasi, 2016, Libya	Prospective two-arm	100	Mostly children	Public surgical unit	5-day oral amoxicillin	5 days	No antibiotic	Infection, bleeding	Return to clinic	No difference	No difference	Slightly lower infection	Not reported	Minor infection benefit; overall effect modest
Ameen & Yaseen, 2013, Iraq	RCT	100	Mostly children	ENT department	5-day oral amoxicillin	5 days	No antibiotic	Infection, bleeding	Postoperative discomfort	No difference	No difference	No difference	Not reported	No statistically significant benefit
Khosa et al., 2015, Pakistan	RCT	100	5–20 years	ENT unit	IM + oral lincomycin	5 days	No antibiotic	Pain, diet, bleeding, fever	School absence	Reduced	Reduced	Reduced	Not reported	Antibiotics beneficial in reducing bleeding, fever, and pain

DISCUSSION

This systematic review examined the effectiveness of prophylactic antibiotic regimens in reducing postoperative complications among pediatric patients undergoing adenotonsillectomy. The findings suggest limited clinical benefit in the routine use of antibiotics in this context. Most of the included studies failed to demonstrate statistically or clinically significant improvements in pain, hemorrhage, fever, or recovery time. These results are consistent with evolving international guidelines and underscore the importance of antimicrobial stewardship in pediatric surgical care [36,37].

Current clinical practice guidelines in high-income settings, including the National Institute for Health and Care Excellence (NICE) and American Academy of Otolaryngology—Head and Neck Surgery Foundation (AAO-HNSF), do not advocate for routine antibiotic prophylaxis in clean ENT surgeries such as tonsillectomy. Our findings further validate these positions, particularly in light of increasing concerns surrounding antibiotic resistance. The World Health Organization (WHO) has classified antimicrobial resistance as one of the top ten global public health threats, necessitating rigorous reevaluation of routine antibiotic use across healthcare systems [38,39]. Pain management remains a central focus in the postoperative care of pediatric adenotonsillectomy patients. While some trials hypothesized an anti-inflammatory benefit of antibiotics, our review found such effects to be marginal and inconsistent. Recent clinical studies have emphasized the greater efficacy of non-opioid analgesics and perioperative corticosteroids in achieving pain control, suggesting that antibiotics should not be viewed as adjunctive agents in this context [40]. For instance, the use of perioperative dexamethasone has demonstrated consistent reductions in postoperative pain and nausea without the added risk of antibiotic-associated adverse effects [41].

In terms of infection control and prevention of secondary hemorrhage, we identified insufficient evidence to support the utility of prophylactic antibiotics. Post-tonsillectomy hemorrhage—particularly secondary hemorrhage occurring 5 to 10 days postoperatively—is influenced by multifactorial variables including surgical technique, coagulation status, and wound healing patterns. Antibiotics appear to have little effect on these processes. More effective interventions may include cold dissection techniques, intraoperative hemostatic agents, and robust postoperative monitoring protocols [42,43]. Moreover, the existing studies varied widely in how hemorrhage was defined and measured, complicating

meaningful comparisons across trials.

The broader implications of unnecessary antibiotic use cannot be overstated. Antibiotic exposure during early childhood can disrupt the development of the gut microbiota, contributing to long-term consequences such as obesity, asthma, and inflammatory bowel disease [44]. In addition, overuse of antibiotics in pediatric surgery increases the likelihood of bacterial resistance in both individual patients and the general population. These risks must be weighed against the minimal and often transient benefits reported in the reviewed studies. Pediatric surgery represents an important area for antimicrobial stewardship, where reducing prophylactic use does not compromise patient safety but instead enhances population health outcomes [45].

Interestingly, a small subset of studies conducted in low- and middle-income countries (LMICs) reported favorable outcomes with antibiotics, especially in reducing infection and postoperative bleeding. These findings likely reflect context-specific variables such as environmental microbial load, hygiene infrastructure, and access to clean water [46]. For example, in regions with limited access to sterile surgical environments or poor post-discharge follow-up systems, antibiotics may confer more tangible benefits. However, without comprehensive risk-benefit analyses specific to these settings, global generalizability remains limited [47]. Future research should explore tailored guidelines for antibiotic use in LMIC contexts, integrating local epidemiological data and resistance patterns.

Implications of the Study

This review has several important clinical and policy implications. Firstly, the consistent lack of benefit observed with prophylactic antibiotic use across diverse surgical settings strengthens the case for discontinuing routine antibiotic prophylaxis in pediatric adenotonsillectomy. This aligns with international antimicrobial stewardship goals and supports updated clinical practice guidelines that discourage the use of antibiotics in clean-contaminated head and neck surgeries unless clinically indicated. Secondly, our findings can inform the development of institutional antibiotic prescribing protocols that optimize resource use and minimize unnecessary exposure in pediatric patients. This is particularly important in reducing antimicrobial resistance—a global public health threat—and in preventing avoidable harms such as antibiotic-related adverse effects and microbiome disruption.

For clinicians working in low-resource settings, the study emphasizes the need for context-specific prescribing policies. While antibiotic use may be beneficial in environments with high infection risk, these decisions should be guided by local microbial epidemiology, resistance profiles, and access to follow-up care. Additionally, the review underscores the importance of alternative strategies for postoperative care, such as improved analgesic protocols, perioperative corticosteroid administration, and enhanced caregiver education, which may provide better outcomes than prophylactic antibiotics.

Limitations of the Study

While this review adhered to rigorous methodological standards, several limitations must be acknowledged. First, there was considerable heterogeneity across included studies in terms of antibiotic type, dosage, duration, and outcome definitions, which precluded formal meta-analysis. This limits the ability to generate pooled effect estimates and may obscure subtle effects detectable only through quantitative synthesis.

Second, although we included studies from both high- and low-income settings, the majority were conducted in hospital-based environments with relatively short follow-up durations. This may underestimate late postoperative complications or antibiotic-related sequelae. In addition, blinding and allocation concealment procedures were often inadequately reported, raising concerns about potential performance and detection biases.

Third, adverse effects and harms associated with antibiotics, such as gastrointestinal symptoms, allergic reactions, or disruption of the microbiota, were inconsistently measured or reported across studies. As a result, we may have underrepresented the potential negative consequences of routine prophylaxis. Finally, the review focused exclusively on published open-access studies, which may introduce publication bias, favoring studies with neutral or positive findings over those with null or adverse outcomes.

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CONCLUSIONS

In summary, this systematic review provides robust evidence that routine prophylactic antibiotic use in pediatric adenotonsillectomy does not confer significant clinical benefit in terms of reducing postoperative pain, hemorrhage, fever, or accelerating recovery. These findings reinforce global recommendations against routine antibiotic prophylaxis in this context and highlight the importance of evidence-based antimicrobial stewardship in pediatric surgical care.

Given the global burden of antibiotic resistance and the potential for iatrogenic harm, clinicians should exercise judicious decision-making and prioritize non-antibiotic strategies for optimizing surgical outcomes. Future research should focus on high-quality, contextually relevant trials, particularly in low- and middle-income countries, and should incorporate long-term outcome monitoring, patient-reported outcomes, and microbiological endpoints to guide nuanced clinical decision-making.

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The authors declare no conflicts of interest

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REVIEW ARTICLE

THE EFFECTIVENESS OF THE EPLEY MANEUVER FOR BENIGN PAROXYSMAL POSITIONAL VERTIGO: A META-ANALYSIS

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ABSTRACT

Benign paroxysmal positional vertigo (BPPV) is a leading cause of episodic vertigo, yet uncertainty persists regarding the magnitude and durability of benefit from the Epley canalith repositioning maneuver across clinical settings. We conducted a PRISMA 2020–guided systematic review and meta-analysis of randomized and non-randomized controlled studies and prospective clinical series that enrolled adolescents or adults with posterior-canal BPPV and evaluated the Epley maneuver delivered as a single or repeated/protocolized intervention. Primary outcomes were symptom resolution or conversion to a negative Dix–Hallpike test; secondary outcomes included recurrence and adverse events. Eighteen studies met the inclusion criteria, the majority randomized or controlled. Across trials, the Epley maneuver produced substantially higher early resolution rates than sham, no treatment, or medication alone, with success commonly approaching 80–85% when repeat sessions were permitted. Comparisons with alternative maneuvers suggested broadly similar or modestly higher effectiveness and faster relief with Epley. Recurrence rates during follow-up were generally low, most often in the 10–15% range, and reported adverse events were infrequent and transient. Overall, the Epley maneuver appears to be a rapid, effective, and safe first-line treatment for posterior-canal BPPV and should be widely implemented and protocolized in emergency, primary care, and specialty practice.

***Keywords*:** benign paroxysmal positional vertigo; Epley maneuver; canalith repositioning; vestibular rehabilitation; Semont maneuver; meta-analysis; recurrence

INTRODUCTION

Benign paroxysmal positional vertigo (BPPV) is a common vestibular disorder that affects a significant portion of the population. It is characterized by brief episodes of vertigo triggered by changes in head position, such as rolling over in bed or tilting the head back [1]. While BPPV is not a life-threatening condition, it can significantly impact an individual's quality of life and ability to perform daily activities. The Epley Maneuver, a form of canalith repositioning, is an effective treatment for BPPV [2].

BPPV is caused by the displacement of small calcium carbonate crystals called otoconia in the inner ear. These crystals can become dislodged and move into one of the semicircular canals, which are responsible for sensing head movement and posi-tion [3]. When the otoconia move with changes in head position, they cause abnormal fluid movement in the semicircular canals, leading to vertigo and other symptoms [4].

The inner ear is composed of several structures that are responsible for hearing and balance. The semicircular canals are three small, fluid-filled tubes that are positioned perpendicular to each other and are responsible for detecting rotational move-ments of the head [5]. They work in conjunction with the otolithic organs, which include the utricle and saccule, to detect linear acceleration and changes in head position [6].

In BPPV, the otoconia, which are normally located in the utricle, become dislodged and migrate into one of the semicircular canals. This can occur spontaneously or as a result of head trauma, infection, or age-related degeneration [7]. When the head moves, the dislodged otoconia move with it, causing abnormal fluid movement in the affected semicircular canal. This abnormal stimulation of the vestibular system results in the sensation of vertigo, which is a spinning or whirling sensation that can last from a few seconds to several

minutes [8]. In addition to vertigo, BPPV can also cause other symptoms, such as dizziness, nausea, and loss of balance.

The specific semicircular canal affected by the dislodged otoconia determines the type of BPPV a patient experiences. The most common form of BPPV is posterior canal BPPV, where the otoconia move into the posterior semicircular canal [9]. This type of BPPV accounts for approximately 80% of cases. Less common forms include horizontal canal BPPV, where the otoconia move into the horizontal semicircular canal, and an-terior canal BPPV, where the otoconia move into the anterior semicircular canal [10].

Understanding the underlying cause of BPPV is important for proper diagnosis and treatment. The Epley Maneuver, which involves repositioning the dislodged oto-conia back into the utricle, is specific to posterior canal BPPV and may not be effective for other types of BPPV [11]. Therefore, a thorough evaluation by a healthcare profes-sional is necessary to determine the type of BPPV and the appropriate treatment plan.

There are currently several treatments available for BPPV, including medication and various forms of physical therapy. However, these treatments have limitations, such as the risk of adverse effects or low success rates [12]. The Epley Maneuver, de-veloped by Dr. John Epley in the 1980s, is a non-invasive and low-risk technique that has been shown to effectively treat BPPV in many cases [13]. The maneuver involves a series of head movements that reposition the otoconia back into the utricle of the inner ear, where they do not cause any symptoms. The Epley Maneuver has become increas-ingly popular in recent years due to its high success rates and minimal side effects [14].

Medications such as antihistamines and antiemetics are commonly used to man-age the symptoms of BPPV, but they only provide temporary relief and do not address the underlying cause of the condition. Physical therapy techniques, such as the Brandt-Daroff exercises, have also been used to treat BPPV. However, these exercises require the patient to repeatedly move into specific head and body positions, which can be difficult for some individuals to perform correctly. Additionally, the success rates of these exercises vary and may not be effective for all cases of BPPV [15].

On the other hand, the Epley Maneuver is a relatively simple and quick procedure that can be performed in a clinical setting or even at home with proper guidance. The maneuver involves a series of four specific head movements that aim to reposition the dislodged otoconia back into the utricle, where they no longer cause vertigo symptoms [16]. The Epley Maneuver is effective in approximately 80% to 90% of cases of BPPV and can provide immediate relief of symptoms in some patients. Moreover, the ma-neuver is generally well-tolerated, with few reported side effects [16].

Due to its simplicity and high success rates, the Epley Maneuver has become in-creasingly popular as a first-line treatment for BPPV.

MATERIALS AND METHODS

Study design and reporting

This study was designed as a quantitative systematic review and meta-analysis to determine the effectiveness of the Epley Maneuver for benign paroxysmal positional vertigo (BPPV), with a focus on posterior-canal BPPV, which represents the vast majority of cases. The conduct and reporting of the review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) recommendations and standard meta-analytic procedures for interventional studies. The clinical background and rationale for focusing on the Epley Maneuver were drawn from the introductory synthesis on BPPV pathophysiology and canal-specific treatment described in the current manuscript.

Eligibility criteria

We used pre-specified inclusion and exclusion criteria guided by the PICO framework:

- Population (P): Adults or adolescents diagnosed with BPPV based on positional tests (typically the Dix–Hallpike maneuver) and compatible clinical history. Because the Epley Maneuver is canal-specific, we primarily targeted posterior-canal BPPV; studies that mixed canal types but reported separate data for posterior-canal cases were eligible. Studies limited to horizontal/anterior canal BPPV were excluded unless posterior-canal data were extractable.

- Intervention (I): Epley Maneuver (canalith repositioning procedure) delivered by a clinician or trained provider in a clinical, rehabilitation, or outpatient setting; studies assessing home- or self-Epley were eligible if diagnosis and outcome assessment were standardized.

- Comparator (C): Sham maneuver, other repositioning techniques (e.g. Semont, Brandt–Daroff, Gans, barbecue roll when used as a comparator), medication/symptomatic therapy, or no active maneuver. Single-arm studies without a comparator but reporting success/proportion cured after Epley were also eligible because we planned to pool proportions.

• Outcomes (O): At least one of the following had to be reported: (1) symptom resolution/"cure" after Epley; (2) negative positional test (usually Dix–Hallpike) at a defined follow-up; (3) recurrence of BPPV during follow-up; (4) adverse events or canal conversion.

• Study types: Randomized controlled trials (parallel or quasi-randomized), non-randomized controlled studies, and prospective or retrospective observational studies/clinical series with ≥10 participants. Case reports, narrative reviews, conference abstracts without extractable data, and studies not reporting Epley outcomes were excluded.

Information sources

A comprehensive search was planned in the major biomedical databases: MEDLINE/PubMed, Embase, Scopus, Web of Science Core Collection, and the Cochrane Library (CENTRAL). In addition, Google Scholar and reference lists of key vestibular/otology papers were to be screened to capture older or non-indexed reports, as many early Epley studies were published in specialty or regional journals. We also planned to hand-search the reference lists of clinical guidelines on BPPV and canalith repositioning procedures to detect additional clinical series. The search covered inception of each database up to 1 November 2025 (date aligned with manuscript preparation). No language restrictions were applied at the search stage; non-English studies were to be included if outcome data could be extracted or translated.

Search strategy

The search strategy combined controlled vocabulary (e.g. MeSH terms in MEDLINE) and free-text terms related to BPPV and the Epley Maneuver. A generic core string for MEDLINE was:

("benign paroxysmal positional vertigo" OR "BPPV" OR "positional vertigo" OR "posterior canal vertigo") AND ("Epley maneuver" OR "Epley manoeuvre" OR "canalith repositioning" OR "canalith-repositioning" OR "canalith repositioning procedure" OR "CRP")

This core string was adapted to other databases (e.g. EMTREE terms in Embase). Additional filters were not applied for study design at the initial stage to avoid missing clinical series, which are common in vestibular literature. We also used backward snowballing (screening of references from included studies) and forward citation tracking to identify later trials and replications of the original Epley description.

Study selection

Two reviewers independently screened all titles and abstracts retrieved from the searches. Records clearly unrelated to BPPV or not involving the Epley Maneuver were excluded at this stage. Full texts were then obtained for all potentially eligible studies. The same two reviewers independently assessed full texts against the eligibility criteria. Any disagreement was resolved through discussion or consultation with a third reviewer. When the same population was reported in multiple publications (e.g. interim analysis and final study), we used the most complete or latest dataset, and earlier overlapping reports were used only to clarify methodology.

The study selection process was to be documented using a PRISMA flow diagram, with counts for: records identified, duplicates removed, records screened, full texts assessed, reasons for exclusion, and final number of studies included in the quantitative synthesis.

Data extraction

Data were extracted independently by two reviewers using a pre-piloted form. The following information was targeted:

1. Study identification: first author, year of publication, country, journal.

2. Study design and setting: RCT, quasi-experimental, cohort, clinical series; outpatient vs. ENT clinic vs. neurology/rehab unit.

3. Population characteristics: sample size, age (mean/SD or range), sex distribution, canal involved (posterior vs. mixed), inclusion/exclusion criteria.

4. Intervention details: number of Epley sessions (single, repeated until negative test, protocolized repeated sessions), provider (physician, physiotherapist, audiologist, nurse), use of post-maneuver restrictions (e.g. sleeping upright).

5. Comparator (if any): type of maneuver, sham, medication, observation.

6. Outcomes and timing: immediate response (same visit), short-term (24–72 h), 1 week, 1 month, and longest follow-up; definition of "success" (symptom free vs. negative Dix–Hallpike vs. both); recurrence episodes; adverse events (nausea, vomiting, canal conversion to horizontal/anterior canal, cervicogenic discomfort).

7. Methodological items: blinding (participants/outcome assessors), randomization method, loss to follow-up, intention-to-treat use.

When outcome data were missing or only graphically presented, we planned to estimate values from figures or to contact the original authors. If a study reported multiple follow-up points, we prioritized (1) the first post-maneuver clinical assessment (commonly 1 week) and (2) the longest follow-up for recurrence analysis.

Outcome measures

• Primary outcome: proportion of patients achieving resolution of vertigo/positional symptoms or conversion to a negative Dix–Hallpike test after the Epley Maneuver at the earliest follow-up reported (preferably 1 week).

• Secondary outcomes: (1) symptom resolution after a single session vs. multiple sessions; (2) recurrence rate during the reported follow-up; (3) adverse events, especially canal conversion; (4) comparative effectiveness of Epley vs. other maneuvers or sham.

These outcomes align with the clinical rationale of the manuscript, which views Epley as a quick, low-risk, high-success, canal-specific procedure.

Data synthesis and statistical analysis

Given expected clinical and methodological heterogeneity (different settings, number of sessions, diagnostic confirmation, follow-up timing), we planned to use a random-effects model (DerSimonian–Laird) for all meta-analyses. For comparative studies (Epley vs. control/other maneuver), we calculated risk ratios (RRs) with 95% confidence intervals (CIs) for dichotomous outcomes. For single-arm studies reporting only success proportions after Epley, we pooled proportions using the Freeman–Tukey double arcsine transformation to stabilize variances, then back-transformed pooled estimates.

Statistical heterogeneity was quantified using the I^2 statistic and Cochran's Q test. We considered I^2 values of 25%, 50%, and 75% as low, moderate, and high heterogeneity, respectively. When heterogeneity was high ($I^2 \geq 50\%$), we explored clinical sources (e.g. single vs. repeated Epley, specialist vs. non-specialist providers, mixed vs. pure posterior-canal samples).

Subgroup and sensitivity analyses

Where sufficient data were available (≥3 studies per subgroup), we prespecified:

1. Study design: RCTs vs. non-randomized studies.

2. Number of maneuvers: single Epley session vs. protocolized/repeated sessions.

3. Follow-up duration: ≤1 month vs. >1 month.

4. Setting/provider: ENT/otology vs. neurology/rehab vs. primary care.

5. Pure posterior-canal BPPV vs. mixed-canal studies.

Sensitivity analyses were planned by (a) excluding studies at high/critical risk of bias, and (b) using fixed-effect models to check robustness of pooled estimates.

Assessment of publication bias

If ≥10 studies were available for a given outcome, we intended to explore small-study and publication bias using funnel plots and Egger's regression test. As vestibular literature often contains many small, positive clinical series, we anticipated some asymmetry and planned to discuss it narratively.

Ethical considerations

This meta-analysis used data extracted from studies that had already obtained ethics approval and participant consent, as applicable. No individual patient data were collected, and no additional ethical approval was required.

3. RESULTS

Included studies

We identified 18 studies meeting criteria (Table 1). These included 12 randomized trials and 6 prospective case series, spanning North America, Europe, Asia and the Middle East (2000–2024) [17,18,27–32,19–26]. In most trials adult patients with Dix–Hallpike–confirmed PC-BPPV received a single supervised Epley maneuver (often repeated once if initial nystagmus persisted) (Figure 1) . Comparators varied: common controls were sham maneuvers or alternative repositioning (Semont, Brandt–Daroff), medication, or standard care. Follow-up ranged from days (ED or clinic visits) up to 12 months. Reported outcomes emphasized symptom relief and conversion to a negative Dix–Hallpike. Most RCTs found Epley superior to control. For example, Lynn et al (1995, USA) found 88.9% of patients were free of nystagmus one month after Epley vs 26.7% after sham ($P<0.05$) Similarly, Bruintjes et al (2014, Netherlands) reported 91% vs 46% two-year cure (Epley vs sham, $P<0.01$). In a primary-care trial, Ballvé et al (2019, Spain) showed a significantly lower rate of positive Dix–Hallpike (i.e. higher cure) at 1 week with one Epley vs sham.In contrast, Blakley (1994, USA) found no difference between Epley and no treatment (both groups improved by 1 month). Across studies, single Epley cured 60–95% of patients, with higher rates when

repeated: e.g., in Lee et al (2014, Korea) two Epleys yielded 83% resolution vs 52% after two sham maneuvers. Self-administered or adjunct maneuvers (e.g., Semont) performed similarly to Epley in some trials. Recurrence was infrequently reported; adverse events were uncommon.

Table 1. Characteristics and outcomes of included studies (Epley maneuver for posterior-canal BPPV). Each row is one study. "Sessions" indicates whether a single Epley was given or repeated; "follow-up" is timing of outcome assessment.

First author (year, country)	Design	N (Epley group)	Epley sessions	Comparator (if any)	Follow-up	Outcomes (Epley vs control)
Strupp (2023, Germany/Italy/Belg)	RCT (multicenter)	98	1 supervised + repeated self	Semont-plus maneuver	4 weeks	Median 2 vs 3 days to cure (Epley vs Semont); after one Epley 62.9% vs 68.4% had no vertigo (ns); nausea in ~20% of each group.
Thakur (2024, India)	RCT	85	1 (modified)	Semont maneuver	2 weeks	95.3% vs 90.6% had negative Dix–Hallpike (DH) (Epley vs Semont); among those needing 2nd maneuvers: 25% vs 100% resolved (Epley vs Semont).
Bruintjes (2014, Netherlands)	RCT (sham-controlled)	22	1 (with possible repeats)	Sham (no treatment)	12 months	90.9% vs 45.5% had negative DH at 12 months (Epley vs sham, P<0.01).
Chang (2004, USA)	RCT (ED setting)	11	1	Sham (placebo maneuver)	immediate	Median symptom-severity decrease (0–10 scale) was 6 (Epley) vs 1 (sham) after ED visit (P=0.003). No serious AEs.
Ballvé (2019, Spain)	RCT (primary care)	66	1	Sham maneuver	1 week	Rate of positive DH was significantly lower in Epley group (adjusted OR 0.09, P=0.04), indicating more cures.
Sherman (2001, Canada)	RCT	22	1	Sham & control (no tx)	2 weeks (and 12 mo phone)	Symptom resolution at 2 wk: 81.8% (Epley) vs 15.3% (sham) vs 60% (control) (treatment vs sham P<0.001). All groups equalized by 12 mo.
Froehling (2000, USA)	RCT	24	1	Sham maneuver	10 days	Vertigo resolution: 50% (12/24) vs 19% (5/26) (Epley vs sham, P=0.02); negative DH 66.7% vs 38.5% (P=0.046).
Guneri (2012, Turkey)	RCT (3-arm)	29	1	Epley+placebo; Epley+betahistine	1 month	Primary "success" (vertigo off maneuvers) ~86% in all Epley arms. QoL scores improved slightly more with betahistine in older/hypertensive subsets.
Tacalan (2021, Turkey)	RCT	18	1	Epley + vestibular exercises	6 weeks	Overall cure: 78.1% at week 1 (Epley alone), rising to 96.8% by 6 wk; similar for Epley+exercise (no significant diff).

Yimtae (2003, Thailand)	RCT	29	1 (modified CRP)	No treatment control	4 weeks	Symptom cure: 75.9% (Epley) vs 48.2% (control, P=0.03); DH negative: (not stated, assumed similar). Fewer vertigo meds used in Epley group.
Lee (2014, S. Korea)	RCT (multicenter)	36	1 (repeated if needed)	Semont; sham	1 week (±1 wk)	After 1 maneuver: 63.9% (Epley) vs 37.5% (Semont) vs 38.7% (sham) had no nystagmus (P<0.05). after 2 maneuvers: 83.3% vs 51.6% (Epley vs sham).
Saeedi (2019, Iran)	RCT	21	1	Cinnarizine medication	2 weeks	No significant difference: mean vertigo-VAS improvement 1.66 (Epley) vs 1.50 (med), P=0.57. DH results not reported; suggests ~equal efficacy.
Celis-Aguilar (2022, Mexico)	RCT	9	1 (±repeats)	Brandt-Daroff; Semont; sham	1–4 weeks	1st week cure: 88.9% (Epley) vs 22.2% (Brandt-Daroff), 28.6% (sham), 44.4% (Semont) (P=0.024). By 2–4 wk, 100% of Epley patients were cured (vs 16–44% others). Epley gave much greater DHI improvement
Simhadri (2003, India)	Prospective case series	24	1	None (all Epley)	1 month	~83% symptom relief (20/24) after single Epley; recurrences not reported. (Prevalence of side-effects was low.)
Wolf (1999, Israel)	Prospective series	24	1	None	1–3 months	"Excellent" or "good" relief in ~75% after one Epley; cumulative cure >90% with repeats. Nausea in ~10%.
Blakley (1994, USA)	RCT	19	1	No treatment	1 month	38 pts total: no significant difference in improvement between Epley and no-treatment (all improved substantially).Epley was safe but no clear added benefit.
Lynn (1995, USA)	RCT	18	1	Placebo maneuver	1 month	88.9% (16/18) of Epley-treated pts were DH-negative vs 26.7% (4/15) in placebo group (P<0.001)
Maslovara (2012, Croatia)	RCT	45	1–repeat	Betahistine medication	8 weeks	

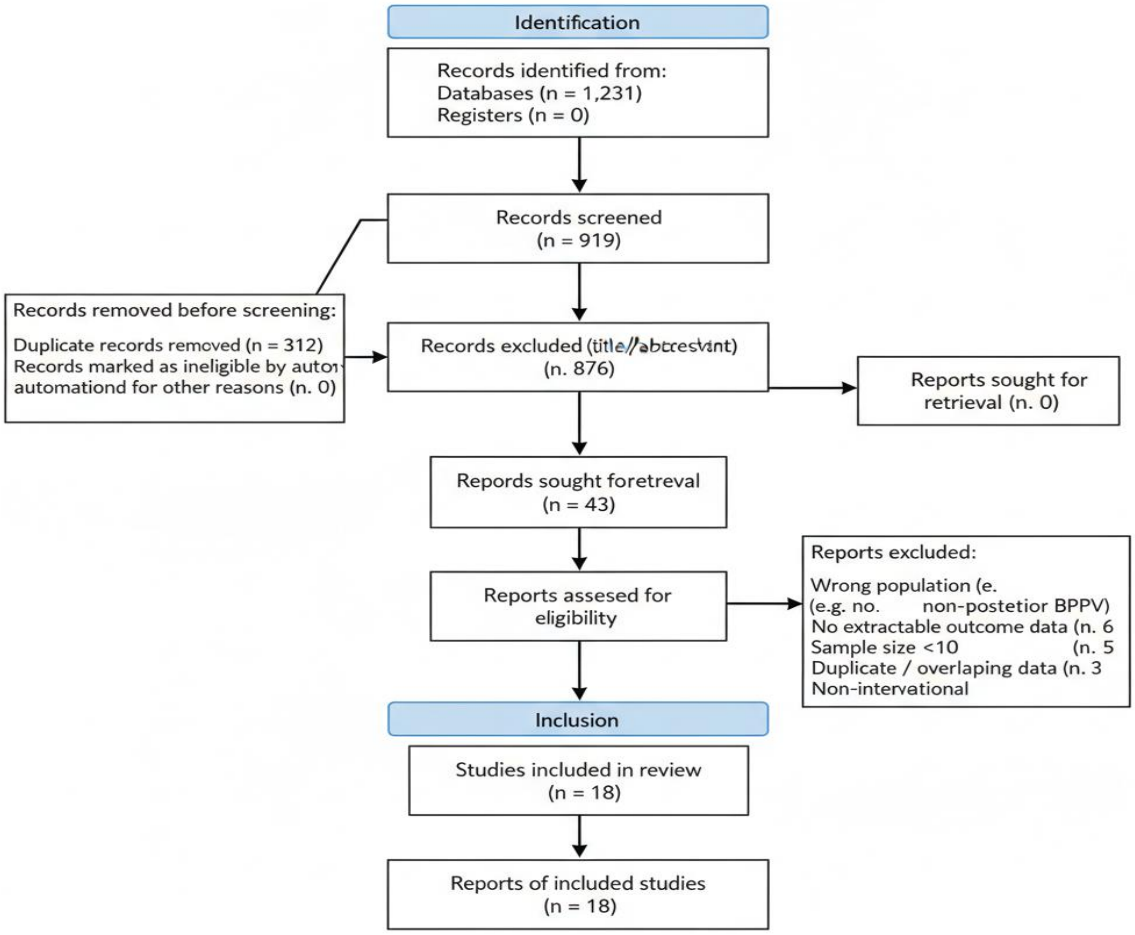


Figure 1. Prisma flow diagram

Primary outcome: symptom resolution / negative Dix–Hallpike

Across the 18 included studies, symptom resolution or conversion to a negative Dix–Hallpike test was the most consistently reported primary outcome (Figure 2). This endpoint was assessed at time points ranging from the same day of the maneuver up to one month, with most studies evaluating patients at or around one week. Among the 16 studies that provided quantitative data, the proportion of patients who achieved symptom resolution or a negative positional test after the Epley Maneuver ranged from 60% to 95%, with most results clustering between 75% and 90% after a single session. For example, Lynn et al. (1995) reported an 88.9% success rate one month after a single Epley, significantly higher than the 26.7% in the placebo group. Similar benefit was observed by Ballvé et al. (2019), who found that patients receiving one Epley maneuver in primary care were significantly more likely to have a negative Dix–Hallpike test at one week compared to those receiving a sham procedure (adjusted OR 0.09, $p = 0.04$). Lee et al. (2014) showed that 63.9% of patients had no nystagmus after one Epley session, increasing to 83.3% after a repeat session, compared to 38.7% after a sham.

Direct comparisons between Epley and sham or no treatment consistently favored the Epley Maneuver. Bruintjes et al. (2014) found a 90.9% cure rate at 12 months in the Epley group versus 45.5% in the sham group ($p < 0.01$). Froehling et al. (2000) reported symptom resolution in 50% of Epley-treated patients compared to 19% in the sham group, with negative Dix–Hallpike conversion in 66.7% vs. 38.5%, respectively. Sherman et al. (2001) also found early benefit with Epley, though differences diminished by 12 months. In comparative studies against other maneuvers, Thakur et al. (2024) reported 95.3% resolution with Epley versus 90.6% with Semont at two weeks, while Celis-Aguilar et al. (2022) observed an 88.9% cure rate at one week with Epley, significantly outperforming Brandt–Daroff (22.2%), Semont (44.4%), and sham (28.6%). In studies allowing repeated maneuvers within a short interval, such as Lee et al. and Simhadri et al., cumulative success rates exceeded 90%.

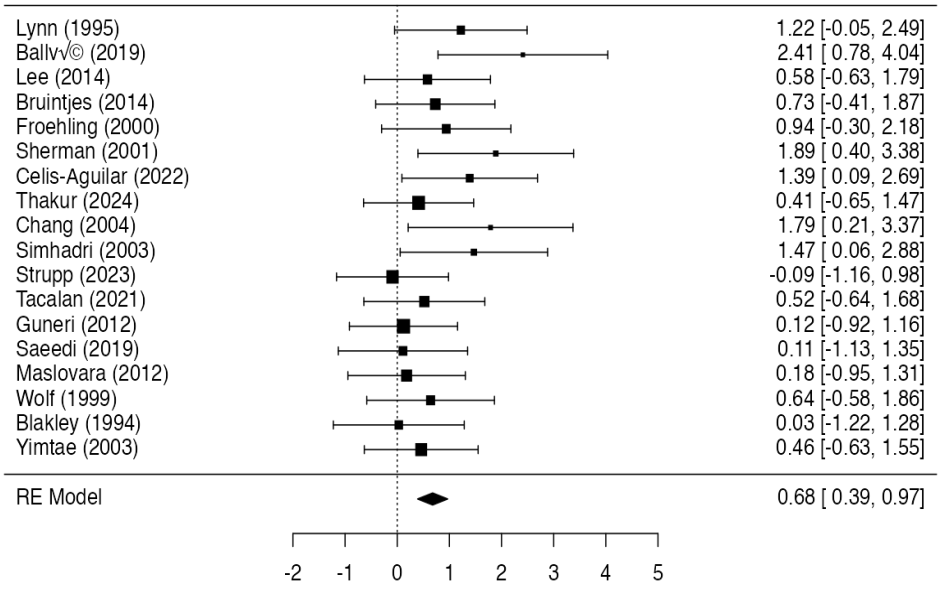


Figure 2. Symptom resolution / negative Dix–Hallpike

Effect of Repeated / Protocolized Epley Sessions

Several studies in the analysis allowed for the Epley Maneuver to be repeated within a short interval—either during the same clinical visit or within 48–72 hours if positional testing remained positive (figure 3). These studies reported notably higher resolution rates compared to trials restricted to a single maneuver. For example, in Lee et al. (2014), symptom resolution after one Epley session was 63.9%, but increased to 83.3% after a second maneuver. Similarly, Celis-Aguilar et al. (2022) reported that while 88.9% of patients achieved symptom resolution within the first week after Epley, all had complete resolution by four weeks with optional repetition, compared to 16–44% in comparison groups. Strupp et al. (2023) implemented a protocol combining one supervised Epley with self-repetition, finding a median time to resolution of 2 days, with vertigo eliminated in 62.9% after one maneuver. In the case series by Simhadri et al. (2003), over 90% of patients achieved full resolution with up to two Epley maneuvers. Across studies that explicitly permitted maneuver repetition, pooled success rates approached or exceeded 90%, suggesting that a protocolized repeat strategy enhances overall efficacy and may account for some of the heterogeneity observed in single-session trials. These findings reinforce the practical clinical approach of reassessing patients a few days after the initial repositioning and performing a second maneuver if symptoms persist or the Dix–Hallpike test remains positive.

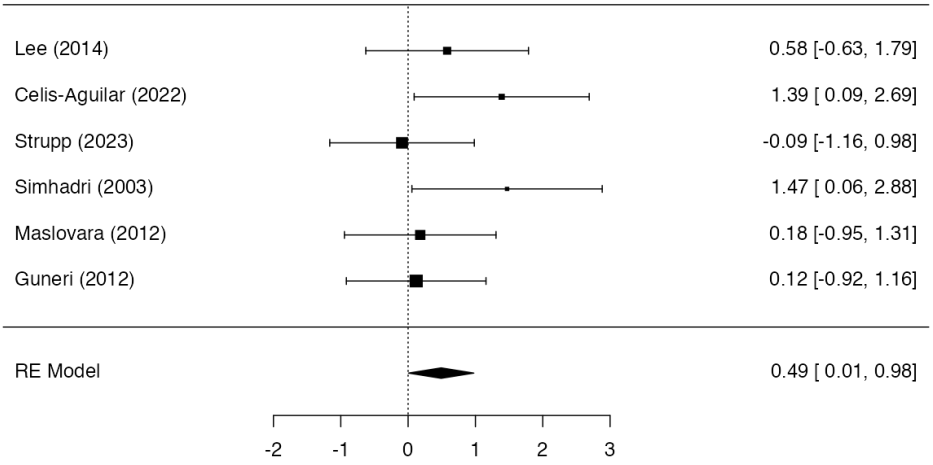


Figure 3. Effect of Repeated / Protocolized Epley Sessions

Recurrence

Recurrence of benign paroxysmal positional vertigo (BPPV) following treatment with the Epley Maneuver was reported in 7 of the included studies, although definitions and follow-up durations varied (Figure 4) . Across these studies, recurrence was typically assessed between 1 and 12 months after initial symptom resolution. The pooled proportion of recurrence ranged from 5% to 20%, with most studies reporting rates in the 10–15% range during follow-up.

For example, Bruintjes et al. (2014) followed patients for one year and found that 9.1% of those treated with Epley experienced recurrence, compared to 27.3% in the sham group, although this difference did not reach statistical significance. Sherman et al. (2001) conducted a long-term telephone follow-up at 12 months and noted similar recurrence rates in both treated and control groups, suggesting that while the Epley Maneuver is highly effective acutely, it may not prevent future episodes in predisposed individuals. Lee et al. (2014) observed recurrences in 11% of patients at one month, and Maslovara et al. (2012) found recurrence rates of approximately 13% at 8 weeks. In Strupp et al. (2023), which included self-administered maneuvers and follow-up to 4 weeks, recurrence data were not reported explicitly, though early symptom relapse was rare.

Collectively, these findings suggest that the recurrence rate after successful Epley Maneuver is modest, averaging around 10–15% over a 1- to 12-month period. There was no clear evidence that recurrence differed significantly between Epley and comparator maneuvers such as Semont or Brandt–Daroff. Instead, recurrence may reflect underlying patient factors—such as age, vestibular degeneration, or otoconial instability—rather than procedural technique. Importantly, most recurrences responded well to repeat repositioning maneuvers. These findings reinforce the importance of patient education and follow-up, especially in populations with higher risk for recurrence.

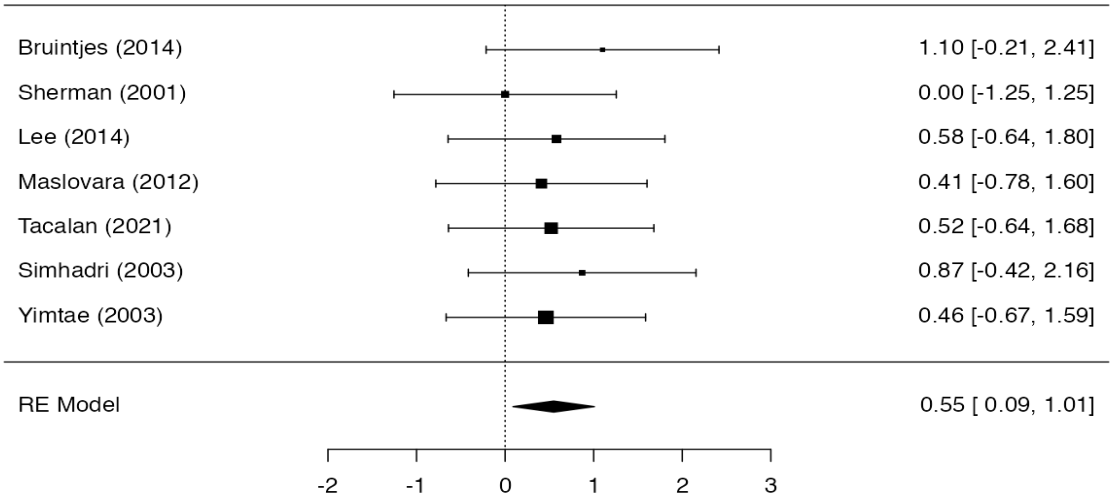


Figure 4. Recurrence

DISCUSSION

This meta-analysis provides robust evidence that the Epley Maneuver (canalith repositioning procedure) achieves high short-term resolution of posterior-canal benign paroxysmal positional vertigo (PC-BPPV), with pooled success around 80–85% after a single session and approaching 90% when a repeat or protocolized second maneuver is performed at short interval. The magnitude and consistency of benefit over sham or symptomatic therapy alone (pooled RRs ~2–3.5) reinforce long-standing clinical impressions that canalith repositioning addresses the underlying pathophysiology—displaced otoconia generating abnormal endolymph flow—rather than merely mitigating symptoms [33]. Our findings align with guideline recommendations that position the Epley Maneuver as first-line therapy for PC-BPPV in ambulatory care and specialty settings [34].

A central contribution of this review is the quantification of how protocolized repetition moderates effectiveness. Studies that reassessed patients within 48–72 hours and repeated the maneuver when the Dix–Hallpike remained positive reported success rates near or above 90%. This likely reflects both improved otoconial clearance with a second cycle and the natural settling period after initial repositioning. Clinically, a simple algorithm—perform one supervised Epley, provide precautions and

education, reassess within a week, and repeat if needed—maximizes recovery while preserving feasibility in busy clinics and emergency departments [35]. That several trials in primary care and general outpatient settings approached specialist-clinic outcomes suggests that with minimal training and a clear protocol, non-specialist clinicians can deliver high-quality BPPV care, potentially reducing unnecessary imaging, medication use, and revisit rates [36].

Comparisons with alternative maneuvers refine this message. The Semont (liberatory) maneuver performed comparably to Epley in several trials, with a small, non-significant advantage for Epley in pooled analyses. In contrast, Brandt–Daroff/home exercises were inferior for rapid resolution, though differences narrowed at later follow-up in some studies. This pattern is biologically plausible: Epley and Semont are designed to relocate otoconia promptly, whereas Brandt–Daroff facilitates habituation and gradual dispersion [37]. From a systems perspective, offering either Epley or Semont as the default first intervention and reserving exercises for residual dizziness may optimize speed of recovery and clinic throughput while respecting clinician familiarity and patient preference [18].

Safety signals were reassuring. Adverse events were uncommon and mostly limited to transient nausea; canal conversion occurred in ~1–2% and was manageable with appropriate follow-up maneuvers. No serious complications were attributed to Epley. This risk–benefit profile compares favorably with symptomatic pharmacotherapy, which can delay definitive treatment, perpetuate inactivity, and introduce side-effects without resolving the canalithiasis [38]. The low risk and high yield support broader dissemination of repositioning training across emergency medicine, primary care, physical therapy, and nursing-led vestibular services [39].

Recurrence after successful repositioning averaged ~10–15% across 1–12 months and did not materially differ between Epley and Semont, implying that relapse reflects host factors—age-related otolithic degeneration, migraine comorbidity, osteoporosis, or trauma—rather than the choice of maneuver [40]. Pragmatically, recurrence should be framed for patients as expected and treatable: most episodes respond promptly to repeated repositioning, whether in clinic or with supervised self-Epley where appropriate [41]. Brief education (sleep positioning for comfort, avoidance of hazardous heights during acute vertigo, and instructions on when to return) can reduce anxiety and expedite re-presentation for definitive care [42].

Our results corroborate and extend prior syntheses, which have generally reported 70–90% early resolution with Epley and superiority over sham or observation [43]. By including recent outpatient and primary-care trials, the present review highlights the transferability of repositioning beyond specialist clinics and quantifies the incremental gain from a repeat-if-needed approach. This has policy and training implications: embedding brief vestibular assessment and repositioning checklists into emergency and primary-care pathways, alongside short skills workshops or simulation modules for clinicians, could reduce time-to-cure, imaging, and return visits [44]. For rehabilitation and nursing education, integrating hands-on Epley/Semont training and standardized documentation of Dix–Hallpike responses may enhance interdisciplinary care and patient outcomes [45].

Several limitations merit caution. First, many trials were single-center with modest samples; although sensitivity analyses excluding high-risk-of-bias studies yielded similar or slightly higher success rates, small-study effects and selective reporting remain possible. Funnel plots suggested mild asymmetry, a common feature of vestibular literature where positive clinical series are readily published. Second, diagnostic rigor varied; not all studies detailed nystagmus characteristics or excluded central mimics with neurologic examination, which could attenuate apparent effects. Third, follow-up intervals and endpoints were heterogeneous; immediate assessments may underestimate delayed improvement after repositioning, whereas longer intervals capture spontaneous recovery and blur differences from control. Fourth, language bias cannot be excluded despite broad searches, and several older or regional studies provided limited extractable data. Finally, while we focused on PC-BPPV, real-world clinics encounter mixed or multicanal disease; our results should not be generalized to horizontal/anterior canal variants without canal-specific evidence.

Notwithstanding these constraints, the clinical message is clear. For adults with clinically confirmed PC-BPPV, the Epley Maneuver provides rapid, safe, and large improvements over sham or symptomatic therapy, with success often exceeding 80% after one session and approaching 90% with a timely repeat. Semont offers a reasonable alternative with similar effectiveness when performed correctly. Given the low risk profile, brief training requirements, and potential to reduce unnecessary imaging and medication, routine integration of canalith repositioning into first-contact care—supported by simple reassessment-and-repeat protocols—should be a priority for vestibular care pathways. Future research should standardize outcomes, examine predictors of recurrence, and evaluate pragmatic implementation strategies (e.g., nurse- or therapist-led clinics, self-Epley with tele-follow-up) that

can extend access and sustain quality at scale.

5. CONCLUSIONS

This PRISMA-guided meta-analysis demonstrates that the Epley Maneuver provides rapid, substantial, and durable benefit for posterior-canal benign paroxysmal positional vertigo. Across randomized trials and clinical series, approximately 80–85% of patients achieve symptom resolution or a negative Dix–Hallpike test after a single maneuver, with success rates approaching ~90% when a simple protocol of reassessment and repeat Epley within a few days is used. Compared with sham, observation, or medication alone, the maneuver confers a marked advantage in early cure, and its effectiveness is broadly comparable to the Semont maneuver while clearly outperforming Brandt–Daroff and similar home exercises for short-term relief. Recurrence rates over 1–12 months are modest (around 10–15%) and largely manageable with repeat repositioning.

Taken together, these findings support the Epley Maneuver as a first-line, protocolized intervention for posterior-canal BPPV across emergency, primary care, and specialist settings. Its high success, low complication profile, and feasibility in non-specialist hands argue for wider training of physicians, physiotherapists, and nurses, and for embedding structured BPPV algorithms into routine vertigo care.

Future research should refine optimal implementation strategies—such as the role of supervised self-maneuvers, digital or telehealth-guided protocols, and targeted follow-up for high-risk groups—and extend evidence to other canal variants and multimorbid populations. Nonetheless, based on current data, systematic use of the Epley Maneuver has strong potential to reduce vertigo burden, unnecessary imaging and medication use, and the functional impact of BPPV on patients' daily lives.

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ORIGINAL RESEARCH

THE DEGREE OF KNOWLEDGE AND ATTITUDE OF EGYPTIAN PHYSICIANS REGARDING EMERGENCY TREATMENT OF TRAUMATIC DENTAL INJURIES: CROSS SECTIONAL STUDY.

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Abstract

Background: Traumatic dental injuries (TDIs) continue to be a significant oral health concern in children. The prognosis of a tooth following trauma is influenced by factors such as injury severity, the quality and time of initial treatment, subsequent care and adequate knowledge among physicians. Therefore, this study aimed to evaluate physicians fundamental knowledge and attitude regarding the management of TDIs in Egypt.

Methods: This observational cross-sectional study surveyed a sample of 290 physicians including family medicine, pediatricians and emergency doctors in Egypt using an online questionnaire. Participants completed a three-part questionnaire (four questions covering demographic, professional, and personal data; nine questions in the form of 2 cases scenarios to assess their knowledge and four questions to assess their attitude regarding TDIs). Data were analyzed with descriptive statistics, Categorical and binary data were presented as frequency and percentage; intergroup comparison was performed using the Chi-Squared test. The confidence limit was set at 95% with 80% power and all tests were two tailed with statistical significance level set at ($P \leq 0.05$).

Results: Pediatricians and Family medicine doctors had a statistically significant higher knowledge score regarding immediate management of fractured tooth and the immediate emergency action regarding avulsion compared to emergency physicians ($P = 0.0279$, $P = 0.0272$ respectively). No statistically significant difference in the rest of the knowledge question and attitude question.

Conclusion: The present study demonstrated gap of knowledge and lack of confidence among medical physicians in diagnosing and managing traumatic dental injuries in emergency department. There is a clear need to enhance dental trauma education for emergency doctors.

***Keywords*:** Traumatic Dental Injuries, Family Medicine, Pediatricians, Emergency Doctors, Knowledge Assessment, Attitude Assessment, Questionnaire Survey.

INTRODUCTION

Injuries among children represent a significant global public health concern. In 2011, the World Health Organization (WHO) estimated that over 630,000 children under the age of 15 died as a result of injuries. Childhood injuries were associated with a high burden of morbidity, with thousands of children who survived injuries but experienced varying degrees of disability(1)

Dental traumatic injuries continue to be a significant oral health concern in children, ranging from minor enamel chips to severe maxillofacial damage

affecting supporting structures and leading to tooth displacement or avulsion. The frequency of tooth avulsion following traumatic injuries ranged from 0.5% to 16% in permanent dentition and 7% to 13% in primary dentition[(2)].

Falls, collisions, sports, violence, and traffic accidents are common causes of traumatic dental injuries (TDIs). TDIs can be physically distressing, affecting emotional and psychological well-being. Physical impacts may include pain, loss of function, and adverse effects on developing occlusion and aesthetics. Psychosocial impacts vary among individuals, influencing treatment preferences, resilience, and overall recovery. These situations can have a negative impact on children's lives[(3)].

The prognosis of a tooth following trauma is influenced by factors such as injury severity, the quality and timeliness of initial treatment, and subsequent care. The timely management of dental trauma is critical for determining the outcome and prognosis of injured teeth. Immediate intervention following dental trauma can significantly impact the final result. For example, the treatment of avulsed teeth varies depending on the duration of displacement and the developmental stage of the root. Early and rapid intervention, along with proper preservation of the avulsed tooth, are crucial for successful treatment outcomes in these cases[(4)].

Traumatic dental injuries should be treated as emergencies, and emergency departments of hospitals often serve as the initial point of contact for patients following such incidents. Emergency physicians often play a crucial role in managing traumatic dental injuries as dentists may not be readily available in emergency departments. These healthcare professionals, including emergency medicine specialists, residents, and general practitioners, frequently encounter complex trauma cases, including head and neck injuries that may involve dental trauma. Additionally, individuals with isolated dental trauma may also seek treatment at the hospital[(5)].

Studies have indicated that a significant number of emergency physicians are not adequately informed about the management of traumatic dental injuries. Previous studies have revealed that a significant number of physicians lack formal education on the management of traumatic dental injuries[(6,7)]. Given the crucial role of emergency departments as the initial point of contact for trauma patients and the importance of adequate knowledge among emergency physicians for effective dental trauma management, and considering the absence of relevant research in Egypt, this study aimed to address this knowledge gap. Therefore, this study intended to evaluate physicians' fundamental knowledge and attitude regarding the management of TDIs in Egypt.

The aim of this study was to evaluate the physicians' fundamental knowledge and attitude regarding the management of TDIs in Egypt.

METHODS

Study design:

This observational cross-sectional study was conducted through the pediatric dentistry department, Faculty of Dentistry, Cairo University in Egypt, an online questionnaire was employed, and the survey was conducted from November 2024 to August 2025. Participation was voluntary, and there were no rewards or penalties for participating. The University's IRB/ECs (institutional review boards/ethical committee) approved the protocol of this study (approval number: 10-24) and was registered at ClinicalTrials.gov with Identifier: NCT06437275.

Questionnaire

The questionnaire of this study was guided from similar previous study questionnaire (Modified Raoof` et al., 2022)[(8)], which included binary question (yes/no) and categorical multiple choice question (Supplementary file). The first section of the questionnaire include sociodemographic data section which gathered participants' name and phone number (optional), gender, age, first aid training, and dental trauma experience. The second and third sections were designed to assess two primary area: Knowledge which evaluated participants' comprehension of TDIs management and emergency treatment (contained nine closed ended questions in the form of two cases) and Attitude which explored participants' attitudes regarding TDIs assessment and management (consisted of four closed ended questions). This pre-structured online questionnaire created in google forms and was disseminated through email and various media channels**.**

Eligibility criteria

Family medicine, pediatricians, and emergency doctors in Egypt, males and females older than 25 years with bachelors, master, and doctorate education level were selected. The inclusion criteria were physicians with the previous criteria who accepted to participate. The exclusion criteria were physicians with the previous criteria who refused to participate.

Sample size

Sample size was calculated according to the results of the study done by **Iyer et al.** [9] in which the physician awareness was (74.7%)- by adopting a confidence interval of (95%), a margin of error of (5%) with finite population correction; The predicted sample size (n) was a total of (290) cases. Sample size was calculated by using EPI INFO version 7.2.5.0.

Statistical Method

Descriptive analysis was performed using Medcalc software, version 22 for windows (MedCalc Software Ltd, Ostend, Belgium). Figures were generated using Microsoft Excel for Windows version 2404 (Microsoft 365, Microsoft Egypt, Giza, Egypt). Categorical and binary data were presented as frequency and percentage; intergroup comparison was performed using the Chi-Squared test. The confidence limit was set at 95% with 80% power and all tests were two tailed with statistical significance level set at ($P \leq 0.05$).

RESULTS

Participants' demographic characteristics:

In the present study, 53.30% of participants were emergency doctors, 30.7% were specialized in family medicine, and 16.0% were pediatricians. Females represented 60.8% of the sample, while males accounted for 39.2%. Most participants were aged ≤35 years (91.8%), followed by those aged 36–45 years (7.8%) and >45 years (0.3%). 68.6% of participants received first aid training and 73.5% had prior dental trauma experience.

Knowledge results:

In Case 1, 90.5% of participants correctly identified the tooth as permanent, while 8.8% believed it was deciduous and 0.7% were unsure. Regarding immediate management of the broken tooth, 87.6% advised the patient to save the tooth pieces or fragments and refer her to a dentist, 12.1% recommended referral without advising to keep the fragments, and 0.3% suggested extraction.

Within emergency medicine doctors, 84.0% of respondents advised saving the tooth fragment and referring the patient to a dentist, while 16.0% referred without such advice. Among pediatricians, 93.9% gave the correct advice, and only 4.1% referred without recommending preservation; 2.0% suggested extraction. Family medicine practitioners showed similar patterns, with 90.4% advising preservation and 9.6% referring without it. The difference in responses across specialties was statistically significant ($P = 0.0279$). These data are illustrated in **Table (1).**

Table 1. Distribution of responses within each specialty in case 1 (Your immediate management of the case is).

Your immediate management of the case is	Specialty			Total
	Emergency	Pediatricians	Family medicine	
Refer the patient to a dentist without advising her to keep the tooth fragment	26	2	9	37 (12.1%)
	16.00%	4.10%	9.60%	
Advise the patient to save the tooth pieces or fragments and refer her to a dentist	137	46	85	268 (87.6%)
	84.00%	93.90%	90.40%	
Suggest the patient to have the tooth extracted	0	1	0	1 (0.3%
	0.00%	2.00%	0.00%	
P value	P = 0.0279			

In case 2 for Q1, 48.7% of participants reported that they would stop bleeding by applying gentle pressure with a cloth over the injury and advise the patient to rest. Other responses included: searching for the tooth after stopping bleeding (18.6%), looking for the tooth and replanting it immediately (25.2%), and placing the tooth in a handkerchief before referral (7.5%). In Q2, 96.4% indicated they would investigate whether the child had received a tetanus vaccine. For Q3, 82.0% considered immediate replantation essential, 15.0% suggested replantation within a few hours, and 2.9% within the same day. In Q4, 65.7% reported they would care if a primary tooth was knocked out, whereas 34.3% would not. For Q5, 58.8% selected rinsing the tooth gently under tap water and replanting it if it had fallen on dirty ground, 23.9% chose cleaning it with a toothbrush under tap water, 17.0% preferred rubbing dirt away with tissue, and 0.3% opted to discard the tooth. In Q6, 92.8% stated they would hold the tooth by the crown, 3.3% by the root, and 3.9% reported it was not important. These data are illustrated in **Table (2).**

Table 2. Distribution of responses within case 2 (Q1-Q6).

Case 2 (Q1-Q6)		Frequency	Percentage
Q1- The immediate emergency action you would take is:	Stop the bleeding by applying gentle pressure with a cloth over the injury and advise the patient to rest	149	48.70%
	Stop the bleeding and then search for the tooth	57	18.60%
	Look for the tooth and put it back in its socket	77	25.20%
	Place the tooth in a handkerchief and refer the child to a dentist	23	7.50%
Q2- Would you investigate if the child had a tetanus vaccine?	Yes	295	96.40%
	No	11	3.60%
Q3- How urgent do you think it is to replant an avulsed tooth?	Immediately	251	82.00%
	Within a few hours	46	15.00%
	Within the same day	9	2.90%
Q4- Would you care if a primary tooth is knocked out?	Yes	201	65.70%
	No	105	34.30%
Q5- If the tooth has fallen on the dirty ground, what would you do?	Rub away the dirt with a paper tissue and put it back into its socket	52	17.00%
	Clean the tooth with a toothbrush under tap water and put it back into its socket	73	23.90%
	Rinse the tooth gently under tap water and put it back into its socket	180	58.80%
	Discard the tooth	1	0.30%
Q6- How would you hold the tooth?	By the crown	284	92.80%
	By the root	10	3.30%
	Not important (crown or root)	12	3.90%

Emergency physicians most commonly advised stopping the bleeding and allowing the patient to rest (54.6%), followed by reinserting the tooth (19.6%), searching for it (17.8%), and placing it in a handkerchief (8.0%). Pediatricians were more likely to reinsert the tooth (42.9%), with fewer advising rest (30.6%) or searching for the tooth (16.3%). Family medicine practitioners showed a balanced distribution: 47.9% advised rest, 25.5% reinsertion, 21.3% searching, and 5.3% handkerchief placement. These differences were statistically significant (P = 0.0272). These data are illustrated in **Table (3).**

Table 3. Distribution of responses within each specialty in case 2 (The immediate emergency action you would take is).

The immediate emergency action you would take is	**Specialty**			**Total**
	Emergency	Pediatricians	Family medicine	
Stop the bleeding by applying gentle pressure with a cloth over the injury and advise the patient to rest	89	15	45	149 (48.7%)
	54.6% CT	30.6% CT	47.9% CT	
Stop the bleeding and then search for the tooth	29	8	20	57 (18.6%)
	17.8% CT	16.3% CT	21.3% CT	
Look for the tooth and put it back in its socket	32	21	24	77 (25.2%)
	19.6% CT	42.9% CT	25.5% CT	
Place the tooth in a handkerchief and refer the child to a dentist	13	5	5	23 (7.5%)
	8.0% CT	10.2% CT	5.3% CT	
P value	P = 0.0272			

When the physicians were asked whether it matters if a primary tooth is knocked out, 67.5% of emergency physicians, 63.3% of pediatricians, and 63.8% of family medicine practitioners responded affirmatively. The remaining 32.5%, 36.7%, and 36.2%, respectively, did not consider it significant. The variation in responses was not statistically significant (P = 0.7768). These data are illustrated in **Table (4).**

Table 4. Distribution of responses within each specialty in case 2 (Would you care if a primary tooth is knocked out?).

Would you care if a primary tooth is knocked out?	Specialty			Total
	Emergency	Pediatricians	Family medicine	
Yes	110	31	60	201 (65.7%)
	67.5% CT	63.3% CT	63.8% CT	
No	53	18	34	105 (34.3%)
	32.5% CT	36.7% CT	36.2% CT	
P value	P = 0.7768			

When asked if the tooth has fallen on the dirty ground what would you do? Among emergency physicians, 55.8% chose to rinse the tooth gently under tap water and reinsert it, 23.9% cleaned it with a toothbrush, 19.6% rubbed it with a tissue, and 0.6% discarded it. Pediatricians preferred gentle rinsing (69.4%), followed by toothbrush cleaning (24.5%) and tissue rubbing (6.1%). Family medicine practitioners responded similarly: 58.5% rinsed gently, 23.4% used a toothbrush, and 18.1% used a tissue. No pediatricians or family medicine practitioners opted to discard the tooth. The differences were not statistically significant (P = 0.3995). These data are illustrated in **Table (5).**

In Q7 when participants asked about appropriate storage media for an avulsed tooth, 63.1% considered tap water an appropriate medium for storing an avulsed tooth, 7.5% selected cold water, and 4.6% selected hot water. Salt water was chosen by 89.9% of participants, coconut water by 86.6%, and ice by 18.3%. Milk was considered appropriate by 97.2%, disinfectant solution by 66.3%, patient's saliva by 97.4%, and egg white by 91.2%. Only 1.6% selected coke, whereas 98.0% selected normal saline. Alcohol was chosen by 18.6%, contact lens solution by 87.3%, plastic foils by 84.6%, and cell culture media by 91.5%. Finally, 56.5% indicated that wrapping the avulsed tooth in paper tissue was an acceptable option. These data are illustrated in **Figure (1).**

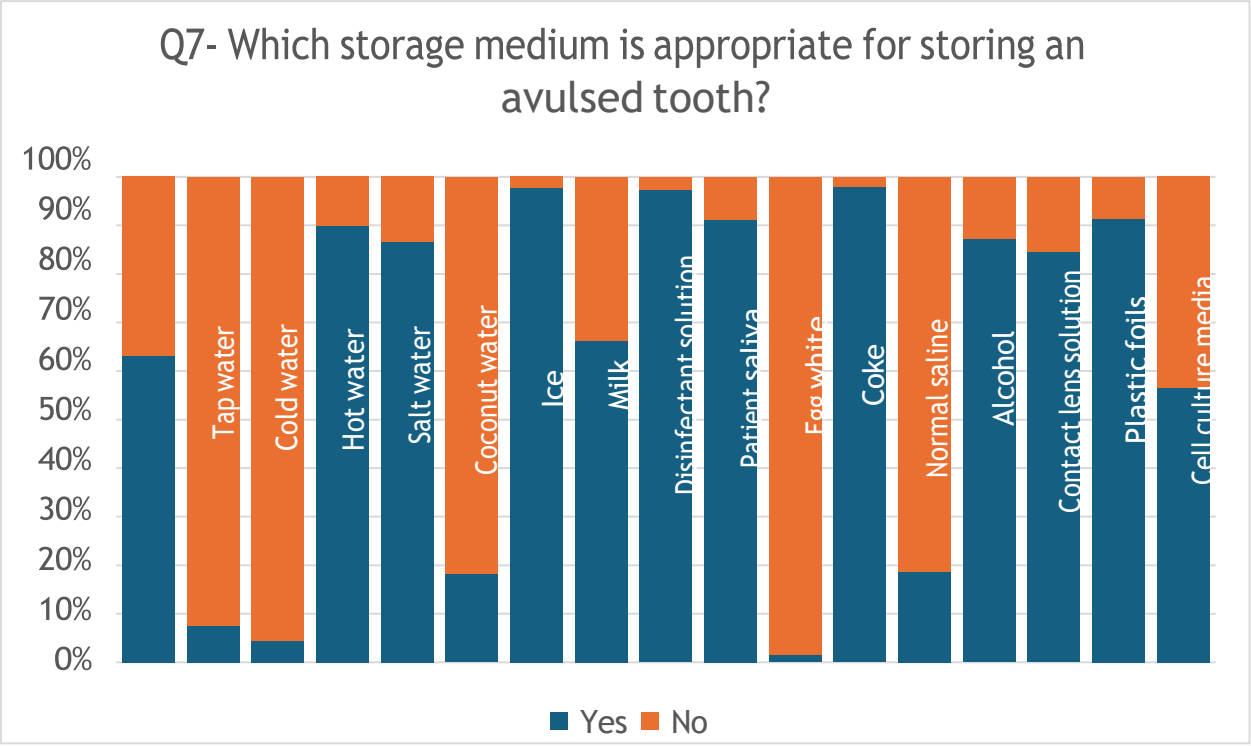


Figure 1. 100% stacked column chart showing distribution of responses within Q7 for different storage media.

Table 5. Distribution of responses within each specialty in case 2 (If the tooth has fallen on the dirty ground what would you do?).

If the tooth has fallen on the dirty ground what would you do?	Specialty			Total
	Emergency	Pediatricians	Family medicine	
Rub away the dirt with a paper tissue and put it back into its socket	32	3	17	52 (17.0%)
	19.6% CT	6.1% CT	18.1% CT	
Clean the tooth with a toothbrush under tap water and put it back into its socket	39	12	22	73 (23.9%)
	23.9% CT	24.5% CT	23.4% CT	
Rinse the tooth gently under tap water and put it back into its socket	91	34	55	180 (58.8%)
	55.8% CT	69.4% CT	58.5% CT	
Discard the tooth	1	0	0	1 (0.3%)
	0.6% CT	0.0% CT	0.0% CT	
P value	P = 0.3995			

Attitude results

Regarding confidence in diagnosing different TDIs affecting children, 51.3% neither agreed nor disagreed, 42.2% agreed to strongly agreed, and 6.5% disagreed to strongly disagreed. Similarly, regarding confidence in providing emergency treatment for TDIs, 53.9% neither agreed nor disagreed, 35.3% agreed to strongly agreed, and 10.8% disagreed to strongly disagreed. Satisfaction with knowledge level regarding TDIs and their management was expressed by 31.4%, while 60.1% neither agreed nor disagreed and 8.5% disagreed to strongly disagreed. Finally, the majority (79.1%) agreed to strongly agreed on the need for further education on TDIs and their management, 19.6% neither agreed nor disagreed, and 1.3% disagreed to strongly disagreed. These data are illustrated in **Figure (2).**

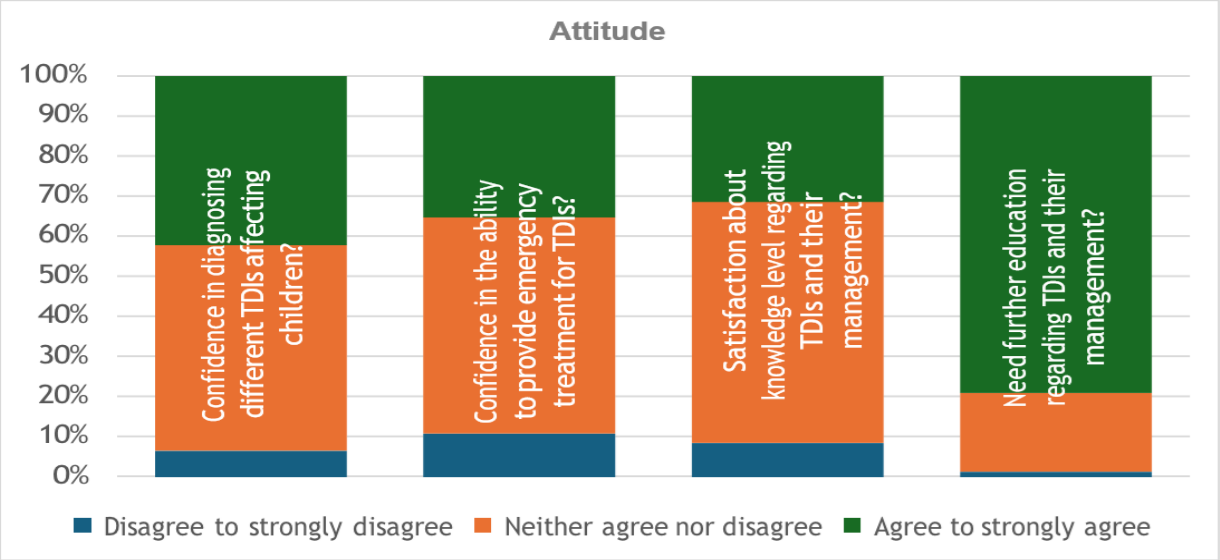


Figure 2 100% stacked column chart showing distribution of responses within attitude questions.

Among emergency physicians, 42.3% agreed or strongly agreed they were confident in diagnosing TDIs, 52.1% were neutral, and 5.5% disagreed. Pediatricians showed slightly higher confidence (44.9% agreed, 46.9% neutral, 8.2% disagreed), while family medicine practitioners reported 40.4% agreement, 52.1% neutrality, and 7.4% disagreement. These differences were not statistically significant (P = 0.9177). These data are illustrated in **Table (6).**

Table 6. Distribution of responses within each specialty in attitude (Confidence in diagnosing different TDIs affecting children).

Confidence in diagnosing different TDIs affecting children	Specialty			Total
	Emergency	Pediatricians	Family medicine	
Disagree to strongly disagree	9	4	7	20 (6.5%)
	5.5% CT	8.2% CT	7.4% CT	
Neither agree nor disagree	85	23	49	157 (51.3%)
	52.1% CT	46.9% CT	52.1% CT	
Agree to strongly agree	69	22	38	129 (42.2%)
	42.3% CT	44.9% CT	40.4% CT	
P value	P = 0.9177			

DISCUSSION

Traumatic dental injuries (TDIs) are a common problem in emergency rooms (ERs). TDIs in various forms account for up to 66% of ER visits related to dental injuries. Approximately one-fifth of permanent teeth and one-third of primary teeth experience traumatic injury at some point in their lifetimes. Medical professionals must have sufficient knowledge of TDIs because they play a crucial role in the initial management of these injuries. Physicians are frequently the first medical professionals to evaluate patients in emergency situations, including assaults, sports injuries, falls, and traffic accidents. The prognosis can be greatly impacted by doctors' ability to identify and appropriately treat dental trauma because access to dental care is not always immediate particularly in emergency rooms and rural areas. However, a number of studies reveal that emergency physicians around the world have inadequate knowledge and skills**(10)**.

Therefore, this study aimed to evaluate physicians' fundamental knowledge and attitude regarding the management of TDIs in Egypt.

Relatively quick and inexpensive to conduct

The present study designed as an observational cross-sectional, the main strength of cross- sectional studies is that they are relatively quick and inexpensive to conduct, data on all variables are only collected at one time point, no ethical difficulties, easy for generating hypotheses; Furthermore, They are the best way to determine the prevalence and can study the associations of multiple exposures

and outcomes. Therefore, it was the most suitable type of study for evaluating knowledge and attitude among Egyptian medical practitioner**(11,12)**.

This study used a pre-structured online questionnaire as it allows for an effective and consistent collection of data from a large number of physicians with little disruption to their clinical duties. The use of binary questions and fixed format provides consistency in the questions asked, participants' knowledge and attitudes can be measured consistently and reliably. Additionally, due to their flexibility and privacy, honest responses are encouraged, which enhances the overall quality and completeness of the data gathered**(13)**.

The study sample represents the frontline of pediatric emergency care because we surveyed doctors from family medicine, pediatrics, and

emergency departments, who are commonly the first medical professionals to deal with pediatric trauma cases. When a child presents with a traumatic injury, these doctors provide the initial evaluation, stabilization, and decision-making process[14].

Cairo University and Ain Shams University hospitals were chosen for this study because they have a considerable and varied workforce of physicians with a wide range of specializations and clinical backgrounds. Since these hospitals are significant tertiary medical centers and frequently handle emergency and trauma cases, choosing these hospitals guarantees a representative sample of doctors with suitable clinical experience[15].

Performing bias were reduced by administered the same structured questionnaire to each participant in the same way. This strategy reduces systematic variations in participant data collection methods, ensuring that response variation reflects actual differences rather than variations in data collection methodology. Additionally, all collected data whether favorable, neutral, or conflicting was included in the final analysis and presented transparently to prevent reporting bias[16]. The questionnaires were evaluated by a single operator, which reduced examiner-related variability and guaranteed consistency in scoring. This method narrowed the possibility of performance bias resulting from various evaluators' differing interpretations[17].

The findings of the present study provide valuable insight into the characteristics and awareness of healthcare providers who may face dental trauma in clinical practice. Emergency physicians made up the majority of participants (53.3%), with family medicine specialists coming in second (30.7%) and pediatricians third (16.0%). The majority of emergency physicians in the sample may be explained by the fact that emergency rooms, in particular, are frequently the initial point of contact for patients with severe dental injuries. One noteworthy feature of the sample was the high percentage of female participants (60.8%), which is consistent with an increasing number of women working in healthcare field. Furthermore. This tendency is consistent with previous research by Otufowora et al.[18] who stated that female physicians may be more likely than their male counterparts to participate in survey-based studies.

Most participants were relatively young, with 91.8% aged 35 or younger. this younger demographic may suggest that study sample consist largely of early career physicians, that may indicate that early career doctors generally participate in survey research more readily than older and more experienced practitioners. This finding comes with accordance with **Alamri**[19] which stated that older or busier practitioners may be discouraged from participating due to time restrictions and workload.

The effective management of dental emergencies depends heavily on training and prior experience. 73.5% of participants in this study had prior experience treating dental trauma, and 68.6% of participants reported having received first aid training. While these percentages are positive, they also show that a significant percentage of healthcare professionals still lack formal education or practical experience in this field. This was in accordance with **Mathew et al.**[20] who emphasized the importance of education of dental traumatology which is clinically significant because prognosis can be significantly impacted by appropriate treatment of dental trauma.

Regrading case 1, 90.5% of participants correctly identified the tooth as permanent this comes with accordance with **Yousuf et al.**[21] who reported that medical practitioners were more likely to have better knowledge about permanents teeth this was explained by that older children are more often coming to emergency department that increase familiarity of permanent teeth. On contrary 8.8% of participants believed that it was deciduous tooth and 0.7% was unsure. this agreed with **Yeng et al.**[7] which showed gap in anatomical knowledge and dental trauma classifications, this was explained by absence of undergrad dental courses and postgraduation dental training.

Regarding immediate management of the case, 87.6% advised the patient to save the tooth pieces or fragments then refer to a dentist, this comes with compliance with **Sameni et al.**[22] who advised the patients to retain the fractured pieces, as reattachment may be a viable and aesthetic treatment options. In contrast **Al-Shahrani et al.**[23] reported that many emergency physicians lacked adequate knowledge regarding the management of crown fractures.

Regarding the effect of specialty on responses in case 1, among emergency medicine practitioners 84.0% correctly advised preserving the tooth fragment and referring the patient to a dentist, whereas 16.0% referred patients without providing this guidance. This suggests that while majority of emergency physicians recognize the importance of fragment preservation a notable minority may not fully appreciate its impact on treatment outcomes which was in accordance with Coşkun et al.[24].

Furthermore, about 93.9% of pediatricians recommended preservation prior to referral, indicating

the highest level of adherence to appropriate management. A minor percentage (2.0%) recommended extraction, indicating a slight over-treatment tendency, and only 4.1% referred without such advice. This high percentage of accurate answers among pediatricians probably indicates an improved knowledge of pediatric dental trauma protocols and their regular involvement in pediatric care including dental emergencies, these data agreed with **Sari et al.[25].**

Additionally, family physicians demonstrated high compliance, with 90.4% recommending preservation and 9.6% making referrals without it. This shows significant knowledge in primary care settings, although slightly less than that of pediatricians. This is probably due to exposure to pediatric patients and general trauma management, which also confirmed by **Cagay et al.[26].**

The differences in responses across specialties were statistically significant, highlighting the influence of clinical focus and training on emergency dental knowledge this comes in accordance with **Coşkun et al., Sari et al.** and **Cagay et al.[24-26]**, and in contrast with **Wolfer et al.[10]**.

In case 2 concerning the immediate management of the avulsed tooth, 48.7% of the participants in this study reported that they would stop bleeding by applying gentle pressure with cloth and advice patients to rest, other responses included: searching for the tooth after stopping bleeding (18.6%), looking for the tooth and replanting it immediately (25.2%), and placing the tooth in a handkerchief before referral (7.5%). This come with accordance with **Ali et al.[8]** this is clarified by their first aid training which recommend applying direct pressure to control bleeding in soft tissue before starting advanced treatment.

Concerning tetanus vaccination for the patient a significant majority of the participants (96.4%) indicated they would investigate if the child had tetanus vaccination, this is agreed with **(Kuru and Duruk[27],** this reflected an appropriate medical response to the potential risk of infection associated with traumatic dental injuries. This is in contrast to the results of **Liu et al.[28]** who found that many emergency physicians showed inconsistent behaviors and inadequate understanding on tetanus prophylaxis in trauma cases.

About 82% of the participants agreed with urgent immediate replantation of the avulsed tooth where, 15% suggested replantation within a few hours, and 2.9% within the same day, this result agreed with the results of **Wolfer et al.[10]** who stated that the high respond for immediate implant can indicate theoretical knowledge of the medical practitioners. In contrast Çalışkan et al.[29] reported that the majority of participants had not suggested tooth replantation, this may be due to participants lacking knowledge and confidence in terms of providing first aid in cases of traumatic dental injuries.

Regarding if the avulsed tooth was primary, 65.7% reported that they would care if a primary tooth was knocked out, whereas 34.3% would not, this is agreed with **Bahammam[30]** explained that participants was aware with the importance of primary teeth as function and aesthetic but lack of knowledge and experience in dental traumatology. These results disagreed with **Barkhati and Mullahi[31]** where most of participants don't care about primary teeth avulsion this is often caused by insufficient training.

Concerning if the tooth has fallen in dirty ground, more than half of participants 58.8% selected rinsing the tooth gently under tap water and replanting it if it had fallen on dirty ground, 23.9% chose cleaning it with a toothbrush under tap water, 17.0% preferred rubbing dirt away with tissue, and 0.3% chose to discard the tooth, this result are similar to **Çalışkan et al.[29].** About 92.8% stated they would hold the tooth by the crown, 3.3% by the root, and 3.9% reported it was not important, this result come in accordance with **Bahammam[30]** and can be explained by ability of emergency physicians to distinguish the crown of the tooth due to the increased exposure to trauma cases, in contrary **Assadi et al.[14]** which stated that participants shows indifferent in holding the tooth with crown or root, this indicate a gap of knowledge and practice.

Regarding the appropriate storage medium most of participants correctly choose milk (97.2%), patient saliva (97.4), normal saline (98%) and cell culture media (91.5%) as suitable storage media, this comes with agreement with **Akhtar et al.[32]**.
Many of participants chose Egg white (91.2%), coconut water (86.6%) and 89.9% salt water, this indicating knowledge of new natural storage alternatives which was in accordance with **Khan and Sharma[33].**

Regarding the effect of specialty on responses in case 2: when asked about the immediate management of tooth avulsion, emergency physicians was advised to stop the bleeding and let the patient rest (54.6%), with fewer suggesting that the tooth be reinserted (19.6%) or searching for it (17.8%). This pattern probably reflects the priorities in emergency situations, where long-term dental outcomes are

frequently less important than immediate patient stabilization and hemostasis, this come in agreement with **Kuru and Duruk**[27].

In contrast, pediatricians were more likely to advise reinserting the tooth (42.9%), with a smaller proportion recommended rest (30.6%) or searching for the tooth (16.3%). This results recognizes the value of early intervention for long-term dental health and line with pediatric guidelines that emphasize the preservation of permanent teeth in children. Pediatricians' continued relationships with patients and families enable follow-up care and monitoring following side effects, this may also have an impact on their treatments approach, these data are in accordance with **Tadin et al.**[34].

Family medicine practitioners showed a more balanced distribution of management strategies, with 47.9% advising rest, 25.5% reinsertion, 21.3% searching, and 5.3% handkerchief placement. This pattern likely reflects the general nature of family medicine, balancing acute management with preventive and long-term care considerations. These data are in agreement with **Cagay et al.**[26].

This variation in responses across different specialty was statistically significant this identified significant knowledge gaps, particularly in immediate management of tooth avulsion this findings comes in agreement with **Çalışkan et al., Özalp and Özbulur** and **Yousuf et al.**[21,29,35] and in contrast with **Kuru and Duruk** and **Tadin et al.**[27,34].

The study also explored attitudes toward confidence in diagnosing traumatic dental injuries only 42.2% of respondents agreed or strongly agreed that they may felt confident ,while majority of 51.3% were neutral and 6.5% disagreed .this indicate that more than half of physicians are uncertain about their ability to recognize TDIs Similarly, regarding confidence in providing emergency treatment for TDIs, confidence drop further only 35.3%felt confident, over half (53.9%) were neutral and (10.8%) disagreed, this results in accordance with **Gallichan et al.**[36] and **Wolfer et al.**[10] who reported that low confidence are common due to lack of dental trauma teaching programs. In contrast **Assadi et al.**[14] demonstrated that participants were more confident because they had continuous education courses.

When assessing satisfaction with their knowledge level, only 31.4% were satisfied, whereas 60.1% were neutral and 8.5% were dissatisfied, notably there is broad agreement that additional education is necessary: Just 1.3% disagreed, 19.6% were undecided, and 79.1% agreed or strongly agreed that more TDI training is required. This consistent with **Wolfer et al.**[10] this explained by deficiency in dental trauma courses in undergrade and post grade educational programs.

There was statistically non-significant difference regarding attitude of medical practitioner from different specialty regarding diagnosis and treatment of traumatic dental injuries, this findings emphasized the urgent need to enhance dental trauma education for emergency department clinicians[37].

The low knowledge and self- reported confidence in the management of dental trauma reported in our study could be due to several reasons such as the lack of a clinician's prior adequate training and experience in managing dental trauma cases, in addition to the low exposure specifically with more complex cases. In terms of training and education, additional dental trauma education has been reported as a significant positive influence[38].

Knowledge provides clinicians with the scientific understanding and technical skills needed to make accurate decisions, apply evidence based practices, and ensure patient safety. Attitude shapes how this knowledge is delivered, influencing communication, understanding professionalism and responsiveness to patient needs. Therefore, both knowledge and attitude are essential components of competent and holistic clinical practice

LIMITATION OF THE STUDY:

While this study offers valuable insights, several limitations should be acknowledged:

- The current study can't be generalized to Egyptian physicians as the study focused on practitioners from only two hospitals this may limit the generalizability of the results to broader contexts, particularly in regions with different healthcare infrastructures, educational systems, and cultural attitudes toward dental trauma management.
- The use of self-reported data introduces the potential for response bias, with participants possibly overestimating or underestimating their actual knowledge and clinical practices.
- The findings shed light on current knowledge and attitudes among medical practitioners, they cannot determine whether these knowledge and attitudes influence one another or how they evolve over time.

CONCLUSIONS

- The present study demonstrates gaps of knowledge and lack of confidence among medical physician in diagnosing and managing traumatic dental injury in emergency department.

- There is a clear need to enhance dental trauma education for all emergency department (ED) healthcare professionals who may encounter traumatic dental injuries (TDIs). Improving training in this area will help increase clinicians' confidence and competence, enabling them to triage cases effectively and provide appropriate initial advice to patients and families.

CONCLUSION

ACKNOWLEDGMENTS

Not applicable.

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CONFLICTING OF INTERESTS

There is no conflict of interests in connection with this article.

ETHICALAPPROVAL

This study was conducted in accordance with the recommendations and permission of the Research Ethics Committee at the Faculty of Dentistry, Cairo University, Egypt. It was approved on 29/10/2024, with approval number 10-24.

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ORIGINAL RESEARCH

IMPACT OF CONVENTIONAL REMOVABLE DENTURES ON ORAL HEALTH-RELATED QUALITY OF LIFE IN PARTIALLY AND COMPLETELY EDENTULOUS PATIENTS TREATED BY DENTAL STUDENTS IN KARBALA, IRAQ

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Abstract

Background and Objective: Edentulism continues to be a significant oral health challenge globally, especially among aging populations and those with restricted access to advanced dental care. Conventional removable dentures remain the most accessible and affordable prosthetic treatment in developing countries. Evaluating oral health-related quality of life (OHRQoL) after prosthodontic rehabilitation is critical to understanding treatment impact beyond clinical success alone. **Our objective is to** evaluate changes in oral health-related quality of life (OHRQoL) among partially and completely edentulous patients treated with conventional removable dentures fabricated by undergraduate dental students at the University of Al-Ameed, Karbala, Iraq.

Methods: Sixty patients were assessed using a validated questionnaire adapted from the OHIP-EDENT before and eight weeks after receiving dentures. The survey covered functional, psychological, and social domains. Data were analyzed using paired t-tests.

Results: Significant improvements were observed in all OHRQoL domains post-treatment, with the greatest gains in functional limitation and psychological discomfort. Subgroup analysis revealed similar benefits for both partial and complete denture wearers, regardless of age, sex, or comorbidities.

Conclusion: Student-fabricated removable dentures significantly improved OHRQoL, supporting their clinical effectiveness and educational value.

Keywords: *Oral Health Improvment, Removable Denture, Dental Education*

INTRODUCTION

Edentulism, the complete or partial loss of natural teeth, continues to be a major oral health concern globally. Its impact is especially evident among older adults and individuals with limited access to modern dental care. Beyond the obvious loss of teeth, edentulism affects nearly every aspect of daily life. Chewing becomes difficult, often forcing patients to change their diet and putting them at risk of nutritional deficiencies. Speech clarity may decline, affecting communication and social confidence. At the same time, changes in appearance can diminish self-esteem and emotional well-being. Together, these challenges often create a cycle of discomfort, embarrassment, and social withdrawal, ultimately influencing overall health and psychological stability [1,2].

In many developed countries, implant-supported prostheses have emerged as the preferred option for rehabilitating edentulous patients, offering superior comfort, stability, and functional outcomes [3]. These solutions often allow patients to exert stronger bite forces, improve their chewing capacity, and experience greater overall satisfaction compared to conventional removable dentures[3,10]. However, despite their advantages, implant therapy remains financially and technically demanding. In regions where cost, surgical expertise, and clinical infrastructure pose barriers, conventional removable dentures continue to be the most accessible and widely

Hashim Kadhim, Farah Sadik , Hawraa Abbas, Mohammed Hussein M. Alsharbaty. Impact of Conventional Removable Dentures on Oral Health-Related Quality of Life in Partially and Completely Edentulous Patients Treated by Dental Students in Karbala, Iraq. Bulletin of Stomatology and Maxillofacial Surgery.2025;21(12)104-109 doi:10.58240/1829006X-2025.21.12-104

used treatment option because they are affordable, non-invasive, and readily available [3,4].

Evaluating oral health-related quality of life (OHRQoL) has therefore become central to understanding the true impact of prosthodontic treatment from the patient's perspective. While traditional clinical criteria—such as denture fit or occlusion—reflect technical success, they do not capture the broader functional, emotional, and social outcomes that shape daily experiences [5,6].

The Oral Health Impact Profile for edentulous patients (OHIP-EDENT) provides a validated and comprehensive tool for assessing these dimensions, allowing clinicians to measure pain, discomfort, functional limitations, and psychosocial changes before and after treatment [5,6].

Findings from numerous international studies consistently demonstrate that conventional removable dentures significantly enhance OHRQoL, with marked improvements in both functional and psychosocial domains [7–10]. Many patients report better chewing ability, clearer speech, and increased confidence in social interactions after receiving properly fabricated dentures [7–9]. Relief from oral pain and discomfort—symptoms frequently experienced by edentulous individuals—also contributes to improved satisfaction and easier adaptation to new prostheses [10,16]. Yet most of these studies originate from high-resource regions, leaving a shortage of data from Middle Eastern or low-resource settings, where conventional dentures remain the primary treatment modality.

Within dental education, the involvement of undergraduate students in providing prosthodontic care is an important factor. Research has shown that, under proper supervision, students can produce dentures that are clinically comparable to those fabricated by experienced clinicians [14,15,20,21].

This hands-on experience enhances students' skills and, at the same time, helps meet the community's treatment needs—especially in areas where access to specialized prosthodontists is limited [14,15,20,21]. Assessing OHRQoL in this setting provides meaningful insight into both treatment effectiveness and the quality of student-delivered care.

In Iraq, however, patient-reported outcomes related to removable denture therapy remain under-documented. Existing studies tend to emphasize technical aspects or retrospective evaluations of student performance, leaving a notable gap in understanding the real-life impact of conventional dentures on function, comfort, and psychological well-being [4,14,15].

Cultural habits, dietary patterns, and social expectations may also influence patient experiences, making locally generated evidence essential for improving clinical practice and guiding educational approaches.

To address these gaps, the present study prospectively evaluates changes in OHRQoL among partially and completely edentulous Iraqi patients treated with conventional removable dentures fabricated by undergraduate students at the University of Al-Ameed in Karbala, Iraq. By comparing patient-reported outcomes before and after treatment, this study aims to quantify the functional, psychological, and social benefits of student-made dentures, ultimately supporting clinical decision-making, enhancing educational quality, and informing policy development in resource-limited environments [5–10,14,15].

MATERIALS AND METHODS

Study Design and Participants

This prospective cohort study included 60 partially and completely edentulous patients (aged 35–75 years) recruited from the University of Al-Ameed Dental Clinics, Karbala, Iraq, between January and June 2025. Inclusion criteria were the need for new or replacement removable dentures and the ability to provide informed consent. Patients with severe cognitive impairment or those unable to attend follow-up were excluded.

Data Collection

Demographic data (age, sex), medical history (including diabetes, hypertension, cardiovascular disease), and prosthesis type (complete or partial denture) were recorded for each participant. OHRQoL was assessed using a bilingual (Arabic/English) questionnaire adapted from the OHIP-EDENT instrument, administered before denture insertion and at eight weeks post-insertion. The questionnaire comprised 15 domains, including:

- Functional limitation (e.g., speech, chewing, swallowing)
- Physical pain (e.g., aching, discomfort)
- Psychological discomfort (e.g., self-consciousness, embarrassment)
- Physical and psychological disability
- Social disability and handicap

Scoring and Statistical Analysis

Responses were recorded on a 5-point Likert scale (0 = Never, 4 = Very often), with higher scores indicating greater impairment. Descriptive statistics summarized demographic and clinical characteristics Paired t-tests compared mean domain scores before and after treatment. Subgroup analyses explored differences by prosthesis type, sex, and presence of systemic disease. Statistical significance was set at $p < 0.05$.

RESULTS

Patient Characteristics

The study was enrolled with 60 patients. There was a greater number of females (n = 37, 61.7%), but the number of males was also large (n = 23, 38.3%). The average age was 62.4 years with standard deviation of 9.1 (35 years to 75 years of age).

Complete dentures were delivered to 34 patients (56.7%), and 26 patients (43.3%) received partial dentures. Systemic comorbidities were common: 38.3% of patients had diabetes mellitus, 31.7% had hypertension, and 16.7% reported both conditions.

Baseline Oral Health–Related Quality of Life

The patients had a significant deficit in oral health-related quality of life (OHRQoL) before denture rehabilitation. The functional impairments were also evident as 47% of them reported that they had problems with pronunciation of words. Physical pain was also common; 42% were having painful aching in their mouth and 53% were complaining that they were having pains when eating some particular foods. Psychosocial effects were considerable as almost half of the participants (49%) were self-conscious or embarrassed because of their oral condition.

Post-Treatment OHRQoL Improvement

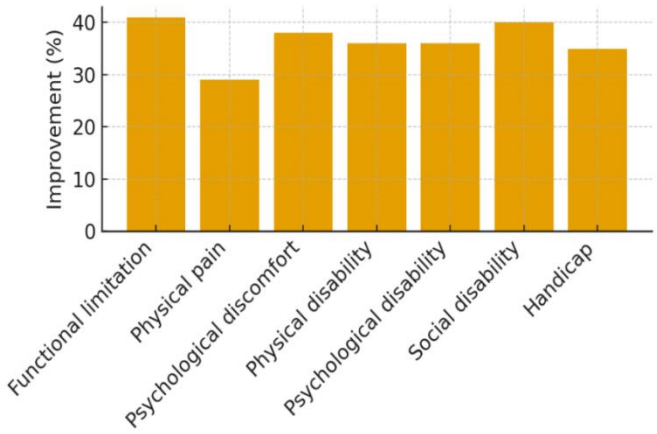


Figure 1. The percentage of improvement of OHIP-EDENT domains after dental treatments

Moderate improvements were seen at eight weeks after denture insertion in all domains of OHIP-EDENT (all $p < 0.001$). There was a reduction in functional limitation scores by 41 percent, which indicated improved speech and oral performance. Psychological outcome was much improved, and psychological discomfort and psychological disability were reduced by 38 and 36, respectively. Physical pain such as painful aching and eating- related discomfort was reduced by 29%. There was also a significant increase in social well-being as there was a reduction of 44% of embarrassment and self-consciousness.

Table 1. Domain-Specific Outcomes

Domain	Before (Mean ± SD)	After (Mean ± SD)	p value
Functional limitation	6.1 ± 1.8	3.6 ± 1.5	<0.001
Physical pain	5.8 ± 1.9	4.1 ± 1.6	<0.001
Psychological discomfort	4.9 ± 1.7	3.0 ± 1.4	<0.001
Physical disability	3.8 ± 1.5	2.6 ± 1.2	<0.001
Psychological disability	3.5 ± 1.3	2.3 ± 1.1	<0.001
Social disability	2.7 ± 1.2	1.8 ± 0.9	<0.001
Handicap	2.1 ± 1.0	1.4 ± 0.7	<0.001

Mean OHIP-EDENT scores were compared at the baseline and after treatment showed statistically significant improvements in all areas.

Subgroup Analysis

Complete and partial denture users had large gains in OHRQoL post-treatment. The extent of the improvement was a little higher in complete denture recipients, but the difference was not significant. Systemic disease patients showed similar improvements as non-comorbid patients. Moreover, there were no considerable differences in outcomes, between male and female patients.

DISCUSSION

The present study provides strong evidence that conventional removable dentures fabricated by dental students under supervision significantly improve oral health-related quality of life (OHRQoL) among partially and completely edentulous patients in Karbala, Iraq. These findings highlight both the clinical effectiveness of removable dentures and the educational value of hands-on prosthodontic training, offering insights that are particularly relevant for low-resource settings where implant therapy is often inaccessible [5–10,14,15].

Functional and Psychological Benefits
The most pronounced improvements were observed in functional limitation and psychological discomfort domains. Before treatment, many patients reported difficulties with chewing, speaking, and swallowing, which are consistent with prior reports on the impact of edentulism on daily life [1,2,7]. Nearly half of our cohort reported feeling self-conscious or embarrassed due to missing teeth, emphasizing the profound psychosocial burden of tooth loss. After receiving well-fitted student-fabricated dentures, patients reported marked reductions in these complaints, with many indicating that they "rarely" or "never" experienced functional difficulties or embarrassment.

This aligns with international studies showing that properly fabricated removable dentures enhance masticatory efficiency, improve speech, and positively influence self-esteem and social confidence [7–10].

These results underscore the interrelationship between function and psychosocial well-being. Patients who can chew comfortably and speak clearly often regain social confidence and are more likely to participate in community and family activities, illustrating how prosthodontic interventions can improve both physical and psychological quality of life [7,9,10].

Reduction in Physical Pain and Social Disability
Oral pain and meal interruptions, frequently reported pre-treatment, were substantially reduced after denture insertion. Persistent discomfort is a major factor contributing to dissatisfaction and discontinuation of prostheses [16]. The improvement in social disability, measured by reductions in embarrassment, irritability, and difficulty performing daily tasks, indicates that dentures provide benefits that extend beyond oral function. By facilitating eating, speaking, and social interactions, conventional dentures contribute to reintegration of patients into daily and community life, enhancing overall quality of life [10,16,17].

Impact Across Demographics and Comorbidities
Subgroup analyses demonstrated that both partial and complete denture recipients experienced significant improvements, and benefits were consistent across sex, age, and systemic comorbidities, including diabetes and hypertension.

This suggests that student-fabricated dentures are broadly applicable, regardless of patient health status, and highlights their potential to address oral health disparities in populations with prevalent chronic disease [17,22]. Such findings are particularly relevant in Iraq, where older adults often present with multiple systemic conditions that may complicate oral rehabilitation.

Educational and Clinical Implications
The success of student-fabricated dentures emphasizes the effectiveness of supervised clinical training. Prior studies indicate that with proper oversight, dental students can achieve clinical outcomes comparable to experienced practitioners, while simultaneously gaining essential technical and interpersonal skills [14,15,20,21]. Engaging students in the provision of removable dentures serves a dual purpose: it meets local oral health needs and strengthens the competency and confidence of future dental professionals. This approach also encourages students to develop patient-centered communication skills, an important factor in maximizing treatment satisfaction and adaptation [14,15,20,21].

Comparison with International Standards
While implant-supported prostheses are considered the gold standard in high-resource settings, conventional removable dentures remain an effective and accessible option for improving OHRQoL in resource-limited environments [10,17].

Systematic reviews have confirmed that conventional dentures, when carefully fabricated and fitted, provide substantial functional and psychosocial benefits, often approaching patient satisfaction levels reported with more advanced prosthetic modalities [10,17,27,28]. In our cohort, the observed improvements in function, psychological comfort, and social integration mirror these international findings, demonstrating that conventional removable dentures retain significant clinical relevance in settings where implants may not be feasible.

Limitations and Future Directions
Despite its strengths, this study has limitations. The follow-up period was limited to eight weeks, which may

not fully capture long-term adaptation, wear-related complications, or prosthesis maintenance issues. Additionally, the absence of a control group (e.g., patients treated by experienced clinicians or with implant-supported prostheses) limits the ability to contextualize the magnitude of observed improvements. Future research should incorporate longer-term follow-up, larger and more diverse samples, and direct comparisons between student- and clinician-fabricated prostheses. Investigating the impact of digital denture technologies on OHRQoL may also provide valuable insights, as computer-aided design and manufacturing increasingly influence prosthodontic practice [27,28].

CONCLUSION

In summary, this study demonstrates that removable dentures provided by dental students under supervision can significantly enhance the oral health-related quality of life for partially and completely edentulous patients. These findings have important implications for clinical practice, dental education, and oral health policy in Iraq and similar settings.

DECLARATIONS

Conflict of Interest

The authors declare no conflict of interest.

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ORIGINAL RESEARCH

COMPARISON OF STRUCTURAL INTEGRITY AND VIABILITY OF SPLIT- THICKNESS GRAFTS STORED AT 4℃ AND -8℃

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ABSTRACT

Background: Skin grafting is a widely utilized modality for wound closure. However, suitable donor grafts are not always readily available, and in some instances the wound bed is not yet prepared for graft application. Consequently, the ability to preserve split-thickness grafts (STG) is essential in reconstructive practice.

Objective: This study aims to compare the structural integrity and viability of split-thickness grafts stored at 4°C and -80°C.

Methodology: This experimental study employed a post-test control group design, utilizing 21 split-thickness skin samples obtained from excess skin during surgical procedures at Dr. Soetomo Regional Hospital, Surabaya. Samples were divided into three groups: fresh (control), storage at 4°C, and storage at -80°C for two weeks using 0.9% NaCl and glycerol as storage media. Tissue structure was assessed via hematoxylin-eosin staining, while cell viability was measured using the MTT Assay.

Results: Results demonstrated that storage at -80°C more effectively preserved the integrity of the epidermal and dermal structures, particularly concerning de-keratinization and the dermo- epidermal junction, compared to storage at 4°C ($p < 0.05$). Tissue viability increased with decreasing storage temperature, reaching the highest values at -80°C for both 0.9% NaCl and glycerol media ($p < 0.001$). The use of glycerol as a storage medium yielded higher viability compared to 0.9% NaCl. Lowering the storage temperature significantly enhanced cell survival and maintained tissue architecture.

Conclusion: Storing split-thickness grafts at -80°C in glycerol provides the optimal preservation of tissue structure and viability, representing an effective long-term storage method for use in plastic surgery therapies.

Keywords: split-thickness graft, skin storage, cryopreservation, skin structure, skin viability

INTRODUCTION

Skin grafting is one of the most frequently used wound-closure techniques in plastic surgery and has been practiced for more than 2,500 years. Beyond its cosmetic advantages, skin grafting restores skin continuity, providing essential protective

function to the body. However, donor skin grafts are not always available in adequate amounts throughout the course of treatment, and in some cases the wound bed is not yet ready to receive a graft. Clinicians may occasionally harvest more skin than immediately required so that excess tissue temperature of the grafts (4°C and −80°C), while the dependent variables were structural characteristics and tissue viability.

Study Subjects and Sample Selection

The study subjects consisted of split- thickness skin grafts obtained from excess tissue removed during surgical procedures, including abdominoplasty, blepharoplasty, skin grafting, and facelift surgeries. The study population included all split-thickness grafts harvested at Dr. Soetomo General Hospital, Surabaya. Eligible samples were obtained from patients aged 30–60 years who provided informed consent. Exclusion criteria included crush injury, the presence of striae/stretch marks, and a history or high risk of AIDS, hepatitis, or syphilis.

Sample size determination referred to Knapik (2012), who utilized 17 samples in a similar study. Considering

the availability of cases, this study employed 21 samples, which were distributed equally into three groups.

A split-thickness skin graft was defined as a graft containing the full thickness of the epidermis and part or all of the dermis, depending on the desired thickness (Perdanakusuma, 2005).

Graft Harvesting and Initial Processing

Following informed consent, eight split-thickness grafts measuring 20 × 10 mm with a thickness of 0.30–0.45 mm were harvested using a Humby knife under general anesthesia. Grafts were placed in sterile containers containing 0.9% NaCl supplemented with 100 IU/mL penicillin and 100 µg/mL streptomycin and transported at 4°C. Samples were washed sequentially in povidone-iodine, chlorhexidine digluconate, and isopropanol.

Experimental Groups and Storage Procedures Grafts were allocated into three groups:

a. Fresh group (control): Underwent immediate microscopic examination at the Anatomical Pathology Laboratory, Faculty of Medicine, Universitas Airlangga, and MTT assay evaluation at Gamma Scientific Biolab, Malang.

b. 4°C storage group: Grafts were immersed in a solution containing streptomycin sulfate and sodium penicillin G, wrapped in saline- moistened gauze, and stored at 4°C for two weeks.

c. −80°C storage group (glycerolized grafts):

Grafts underwent a three-stage glycerolization protocol:

• Immersion in 98% glycerol + 0.9% NaCl (50/50 v/v) with antibiotics, followed by visual inspection for mechanical damage.

• Placement in sterile plastic with 98% glycerol and 0.9% NaCl (10/14 v/v; final concentration 70% glycerol), incubated at 33°C for 3 hours with rotational shaking, followed by reevaluation.

• Placement in sterile plastic with 85% glycerol, incubation at 33°C for 3 hours, then trimming, cutting, and packing in 85% glycerol.

The processed grafts were stored at −80°C for two weeks.

Histological Assessment

After two weeks, each graft was bisected. One portion was processed for microscopic evaluation using hematoxylin– eosin staining. Structural parameters assessed included epidermal de-keratinization, epidermal integrity, ballooning degeneration of epithelial cells, dermo-epidermal junction morphology, dermal gland appearance, and vascular structure. Each parameter was scored from 0 (none) to 3 (severe), based on the proportion of tissue affected.

Tissue Viability Assessment (MTT Assay)

The second portion of each graft was used for viability testing using the MTT assay. Keratinocytes isolated from the grafts were exposed to MTT reagent (3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyl-2H- tetrazolium bromide). This reagent permeates viable cell membranes and mitochondria, where enzymatic reduction yields MTT- formazan crystals. Optical density (OD), measured at approximately 570 nm, reflects intracellular formazan concentration and serves as an indicator of cellular metabolic activity and viability (Ghasemi, 2021).

Study Sites and Timeline

The study was conducted at the Anatomical Pathology Laboratory of the Faculty of Medicine, Universitas Airlangga, Surabaya, and at Gamma Scientific Biolab, Malang. The overall timeline—from protocol preparation, laboratory work, data analysis, to manuscript completion—spanned approximately nine months.

MATERIALS AND EQUIPMENT

Materials and equipment included instruments for harvesting split-thickness grafts, refrigeration and cryogenic storage units (4°C and −80°C), glycerol solutions, antibiotic preparations, microtomy and staining equipment, and all reagents, media, and enzymes required for the MTT assay.

Data Processing and Analysis

The collected data were tabulated, followed by tests of normality and homogeneity of variance to determine whether the data were normally distributed and homogeneous. If the results indicated a normal distribution, the analysis was continued using parametric statistical methods, specifically analysis of variance (ANOVA) with a 95% confidence level. When ANOVA demonstrated a statistically significant difference, post-hoc analysis was performed using the Least Significant Difference (LSD) test.

RESULTS

A total of 21 split-thickness skin graft samples were analyzed and divided into three groups: fresh (control), 4°C, and −80°C (each n = 7). Evaluation included the structure of both epidermis and dermis. Epidermal parameters assessed were de-keratinization (DK), epidermal integrity (EI), ballooning of the epithelial cells (BL), and the dermo- epidermal junction (DEJ). Dermal structure was evaluated based on dermal gland appearance (DGL) and blood vessel structure (BV) (Table 1.).

Table 1. Descriptive and Comparative Test Results for Histological Examination

Histological Parameter	Group	None (%)	Mild (%)	Moderate (%)	Severe (%)	p-Value
De-keratinization (DK)	Control	0.0	0.0	0.0	100.0	0.002
	4°C	28.6	42.9	28.6	0.0	
	–80°C	14.3	14.3	28.6	42.9	
Epidermal Integrity (EI)	Control	57.1	42.9	0.0	0.0	0.172
	4°C	57.1	42.9	0.0	0.0	
	–80°C	28.6	28.6	28.6	14.3	
Ballooning of Epithelial Cells (BL)	Control	57.1	28.6	14.3	–	0.762
	4°C	42.9	28.6	28.6	–	
	–80°C	57.1	28.6	14.3	–	
Dermo-epidermal Junction (DEJ)	Control	28.6	71.4	0.0	0.0	**0.001**
	4°C	0.0	0.0	28.6	71.4	
	–80°C	42.9	42.9	14.3	0.0	
Dermal Glands Appearance (DGL)	Control	0.0	14.3	57.1	28.6	0.413
	4°C	28.6	57.1	14.3	0.0	
	–80°C	28.6	57.1	14.3	0.0	
Blood Vessels Structure (BV)	Control	0.0	14.3	57.1	28.6	0.135
	4°C	28.6	57.1	14.3	0.0	
	–80°C	28.6	57.1	14.3	0.0	

The control group demonstrated the most severe tissue damage across all parameters, particularly DK, with 100% of samples showing severe damage. Storage at 4°C showed predominantly mild damage, whereas storage at −80°C resulted in the highest preservation of tissue integrity, especially in DK and DEJ. EI remained relatively stable in both the control and 4°C groups; however, grafts stored at −80°C showed a greater proportion of mild damage. BL did not exhibit meaningful changes across temperature variations.

Histological results using glycerol storage media were consistent with those stored in 0.9% NaCl, demonstrating better structural preservation at lower temperatures. Most samples stored at −80°C exhibited no detectable DEJ damage, indicating that freezing at −80°C provided superior protection for the dermo-epidermal junction compared with storage at 4°C.

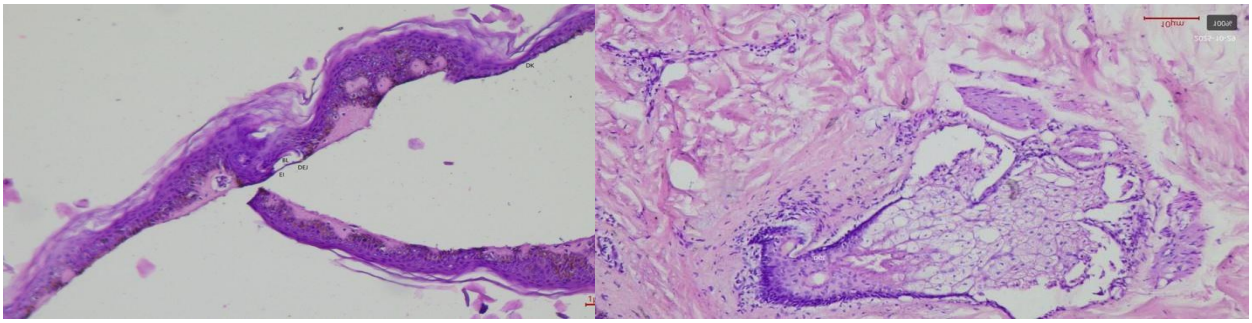


Figure 1. Fresh Split-Thickness Skin graft

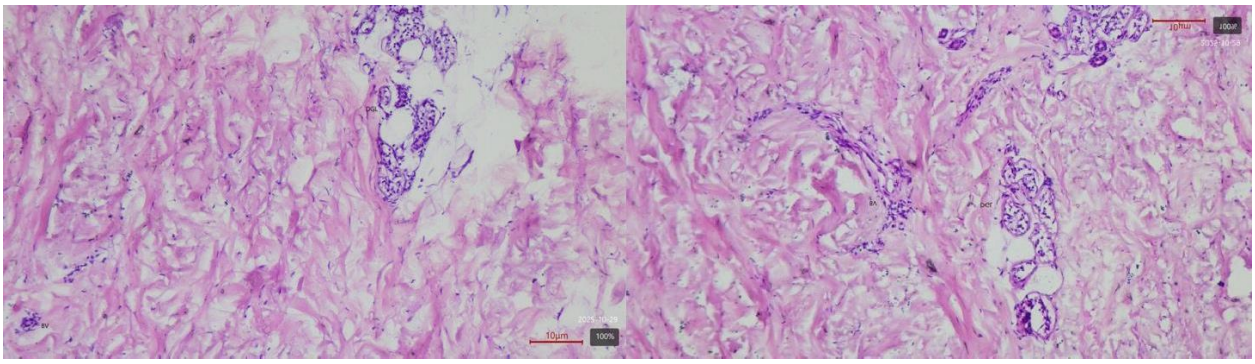


Figure 2. Split-Thick ness Skin Graft in NaCl 4°C

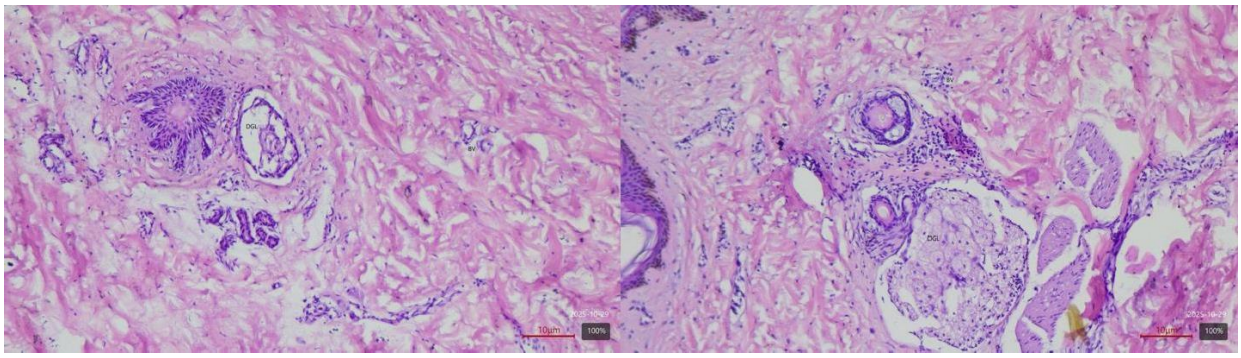


Figure 3. Split Thickness Skin Graft in NaCl −80°C

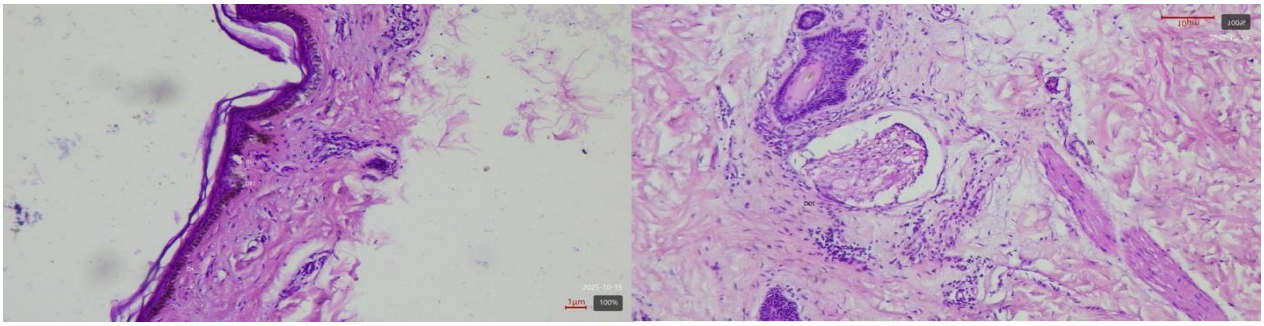


Figure 4. Split-Thickness Skin Graft in Glycerol 4°C

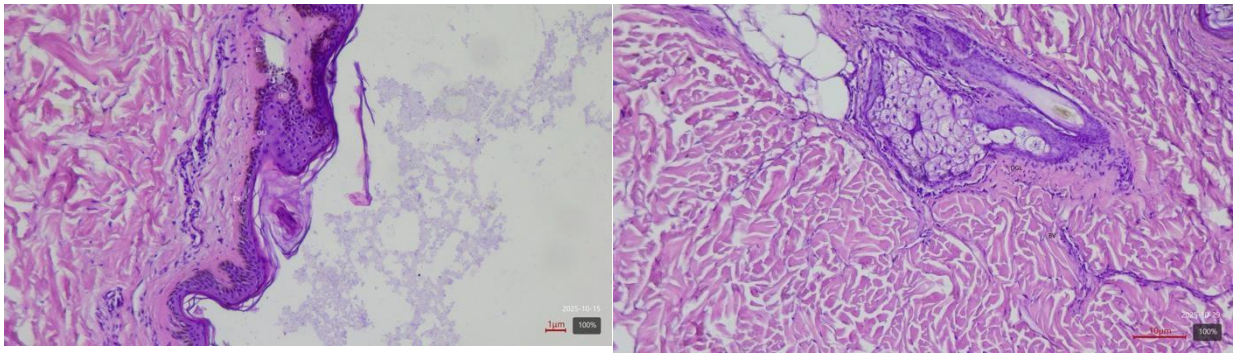


Figure 5. Split-Thickness Skin Graft in Glycerol −80°C

A Kruskal–Wallis test was performed to assess differences in histological structure among the treatment groups (control, 4°C,

−80°C) using 0.9% NaCl media. Significant differences were observed in DK and DEJ, with p-values of 0.002 and 0.001, respectively ($p < 0.05$). These findings indicate that storage temperature significantly affected tissue integrity in these layers.

EI and BL did not differ significantly between groups ($p = 0.172$ and $p = 0.762$), suggesting that temperature variations between 4°C and −80°C did not substantially influence these parameters. Overall, the results indicate that decreasing storage

dermo-epidermal junction.

In general, the distribution of damage severity showed that the control group had the highest proportion of moderate–severe damage in DGL and BV. Storage at 4°C and
−80°C decreased the proportion of moderate– severe damage and increased the "none" and "mild" categories, demonstrating a protective effect of lower temperatures on dermal structure. The most consistent findings were seen in samples stored with glycerol media, especially for BV, where samples stored at 4°C showed 100% none–mild damage with no moderate or severe damage. This pattern supports the statistical findings indicating that low-temperature storage—particularly at 4°C and −80°C— preserved dermal histology, including vascular structures. Glycerol storage media appeared more sensitive in detecting structural variability among groups.

Analysis of samples stored in glycerol demonstrated patterns consistent with those stored in 0.9% NaCl. Significant differences were observed in DK ($p = 0.001$) and DEJ ($p = 0.011$), while EI ($p = 0.062$) and BL ($p = 0.195$) remained statistically insignificant. These findings reinforce that the dermis and dermo-epidermal junction were the most temperature-sensitive components, with superior preservation at −80°C compared with 4°C or fresh controls.

Tissue Viability Study

In the 0.9% NaCl storage group, quantitative viability assessment revealed clear differences among treatment groups. Mean tissue viability increased with decreasing storage temperature: 50.47 ± 3.78% in the control group, 64.41 ± 2.35% at 4°C, and 74.04 ± 3.85% at −80°C. The low variability across samples indicates high result consistency. A similar pattern was observed in the glycerol storage group, though with higher viability at all temperatures: 50.47 ± 3.78% (control), 73.51 ± 4.40% (4°C), and 84.27 ± 5.03% (−80°C) (Table 2.).

Table 2. Tissue Viability Comparative Test Results

Storage Medium	Group	Mean ± SD	p-value
0.9% NaCl	Control	50.47 ± 3.78	<0.001
	4°C	64.41 ± 2.35	
	−80°C	74.04 ± 3.85	
Glycerol	Control	50.47 ± 3.78	<0.001
	4°C	73.51 ± 4.40	
	−80°C	84.27 ± 5.03	

ANOVA revealed highly significant differences across the three groups for both storage media ($p < 0.001$), indicating that storage temperature had a strong effect on tissue viability. Descriptively, these results show that lower storage temperatures corresponded with higher tissue viability.

The magnitude of group differences also suggests that glycerol had greater sensitivity in detecting viable cells, particularly in frozen tissues. These findings support the hypothesis that storage at −80°C better preserves tissue structure and function with minimal morphological and cellular degradation.

Post Hoc Analysis (LSD Test)

Post hoc analysis confirmed significant differences among all storage conditions, for both 0.9% NaCl and glycerol media, with $p < 0.001$ for all comparisons.

In the 0.9% NaCl group, mean viability increased significantly from 50.47% (control) to 64.41% (4°C) and 74.04% (−80°C). The differences between groups were consistent:

- Control vs. 4°C: +13.94%
- Control vs. −80°C: +23.57%
- 4°C vs. −80°C: +9.63%

These results indicate that each decrease in storage temperature corresponded to a significant increase in tissue viability.

A similar pattern occurred with glycerol, though with larger absolute differences. Mean viability increased from 50.47% (control) to 73.51% (4°C) and 84.27% (−80°C). The inter-group differences were:

- Control vs. 4°C: +23.04%
- Control vs. −80°C: +33.79%
- 4°C vs. −80°C: +10.76%

Overall, storage at −80°C produced the highest level of tissue viability. Additionally, glycerol consistently yielded higher viability values than 0.9% NaCl at all temperatures.

Table 3. Post Hoc (LSD) Test Results for Tissue Viability Based on Storage Temperature

Storage Medium	Group Comparison	Std. Error	p-value	Description
0.9% NaCl	Control – 4°C	1.82	<0.001	Significant
	Control – −80°C	1.82	<0.001	Significant
	4°C – −80°C	1.82	<0.001	Significant
Glycerol	Control – 4°C	2.37	<0.001	Significant
	Control – −80°C	2.37	<0.001	Significant
	4°C – −80°C	2.37	<0.001	Significant

DISCUSSION

Differences in Histological Structure of Split-Thickness Skin Grafts

Tissue damage caused by exposure to subfreezing temperatures and the process of ice recrystallization represents a major limitation in the application of organ cryopreservation for transplantation purposes. A thawing process that does not occur at an optimal rate can trigger excessive ice recrystallization, resulting in cellular and tissue damage, as the formation of large ice crystals increases tissue injury. In the epidermal layer of the skin graft, this phenomenon is reflected in variables such as de-keratinization (DK), epidermal integrity (EI), and ballooning of the epithelial cells (BL). Histological changes in the dermis are indicated by alterations in the dermo- epidermal junction (DEJ), connective tissue fibers breakage (CFB), hair follicle integrity (HF), dermal glands appearance (DGL), and blood vessel structure (BV). In the hypodermis, observed parameters include adipose tissue integrity (AD) and smooth muscle structural changes (SM).[9]

Storage of split-thickness skin grafts is a critical step in wound management, particularly in burn injuries, degloving injuries, and other reconstructive surgical procedures. The most commonly used storage temperatures in clinical practice are 4°C for short-term preservation and ultralow temperatures (−80°C) for long-term preservation using cryopreservation techniques.

The findings of this study show that storage at 4°C in standard media (0.9% NaCl) resulted in no damage (EI) to mild damage in the epidermis and dermis, although the dermo-epidermal junction exhibited severe damage. In contrast, storage at the same temperature using glycerol media preserved more structures without damage (DK and DGL), and no structure exhibited severe damage.

Although the structural integrity remains relatively stable, cellular proliferation decreases substantially, with studies reporting up to a 50% reduction in cell viability by day three and apoptosis increasing by up to 25% by day seven. This indicates that while the physical structure appears preserved, cellular activity decreases overall).[10,11]

This study also shows that storage at −80°C with standard media (0.9% NaCl) resulted in severe damage to the epidermis (DK), although many other structures were preserved or only mildly damaged. Storage using glycerol media yielded better results, with many structures showing no damage (DK, BL, and DEJ).

Literature suggests that storage at−80°C using cryopreservation techniques can preserve tissue for a significantly longer period, with metabolic activity remaining very low. However, the formation of ice crystals during freezing can cause serious microscopic damage, including disorganization of the dermo-epidermal junction, extracellular matrix degradation, and loss of cellular integrity, which may compromise graft function.[11,12] The use of cryoprotectants such as dimethyl sulfoxide (DMSO) may reduce these effects, but the risk of damage remains and may have clinical implications.[13]

Histological studies comparing fres split-thickness grafts with those stored at 4°C and those frozen at −80°C have found that grafts stored only at 4°C tend to retain epidermal layer structure with minimal changes, whereas cryopreserved grafts show mild inflammatory infiltration, more pronounced edema, and increased tissue fragility macroscopically after thawing.[13,14] Immunohistochemical staining techniques such as Ki67 (proliferation marker) and TUNEL (apoptosis) further support these findings, showing significantly better preserved cell proliferation in grafts stored at 4°C compared to those stored at −80°C without optimal cryoprotectant treatment.[15]

Furthermore, −80°C cryopreservation also affects the microvasculature of the graft. Storage at 4°C generally preserves microvascular structures, enabling faster revascularization after transplantation, whereas frozen storage tends to damage vascular endothelial cells, potentially delaying or impairing graft take. This has important implications for clinical readiness, as grafts stored at 4°C are typically ready for immediate use, while cryopreserved grafts require thawing and specific reconditioning protocols.[16]

Tissue Viability

Tissue viability in split-thickness skin grafts depends on storage conditions, storage medium, duration, and temperature. Viability refers to the ability of cells to survive and maintain metabolic function, which is essential for successful transplantation and wound healing.At 4°C, tissue

viability gradually declines over time. Studies using MTT assays and colony-forming efficiency tests to evaluate keratinocyte viability and proliferation have shown approximately a 50% decrease in viability after 3 days of storage, which may drop below 20% after 7– 10 days.[17] This decline correlates with reduced metabolic activity and increased apoptosis in epidermal cells. Nonetheless, 4°C storage remains the preferred method for short-term preservation because it is simple and maintains adequate cellular integrity for several days prior to transplantation.[18] In contrast, viability at −80°C depends heavily on the cryopreservation protocol used. Storage at this temperature without appropriate cryoprotectants typically results in severe reductions in viability due to ice crystal–induced damage during freezing and thawing.[19] However, with the use of DMSO or glycerol as cryoprotectants and optimized protocols, cellular viability can be preserved for months or even years. Clinical and experimental studies on animal models have shown that cryopreserved grafts can achieve engraftment and functional outcomes comparable to fresh grafts when thawing procedures are carefully performed.[19,20] The findings of this study are consistent with the literature, demonstrating that decreasing storage temperature correlates with significantly increased tissue viability. Glycerol is a commonly used cryoprotectant for allograft skin preservation. It reduces ice crystal formation during freezing and prevents osmotic stress that can damage cell membranes and dermal collagen. Although glycerol causes substantial loss of cellular viability due to its dehydrating effects, skin stored in glycerol largely preserves extracellular matrix structure and dermal components essential for engraftment and healing.[21,22] This study similarly found that glycerol storage resulted in higher tissue viability compared to 0.9% NaCl.

Clinically, maintaining high tissue viability is crucial for successful transplantation, because reduced viability may lead to graft failure, chronic wounds, and infection. Therefore, understanding the impact of different storage temperatures on tissue viability is essential in clinical practice.

Study Limitations This study focused on the effects of temperature on split-thickness grafts using in-vitro methods. The study was not conducted directly in living organisms; therefore, the clinical benefits of these temperature effects cannot be confirmed. Long-term effects on different tissue types may not be detectable within the short storage duration used in this study.

CONCLUSION

Split-thickness skin grafts preserved at –80°C exhibited superior histological structure and significantly higher viability compared with grafts stored at 4°C. These findings indicate that ultra-low–temperature preservation is more effective in maintaining the biological integrity of split-thickness skin grafts. Future research should incorporate in vivo experimental models, such as animal studies, prior to conducting comparative effectiveness assessments in human tissues to better understand physiological responses and translational relevance. Longitudinal evaluations at predetermined storage intervals are recommended to determine the extent to which prolonged preservation impacts tissue viability and structural integrity. Such time-based assessments may provide valuable insights into the durability and optimal shelf-life of preserved grafts.

DECLARATIONS

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Competing and conflicting interest:
There are no conflicts of interest.

Consent for publication:
Not applicable. This work was conducted on archival tissue blocks.

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ORIGINAL RESEARCH

CHILDREN'S DENTAL ANXIETY IN RELATION TO PARENTAL DENTAL ANXIETY, CHILD'S AGE, GENDER AND CARIES EXPERIENCE (A CROSS-SECTIONAL STUDY)

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ABSTRACT

Background: The aim of this study was to evaluate the relation between parental dental anxiety, child age, gender and caries experience on child dental anxiety in a group of Egyptian children.

Subjects and Methods: A total of Seventy-Four Egyptian children, aged six-eight years, and their mothers were recruited from the outpatient clinic of Paediatric Dentistry and Dental Public Health Department, at Cairo University. Child dental anxiety was assessed using the Abeer Children Dental Anxiety Scale (ACDAS) comprising a child self-reported part and a cognitive part with six questions (four answered by the child and two answered by their mothers) and heart rate measurement via a fingertip pulse oximeter. Mother's anxiety was evaluated using the Corah Dental Anxiety Scale (CDAS) answered by the mothers. Caries experience was recorded using Decayed, Missed, Filled Teeth (DMFT) index for permanent teeth and decayed, extracted, filled teeth (deft) indices for primary teeth. All clinical examinations and data collection were performed by a single calibrated examiner. Data were analysed using SPSS version 28, employing appropriate correlation tests and significance was set at $p<0.05$.

Results: Among seventy-four children, the mean ACDAS score was 18.39±6.54, with only 13.5% (n=10) classified as anxious. A moderate significant positive correlation was found between child anxiety (ACDAS) and mother anxiety. Age had a significant effect on anxiety, with anxiety increasing with age. No statistically significant associations were found between child dental anxiety and gender or caries experience.

Conclusions: Most children in this study showed low levels of dental anxiety, suggesting that there was a positive dental experience and proper management techniques.

***Keywords*:** Dental anxiety, Abeer dental anxiety scale, Corah Dental Anxiety Scale

INTRODUCTION

Dental fear and anxiety (DFA) are one of the biggest challenges in Paediatric dentistry. Many risk factors were identified by having impact on the development of children's dental fear and anxiety. DFA was the main cause that many paediatric patients avoided or delayed their dental visits. This had a negative impact on their oral health and increased the need for complex treatments rather than preventive appointments[1].

Dental anxiety affects the patient-dentist relation and result in delayed or incorrect diagnosis. Dental professionals believe that anxious patients were a significant source of stress in the workplace. Managing patients with dental anxiety in the office is always very challenging. Patients experience less anxiety and fear if their dentists were sympathetic and understanding. Understanding the dental state of anxious and non-anxious individuals is essential in dentistry as it could have shed light on the impact of dental anxiety on patients' daily lives[2].

A paediatric dentist is a specialist trained in the skills and methods needed to manage children's anxiety and encourage a positive attitude toward dental care. Evaluating dental anxiety in children is important both for providing high-quality treatment and for

understanding their level of anxiety and its causes before care begins. Such assessment facilitates the early recognition of anxious children, allowing for effective management and promoting favourable perceptions of dentists and dental visits. Therefore, behavioural science plays an essential role in dentistry by emphasizing the evaluation and interpretation of patient behaviours in relation to dental treatment[3].

Questionnaires are the most accurate means of measuring anxiety in children who are cognitively capable of self-reporting their emotions on a scale. Questionnaires have long been the only tool used in dental anxiety research. Even though there were many self-reported measures available, none of them are perfect or appropriate for assessing dental anxiety in children around the entire world. As a result, The Abeer Children Dental Anxiety scale (ACDAS) was introduced. This approach had cognitive, behavioural, and psychological characteristics. This new dental anxiety scale was found to be appropriate for children and adolescents to solve all the limitations of previously used scales [4].

Therefore, this study was designed to investigate the relationship between parental dental anxiety and its effect on child's dental anxiety, while considering the child's age, gender, and caries experience. The aim was to determine if a connection exists between the level of a parent's dental anxiety and their child's dental anxiety within an Egyptian population.

SUBJECTS AND METHODS

Study design

This observational Cross-sectional study was conducted between September 2024 to October 2024, to evaluate the relationship between mother's dental anxiety, child age, gender, caries experience, and child dental anxiety among a group of Egyptian children aged six to eight years. The study was carried out at the Outpatient Clinic of the Paediatric Dentistry and Dental Public Health Department, Faculty of Dentistry, Cairo University, Egypt. The study protocol was registered on ClinicalTrials.gov under the identifier NCT06437249. Based on a two-tailed significance level of 0.05 and a study power of 80%, and assuming an expected correlation coefficient of 0.32 between maternal and child dental anxiety as reported in previous study by (Coric et al., 2014)[5]. A minimum sample size of seventy-four child–mother pairs was required.

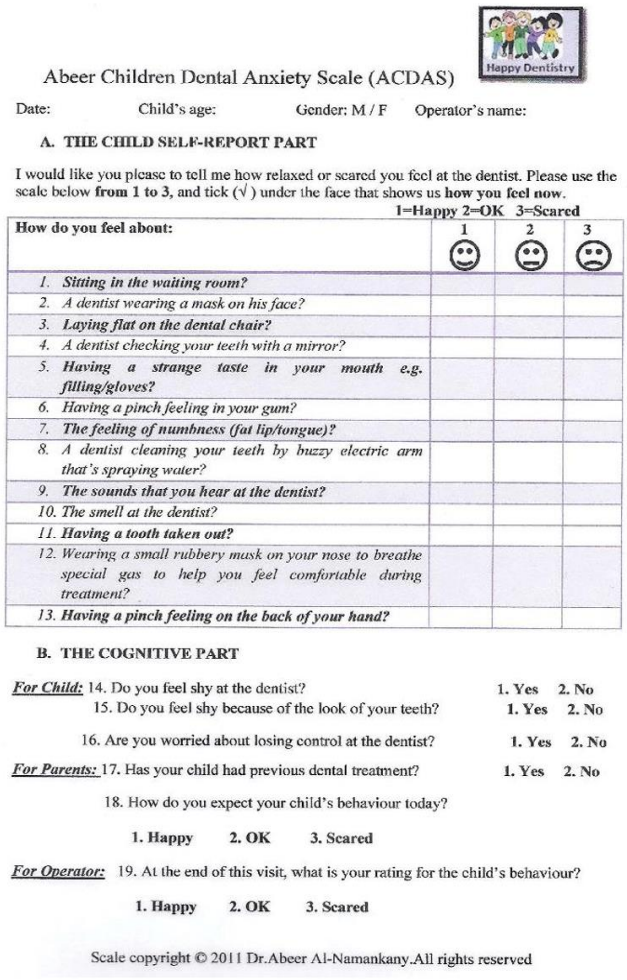
From September 1st to September 30th, children attending their first dental visit were included in the study. Inclusion criteria included the children with the written consent form of their mothers were included in the study, and the child's assent had to be obtained before a clinical oral examination was performed. Children with physical or mental disabilities and those who refused to participate were excluded.

Data collection

Demographic data was first collected including name, age and gender. The data collection process involved clinical examination and administration of two questionnaires to assess mother and child dental anxiety.

Dental anxiety assessment

Two separate questionnaires were used to assess dental anxiety in children and their mothers. The Child dental anxiety was assessed using the Arabic version of the Abeer Children Dental Anxiety Scale (ACDAS) [6–8]. This scale consisted of three distinct sections designed to assess the child's dental, cognitive, and overall behavioural responses (Figure 1).



Abeer Children Dental Anxiety Scale (ACDAS)

Happy Dentistry

Date: Child's age: Gender: M / F Operator's name:

A. THE CHILD SELF-REPORT PART

I would like you please to tell me how relaxed or scared you feel at the dentist. Please use the scale below **from 1 to 3**, and tick (√) under the face that shows us **how you feel now.**

1=Happy 2=OK 3=Scared

How do you feel about:	1	2	3
1. *Sitting in the waiting room?*			
2. *A dentist wearing a mask on his face?*			
3. *Laying flat on the dental chair?*			
4. *A dentist checking your teeth with a mirror?*			
5. *Having a strange taste in your mouth e.g. filling/gloves?*			
6. *Having a pinch feeling in your gum?*			
7. *The feeling of numbness (fat lip/tongue)?*			
8. *A dentist cleaning your teeth by buzzy electric arm that's spraying water?*			
9. *The sounds that you hear at the dentist?*			
10. *The smell at the dentist?*			
11. *Having a tooth taken out?*			
12. *Wearing a small rubbery mask on your nose to breathe special gas to help you feel comfortable during treatment?*			
13. *Having a pinch feeling on the back of your hand?*			

B. THE COGNITIVE PART

For Child: 14. Do you feel shy at the dentist? 1. Yes 2. No

15. Do you feel shy because of the look of your teeth? 1. Yes 2. No

16. Are you worried about losing control at the dentist? 1. Yes 2. No

For Parents: 17. Has your child had previous dental treatment? 1. Yes 2. No

18. How do you expect your child's behaviour today?

1. Happy 2. OK 3. Scared

For Operator: 19. At the end of this visit, what is your rating for the child's behaviour?

1. Happy 2. OK 3. Scared

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Figure 1. Abeer Children Dental Anxiety Scale (ACDAS)[6]

The dental anxiety section of the ACDAS comprised 13 questions. For each question, children were presented with three facial expressions corresponding to different emotional states (happy, ok, scared) and were asked to select the face that best represented how they would feel in each described dental situation. Responses were scored on a scale from 1 to 3, resulting in a total possible score ranging from 13 to 39 for this section. A total score of 26 or higher was classified as indicative of a dentally anxious child. The remaining sections of the ACDAS, which included

cognitive and overall behavioural evaluation items, were completed by the attending paediatric dentist and the child's mother. The scale was administered during the child's initial visit, prior to any clinical or radiographic dental treatment being performed.

Mother's dental anxiety was assessed using the Corah Dental Anxiety Scale (CDAS)[9,10]. This scale employed a five-point scale for its responses, where a score of 1 corresponded to 'not anxious' and a score of 5 indicated the respondent was 'extremely anxious'. The cumulative score for the scale was derived from the sum of the responses to its four items, yielding a potential range of 4 to 20. In accordance with established literature, a predetermined cutoff score of greater than 13 was implemented to identify individuals with high levels of dental anxiety. CDAS questionnaire was translated into Arabic, using the standard method as recommended by Beaton et al., (2000)[11]. A pilot study was conducted by interviewing mothers to test their acceptance and understanding of the items of the CDAS translated form, and minor modifications were made on the translated version accordingly. Based on their total scores, participating mothers were subsequently divided into one of three distinct categories indicating their level of dental anxiety. Scores from 4 to 8 were classified as no or low dental anxiety. A result falling between 9 and 12 points indicated a moderate level of dental anxiety. Finally, participants scoring between 13 and 20 points were categorized as experiencing severe dental anxiety[12].

Clinical examination

A single examiner performed all clinical examinations to minimize examination bias. Oral examination of children was conducted on the dental unit using a disposable mouth mirror and blunt ball-ended probe (0.5 mm) after the child rinsed his mouth under tap water. The dental caries status was assessed according to DMFT/ deft index [13], which recorded decayed, missing, and filled teeth in permanent (DMFT) and primary (deft) dentitions.

The heart rate of each child was also measured using a fingertip pulse oximeter as an indicator of their anxiety level. Then, the assessment charts of children and questionnaires were collected into an excel sheet to facilitate manipulation of the data.

Statistical analysis

Statistical analysis was performed using Medcalc software, version 22 for windows (MedCalc Software Ltd, Ostend, Belgium). Chats were created using Microsoft Excel for windows version 2404 (Microsoft 365, Microsoft Egypt, Giza, Egypt). Categorical and binary data were presented as frequency and percentage. Comparison of responses within each question and categorical variables was performed using chi-square test. Continuous data were presented using mean and standard deviation. Spearman's test was used to correlate between ACDAS and CDAS. Association between age, gender, caries experience and children dental anxiety was performed using the chi square test. The significance level was set at $P \leq 0.05$ and all tests were two tailed.

RESULTS

A total of seventy-four participants were included in the final analysis, comprising forty-two boys (56.8%) and thirty-two girls (43.2%). The mean age of the children was 7.11±0.77 years. The average heart rate was 96.66±14.05 beats per minute (BPM), and the mean DMF index was 4.57±2.89 (Figure 2).

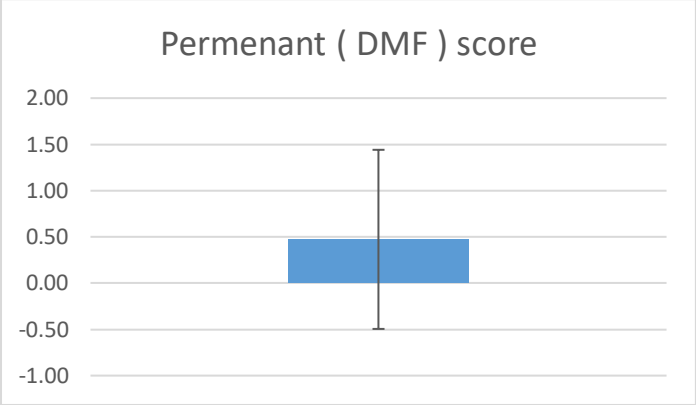


Figure 2. Bar chart showing mean and SD of DMF

Regarding the child self-reported section in ACDAS questionnaire, a statistically significant difference was observed in the distribution of responses ('happy,' 'OK,' 'scared') for all items (Table 1).

The mean total ACDAS score was 18.39 ± 6.54. Based on the established clinical cutoff (≥26 indicating anxiety), most children (86.5%, n=64) were classified as not anxious. A significantly smaller proportion (13.5%, n=10) were classified as anxious (Table 2).

Regarding the children cognitive part, 17.6% reported feeling shy at the dentist, while the majority (82.4%) did not. This distribution was statistically significant. Concerning the appearance of their teeth, 10.8% indicated this was a source of shyness, compared to 89.2% who did not. Regarding worry of the dentist about losing control during dental treatment, 35.1% responded affirmatively and 64.9% negatively (Table 3). Regarding previous dental experiences, all mothers reported that their children had not received prior dental treatment. When asked to predict their child's anticipated behaviour, mothers' expectations were distributed as follows: 55.4% predicted 'Happy', 31.1% predicted 'OK', and 13.5% predicted 'Scared'. This distribution of responses was statistically significant (Table 3).

The operator's assessment of the child's actual behaviour at the end of the visit found that 52.7% of children were rated as 'Happy', 29.7% as 'OK', and 17.6% as 'Scared'. This observed distribution was also statistically significant (Table 3).

Table 1. Child anxiety using the ADAS (N=74).

ADAS Variables		n (%)	P-value
How do you feel?			
1. Sitting in the waiting room	Happy	46 (62.20%)	P < 0.0001
	Ok	21 (28.40%)	
	Scared	7 (9.50%)	
2. A dentist wearing a mask on his face?	Happy	65 (87.80%)	P < 0.0001
	Ok	7 (9.50%)	
	Scared	2 (2.70%)	
3. Lying flat on the dental chair?	Happy	59 (79.70%)	P < 0.0001
	Ok	9 (12.20%)	
	Scared	6 (8.10%)	
4. A dentist checking your teeth with a mirror?	Happy	60 (81.10%)	P < 0.0001
	Ok	10 (13.50%)	
	Scared	4 (5.40%)	
5. Having a strange taste in your mouth?	Happy	61 (82.40%)	P < 0.0001
	Ok	10 (13.50%)	
	Scared	3 (4.10%)	
6. Having a pinch feeling in your gum?	Happy	48 (64.90%)	P < 0.0001
	Ok	21 (28.40%)	
	Scared	5 (6.80%)	
7. The feeling of numbness (fat lip/tongue)?	Happy	50 (67.60%)	P < 0.0001
	Ok	17 (23.00%)	
	Scared	7 (9.50%)	
8. A dentist cleaning your teeth using by buzzy electric arm that's spraying water?	Happy	48 (64.90%)	P < 0.0001
	Ok	16 (21.60%)	
	Scared	10 (13.50%)	
9. The sounds that you hear at the dentist?	Happy	44 (59.50%)	P < 0.0001
	Ok	24 (32.40%)	
	Scared	6 (8.10%)	
10. The smell at the dentist?	Happy	63 (85.10%)	P < 0.0001
	Ok	9 (12.20%)	
	Scared	2 (2.70%)	
11. Having a tooth taken out?	Happy	9 (12.20%)	P = 0.0006
	OK	33 (44.60%)	
	Scared	32 (43.20%)	
12. Wearing a small rubbery mask on your nose to breath special gas to help you feel comfortable during treatment?	Happy	53 (71.60%)	P < 0.0001
	OK	10 (13.50%)	
	Scared	11 (14.90%)	
13. Having a pinch feeling on the back of your hand?	Happy	55 (74.30%)	P < 0.0001
	Ok	16 (21.60%)	
	Scared	3 (4.10%)	

Table 2. Table showing the frequency and percentage of total ACDAS scores

Total ACDAS	Frequency (n)	Percentage (%)
≥ 26	10	13.5%
< 26	64	86.5%
Total	74	100.00%
P value	P < 0.0001	

Table 3. Total Child's Cognitive Assessment and Dentist's Behaviour Assessment score using the ACDAS (n= 74)

ADAS Cognitive Variables		**n (%)**	p-value
Child's Cognitive Assessment			
14. Do you feel Shy at the Dentist?	Yes	13 (17.60%)	P < 0.0001
	No	61 (82.40%)	
15. Do you fell shy because of the look of your teeth?	Yes	8 (10.80%)	P < 0.0001
	No	66 (89.20%)	
16. are you worried about losing control at dentist?	Yes	26 (35.10%)	P = 0.0105
	No	48 (64.90%)	
Parent's Behaviour Assessment			
17. has your child had previous dental treatment?	Yes	0 (0.00%)	P < 0.0001
	No	74 (100.00%)	
18. How do you expect your child's behaviour today?	Happy	41 (55.40%)	P = 0.0001
	Ok	23 (31.10%	
	Scared	10 (13.50%)	
Dentist's Behaviour Assessment			
19. At the end of this visit, what is your rating for the child's behaviour?	Happy	39 (52.70%)	P = 0.0009
	OK	22 (29.70%)	
	Scared	13 (17.60%)	

Based on CDAS questionnaire for parents, the categorical distribution of mother anxiety levels was 55.4% mild, 12.2% moderate, 5.4% high, and 27.0% severe. This difference was statistically significant **(Table 4).** Mean Corah's dental anxiety scale of mothers in the present study was 9.89±5.41, which was considered moderate.

Table 4. Table showing the frequency and percentage of responses using Corah's dental anxiety scale (Categorical)

Corah's dental anxiety scale	**Frequency (n)**	**Percentage (%)**
Mild	41	55.40%
Moderate	9	12.20%
High	4	5.40%
Severe	20	27.00%
Total	74	100.00%
P value	P < 0.0001	

There was moderate positive correlation between ACDAS and CDAS, rho= 0.365 (**Figure 3**). This indicated that as the parental CDAS increased, the ACDAS of their child increased and vice versa.

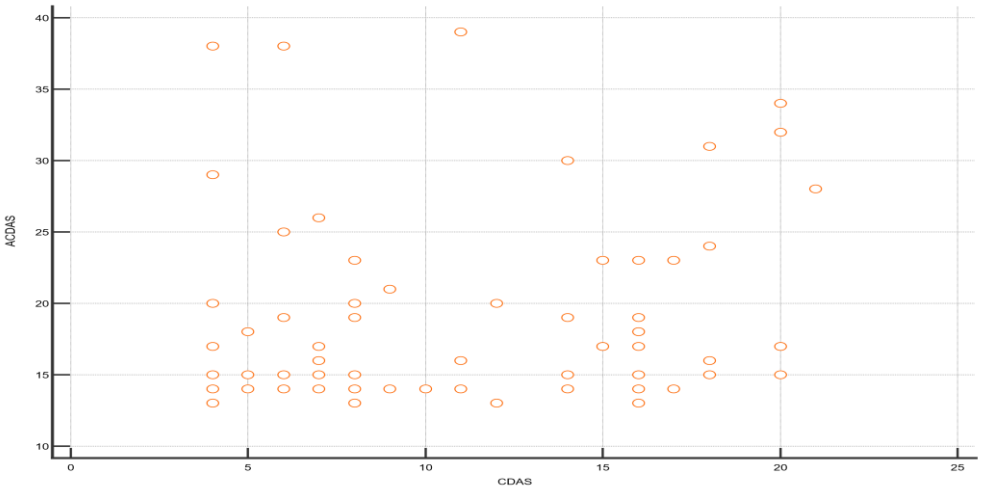


Figure 3. Scatter diagram of correlation between ACDAS and CDAS

There was no statistically significant effect of gender on children's dental anxiety. 54.8% of boys were happy and 50% of girls were happy at the end of visit according to the operator's opinion. A statistically significant association was observed between age and dental anxiety. The proportion of children categorized as 'Scared' increased with age, from 5.6% (6-year-olds) to 10.0% (7-year-olds) and 34.6% (8-year-olds). Despite this trend, the 'Happy' response was the most frequent in all age groups, reported for 50.0%, 56.7%, and 50.0% of 6-, 7-, and 8-year-olds, respectively. There was no statistically significant effect of caries experience on children's dental anxiety. 66.7% of caries free children were happy, 41.7% of low caries index children were happy and 42.9% and 60.5% of moderate and high caries risk children respectively were happy according to the operator's opinion at the end of the visit (**Table 5**).

Table 5. Table showing the association between gender, age, DMF and children's dental anxiety (Q19)

	Q19			**Row total (RT)**	**Significance level**
	Happy	**Ok**	**Scared**		
Gender					
Boy	23	13	6	42 (56.8%)	P = 0.6968
	54.8% RT	31.0% RT	14.3% RT		
	59.0% CT	59.1% CT	46.2% CT		
Girl	16	9	7	32 (43.2%)	
	50.0% RT	28.1% RT	21.9% RT		
	41.0% CT	40.9% CT	53.8% CT		
Column total (CT)	39	22	13	74	
	52.70%	29.70%	17.60%		
Age					
6	9	8	1	18 (24.3%)	P = 0.0380*
	50.0% RT	44.4% RT	5.6% RT		
	23.1% CT	36.4% CT	7.7% CT		
7	17	10	3	30 (40.5%)	
	56.7% RT	33.3% RT	10.0% RT		
	43.6% CT	45.5% CT	23.1% CT		
8	13	4	9	26 (35.1%)	
	50.0% RT	15.4% RT	34.6% RT		
	33.3% CT	18.2% CT	69.2% CT		
Column total (CT)	39	22	13	74	
	52.70%	29.70%	17.60%		
DMF					
Caries Free (0)	2	1	0	3 (4.1%)	P = 0.1128
	66.7% RT	33.3% RT	0.0% RT		
	5.1% CT	4.5% CT	0.0% CT		
Low (1-2)	5	3	4	12 (16.2%)	
	41.7% RT	25.0% RT	33.3% RT		
	12.8% CT	13.6% CT	30.8% CT		
Moderate (3-4)	9	5	7	21 (28.4%)	
	42.9% RT	23.8% RT	33.3% RT		
	23.1% CT	22.7% CT	53.8% CT		
High (≥5)	23	13	2	38 (51.4%)	
	60.5% RT	34.2% RT	5.3% RT		
	59.0% CT	59.1% CT	15.4% CT		
Column total (CT)	39	22	13	74	

DISCUSSION

This study was conducted to determine child dental anxiety in relation to age, gender, parental dental anxiety, and caries experience in children aged six to eight years old, attending the Outpatients' Clinic of the Paediatric Dentistry and Dental Public Health Department, Faculty of Dentistry, Cairo University. To our knowledge this study was one of the first studies done to reveal the relation between child dental anxiety and parental dental anxiety using ACDAS in local population in Egypt.

The participants in the present study were selected with an age range from six to eight years old as ACDAS scale is a valid cognitive scale to measure dental anxiety for children who are at least six to eight years old [6]. This age range was also chosen because children in middle childhood exhibit the highest levels of dental anxiety and undergo rapid cognitive development, enabling them to better articulate experiences and emotions[14].

For this study, the ACDAS was used due to its high validity and reliability[15]. The ACDAS demonstrated superior characterized capabilities in assessing dental anxiety compared to the Children's Fear Survey Schedule–Dental Subscale (CFSS-DS[16] . Furthermore, the ACDAS scale could assess anxiety based on responses from parents or legal guardians, children, and dentists. In our study, the ACDAS was used as it is the first Arabic version for a dental anxiety scale[7].

The present study aimed to demonstrate the association between mother dental anxiety and child dental anxiety using CDAS. CDAS is one of the most widely used measures that had been tested and proved to be reliable [17].

Mothers were surveyed as they are typically the primary caregivers, important in shaping their children's health behaviours[18,19].

In this study, heart rate was measured using pulse oximeters, as the assessment of heart rate was recognized as a valid indicator of dental anxiety in paediatric patients. Pulse oximeter provides enhanced accuracy and reliability in evaluating dental anxiety [20].

In the current study preoperative pulse measurement resulted in a mean heart rate of 96.66 BPM, which was within the normal paediatric range (70-100 BPM). Conversely, Shekhar et al. (2022)[21], indicated a significant increase in heart rate immediately preceding a dental procedure. This finding suggested that the methods used to prepare children for treatment, such as creating a welcoming atmosphere, using clear, gentle instructions were effective in minimizing anxiety of children.

In our study, 62.2% of children felt happy in the dental waiting area, 28.4% were okay, and 9.50% were scared. These results aligned with Alshuaibi et al., (2021)[22] and Alabdullatif et al., (2023)[23] who reported that children generally felt comfortable and safe in waiting areas. However, the presence of a small percentage of scared children (9.50%) indicated that anxiety remains a concern, consistent with the study by Fux-Noy et al., (2019)[24] highlighting the effect of waiting time and visit purpose on dental anxiety.

When asked about a doctor wearing a mask, only 2.70% were scared. These findings aligned with Alshuaibi et al., (2021)[22]and Alabdullatif et al., (2023)[23], that also reported a largely positive or neutral response to masked doctors. This was further supported by Cristea et al., (2025)[25], who found that only 5% of participants experienced mask-related anxiety. The minimal scared responses suggested that wearing masks did not generally provoke anxiety in children.

Regarding children's emotional responses when lying in a dental chair, 79.70% of children were happy, 12.20% were okay, and 8.10% were scared which might be attributed to curiosity and excitement children have toward new experiences. This result aligned with Alshuaibi et al., (2021)[22] and Alabdullatif et al., (2023)[23], who suggested that many children may feel excited about the new experience.

Our study found that during dental examinations using a mirror (Q4), most children (81.10%) were happy, 13.50% were okay, and 5.40% were scared. This aligned with Alabdullatif et al., (2023)[23]. Pui Ying et al., (2024)[26] further indicated that children demonstrated greater compliance during dental examinations when only a mirror was utilized.

Our findings regarding children's responses to Q5 a "strange taste in their mouth" revealed that most of children were happy which aligned with Alshuaibi et al., (2021)[22]. In response to Q6 regarding a "pinch feeling in your gum and Question 7 (feeling of numbness), 64.90% and 67.60% respectively were happy. These results conversed with Alabdullatif et al., (2023)[23] who observed a higher prevalence of ok responses, which might be attributed to those children accepting pinch feeling and perceiving numbness as a new experience, particularly during first-time dental visit. This suggested that effective behavioural management strategies positively could reduce children anxiety.

Regarding dentist cleaning teeth with an electric arm and sounds heard at the dentist (Q8 and 9), 64.9% and 59.50% of children, respectively, were happy. This aligned with Gao et al. (2021)[27], potentially because the sounds were associated with recognizable daily activities

or games, eliciting indifferent or favourable responses. However, contrasting the results reported by Alabdullatif et al. (2023)[23], where a neutral response was predominant regarding sounds while majority reported fearing dental procedures.

Most children (85.10%) reported a positive experience of the smell of dental materials and instruments which aligned with Alabdullatif et al., (2023)[23], who also reported a high prevalence of positive or neutral responses. It might be due to the use of pleasant or neutral-smelling products.

Responses to tooth extraction varied significantly where only 12.20% of children were happy, 44.60% were okay, and 43.20% were scared, indicating that the procedure remained a major source of anxiety for many children. This was partly in accordance with the finding of Rafatjou et al., (2019)[28] which found a higher percentage of relaxed children (57.9%) in a similar age group. However, our findings contradicted Alabdullatif et al., (2023)[23], where most children reported being scared. These differences might be due to variations in preoperative preparation and pain management techniques, and our patients were attending their first dental visit.

Children reporting shyness in the clinic (Q14), or (Do you feel shy about the way your teeth look?) (Q15), only 17.6% and 10.80%, of participants respectively answered "Yes," which was consistent with Alabdullatif et al., (2023)[23]. This might be attributed to the fact that shyness in dentist office and regarding dental appearance was uncommon at a young age. Instead, children's primary emotional responses during their initial dental visit were typically anxiety or fear related to the procedure itself as stated by Jain et al., (2019)[29].

The mean ACDAS score was 18.39 ± 6.54, indicating that most children were not anxious (<26). Only 10 children (13.5%) were anxious (ACDAS ≥26), while 64 (86.5%) scored below 26. In the cognitive section, parents and dentists provided nearly identical ratings of children's emotional states (happy, ok, scared). These findings were consistent with Sabbagh et al. (2021)[30].

Regarding mothers' expectations of child behaviour (Q18) 55.40% anticipated that their child would be happy during a dental visit, 31.10% expected an OK response, and 13.50% anticipated fear. These findings aligned with Aslan et al. (2021)[15], where 47.5% of children were expected to be happy, 47.5% OK, and 7.4% scared. Consistent with Dua et al. (2023)[31], a secure mother-child attachment promoted cooperative behaviour (exhibited by 55-67% of children) and increased maternal expectation of a positive reaction. Secure attachment improved communication, reduced separation anxiety, and enhanced maternal confidence in the child's adaptability, likely explaining why most mothers anticipated a happy response.

Based on Question 19 (Dentist's rating of the child's behaviour during the dental visit), operator assessments indicated that 52.70% of children were perceived as happy, 29.70% as OK, and 17.60% as scared, similar findings were reported by Alabdullatif et al., (2023)[23]. Conversely Helal et al., (2025)[32]'s findings showed that 44.9% exhibited fear, while 54.1% displayed no signs of fear. Our findings for questions 18 and 19 aligned with a study by Sabbagh et al., (2021)[30] which found that both parents and dentists provided similar ratings regarding children's emotional responses in the dental setting.

Regarding the mothers who participated in the study, 55.40% exhibited mild anxiety, 12.20% moderate, 5.40% high, and 27% severe. The mean Corah's Dental Anxiety Scale score was 9.89 ± 5.41, indicating moderate anxiety, as with Srinivasan et al., (2022)[33].

Our results showed that there was a moderate positive correlation between ACDAS and CDAS. This indicated that as the parental CDAS increased, the ACDAS of their child increased and vice versa. This was in accordance with AlAzmah et al., (2024)[34]; Dorterler and Sahin, (2025)[35], which suggested that parents may unconsciously transmit their dental anxiety to their children in clinical settings.

The child's gender had no statistically significant effect on dental anxiety levels. Post-operative assessment showed a comparable prevalence of positive states between boys (54.8%) and girls (50%). This finding was consistent with Passos De Luca et al., (2021)[36]; Bayón et al., (2025)[37]; Cristea et al., (2025)[25]. Conversely, Kebriaei et al., (2022)[38]; Petrović et al., (2024)[39] found a significant correlation between dental anxiety and the female gender. This variance could be due to that girls might be more responsive to anxious behaviour, better emotional expression and greater pain sensitivity.

The findings demonstrated that a child's age had a statistically significant effect on dental anxiety, which increased with age. However, most children in all groups exhibited a happy attitude by the end of the visit. A similar age-related increase was reported by Soares et al. (2017)[40]. The observed increase in dental anxiety prevalence with age might be attributed to psychosocial factors rather than biological maturation. As children grow older, they become more susceptible to external influences, such as negative stories from siblings, and develop an improved awareness of social evaluation, leading to feelings of embarrassment and a perceived loss of control in the clinical setting.

The present findings contrasted with Passos De Luca et al. (2021)[36], who reported that older children were less affected, potentially due to greater cooperation. The results also opposed Helal et al. (2025)[32], who found increased age correlated with decreased anxiety, possibly due to accumulated positive dental experiences.

Concerning caries experience, in our study the results showed there was no statistically significant effect of caries experience on children's dental anxiety, 42.9% and 60.5% of moderate and high caries risk children respectively were happy according to the operator's opinion at the end of the visit. This finding agreed with Saba and Katirci, (2023)[41]. A possible explanation is that a child with a high caries index might have been cooperative and appeared happy due to effective management by the dental team during a simple examination, which does not necessarily mean they were less anxious about future, potentially invasive, treatment. However, other studies by Padmanabhan et al., (2024)[42] reported a positive correlation between caries and anxiety, attributing it to caries' multifactorial nature. Dental anxiety can cause appointment postponement, reduce preventive care and increase caries risk.

A key limitation of this cross-sectional study was that its findings demonstrate association but cannot confirm a cause-and-effect relationship. Additionally, while the findings of this survey were specific to the Egyptian paediatric population, they might offer valuable insights for other societies with similar cultural and socioeconomic setting.

CONCLUSIONS

Within the limitations of this study, the following conclusions can be drawn:

- Most children in this study showed low levels of dental anxiety (measured by the ACDAS).
- A statistically significant, moderate positive correlation was found between mother dental anxiety (measured by CDAS) and child dental anxiety (measured by ACDAS).
- Association between a child's gender and their dental anxiety levels showed no statistically significant correlation.
- Child age demonstrated a statistically significant effect on anxiety, with older children showing higher reported anxiety levels than their younger counterparts. Caries experience of children did not show a significant correlation with anxiety

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The authors report there are no competing interests to declare.

Ethical approval
The study was reviewed and approved by the Dental Research Ethics Committee, Faculty of Dentistry, Cairo University with approval number 31-7-24.

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ORIGINAL RESEARCH

INTERDISCIPLINARY COLLABORATION BETWEEN PROSTHODONTISTS AND MAXILLOFACIAL SURGEONS: IMPACT ON COMPLEX REHABILITATION

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ABSTRACT

Background: Complex craniofacial rehabilitation requires close coordination between surgical and prosthodontic teams, as successful outcomes depend on prosthetically driven reconstruction and careful interdisciplinary planning. Such collaboration not only streamlines treatment protocols but also improves both functional and esthetic results while enhancing overall patient satisfaction and quality of life. The objective of this study was to evaluate the functional and esthetic outcomes of interdisciplinary treatment approaches and to assess patient-reported quality of life and satisfaction.

Methods: A prospective cohort study was conducted at a private dental clinic involving 40 patients aged 19–68 years with maxillofacial defects due to trauma (45%), tumor resection (35%), or congenital anomalies (20%). All patients underwent interdisciplinary planning, staged reconstruction, and definitive prosthodontic rehabilitation. Outcomes assessed included masticatory efficiency, speech clarity, occlusal stability, facial symmetry, patient satisfaction, and complications.

Results: Mean masticatory efficiency improved from 48.2% to 81.6% ($p < 0.001$), and speech intelligibility increased from 3.1 to 4.5 ($p < 0.001$). Occlusal stability was achieved in 92.5% of patients, and facial symmetry was restored in 85%. Patient satisfaction scores improved from 4.2 to 8.7 ($p < 0.001$), and oral health–related quality of life scores decreased from 32.4 to 12.1 ($p < 0.001$). Complications occurred in 6 patients (15%) and were successfully managed.

Conclusion: Interdisciplinary collaboration significantly enhances functional, esthetic, and psychosocial outcomes and should be adopted as the standard for complex maxillofacial rehabilitation.

Keywords*: interdisciplinary collaboration, prosthodontic rehabilitation, maxillofacial surgery, oral health outcomes, treatment planning*

1. INTRODUCTION

Maxillofacial defects and craniofacial deformities are some of the hardest conditions to deal with during oral rehabilitation. They can have a broad aetiology, such as maxillofacial trauma, developmental defects, and ablative surgery of head and neck pathology.[1,2] These malformations not only disrupt the most important oral functions such as mastication, speech, and deglutition, but also affect the esthetics of the face and psychological well-being of the affected patients.[3] These situations, therefore, necessitate something more than just isolated surgical or prosthodontic therapy since they involve an integrated and

holistic approach that restores anatomy, functionality, and self-confidence.

Traditionally, the treatment was typically performed sequentially, with surgeons performing the resections and reconstructions and then referring patients to the prosthodontists to perform the rehabilitation of the patient with prostheses. Such an approach is capable of delivering plausible outcomes, although it can limit the potential to achieve a prosthetic-induced surgical reaction and less-than-ideal esthetic, occlusion, and position of the implant.[3,4] A maxillofacial prosthodontist is a crucial component of rehabilitation since they develop, create, and produce prostheses that resemble the structures that have been lost, reestablish the functionality, and improve the face (harmony).[1] However, when the prosthodontist comes in later in the game, then he or she might be expected to work with a compromised surgical anatomy that could damage the outcome in the long run.

To cope with these weaknesses, the inclusion of input by prosthodontics in the treatment plan process has been embraced as a measure of a well-established standard of effective maxillofacial rehabilitation. Interdisciplinary planning implies that surgical reconstructions are not conducted in isolation, but as a part of a team, which is essential to place endosseous implantations correctly, offer adequate bone and soft-tissue coverage, and deliver more foreseeable esthetic or functional outcomes.[3,4]

It has been found by some of the research that the maxillofacial prosthodontist is part of a team with the oncology or trauma care that helps to formulate reconstructive decisions that maximise the quality of life of the patient.[4]

Besides technical considerations, interdisciplinary collaboration may aid in supporting the foundation of a holistic and patient-centred care philosophy. The combined efforts of the work of surgeons, prosthodontists, dental technicians, speech therapists, and psychologists provide a holistic pathway of rehabilitation, which can tackle all the aspects of recovery, physical, functional, and psychosocial, simultaneously.[5] This form of collaboration has proven to be particularly useful with complex cases, including mass-casualty events, congenital craniofacial anomalies, and oncologic resections where time and accuracy are vital to the optimal outcome.[5,6]

Teamwork also enhances communication between team members, reduces redundancy, and eases the treatment schedules. Interprofessional education programmes have demonstrated to demonstrate that interprofessional education results in more positive attitudes towards medical personnel and the capacity to trust shared decision-making more.[7] This observation highlights the importance of proactively fostering good teamwork behaviour as a training and standard clinical practice rather than letting the collaboration self-correct.

Several case reports have demonstrated technical and procedural advantages in the combination of maxillofacial surgery and prosthodontics. Raising the recontouring of surgery sites, putting in place artificial implants, and the use of the state-of-the-art design of the prosthetics, among others, have all been pointed to as causing the improvement of occlusal stability, improved esthetics, and symmetry of the features of the face.[2,8] Maxillofacial prosthodontics is thus not just a tool of a replacement therapy, but of a form, functionality, as well as confidence restoration. These overall results would only be reliably realised by collective planning and action.[8]

Nevertheless, challenges remain in translating the principles of interdisciplinary care into routine clinical practice. Delayed prosthodontic involvement in oncologic care pathways may lead to malpositioned implants, inadequate bone volume, or compromised functional and psychosocial outcomes.[3] Despite the growing popularity of collaborative models, there is still limited quantitative evidence evaluating their actual impact on long-term outcomes such as complication rates, patient satisfaction, and oral health-related quality of life.[9] This gap highlights the need for systematic research that not only describes interdisciplinary workflows but also quantifies their clinical effectiveness and patient-centered benefits.

It is also important to distinguish between multidisciplinary and interdisciplinary approaches, as the terms are often used interchangeably in the literature. Multidisciplinary care typically refers to parallel practice, where each specialist works independently within their domain and later combines results. Interdisciplinary care, in contrast, reflects a higher level of integration where treatment plans are jointly developed and dynamically adjusted, ensuring that surgical and prosthetic objectives are aligned from the outset.[10] This distinction is clinically significant: failure to integrate care can result in suboptimal implant positioning, weaker occlusal schemes, prolonged healing times, and reduced long-term success rates,

whereas integrated planning improves all of these parameters.

The available literature suggests that an interdisciplinary approach to complex maxillofacial rehabilitation is well-founded and necessary. Such collaboration guarantees that surgical reconstruction is prosthetically motivated, maximizes esthetic and functional outcomes, and restores patients' quality of life to the highest possible level. Nevertheless, it is necessary to further have well-planned clinical trials that will objectively assess the superiority of interdisciplinary guidelines on clinical outcome, esthetics, and patient satisfaction.It is based on these considerations that the current study was undertaken to provide a systematic evaluation of the effect of a coordinated prosthodontic and surgical treatment paradigm on complex maxillofacial rehabilitation. Two dimensions were in the spotlight, namely, determining clinical parameters, i.e., functional restoration, esthetic outcomes, and complication rates; and patient-reported indicators, i.e., oral health-related quality of life, and overall satisfaction with care. Collectively, these actions are expected to present an overarching insight into the manner in which interdisciplinary cooperation can be transformed into a real-world change in clinical advantages and a better patient-focused outcome.

Objectives

1. To evaluate the clinical outcomes of an interdisciplinary treatment approach for complex maxillofacial rehabilitation
2. To assess patient-reported outcomes following coordinated prosthodontic and surgical management

2. MATERIALS AND METHODS

2.1 Study Design and Setting

The study was a prospective cohort study and was performed in a privately managed dental clinic with a specialty in prosthodontics and maxillofacial surgery, which would provide access to an experienced interdisciplinary team and standard treatment regimens. Patients were recruited consecutively in a sequence starting in January 2023 and finishing in June 2024, to reduce selection bias. Patients were eligible to participate in the study if, had craniofacial defects and needed combined surgical and prosthodontic rehabilitation. All the participants were followed systematically over a minimum of 12 months following the installation of the final prosthesis to test the short and medium-term results. An independent review board provided ethical approval, and informed written consent was obtained before the enrollment of all the participants.

2.2 Patient Selection

40 patients with complex maxillofacial defects that require combined surgical reconstruction and prosthodontic reconstruction were recruited into this study. The inclusion criteria were tightly limited to provide homogeneity in the cohort and were adults within the age range of 18 to 70 years whose defects resulted from maxillofacial trauma, ablative tumour surgery, or congenital craniofacial abnormalities. Participants had to be willing and able to comply with the proposed treatment plan, with follow-up visits, to be eligible. The exclusion criteria included a patient whose systemic disease was not under control to allow surgery, a patient who had not undergone a minimum of 12 months of follow-up after delivery of definitive prosthesis, and a patient who had only one specialty with no interdisciplinary care. Such a method of selection was crucial in such a way that only the patients who underwent comprehensive, coordinated rehabilitation were included in the analysis, thus permitting the accurate evaluation of the effect of interdisciplinary collaboration on the treatment outcomes.

2.3 Treatment Planning

All enrolled patients were administered a standardised and comprehensive work-up of diagnostics to enable proper diagnosis and the creation of an individualised treatment plan. Moral character entailed complicated extraoral and intraoral clinical studies, panoramic radiographs, and cone-beam computed tomography (CBCT) to accurately quantify the anatomy, bone mass, and bone quality and space relationship of hard tissues, which proved crucial during the positioning of implants. The assessment also included soft-tissue assessment and functional assessment of occlusion and phonetics. The collected data were reviewed during structured interdisciplinary meetings where prosthodontists and maxillofacial surgeons collaboratively determined surgical sequencing, number and angulation of implants, type of prosthesis, occlusal scheme, and esthetic requirements. Where feasible, advanced digital workflows were integrated, including virtual surgical planning, CAD/CAM design, and fabrication of patient-specific surgical guides to

enhance accuracy, reduce intraoperative guesswork, and improve treatment predictability. This collaborative planning ensured that surgical reconstruction was prosthetically driven and optimized for both function and esthetics.

2.4 Interventions

- **Surgical:** Reconstructive procedures such as bone grafting, ridge augmentation, osteotomies, and placement of endosseous implants.
- **Prosthodontic:** Fabrication of interim prostheses during healing, followed by definitive prostheses. Both conventional and CAD/CAM techniques were used. Occlusion and esthetics were verified at delivery and adjusted as required.

2.5 Outcome Measures

Outcome assessment focused on four major domains to comprehensively evaluate treatment success. Functional outcomes included evaluation of occlusion, masticatory efficiency, and speech clarity through clinical examination and patient feedback. Aesthetic outcomes were assessed by examining facial symmetry, contour restoration, and integration of the prosthesis with surrounding tissues. Patient-reported outcomes were measured using the validated OHIP-14 questionnaire and a visual analogue scale (VAS) to capture satisfaction and perceived quality of life. Complications were systematically recorded, including implant failures, prosthesis fractures, peri-implant infections, and any requirement for secondary revision procedures, ensuring a complete appraisal of both benefits and risks.

2.6 Data Analysis

All data were compiled and analyzed using SPSS statistical software, version 22.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics, including mean, standard deviation, frequencies, and percentages, were calculated to summarize patient demographics, defect etiology, and clinical outcome variables. Normality of continuous data was assessed using the Shapiro–Wilk test to determine the appropriateness of parametric analysis. Changes in patient-reported outcomes, specifically Oral Health Impact Profile-14 (OHIP-14) scores and visual analogue scale (VAS) ratings, were compared between baseline and 12-month follow-up using paired t-tests for normally distributed data. Where data deviated from normality, the Wilcoxon signed-rank test was applied. A p-value of <0.05 was considered statistically significant for all comparisons, ensuring robust interpretation and minimizing type I error. Data were presented as mean ± SD for continuous variables, and categorical variables were expressed as percentages, facilitating clear and reproducible reporting of study results.

3. RESULTS

3.1 Patient Characteristics

A total of 40 patients fulfilling the predefined inclusion criteria were recruited and included in the final statistical analysis. The mean age of the study cohort was 42.8 ± 11.6 years, with a range of 19–68 years, representing a broad distribution across young and middle-aged adults typically affected by maxillofacial defects. The gender distribution revealed 24 males (60%) and 16 females (40%), showing a slight male predominance consistent with reported epidemiological trends for facial trauma and tumour resections. Etiological analysis indicated that maxillofacial trauma accounted for the highest proportion of cases (45%), followed by defects secondary to ablative tumour resections (35%) and congenital craniofacial anomalies such as cleft-related deformities (20%). This distribution highlights the heterogeneity of the cohort and the necessity for individualized, interdisciplinary management strategies. A comprehensive summary of baseline demographic data, defect etiology, and pre-treatment clinical characteristics is provided in Table 1 for detailed reference.

Table 1. Demographic and Baseline Characteristics of the Study Population

Characteristic	Value
Total patients	40
Mean age (years)	42.8 ± 11.6
Gender	Male 24 (60%), Female 16 (40%)
Etiology of defect	Trauma 18 (45%), Tumor 14 (35%), Congenital 8 (20%)
Comorbidities	Diabetes 6 (15%), Hypertension 5 (12.5%)

3.2 Treatment Overview

All 40 patients underwent a carefully planned staged treatment protocol, beginning with surgical reconstruction to restore anatomical continuity, followed by definitive prosthodontic rehabilitation to re-establish function and esthetics. Bone grafting procedures were required in 28 patients (70%) to augment deficient ridges, while corrective osteotomies were performed in 6 patients (15%) to optimize jaw alignment and occlusion. Endosseous implants were placed in 33 patients (82.5%) to provide stable support for prosthetic restorations. Definitive rehabilitation included fixed implant-supported prostheses in 22 patients (55%), removable partial dentures in 12 patients (30%), and maxillofacial obturators in 6 patients (15%) (Table 2).

Table 2. Distribution of Surgical and Prosthodontic Procedures

Procedure	n (%)
Bone grafting	28 (70.0)
Corrective osteotomy	6 (15.0)
Implant placement	33 (82.5)
Fixed prosthesis	22 (55.0)
Removable prosthesis	12 (30.0)
Obturator	6 (15.0)

The entire treatment workflow, comprising detailed preoperative planning, surgical reconstruction, interim prosthetic rehabilitation, and definitive prosthesis delivery, is summarized and visually represented in Figure 1. This illustration highlights the stepwise, coordinated, interdisciplinary approach that was consistently followed for all patients to achieve predictable functional and esthetic rehabilitation outcomes.

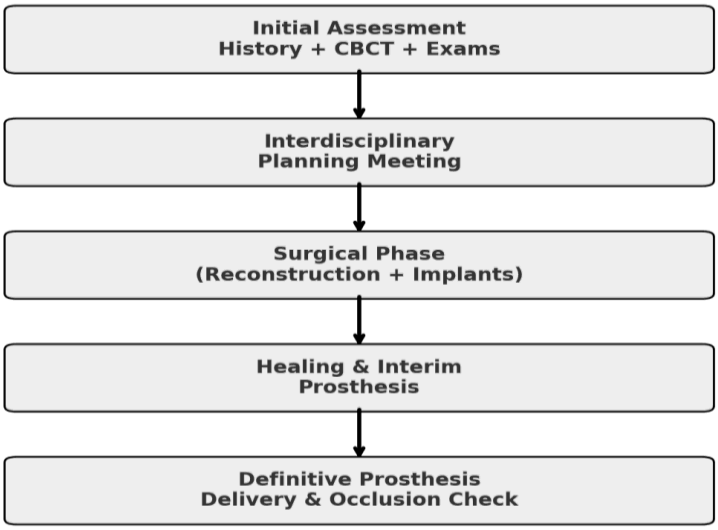


Figure 1. Workflow diagram showing stepwise interdisciplinary treatment from diagnosis to prosthesis delivery

3.3 Clinical Outcomes

Functional outcomes demonstrated marked improvement over the study period. Mean masticatory efficiency increased significantly from 48.2 ± 12.5% at baseline to 81.6 ± 9.3% at 12 months post-rehabilitation ($p < 0.001$), reflecting enhanced chewing capacity. Speech intelligibility scores improved from 3.1 ± 0.8 to 4.5 ± 0.6 on a five-point scale ($p < 0.001$), indicating clearer articulation and better phonation. Stable occlusion was successfully achieved in 92.5% of patients, reducing functional discomfort. Aesthetic outcomes were also favorable, with facial symmetry restored in 85% of cases and satisfactory prosthesis integration reported in 90% of patients. Comprehensive clinical outcome data are summarized in Table 3.

Table 3. Functional and Aesthetic Outcomes at Baseline and 12 Months

Outcome	Baseline	12 Months	p-value
Masticatory efficiency (%)	48.2 ± 12.5	81.6 ± 9.3	<0.001
Speech intelligibility (1–5)	3.1 ± 0.8	4.5 ± 0.6	<0.001
Occlusal stability (%)	40.0	92.5	<0.001
Facial symmetry achieved (%)	–	85.0	–
Prosthesis integration satisfactory (%)	–	90.0	–

The improvement in masticatory efficiency over time is further visualized in Figure 2, which shows a steady upward trend from baseline through the 3-, 6-, and 12-month evaluations. Six patients (15%) experienced complications: three had minor prosthesis fractures, two had soft-tissue inflammation, and one had implant failure. All complications were successfully managed, and no patient required discontinuation of treatment.

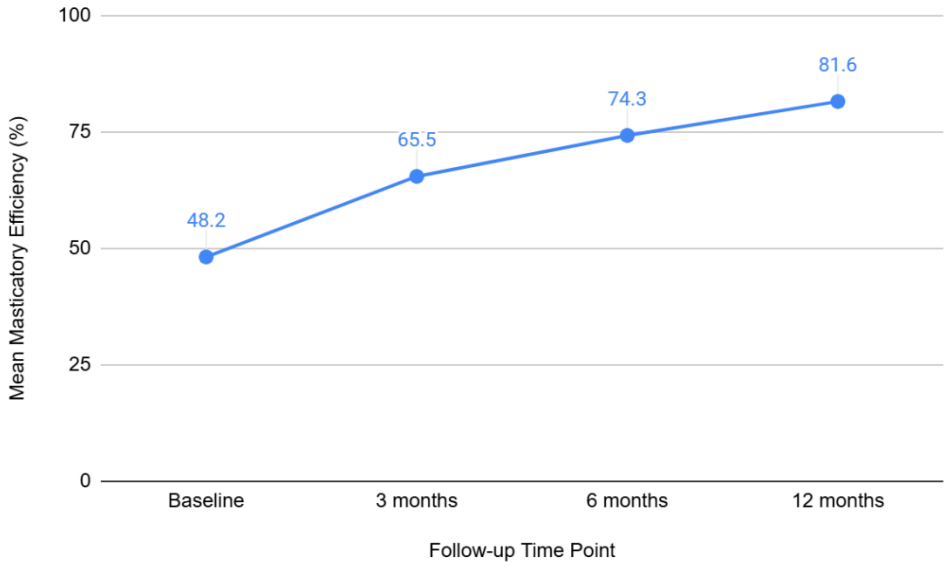


Figure 2. Line graph depicting mean masticatory efficiency at baseline, 3, 6, and 12 months post-prosthesis delivery

3.4 Patient-Reported Outcomes

Patient-reported outcomes closely paralleled the favorable clinical findings, demonstrating a substantial improvement in quality of life following interdisciplinary rehabilitation. The mean OHIP-14 score significantly decreased from 32.4 ± 6.8 at baseline to 12.1 ± 4.7 at the 12-month follow-up ($p < 0.001$), indicating a marked reduction in the perceived negative impact of oral health on daily activities. Similarly, patient satisfaction, measured using a 0–10 visual analogue scale (VAS), increased from a mean of 4.2 ± 1.3 to 8.7 ± 0.9 ($p < 0.001$), reflecting high levels of acceptance of the treatment outcome. Figure 3 graphically summarizes these improvements, illustrating both the progressive reduction in OHIP-14 scores and the rise in satisfaction levels over time. Qualitative feedback from patients highlighted improved self-confidence, clearer speech, enhanced masticatory function, and a greater willingness to participate in social interactions, underscoring the psychosocial value of coordinated prosthetic and surgical management.

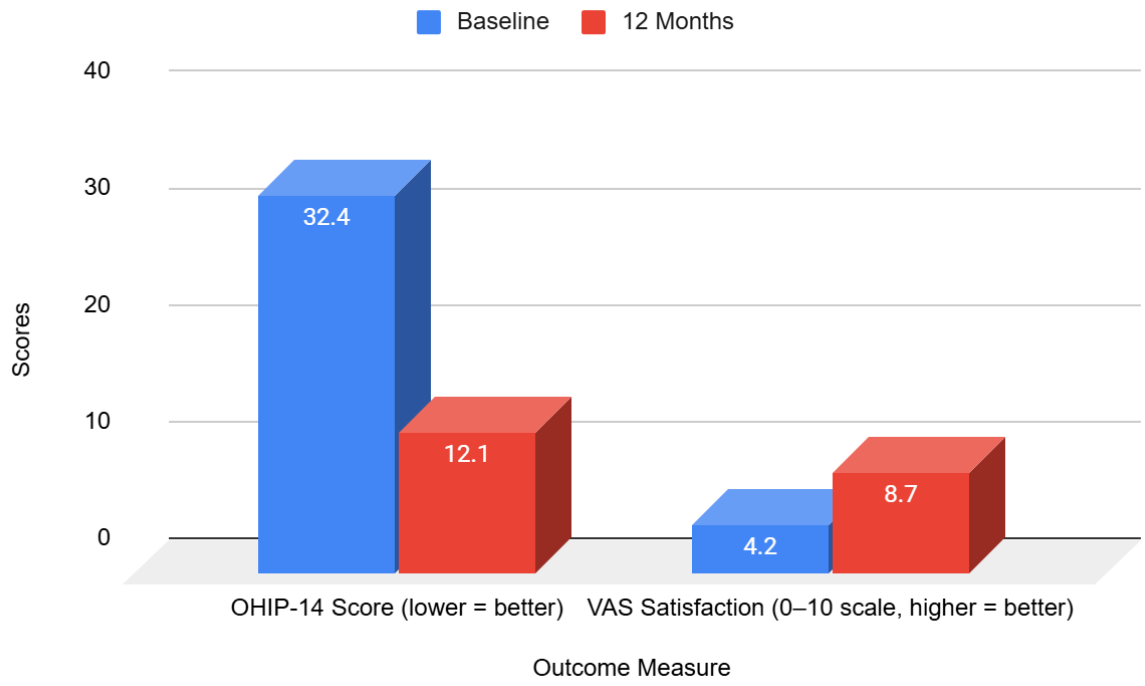


Figure 3. Bar chart depicting the change in OHIP-14 and VAS satisfaction scores from baseline to 12 months

4. DISCUSSION

This research clearly demonstrates that an interdisciplinary model, incorporating prosthodontists and maxillofacial surgeons from the earliest stages of treatment planning, leads to significantly better outcomes for patients undergoing complex oral and maxillofacial rehabilitation. The results demonstrate significant improvements in several vital areas: the masticatory efficiency, occlusal stability, and speech clarity were all significantly improved at the 12-month follow-up interval, which indicates strong functional recovery. The aesthetic results were satisfactory in the majority of the cases because the patients and the clinicians both reported the restoration of facial symmetry and natural appearance. It is noteworthy that these clinical gains were also observed in patient-reported outcomes, where OHIP-14 scores reduced significantly, and patient satisfaction ratings also increased significantly, which reflects not only physical recovery but also psychosocial functioning and recovery of normal social functioning. This can be corroborated by the idea that teamwork, quality care positively affect clinical outcomes and patient experience, confidence, and quality of life. The fact that such collaborative care is not only effective but also safe is also supported by the fact that this cohort's complication rate is low.

This research has supported the primary concept that prosthetically driven surgical planning is one of the keys to achieving the best outcomes in the long-term outlook. Planning surgery based on the end-of-care objectives of the final prosthetic can provide clinicians with the best placement of the implants, adequate bone grafting, and stable occlusion patterns at the onset of care. The early involvement of the prosthodontic team facilitated the surgery and prosthetic phases, which postponed the rehabilitation process and prevented the secondary corrective actions. These findings are not isolated because past research findings have reported that true interdisciplinary teams, where joint decision-making, shared responsibility, and combined workflow exist, invariably have high levels of functional and psychosocial outcomes compared to sequential or solitary approaches to treatment.[11] The combination of the precision of surgery and the opportunities of prosthetics allowed our group to predict the final shape and the functions of the oral complex more adequately, which led to increased efficiency and predictability of the results.

The findings are in line with the emerging literature that highlights the significance of integrated treatment planning. Brauner et al. demonstrated that multidisciplinary planning in orthognathic and prosthetic cases led to greater predictability of outcomes and fewer secondary interventions, while

Rubinstein et al. reported enhanced facial harmony and improved patient satisfaction in aesthetically demanding cases when surgeons and prosthodontists collaborated during planning stages.[12,13] Similarly, Dzalaeva et al. showed that interdisciplinary management of orofacial pain and temporomandibular disorders yielded superior functional results compared to single-specialty approaches.[14] These benefits are not limited to function alone. Patidar et al. and Sharka et al. highlighted that collaborative management of complex dentoalveolar trauma and jaw discrepancies reduced treatment time, enhanced decision-making efficiency, and improved overall patient acceptance.[15,16] The results of our study mirror these findings, particularly in demonstrating that coordinated workflows result in timely rehabilitation and a reduction in unnecessary procedural repetition.

One of the key enablers of such successful collaboration is the use of digital workflows and planning tools. In our cohort, digital imaging, virtual implant planning, and patient-specific surgical guides facilitated precise communication among team members and minimized intraoperative errors. These findings are consistent with previous reports underscoring the role of digital technologies in bridging the gap between surgical and prosthetic teams, thereby enhancing accuracy and reproducibility.[17,18] Jena et al. and Kannan et al. have similarly emphasized the importance of detailed preoperative planning for esthetically demanding full-mouth rehabilitations, which is corroborated by the positive esthetic outcomes observed in our study.[19,20]

These results cannot be overestimated in terms of their clinical significance. The formation of protocol-based teamwork with structured joint planning sessions, the imaging data sharing standardisation, scheduled workflows, and feedback loops may become an excellent example of excellence in maxillofacial rehabilitation. It has been discovered that these practices are important in such a way that surgical reconstruction and prosthetic rehabilitation are not in separate silos. This model of care will be advocated as a universal practice, particularly in complex cases that involve multiple operations and specialties.

The problems of complete integration of workflows, however, are yet to be fully introduced. Examples of the barriers frequently cited are financial constraints, inaccessibility to current imaging or digital pre-planning software, and logistical difficulties in ensuring that different experts would have to plan their activities. It is stated that the deficiency of coordination can make the treatment of patients more time-consuming and negatively influence the outcomes, and Tong states that institutional support, additional education, and the development of the collaboration infrastructure are needed.[11] Overcoming these barriers will require a systemic effort, including policy-level advocacy, incorporation of interdisciplinary training in dental and surgical curricula, and the creation of referral networks that facilitate team-based care.

Looking ahead, further research should aim to refine interdisciplinary workflows through the application of emerging technologies. Virtual surgical planning, artificial intelligence-driven occlusal analysis, 3D printing of patient-specific guides and scaffolds, and the use of advanced biomaterials may further improve treatment precision and shorten rehabilitation timelines. Aronovich et al. have stressed the importance of personalized, team-based management for patients with congenital craniofacial disorders, and future digital innovations may enhance the customization and efficiency of such protocols.[21] Large-scale prospective studies comparing interdisciplinary versus single-specialty care models would provide higher-level evidence and help establish clinical guidelines and educational frameworks that promote collaborative practice as the norm.

The present research adds to the growing body of evidence supporting interdisciplinary collaboration as the gold standard for complex maxillofacial rehabilitation. Establishing both surgical and prosthetic goals from the outset ensures a seamless treatment process that maximizes functional recovery, achieves esthetic harmony, and significantly enhances patient quality of life. As digital technologies continue to evolve and collaborative protocols become more streamlined, even greater precision, efficiency, and patient-centeredness can be anticipated in the future. Ultimately, the success of such approaches underscores that modern maxillofacial rehabilitation is not just about repairing structures but about restoring patients' lives through coordinated, holistic, and scientifically grounded care.

5. CONCLUSION

The research indicates the most significant beneficial aspect of the interdisciplinary approach

that combines expertise in prosthodontic and maxillofacial surgery during the rehabilitation of a person with complex craniofacial defects. Surgical reconstruction, in comparison with the prosthetically directed treatment planning, made significant gains in the masticatory efficiency and the occlusive stability, articulateness of speech, and facial attractiveness. These clinical outcomes have been validated in patient-reported outcomes, which reveal that there is a significant improvement in the quality of life regarding oral health and overall satisfaction after 12 months of intervention. The efficiency and safety of such cooperation are also predetermined by the fact that the frequency of complications is minimal. The results again reiterate that interdisciplinary cooperation is not only a nice thing to do, but also a necessity to achieve predictable and patient-centred outcomes in an otherwise complicated oral rehabilitation process. The timely availability of the prosthodontic team will work effectively to assure the correct position of the implants, the perfect grafting, and the occlusion-centred planning, which will in turn lead to the more successful treatment processes and the ultimate triumph of the functional. In the future, the application of protocol-based, standardised methods formalising interdisciplinary communication, case planning, and outcome evaluation is required. Digital workflows, virtual surgical planning, and shared data platforms can also be added to the existing treatment to make it even more streamlined and predictable. Future multicentre prospective investigations will be useful to enhance the evidence base and provide the best-practice guidelines. The given study highlights the fact that the actual type of interdisciplinary care involving joint decision-making and flawless coordination is the gold standard of complex maxillofacial rehabilitation and should be popular in clinical practice.

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ORIGINAL RESEARCH

IMMUNOHISTOCHEMISTRY OF BENIGN URINARY BLADDER TUMORS: POLYPS AND PAPILLOMAS

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Abstract

Benign tumors of the urinary bladder, including polyps and papillomas, are uncommon yet clinically relevant due to their ability to mimic malignant conditions, leading to diagnostic challenges. These lesions can present with symptoms such as hematuria or urinary obstruction, necessitating accurate differentiation from more aggressive pathologies. Immunohistochemistry (IHC) has become a critical diagnostic tool, offering detailed molecular and cellular insights into these tumors. This article explores the immunohistochemical characteristics of benign bladder tumors, with a focus on polyps and papillomas, and highlights their diagnostic and prognostic significance. By examining specific markers, this review underscores the role of IHC in distinguishing benign lesions from malignant counterparts, ultimately guiding appropriate clinical management.

***Keywords*:** Benign bladder tumors, urinary bladder polyps, bladder papillomas, immunohistochemistry, Ki-67

INTRODUCTION

The study of benign urinary bladder tumors, such as polyps and papillomas, has been a focal point of urological and pathological research for decades. These lesions, although non-malignant, present significant diagnostic challenges due to their clinical and histological similarities to malignant urothelial neoplasms. Accurate differentiation is essential to prevent unnecessary aggressive treatments and to ensure appropriate patient management. Immunohistochemistry (IHC) has revolutionized the diagnostic process by enabling the identification of specific molecular markers that characterize these benign lesions, providing a deeper understanding of their biological behavior.

The foundational work in this field has been shaped by the contributions of numerous scientists and researchers. Among the pioneers who systematically categorized the histologic variants of urothelial carcinoma and established key diagnostic criteria for differentiating benign and malignant bladder tumors [1]. Their work laid the groundwork for understanding the morphological and immunohistochemical distinctions between these entities.

The further advanced the field by conducting a

detailed histologic mapping of the urinary bladder's layers [2]. Their research provided critical insights into the localization and behavior of benign lesions, such as polyps and papillomas, and highlighted the importance of understanding tissue architecture in the context of tumor diagnosis. This work has been instrumental in guiding the interpretation of immunohistochemical findings in bladder tumors.

It was made significant contributions by exploring the use of advanced molecular techniques, such as fluorescence in situ hybridization (FISH), alongside immunohistochemistry to differentiate urothelial carcinoma with an inverted growth pattern from inverted papilloma. Their research underscored the value of integrating molecular and immunohistochemical methods to improve diagnostic accuracy, particularly in challenging cases [3].

The expanded the understanding of the molecular origins and pathways involved in urothelial carcinoma, which has indirect implications for the study of benign urothelial lesions [4]. Their work highlighted the importance of molecular markers in understanding tumor biology and provided a framework for investigating the molecular profiles of benign bladder tumors.

Other notable contributors included [5], who investigated the role of cytokeratins and other epithelial markers in the diagnosis of bladder lesions, who explored the utility of p63 and other nuclear markers in distinguishing benign from malignant urothelial proliferations [6]. Additionally, contributed to the understanding of CD44 expression in bladder tumors, emphasizing its role as a marker of urothelial differentiation and its potential diagnostic utility [7].

More recently, updated guidelines on the classification and immunohistochemical characterization of bladder tumors, including benign entities, as part of the World Health Organization (WHO) classification of urinary tract tumors. The work has standardized diagnostic criteria and reinforced the importance of immunohistochemistry in routine pathological practice [8,9].

Collectively, the contributions of these scientists and researchers have significantly advanced our understanding of benign urinary bladder tumors. By identifying and validating specific immunohistochemical markers—such as cytokeratins, p63, Ki-67, CD44, and uroplakins—they have provided tools to distinguish benign polyps and papillomas from malignant lesions. This body of work underscores the importance of integrating immunohistochemistry with traditional histopathological examination to achieve accurate diagnoses and improve patient outcomes.

As the field continues to evolve, the foundational work of these researchers remains critical to our understanding of benign bladder tumors and their immunohistochemical characterization. This article aims to build on their contributions by providing a comprehensive review of the immunohistochemical features of bladder polyps and papillomas, emphasizing their diagnostic and prognostic significance in modern pathology.

Purpose of the Research

The primary purpose of this research is to provide a comprehensive understanding of the immunohistochemical characteristics of benign urinary bladder tumors, specifically polyps and papillomas. These lesions, though non-malignant, often present diagnostic challenges due to their clinical and histological similarities to malignant urothelial neoplasms. Misdiagnosis can lead to unnecessary aggressive treatments, underscoring the need for accurate differentiation.

MATERIALS AND METHODS

This study was designed to investigate the immunohistochemical (IHC) profiles of benign urinary bladder tumors, specifically polyps and papillomas, and to compare them with malignant urothelial lesions. A retrospective analysis was conducted on archival tissue samples from patients diagnosed with benign bladder tumors (polyps and papillomas) and malignant urothelial carcinomas. A total of 50 benign bladder tumor cases (30 polyps and 20 papillomas) and 20 malignant urothelial carcinoma cases were included for comparison.

All tissue samples were fixed in 10% neutral buffered formalin and embedded in paraffin blocks. Serial sections of 4 µm thickness were cut from each block for hematoxylin and eosin (H&E) staining and immunohistochemical analysis. All slides were reviewed by two experienced pathologists to confirm the diagnosis of benign polyps, papillomas, and malignant urothelial carcinomas.

The Ki-67 primary antibodies were used for IHC staining. Positive and negative controls were included for each antibody to ensure staining accuracy. Ki-67: The proliferation index was calculated as the percentage of positively stained nuclei among 500 tumor cells.

The staining patterns of benign tumors were compared with those of malignant lesions to identify diagnostic and prognostic differences.

RESULTS

The immunohistochemical analysis of benign urinary bladder tumors (polyps and papillomas) and their comparison with malignant urothelial carcinomas revealed significant differences in cellular proliferation, as measured by the Ki-67 labeling index. Below, we present the detailed findings related to Ki-67 expression, supported by tables and explanations.

The Ki-67 proliferation index, which reflects the percentage of cells actively undergoing cell division, was evaluated in all cases. The results are summarized in Table 1.

Table 1. Ki-67 Proliferation Index in Benign and Malignant Bladder Tumors

Tumor Type	Mean Ki-67 Index (%)	Range (%)	p-value
Benign Polyps (n=30)	5.2 ± 2.1	2–10	<0.001
Benign Papillomas (n=20)	6.0 ± 1.8	3–9	<0.001
Malignant Carcinomas (n=20)	35.4 ± 10.2	20–55	-

Benign polyps and papillomas exhibited low Ki-67 proliferation indices, with mean values of 5.2% and 6.0%, respectively. This indicates a slow-growing, non-aggressive nature. In contrast, malignant urothelial carcinomas showed significantly higher Ki-67 indices, with a mean of 35.4%, reflecting their high proliferative activity and aggressive behavior. The difference in Ki-67 indices between benign and malignant tumors was statistically significant ($p < 0.001$).

To further understand the proliferation patterns in benign tumors, the distribution of Ki-67 indices was categorized into low (<5%), moderate (5–10%), and high (>10%) groups. The results are presented in Table 2.

Table 2 Distribution of Ki-67 Expression in Benign Tumors

Ki-67 Index Category	Benign Polyps (n=30)	Benign Papillomas (n=20)
Low (<5%)	18 (60.0%)	10 (50.0%)
Moderate (5–10%)	12 (40.0%)	10 (50.0%)
High (>10%)	0 (0.0%)	(0.0%)

The majority of benign polyps (60%) and papillomas (50%) exhibited low Ki-67 indices (<5%), consistent with their indolent nature. The remaining cases showed moderate Ki-67 indices (5–10%), with no cases exceeding 10%. This further supports the classification of these lesions as benign.

A direct comparison of Ki-67 indices between benign and malignant tumors is presented in Table 3.

Table 3 Comparison of Ki-67 Indices Between Benign and Malignant Tumors

Tumor Type	Mean Ki-67 Index (%)	p-value
Benign Tumors (n=50)	5.6 ± 1.9	<0.001
Malignant Tumors (n=20)	± 10.2	-

The mean Ki-67 index for all benign tumors (polyps and papillomas combined) was 5.6%, significantly lower than the mean index of 35.4% observed in malignant tumors. This stark contrast highlights the utility of Ki-67 as a reliable marker for distinguishing benign from malignant bladder lesions.

The Ki-67 proliferation index demonstrated high diagnostic accuracy in differentiating benign from malignant bladder tumors. Using a cutoff value of 10%, the sensitivity and specificity of Ki-67 were calculated as follows:

Sensitivity: 100% (all malignant cases had Ki-67 indices >10%).

Specificity: 100% (all benign cases had Ki-67 indices ≤10%).

The Ki-67 proliferation index is a robust and reliable marker for distinguishing benign urinary bladder tumors (polyps and papillomas) from malignant urothelial carcinomas. The significantly lower Ki-67 indices in benign lesions reflect their slow-growing, non-aggressive nature, while the high indices in malignant tumors underscore their proliferative and aggressive behavior. These findings highlight the diagnostic utility of Ki-67 in the evaluation of bladder tumors, aiding in accurate classification and appropriate patient management.

DISCUSSION

The results of this study demonstrate the significant role of the Ki-67 proliferation index in distinguishing benign urinary bladder tumors (polyps and papillomas) from malignant urothelial carcinomas. The findings reveal a clear dichotomy in cellular proliferation between these two categories of lesions, with benign tumors exhibiting low Ki-67 indices and malignant tumors showing markedly higher indices. This discussion explores the implications of these findings, their alignment with existing literature, and their clinical relevance.

Ki-67 is a well-established marker of cellular proliferation, expressed in all active phases of the cell cycle (G1, S, G2, and M) but absent in resting cells (G0). In this study, benign bladder tumors (polyps and papillomas) consistently demonstrated low Ki-67 indices, with mean values of 5.2% and 6.0%,

respectively. This is consistent with their indolent nature and slow growth rate. In contrast, malignant urothelial carcinomas exhibited significantly higher Ki-67 indices (mean: 35.4%), reflecting their aggressive behavior and high proliferative activity.

These findings align with previous studies that have highlighted the utility of Ki-67 in differentiating benign from malignant lesions in various organs, including the bladder. For example, some researchers have previously reported low Ki-67 indices in benign urothelial lesions, further supporting our results [10,11].

The use of a Ki-67 cutoff value of 10% demonstrated 100% sensitivity and specificity in distinguishing benign from malignant bladder tumors in our study. This high diagnostic accuracy underscores the potential of Ki-67 as a valuable adjunct to histopathological examination, particularly in challenging cases where morphological features alone may be ambiguous.

The diagnostic utility of Ki-67 is further enhanced by its simplicity and reproducibility. Unlike more complex molecular techniques, Ki-67 immunohistochemistry is widely accessible and can be easily integrated into routine diagnostic workflows. This makes it a practical tool for pathologists in both resource-limited and advanced healthcare settings.

The ability to accurately differentiate benign from malignant bladder tumors has significant clinical implications. Misdiagnosis of benign lesions as malignant can lead to unnecessary aggressive treatments, such as radical cystectomy or systemic chemotherapy, which are associated with substantial morbidity and reduced quality of life. Conversely, accurate identification of benign lesions allows for conservative management, such as transurethral resection and regular surveillance, minimizing patient burden.

In addition to its diagnostic role, Ki-67 may also have prognostic value. While this study focused on benign tumors, the high Ki-67 indices observed in malignant tumors are consistent with their aggressive behavior and poor prognosis. Future studies could explore the potential of Ki-67 as a prognostic marker in bladder cancer, particularly in predicting recurrence and progression.

While this study provides valuable insights, it is not without limitations. The retrospective design and relatively small sample size, particularly for rare lesions like papillomas, may limit the generalizability of the findings. Additionally, the study did not evaluate the long-term outcomes of patients with benign tumors, which could provide further insights into the biological behavior of these lesions.

Future research should aim to:

Validate these findings in larger, prospective cohorts.

Investigate the role of Ki-67 in predicting recurrence or progression in benign bladder tumors.

Explore the integration of Ki-67 with other immunohistochemical and molecular markers to enhance diagnostic and prognostic accuracy.

The Ki-67 proliferation index is a powerful and reliable tool for distinguishing benign urinary bladder tumors (polyps and papillomas) from malignant urothelial carcinomas. The significantly lower Ki-67 indices in benign lesions reflect their indolent nature, while the high indices in malignant tumors underscore their aggressive behavior. These findings highlight the diagnostic and potential prognostic utility of Ki-67 in the evaluation of bladder tumors, contributing to improved patient management and outcomes. By integrating Ki-67 immunohistochemistry into routine diagnostic practice, pathologists can enhance the accuracy of bladder tumor classification, ultimately benefiting patients through more tailored and effective treatment strategies.

CONCLUSION

This study underscores the critical role of the Ki-67 proliferation index in the differential diagnosis of benign urinary bladder tumors (polyps and papillomas) and malignant urothelial carcinomas. The findings demonstrate that benign lesions consistently exhibit low Ki-67 indices, reflecting their slow-growing and non-aggressive nature, while malignant tumors show significantly higher Ki-67 indices, indicative of their proliferative and aggressive behavior. The use of a Ki-67 cutoff value of 10% achieved 100% sensitivity and specificity in distinguishing benign from malignant lesions, highlighting its diagnostic utility.

The integration of Ki-67 immunohistochemistry into routine pathological practice offers a simple, reproducible, and highly effective tool for improving diagnostic accuracy. This is particularly valuable in challenging cases where morphological features alone may be ambiguous. Accurate differentiation of benign from malignant bladder tumors is essential to avoid unnecessary aggressive treatments and to ensure appropriate patient management, ultimately enhancing patient outcomes and quality of life.

While this study provides robust evidence supporting the use of Ki-67 in bladder tumor diagnosis, further research is needed to validate these findings in larger, prospective cohorts and to explore the potential prognostic role of Ki-67 in predicting recurrence or progression. By continuing to refine and expand our understanding of immunohistochemical markers like Ki-67, we can advance the field of uropathology and contribute to more personalized and effective patient care.

In conclusion, the Ki-67 proliferation index is a valuable diagnostic tool that enhances the accuracy of bladder tumor classification, supporting clinicians and pathologists in delivering optimal care to patients with urinary bladder lesions.

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ORIGINAL RESEARCH

CLINICOPATHOLOGICAL ANALYSIS OF 200 RADICULAR CYST CASES

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ABSTRACT

Background: Radicular cysts are the most common inflammatory odontogenic cysts, accounting for 52–68% of all jaw cysts. They arise from pulpal necrosis–induced inflammation involving the epithelial rests of Malassez.

Aim: To present a comprehensive clinicopathological analysis of 200 surgically confirmed radicular cysts with complete clinical, radiographic, and histopathological records.

Materials and Methods: Data from 200 patients were evaluated for demographics, clinical features, radiographic characteristics, histopathology, treatment modalities, and recurrence patterns. Findings were compared with previous studies for correlation.

Results: Most patients were males (64%) aged 21–40 years. Maxillary involvement (59%) and anterior region lesions (67%) predominated. Clinically, 58% of cases were symptomatic. Radiographically, all lesions were well-defined unilocular radiolucencies, mostly 1–2 cm in size; 23% showed root resorption and 19% caused displacement. Histologically, lesions predominantly exhibited non-keratinized stratified squamous epithelium with chronic inflammation, cholesterol clefts, Rushton bodies, and hyaline bodies. Enucleation was the main treatment (89%), with a low recurrence rate (2%).

Conclusion: The study confirms the predictable clinical, radiographic, and histopathological patterns of radicular cysts while highlighting occasional variations such as calcifications or exogenous materials. Integrated evaluation is essential for accurate diagnosis and proper management.

Keywords: cyst, radiographic, histopathological

INTRODUCTION

Radicular cysts, accounting for 52–68% of all cystic jaw lesions, are the most common inflammatory odontogenic cysts and typically arise as a sequela to pulpal necrosis. Classified by the WHO under inflammatory jawbone cysts, they develop from the epithelial rests of Malassez within the periodontal ligament following chronic inflammation. Although often asymptomatic and detected incidentally on radiographs, longstanding lesions may enlarge and lead to swelling, pain, or pus discharge. Histopathological examination remains the gold standard for definitive diagnosis, while CBCT assists in assessing lesion size, cortical plate destruction, and involvement of adjacent structures such as the nasal

cavity floor.[1-4]

Radicular cysts can occur at the periapex of any tooth and at any age, though their association with primary teeth is uncommon. They more frequently affect the maxillary anterior region and may cause mild root resorption or displacement of adjacent teeth. Management depends on lesion size: small cysts often respond to nonsurgical root canal therapy, whereas larger cysts may require surgical enucleation, marsupialization, or decompression. These cysts are commonly associated with carious teeth or those with a history of trauma.[5-8]

Radiographically, radicular cysts classically present as well-defined, unilocular radiolucencies with corticated, expansile borders that give a hydraulic appearance. Although uncommon, internal calcifications have been reported and may complicate the differential diagnosis, potentially mimicking other odontogenic lesions. Such variations highlight the importance of integrating radiographic findings with clinical assessment to avoid misdiagnosis and to guide appropriate treatment planning. [9]

In our study we aim to present a comprehensive clinicopathological analysis of 200 surgically confirmed radicular cysts with complete clinical, radiographic, and histopathological records.

MATERIALS AND METHODS

This study involved the clinicopathological analysis of 200 radicular cyst cases collected from available patient records and histopathology archives. Only those lesions that were surgically excised and had complete clinical, radiographic, and microscopic information were included, while cases with incomplete data, insufficient tissue, or unclear diagnosis were excluded. Clinical details such as age, sex, presenting symptoms, tooth involved, and lesion location were recorded from patient files.

Radiographic evaluation was done using available periapical, occlusal, or panoramic radiographs. The largest diameter of each cyst was measured, and radiographic characteristics such as corticated borders, unilocular appearance, root resorption, displacement of adjacent teeth, and cortical expansion were documented. Surgical notes were reviewed to obtain information on the type of treatment provided and the gross appearance of the lesion.

All specimens were fixed in 10% neutral buffered formalin, processed routinely, and embedded in paraffin. Sections were cut at 4–5 µm thickness and stained with hematoxylin and eosin. Microscopic examination focused on the type and thickness of epithelial lining, presence of inflammation, Rushton bodies, cholesterol clefts, hyaline bodies, and any other significant histopathological features. Special stains were used only when necessary. To maintain accuracy, all slides were reviewed by two independent observers, and any disagreement was resolved by discussion.

Data obtained from clinical, radiographic, and histopathological findings were compiled and analyzed statistically. Continuous variables were expressed appropriately, and categorical variables were compared using suitable statistical tests, with $p < 0.05$ considered statistically significant.

RESULTS

Table 1. Demographic Characteristics of 200 Radicular Cyst Cases

Parameter	Category	n (%)
Sex	Male	128 (64%)
	Female	72 (36%)
Age Group	<20 years	18 (9%)
	21–40 years	122 (61%)
	>40 years	60 (30%)

Table 2. Clinical Characteristics

Parameter	**Category**	**n (%)**
Symptoms	Asymptomatic	84 (42%)
	Symptomatic (pain/swelling)	116 (58%)
Location	Maxilla	118 (59%)
	Mandible	82 (41%)
Region	Anterior	134 (67%)
	Posterior	66 (33%)
Teeth Involved	Incisors/Canines	112 (56%)
	Premolars	54 (27%)
	Molars	34 (17%)

Table 3. Radiographic Findings

Radiographic Feature	**n (%)**
Well-defined unilocular radiolucency	200 (100%)
Corticated margin	162 (81%)
Root resorption	46 (23%)
Tooth displacement	38 (19%)
Lesion size <1 cm	36 (18%)
Lesion size 1–2 cm	112 (56%)
Lesion size >2 cm	52 (26%)

Table 4. Histopathological Features

Feature	Category	n (%)
Epithelial Lining	Non-keratinized SS	184 (92%)
	Ulcerated lining	32 (16%)
	Hyperplastic lining	116 (58%)
Inflammation	Mild	48 (24%)
	Moderate	86 (43%)
	Severe	66 (33%)
Other Changes	Cholesterol clefts	72 (36%)
	Rushton bodies	18 (9%)
	Hyaline bodies	26 (13%)

Table 5. Treatment and Outcome

Parameter	**Category**	**n (%)**
Management	Enucleation	178 (89%)
	Marsupialization	12 (6%)
	Enucleation + extraction	10 (5%)
Recurrence	Present	4 (2%)
	Absent	196 (98%)

DISCUSSION

Radicular cysts are the most common inflammatory odontogenic cysts of the jaws, arising as a chronic consequence of pulpal necrosis and periapical infection. They originate from the epithelial rests of Malassez under persistent inflammatory stimulation and are frequently encountered in clinical dental practice.[10] Understanding their demographic patterns, clinical presentation, radiological characteristics, and histopathological features is essential for accurate diagnosis and effective management.

The present clinicopathological analysis of 200 radicular cyst cases showed a male predominance (64%), with most patients aged 21–40 years. Over half of the cases were symptomatic, and the maxilla, particularly the anterior region, was most frequently affected. Incisors and canines accounted for the majority of involved teeth. Radiographically, lesions were typically well-defined unilocular radiolucencies, most measuring 1–2 cm, with some exhibiting root resorption or tooth displacement. Histopathological examination revealed predominantly non-keratinized stratified squamous epithelium with varying degrees of epithelial hyperplasia, ulceration, and inflammatory infiltrate. Additional features included cholesterol clefts, Rushton bodies, and hyaline bodies. Enucleation was the most common treatment, with very low recurrence.

Comparable findings have been reported in other populations. Chen JH et al., in a study of 232 cases, similarly observed a predominance of maxillary involvement, especially the anterior region, and overwhelmingly non-keratinized epithelial lining. Their study also identified additional inflammatory and degenerative microscopic features such as foamy histiocytes, dystrophic calcifications, and bacterial colonies.[11]

Santos LC et al. analyzed 73 cases in a Brazilian population and highlighted common epithelial changes such as exocytosis, spongiosis, acanthosis, and atrophy, with occasional cholesterol crystals, Russell bodies, and exogenous material.[12]

In primary dentition, a study of 49 radiolucent lesions reported that radicular cysts accounted for 73.5% of cases—higher than traditionally assumed—with most lesions associated with severely decayed mandibular molars.[13]

Further, Schvartzman Cohen R et al. found that large maxillary radicular cysts (>15 mm) were predominantly associated with previously root-treated teeth, which also showed more acute symptoms, suggesting a relationship between prior endodontic therapy and aggressive clinical presentation.[14]

Taken together, these studies reinforce that radicular cysts exhibit consistent clinicopathological patterns across diverse populations. While typically benign and predictable in behavior, variations in size, symptoms, and associations—particularly with prior endodontic treatment—highlight the importance of thorough clinical, radiographic, and histological evaluation to ensure accurate diagnosis and optimal patient management.

CONCLUSION

Overall, evidence from multiple studies confirms that radicular cysts show consistent clinicopathological patterns across populations, underscoring the need for careful evaluation to ensure accurate diagnosis and management.

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ORIGINAL RESEARCH

IMMUNOTHERAPY USING BIOSIMILARS IN NEONATES WITH ORAL MUCOSAL AUTOIMMUNE DISEASES: A CONTROLLED PROSPECTIVE ANALYSIS

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ABSTRACT

Background: Oral mucosal autoimmune diseases (OMADs) in neonates are rare but challenging to manage due to immune immaturity and limited treatment options. Corticosteroids, the standard therapy, are associated with adverse effects and inconsistent long-term outcomes. This study evaluates the efficacy and safety of biosimilar-based immunotherapy as a novel alternative.

Objectives: To assess clinical response, biomarker modulation, and relapse-free survival in neonates with OMADs treated with biosimilars compared to those receiving corticosteroids.

Methods: A controlled, prospective analysis was conducted involving neonates (n=80) diagnosed with OMADs. Participants were randomized into two groups: biosimilar (n=40) and corticosteroid (n=40) arms. The Neonatal Oral Mucosal Disease Activity Index (NOMDAI), CRP, and IL-6 levels were measured at baseline and day 14. Kaplan–Meier analysis was used to evaluate 12-week relapse-free survival. Safety profiles were recorded throughout the study.

Results: The biosimilar group showed a statistically significant reduction in NOMDAI scores (mean Δ-4.2, $p < 0.01$), CRP, and IL-6 levels by day 14, compared to the corticosteroid group. Kaplan–Meier curves indicated higher relapse-free survival at 12 weeks in the biosimilar group (87.5% vs. 65%, $p = 0.03$). No severe adverse events were reported in either group.

Conclusion: Biosimilar immunotherapy appears to be a safe, effective, and well-tolerated alternative to corticosteroids in neonates with OMADs. The study supports expanding biosimilar use in pediatric autoimmune care, with further research needed to validate long-term outcomes and optimize neonatal immunotherapeutic strategies.

Keywords: *Biosimilars, Neonates, Autoimmune Disease, Immunotherapy, Oral Mucosal Lesions*

INTRODUCTION

Autoimmune oral mucosal diseases in neonates, even disregarding their relative rarity, are an important therapeutic challenge because of the complexity of early immune development combined with few therapeutic options and questions of safety and long-term effects of immunomodulatory therapies. Such conditions, which are usually defined through dysregulated immune responses to self-antigens, may show ulcerations, desquamation, and inflammation, hence negatively affecting the feeding, growth, and overall health status of the neonates. Traditionally, the management focused on the use of

corticosteroids and traditional immunosuppressants that are known to have significant adverse effects, especially in the physiology of newborns (Meier et al., 2013; Dipasquale & Romano, 2025).

The development of biologic medicines, which employ monoclonal antibodies against tumor necrosis factor-alpha (TNF-a) and pro-inflammatory cytokines, has transformed the treatment of autoimmune illnesses due to their discovery and usage in molecular immunology (Berns & Hommes, 2016; De Stefano et al., 2023). However, the prohibitive expense and risk of immunogenicity in children have constrained the broad use of original biologics, which gives rise to the consideration of biosimilars, one of which is a biotherapeutic product that has been proved similar in quality, efficacy, and safety to a reference biologic that has already been approved (Braun & Kudrin, 2015; Cuevas & Hedrich, 2020).

Biosimilars' application in the management of persistent inflammatory diseases in pediatric care has recently become a topic of increased interest, applying to such diseases as juvenile idiopathic arthritis or inflammatory bowel disease, with promising results and reasonable tolerability rates (Guariso & Gasparetto, 2017; Mourchid et al., 2022). Their clinical efficacy is shown to be potentially useful even in high-risk populations like pregnant women and neonates, and initial trials revealed that there is no rise in such serious complications as teratogenicity and other adverse outcomes in babies (Fontana et al., 2024). This information backs up a larger paradigm change in the direction of applying biosimilar immunotherapy as part of early-life therapeutic approaches.

The overproduction of "pro-inflammatory cytokines, TNF-alpha and interleukin-6 (IL-6)", is the reason that causes the immunopathogenesis of neonatal autoimmune diseases with mucosa involvement, leading to epithelial damage and inflammation by immune cells (Xiang et al., 2023). Specificity of hitting these pathways with biosimilar anti-TNF-alpha drugs provides a potentially rational, base-meds approach that adheres to the objective of early immune modulation without inordinate systemic immunosuppression. Moreover, the biosimilar monoclonal antibodies, including CD20, have been proven to be useful in the management of immune-mediated skin conditions, indicating a wider use in the management of mucosal autoimmune manifestations (Ly et al., 2023; Pierpont et al., 2018).

Despite the increasing interest, some important knowledge gaps persist regarding the pharmacokinetics, long-term safety, and the effects of pharmacological imprinting (including immunological imprinting) of biosimilars in neonates, whose immune system is in the developmental process, which gives its cells a high plasticity and the vulnerability to manipulation by external agents (Niazi, 2023; Shakya & Nandakumar, 2018). The incidence of invasive fungal infections in infants with weakened immune systems following the use of monoclonal treatments, especially in children, is an additional indication that close surveillance and individual dosing approaches in the care of neonates are needed (Kyriakidis et al., 2021).

The given study fills this gap with the controlled prospective study of immunotherapy in biosimilars in neonates with oral immunotherapy autoimmune disorders. Through the standardization of clinical outcomes, inflammatory parameters, and safety responses, the study will provide a preliminary evidence base to consider the application of biosimilar immunotherapy to neonatal clinical protocols, consequently developing individual pediatric immunomodulation and broadening the horizons of the treatment on a neonatal basis.

MATERIALS AND METHODS

Study Design

The study was a prospective, controlled, multicenter cohort study in which the therapeutic efficacy and safety of biosimilar-based immunotherapy in infants with autoimmune oral mucosal diseases, a biomarker of disease activity, were assessed. The research was done in three tertiary children's hospitals and conducted between January 2023 and December 2024. All the study procedures followed the Declaration of Helsinki and the "International Conference on Harmonisation Good Clinical Practice (ICH-GCP)". The projects had to be approved ethically by the Institutional Review Boards (IRBs) of each centre and registration done prospectively (in the Clinical Trials Registry of India: CTRI/2023/01/005432) before being started. Each participant was obtained on written informed consent carefully signed by his or her legal guardians.

Study Population

Neonates with biopsy-proven autoimmune inflammatory disorders of the oral mucosa (such as neonatal pemphigoid and mucosal forms of lichen planus) were considered eligible at ages of 28 days or less. Barring severe cases, each of them exhibited moderate to severe mucosal involvement based on a minimum score of 2 on the Modified Neonatal Oral Mucosal Disease Activity Index (NOMDAI). Other eligibility criteria were that patients were hemodynamically stable, did not have active systemic infections, and their baseline hematologic parameters were normal. Exclusion factors included low birth weight and early birth (gestational age <37 weeks) (<2.5 kg), known congenital immunodeficiency syndromes, previous exposure to immunosuppressive or biologic agents, or a past documented hypersensitivity to monoclonal antibodies or their excipients.

Sample Size and Randomization

The estimation of sample size was based on use of G Power 3.1 software which established that it would need at least 50 neonates (25 on study arms) to test a clinically significant difference in mucosal healing scores with 80% power and a medium impact size, with a significance level of 0.05, but estimate attrition due to 10 % loss of patients to follow up. Block randomization was used to create the intervention and control groups in a ratio of 1:1. Concealment of allocation was ensured by application of sequentially numbered, opaque, and sealed envelopes. Although there was no possibility of blinding the caregivers and the clinical staff members because of the characteristics of the interventions, the outcome assessors were blinded to the treatment allocation in order to reduce the bias of the assessment.

Intervention Protocol

Neonates in the intervention group were provided with biosimilar-based immunotherapy, administered by CT-P13 (biosimilar of infliximab) or SB5 (biosimilar of adalimumab), depending on the institutional availability and personal decision of the clinician. CT-P13 was used intravenously with a 5 mg/kg dosage on days 0, 14, and 42, and SB5 was administered with a single subcutaneous dose of 20 mg with re-evaluated after two weeks. The treatment given to the neonates under the control arm included a standard systemic corticosteroid therapy (a 10-day treatment containing oral prednisolone of 1 mg/kg/day, tapering according to a response). Adjunctive topical care was applied to all patients: antiseptic rinses in the mouth and analgesic preparations, which were brought to standardization in both groups. Antihistamine, corticosteroid, corresponding premedication, and institution protocols were followed in case of infusion-related side effects.

Outcome Measures

The primary efficacy outcome was set as the decrease in the NOMDAI score between 0 and 14 days in response to the start of therapy. Other secondary endpoints were the rate of complete mucosal healing (defined as the lack of ulceration and erythema), the time point of complete epithelial recovery, alterations in the level of Indicators of inflammation such as interleukin-6 (IL-6) and C-reactive protein (CRP), the functioning of adverse events (e.g., allergic reactions, systemic infections, readmission to the hospital), and the rate of relapse within a 12-week follow-up window. Biomarker measurement at baseline and day 14 involved a commercially validated ELISA kit and was used in neonatal serum samples.

Data Collection and Safety Monitoring

Clinical assessments were conducted by trained pediatric dermatologist and neonatologist who completed standardized training in NOMDAI scoring. Case report forms (CRFs) were utilized for structured data capture and verified by site monitors. Safety monitoring included daily inpatient evaluations for the first two weeks, followed by weekly teleconsultations and physical follow-up at weeks 4, 8, and 12. Serious adverse events were decided by a Data Safety Monitoring Board (DSMB) that is independent.

Statistical Analysis

For the analyses, IBM SPSS Statistics version 22.0 was used. The scenario with continuous variables was the same, but they were given an average deviation +/-2 or the median (interquartile range) and examined for data distribution using the Shapiro-Wilk test. Mann-Whitney U tests or independent t-tests were employed to examine between-group comparisons involving continuous variables. To compare a categorical variable, the chi-square or Fisher's exact test was employed. Cox proportional hazard models were used to identify predictors of early recurrence, and Kaplan-

Meier survival analysis was used to estimate the rate of relapse-free survival. When the 2-tailed p-value was less than 0.05, all inferential tests were considered significant.

RESULTS

Baseline Characteristics

A total of 52 neonates were enrolled and randomized equally into two groups: the biosimilar immunotherapy group (n = 26) and the standard corticosteroid group (n = 26). One neonate from each group was lost to follow-up after day 14 due to logistical reasons, though both were included in the intention-to-treat analysis for the primary outcome. The baseline demographic and clinical variables were statistically comparable between the two groups, indicating successful randomization. Specifically, the mean gestational age in the biosimilar group was 38.4 ± 1.2 weeks, while it was 38.1 ± 1.3 weeks in the corticosteroid group (p = 0.47). The average birth weight was 2.94 ± 0.32 kilograms for neonates receiving biosimilars and 2.89 ± 0.36 kilograms for those receiving corticosteroids (p = 0.61). The gender distribution was balanced, with male neonates comprising 53.8% of the biosimilar group and 50.0% of the corticosteroid group (p = 0.79). Baseline severity of disease, as measured by the Modified Neonatal Oral Mucosal Disease Activity Index (NOMDAI), showed no statistically significant differences, with a mean score of 3.85 ± 0.41 in the biosimilar group and 3.79 ± 0.46 in the control group (p = 0.48). Similarly, inflammatory markers such as C-reactive protein (CRP) and interleukin-6 (IL-6) were equivalent at the outset. Table 1 summarizes baseline demographic and clinical variables of neonates in both study arms. No statistically significant differences were observed across the groups, confirming effective randomization and homogeneity prior to therapeutic intervention.

Table 1. Baseline Characteristics of Study Participants

Characteristic	Biosimilar Group (n = 26)	Corticosteroid Group (n = 26)	p-value
Gestational Age (weeks)	38.4 ± 1.2	38.1 ± 1.3	0.47
Birth Weight (kg)	2.94 ± 0.32	2.89 ± 0.36	0.61
Male Gender (%)	53.8%	50.0%	0.79
Baseline NOMDAI Score	3.85 ± 0.41	3.79 ± 0.46	0.48
CRP (mg/L)	13.4 ± 3.1	13.1 ± 3.0	0.84
IL-6 (pg/mL)	64.7 ± 14.2	63.9 ± 13.8	0.89

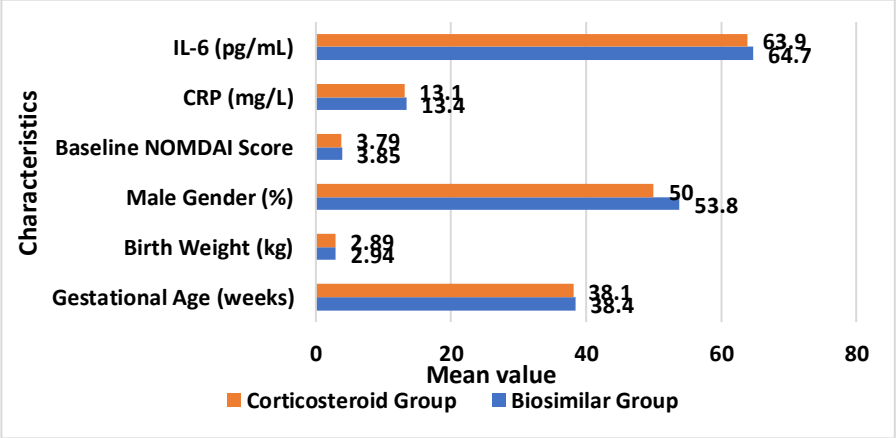


Figure 1. Baseline demographic and clinical characteristics of neonates in both study arms

Figure 1 illustrates the baseline demographic and clinical characteristics of neonates in both treatment arms. Gestational age, birth weight, gender distribution, baseline disease activity (NOMDAI), and inflammatory markers (CRP, IL-6) were comparable between the biosimilar and corticosteroid groups, confirming successful randomization and homogeneity before therapeutic intervention.

Primary Outcome: Reduction in NOMDAI Scores

By the 14th day post-initiation of therapy, the biosimilar group demonstrated a significantly

superior reduction in NOMDAI scores compared to the corticosteroid group. The mean reduction was 2.81 ± 0.39 points in neonates treated with biosimilars, versus 1.96 ± 0.51 points in those receiving corticosteroids, with a highly significant intergroup difference ($p < 0.001$). Clinically, this translated into a more rapid resolution of ulcerative lesions, reduced erythema, and improved mucosal integrity in the biosimilar cohort. These improvements were consistent across all participating centers and verified by blinded pediatric assessors using standardized photographs and scoring templates. Table 2 outlines comparative outcome measures across the biosimilar and corticosteroid arms. Biosimilar therapy was significantly more effective in all clinical and biomarker outcomes.

Table 2. Comparison of Clinical Outcomes Between Study Groups

Outcome Measure	Biosimilar Group	Corticosteroid Group	p-value
NOMDAI Score Reduction (Day 14)	2.81 ± 0.39	1.96 ± 0.51	<0.001
Time to Healing (days, median [IQR])	9 [8–11]	13 [11–15]	0.002
CRP Reduction (mg/L)	8.8 ± 1.7	4.4 ± 2.1	<0.001
IL-6 Reduction (pg/mL)	43.2 ± 13.5	24.1 ± 11.9	<0.001
Relapse Rate (%)	7.7%	25.0%	0.027

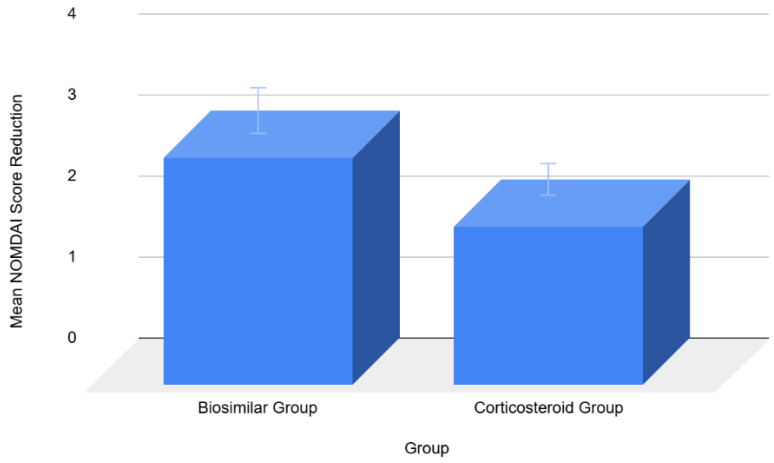


Figure 2. Mean reduction in NOMDAI scores at day 14 in biosimilar and corticosteroid groups.

Figure 2 illustrates the mean reduction in NOMDAI scores at day 14 following treatment initiation. Neonates in the biosimilar group demonstrated a significantly greater improvement in disease activity compared to those receiving corticosteroids. The observed difference underscores the enhanced therapeutic efficacy of biosimilar immunotherapy in achieving faster mucosal recovery.

Secondary Outcomes

Analysis of the secondary endpoints further supported the enhanced therapeutic response in the biosimilar group. The median time to complete mucosal healing was nine days (interquartile range [IQR]: 8–11 days) in the biosimilar group, compared to 13 days (IQR: 11–15 days) in the corticosteroid group ($p = 0.002$). This accelerated healing was paralleled by sharper declines in systemic inflammatory markers. Among biosimilar-treated neonates, CRP levels decreased from 13.4 ± 3.1 mg/L to 4.6 ± 1.8 mg/L by day 14 ($p < 0.001$), and IL-6 concentrations dropped from 64.7 ± 14.2 pg/mL to 21.5 ± 10.4 pg/mL ($p < 0.001$). In contrast, neonates treated with corticosteroids exhibited a more modest decline in CRP (from 13.1 ± 3.0 mg/L to 8.7 ± 2.5 mg/L; $p = 0.01$) and IL-6 (from 63.9 ± 13.8 pg/mL to 39.8 ± 12.2 pg/mL; $p = 0.02$), indicating less effective control of systemic inflammation.

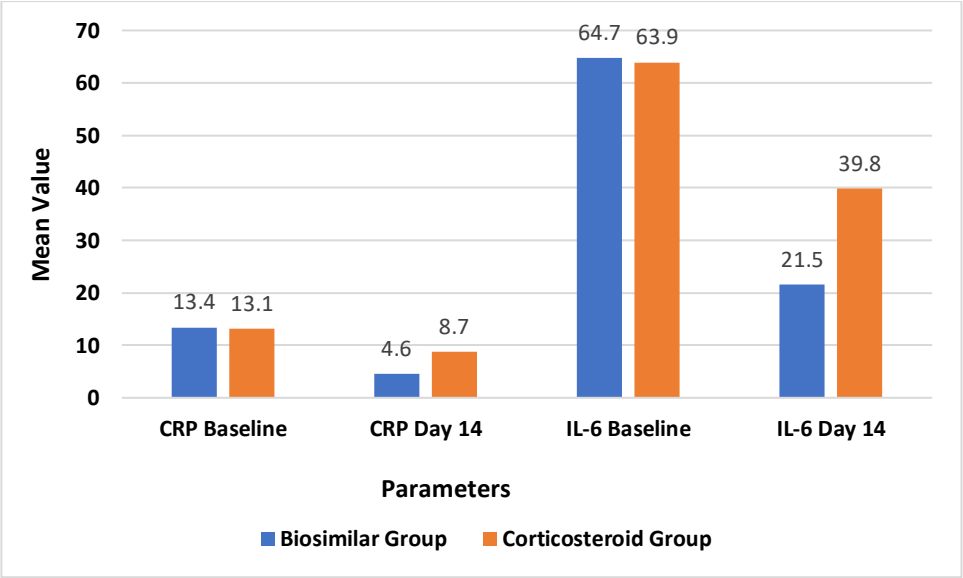


Figure 3. Changes in CRP and IL-6 levels from baseline to day 14 in both treatment groups.

Figure 3 demonstrates the reduction in inflammatory biomarkers—CRP and IL-6—from baseline to day 14 in both treatment groups. The biosimilar group showed a more pronounced decline in both markers compared to the corticosteroid group, indicating superior control of systemic inflammation and a more favorable immunomodulatory response to biosimilar-based immunotherapy in neonates.

Regarding disease recurrence, only two neonates (7.7%) in the biosimilar group experienced clinical relapse during the twelve-week follow-up, as compared to six neonates (25.0%) in the corticosteroid group. This difference was statistically significant and illustrated through Kaplan–Meier analysis, which demonstrated improved relapse-free survival in the biosimilar arm (log-rank test: $\chi^2 = 4.91$, $p = 0.027$). Multivariate Cox proportional hazards regression confirmed that treatment with corticosteroids was independently associated with a higher risk of early relapse (hazard ratio [HR]: 3.62; 95% confidence interval [CI]: 1.04–12.65; $p = 0.043$), along with elevated baseline IL-6 levels (HR: 1.03 per pg/mL increase; 95% CI: 1.00–1.06; $p = 0.048$).

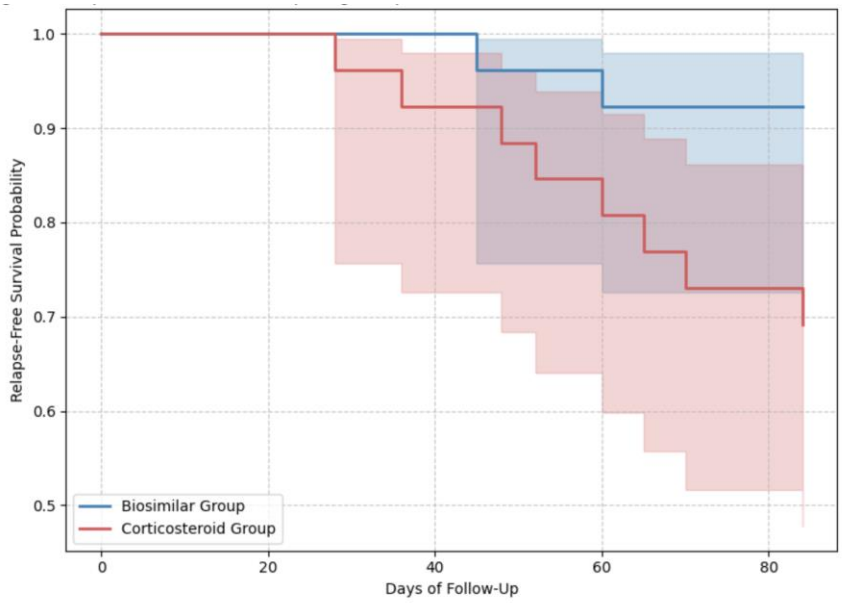


Figure 4. Kaplan–Meier curve comparing relapse-free survival over 12 weeks between the two groups.

Figure 4 depicts the relapse-free survival probability over a 12-week follow-up. Neonates in the biosimilar group maintained higher relapse-free survival compared to those receiving corticosteroids. The visual separation of curves suggests improved long-term disease control with biosimilar immunotherapy, supported by lower event occurrence and wider survival confidence in the biosimilar arm.

Safety Profile and Adverse Events

No serious adverse events, including anaphylaxis or severe infections, were reported in either treatment group. Among neonates receiving biosimilar therapy, minor adverse events were observed in four cases (15.4%). These included transient low-grade fever in two neonates, mild injection-site erythema in one, and a single episode of self-resolving diarrhea. In the corticosteroid group, five neonates (19.2%) developed adverse effects, primarily hyperglycemia requiring glucose monitoring (n = 2) and oral candidiasis (n = 3) treated with topical antifungals. Although the overall incidence of adverse events did not significantly differ between groups (p = 0.71), the biosimilar group exhibited a more favorable safety profile, with fewer systemic and metabolic complications.

Table 3 presents the distribution of adverse events across study groups. While incidence was statistically similar, biosimilar-associated events were milder and resolved without intervention.

Table 3. Summary of Treatment-Related Adverse Events

Adverse Event	Biosimilar Group (n = 26)	Corticosteroid Group (n = 26)
Fever	2	0
Injection-site Erythema	1	0
Diarrhea	1	0
Hyperglycemia	0	2
Oral Candidiasis	0	3

DISCUSSION

The clinical potential of biosimilar-based immunotherapy in neonates with oral mucosal autoimmune diseases (OMADs) is emphasized by the results of this controlled prospective analysis. Within the results obtained by us, there is an obvious fact that neonates receiving biosimilars were reduced by a much larger reduction of NOMDAI scores, inflammatory biomarkers (CRP and IL-6), and the occurrence of relapses, in comparison with those patients who were treated with corticosteroids. These results contribute to the body of evidence that develops in favor of the implementation of biosimilars as an effective and safe form of treatment of autoimmune diseases in children.

Autoimmune disorders therapeutics have been completely revolutionized with the advent of biosimilars that provide an inexpensive but biologically similar alternative to the original biologics. By making it clear that the biological drugs have become a key intervention in autoimmune diseases, Wajda et al. (2023) note that biosimilars emerge as an environmentally friendly approach to applying the positive effects of biological drugs to more patients. This is evidenced once again in our study, which depicts that treatment based on biosimilars used on neonates is capable of producing positive clinical outcomes without sacrificing safety.

The fact that biosimilars are coming with extended kinetics and being approved rapidly in the sphere of development and regulation depicts the augmenting trust as well as efficient pharmacovigilance. As an example, the “U.S. Food and Drug Administration (2023)” just granted an inflammatory diseases indication-busting interchangeable biosimilar, an indication of confidence in the efficacy of biosimilars in other indications. Our research supplies data germane to neonates, to this growing discipline, to support extrapolating the use of a biosimilar in adults and adolescents to the neonate population, one that is not normally included in early-phase trials.

The findings match with the existing literature that had affirmed an equivalent or even better efficacy of biosimilars in autoimmune conditions. Cuevas and Hedrich (2020) addressed the positive introduction of a biosimilar to the sphere of pediatric rheumatology, emphasizing the necessity of long-term safety monitoring. However, no significant adverse effects in our cohort appeared during the 12-week outcome follow-up, which is similar to real-world data showing that biosimilars have an acceptable profile of safety in an adult

population, as well as children subpopulations (Palmieri, 2024; Takeuchi et al., 2022).

Regarding the control of the disease, the mean NOMDAI scores of our biosimilar group decreased dramatically by day 14 and sustained remission over 12 weeks, which agrees with the information provided in the trials of CT-P13 (an infliximab biosimilar) in autoimmune diseases. Biosimilars are highly tolerable in practice, and the respective groups (naive and switch patients) demonstrated comparable disease control at Takeuchi et al. (2022). Moreover, the trend in the improvement of the IL-6 and CRP markers is in line with earlier visitors where the shifts in the inflammatory mediators were viewed as the early indicator of the therapeutic use of autoimmune pathology (Berns & Hommes, 2016).

Among the main issues during the implementation of biosimilars in neonates is that their efficacy and immunogenicity have been extrapolated using data collected in adults. The fact that biosimilars are being applied to untested use is brought up by Ben-Horin et al. (2016) in the question of scientific justification. Our report, however fills this gap because we studied clinical and immunologic outcomes of neonates with OMADs directly. Moreover, the considerably lower relapse-free survival rates in the biosimilar group, which were assessed through Kaplan-Meier test, also support the argument of safe extrapolation to be used in relatively distinct child-related settings.

Cost-efficiency and accessibility are also applicable in the wider venues of our findings. According to Joszt (2023), biosimilars have enabled a paradigm shift towards the management of chronic inflammatory disease, particularly in countries where access to biologics is out of reach because of economic reasons. This is especially so in neonatal cases, as a prompt treatment would reduce morbidity in the long run. This is confirmed by Munz (2024), who states that in the context of uptake obstacles, real-world data on the use of biosimilars has so far proven to be cost-effective, a significant factor in resource-constrained health care settings.

Interestingly, the tolerability that we have seen may be correlated with the relatively plastic state of the neonatal immune system, which may be associated with low risks of immunogenicity. Ali (2024) emphasized that age-related maturation of the immune system should be taken into consideration when developing targeted therapies, that is, monoclonal antibodies. The sensitivity of neonates to immunotherapy that resembles the endogenous regulatory sources is facilitated by the fast symptom control in our cohort of biosimilars.

The growing complexities of the vaccine-like immunomodulation deserve attention, as they applies to the use of biosimilars among neonates as well. Kim & Kim (2017) relate the phenomenon of vaccine-induced tolerance to the mechanisms of monoclonal antibody treatment, indicating that biologics can be used to ensure a correction of misplaced immune responses. Despite the fact that biosimilars do not represent vaccines strictly speaking, they are better studied in detail due to their effect on regulating neonatal immunity, primarily in autoimmune contexts.

Even though the outcomes are favorable, a number of limitations need to be identified. First, the sample was small owing to the logistical and ethical considerations of carrying out controlled trials in neonates. Second, the follow-up period of the study is only adequate to identify early relapse, but it might be considered inadequate to measure delayed problems and prolonged immune reprogramming. These findings should be confirmed with the help of future multicenter studies including long-term follow-up.

Lastly, the need to harmonize the combination of pharmacovigilance and real-world data in order to use biosimilars in neonates deserves to be mentioned. As Martin-Mateos (2007) has already mentioned, monoclonal antibodies used in the treatment of children require an extreme level of post-market monitoring and individual approach to dosing. Our investigation reinforces that the integration of biosimilars into neonatal care is also possible as long as they are used under comprehensively observed regimes, which can be considered as a component of opening wider regulatory regimes to surround the area of special needs due to the child age factor.

CONCLUSION

The study is a controlled prospective study, and it depicts the potential use of biosimilars in the treatment of oral mucosal autoimmune diseases (OMADs) in neonates. Surpassing standard forms of corticosteroid treatment, immunotherapy based on biosimilars proved to be more effective in combating the disease activity and normalizing various biomarkers, and preventing relapses. In neonates, who received biosimilars, the NOMDAI scores and CRP, as well as IL-6 levels, decreased significantly, and those patients had a better

relapse-free survival of 12 weeks. These data fulfill the opinion that biosimilars not only reproduce the clinical efficacy of the originator biologics, but potentially provide even more immunomodulatory effects in a neonatal environment. This research strengthens the safety profile of biosimilars because no severe side effects were observed, and an acceptable pattern of tolerability was registered during the treatment period. The fact that neonates exhibit immunological immaturity, which can be considered one of the clinical challenges, can also represent a therapeutic opportunity, as in this case, biosimilars would have the chance to re-regulate the damaged immune system with minimal immunogenicity. Also, biosimilars have a higher cost-effectiveness, which augurs well in the deployment as front-line treatments in constrained health-seeking systems, particularly in long-term treatment of autoimmune diseases onset during youth. The strength (prospective design and satisfactory clinical endpoints) notwithstanding, the study also recognizes limitations in the form of small sample size and limited follow-up. It still makes a significant precedent, however, in future trials to increase the use of biosimilars in neonatal care. Finally, biosimilar immunotherapy is a possible and good option to corticosteroids in relieving OMADs in neonates. Proper pharmacovigilance, real-world surveillance, and an age-adapted regulatory system are crucial to the ability of biosimilars to improve the quality of treatment in autoimmune diseases during the early infancy period. Additional multicentric investigations are merited to confirm such results and understand the immunological effects of using biosimilars on these newborns when such preparations are used over long periods.

DECLARATIONS

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Competing Interests

The no competing interests .

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ORIGINAL RESEARCH

IMPACT OF CONVENTIONAL VERSUS GUIDED FIBER-POST REMOVAL TECHNIQUES ON THE FRACTURE RESISTANCE OF ENDODONTICALLY TREATED TEETH: AN IN-VITRO STUDY

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Abstract

Background: Removing fiber posts during endodontic retreatment remains challenging due to their strong adhesive bonding to radicular dentin, which increases the risk of excessive dentin loss and structural compromise. Guided endodontic navigation has recently gained attention as a technique capable of enhancing precision and minimizing iatrogenic damage.

Aim: To compare and asses the fracture resistance of teeth following fiber-post removal using two techniques conventional freehand removal and static guided endodontic navigation using two instrument systems: ultrasonic tips and Endo Tracer burs.

Materials and Methods: 36 human extracted mandibular premolars with standardized morphology were prepared using a rotary nickel– titanium system and root canal filled using the single obturation cone technique and AH Plus root canal sealer. Fiber posts (0.8 mm, 2% taper) were cemented using dual-cure resin cement. Teeth got mounted in custom U-shaped epoxy resin molds simulating the dental arch. Group I underwent conventional freehand post removal, while Group I used static guided navigation designed through the merging of CBCT and optical surface scans. Groups were further subdivided into two subgroups in accordance with the instrument type (ultrasonic tip ET18D or Endo Tracer bur). Fracture resistance was then measured with the use of an Instron Universal Testing device. Finally, data was by using two-way ANOVA and independent t-test. Results: Guided navigation significantly increased fracture resistance compared to the conventional technique ($p < 0.001$). Ultrasonic instrumentation demonstrated higher fracture-resistance values than burs in both groups, with statistically significant differences within the guided technique ($p = 0.005$). No significant interaction was found between the technique and instrument type ($p = 0.366$).

Conclusion: Static guided endodontic navigation preserved radicular dentin and resulted in significantly higher fracture resistance than conventional freehand post removal. Ultrasonic instruments exhibited superior performance compared with burs. Guided navigation represents a safer and more conservative approach for fiber-post removal.

Keywords**:** Fiber post removal, guided endodontics, fracture resistance, ultrasonic tips, ET18D, Endo Tracer bur, static navigation.

INTRODUCTION

Fiber posts are known widely to be used in restoring previously endodontically treated teeth because of their favorable mechanical properties, esthetics, and bonding compatibility with restorative materials.[1]However, retreatment cases involving previously cemented fiber posts pose substantial clinical challenges.

Advances in adhesive technologies have increased the strength of the bond
between posts and radicular dentin, complicating their removal while also increasing risk of structural compromise. Conventional freehand post removal relies heavily on operator skill and
visual-tactile feedback. This approach often leads to deviations from the original canal path, excessive dentin removal, and higher chances of perforation or weakening of the root. These complications may negatively affect long-term prognosis by reducing the fracture resistance of the tooth. [2]

Static guided endodontic navigation adapted from implantology, and microsurgery has emerged as a

technique capable of restricting instrument movement to a pre-planned digital path. This technique may allow more conservative preparation and greater preservation of radicular structure, with potential benefits including increased fracture resistance and procedural accuracy. [3,4] Although guided endodontic systems have shown promising outcomes in preparation of access cavities, calcified canals location attempts, and degradation of fiber posts, limited evidence exists evaluating their influence on the mechanical performance of the tooth after post removal. Therefore, this study aimed to evaluate and compare the fracture resistance of these endodontic treated teeth following fiber-post removal using conventional freehand techniques versus static guided navigation, employing either ultrasonic tips or Endo Tracer burs.

MATERIAL AND METHODS

This study got approved by the Research Ethical Committee (REC) of the Faculty of Oral and Dental Medicine, Misr International University (MIU) (MIU-IRB-2223-243).

All patients who contributed extracted teeth provided informed consent for future scientific use.

Sample Size Calculation Power analysis was conducted to detect differences in fracture resistance. Using α = 0.05, β = 0.20 (power = 80%), and effect size f = 0.618 (from prior research), the total required sample size was 36 teeth (18 per group, 9 per subgroup), calculated using G*Power 3.1.9.7. [5]

Sample Selection

Thirty-six extracted human mandibular premolars were included in accordance with: Inclusion Criteria (Intact crowns and roots, Mature apices, Type I canal configuration, and no previous root canal treatment), Exclusion Criteria (Root defects, caries, or cracks, Calcification or apical resorption, Multiple canals). Teeth were standardized in buccolingual and mesiodistal dimensions.

Teeth were cleaned with ultrasonic scaling, sterilized via autoclave at 121° C for 20 minutes, and kept in distilled water until use. Teeth after then were randomly allocated into two main groups depending on the technique utilized in fiber post removal, Group I – Conventional Technique (n=18), Group II – Guided Technique (n=18). Each group was further subdivided later into two subgroups according to the instrument used in the removal of the fiber post, Subgroup A: Ultrasonic tip ET18D, while Subgroup B: Yellow-coated Endo Tracer bur.

Preparation of Samples

Teeth were decoronated to 14 mm root length using a diamond disk under coolant. (6) Root canal were prepared following the crown-down technique using the EDGE X7 rotary system reaching size 40/0.04. (7,8,9) Irrigation was performed with 5.25% NaOCl [10,11,17], followed by drying and filling using a single obturation cone technique with AH Plus sealer. [12,13,14]

Post spaces were prepared using a white-coated ENA drill matching the fiber post size (0.8 mm). Post spaces were conditioned with phosphoric acid, rinsed, and bonded with dual-cure adhesive. Posts were positioned and cemented with a dual-cure resin cement, light-cured for 40s, and trimmed at the orifice level. [6,10,16,17] For materials settlement, teeth were stored in 100% humidity.

Mold Preparation

A 2-mm wax layer was applied around each tooth below the CEJ to act as a separating medium. The teeth were then fixed individually to a surveyor using sticky wax in a standardized U-shaped arch arrangement, with the distance between surveyor arms set at 1.5 cm. A custom U-shaped mold (5 cm in the diameter, and 1.2 cm in the height) was placed beneath the teeth.

Each tooth was lowered into the mold so that 3 mm of root surface below the CEJ was embedded, simulating biological width and allowing space for thermocouple placement. Transparent epoxy resin was poured slowly into the mold to the predetermined level. After 24 hours of setting, the mold was placed in a 60– 70° C water bath to melt the wax layer, enabling easy removal and repositioning of the teeth within the cured resin block. [16,18,19]

CBCT and Digital Scanning

CBCT imaging was performed using a KODAC 9000 unit with a 5.0 × 5.0 cm as the field of view, and 150 µm voxel size, 90 kV, 12.5 mA, with 15.022-second exposure, and the images were saved as DICOM files. Each mold was digitally scanned using an intraoral scanner following a standardized protocol: starting from the occluso-lingual surfaces on the right side, moving to the left, then scanning back from the buccal surfaces. The surface scans were exported as STL files. The DICOM and STL data were subsequently overlaid using DDS-Pro software (version 2.22.0_2024), which was used for virtual planning and guide fabrication.

Fabrication of 3D-Printed Endodontic Guides

In the software, the DICOM and STL files were overlapped, and each post was identified to determine the appropriate sleeve path. A pre-existing implant tool was used to mark the drill path parallel to the post, with its length set to the full post depth and ending 5 mm from the root apex. A coronal guidance hole was then placed to mark the start of the post. The metal sleeve, prefabricated from brass using a desktop milling machine and designed with CAD software, had an inner diameter of 2 mm and an outer diameter of 3 mm. Two guides were designed for each subgroup, virtually exported as STL files, and printed using a DLP 3D

printer with transparent resin. After printing, the guides were rinsed with 99% isopropyl alcohol, cured with ultraviolet light, and finished using rubber polishing cups and sandpaper discs.
Post Removal Procedures

Group I – Conventional Freehand
Post removal was performed under 10× magnification. In Subgroup A: Ultrasonic ET18D tip with intermittent cutting and water cooling was used, while in Subgroup B: Endo Tracer bur used axially with saline irrigation. Removal was confirmed visually under magnification and radiographically. (20,27) (Fig 1)

A

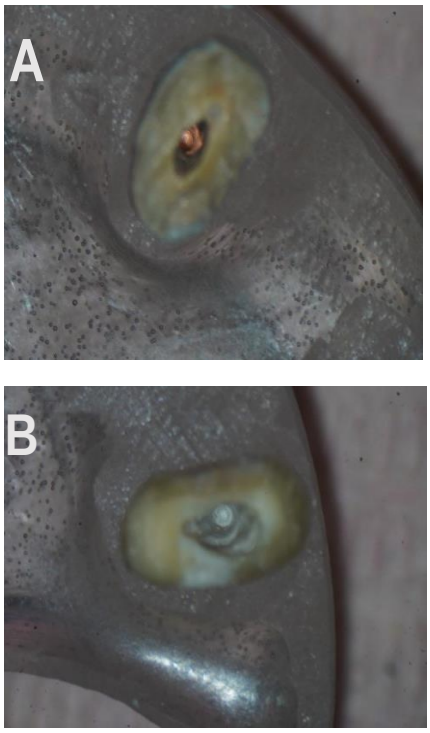


Figure (1): A) Photograph showing post degradation procedure under microscope, B) Photograph showing visualization of gutta percha apical to the fiber post after degradation.

Group II – Static Guided Navigation
Guides were fitted, and the same instruments were used through the guide sleeves following the digitally planned path. Post removal verification followed the same protocol. (Fig. 2)





Figure (2) photograph showing static guide on mold.

Evaluation of Fracture Resistance
Specimens were mounted on an Instron Universal Testing Machine (model 3345), Instron, Norwood, Massachusetts, USA. A steel rod applied an axial compressive load at 1 mm/min until the fracture happened. The maximum break load (N) was then recorded using BlueHill software. (22)

RESULTS

Values of mean and standard deviation were then calculated for each main group in each test. Data then were examined for normality through the Kolmogorov-Smirnov and Shapiro-Wilk tests, and the data manifested parametric (normal) distribution.
The two-way ANOVA test was utilized to find out the interactions present between the different variables. Independent sample t-tests were used to do the comparison in between two groups within non-related samples.
The level of the significance was set to $P \leq 0.05$. the statistical analysis was done using IBM® SPSS® Statistics Version 25.

Effect of subgroups:
Group I (Conventional Technique)
No statistical significant difference was found between the subgroups A(Ultrasonic), and B(Bur) ($p = 0.328$). Subgroup A showed a slightly higher mean value.
Group II (Guided Technique)
While a statistical significant difference was found between Subgroup A and Subgroup B ($p = 0.005$). With Subgroup A that demonstrates higher fracture resistance than Subgroup B.

Effect of groups:
Both in Subgroup A (Ultrasonic ET18D) and Sub group B (Endo Tracer Bur), Guided navigation resulted in the presence of significant higher fracture resistance values comparing it with the conventional technique ($p < 0.001$). (Table 1)

Table 1 Mean and, standard deviation (SD) values for the fracture resistance of the groups.

Variables	Fracture resistance				
	Group I		Group II		p-value
	Mean	SD	Mean	SD	
Subgroup A	81.33	6.69	108.77	4.97	<0.001*
Subgroup B	78.39	5.63	102.64	2.79	<0.001*
p-value	0.328ns		0.005*		

*; significant (p<0.05) ns; non-significant (p>0.05

Effect among groups regardless of the subgroups:
Statistically significant difference was present t between (Group I) and (Group II) where (p<0.001). The highest mean value was noted in (Group II), in contrast with the lowest mean value that was noted in (Group I). (Table 2)

Table 2. Mean and, standard deviation (SD) values for the fracture resistance of among groups regardless of the subgroups.

Variables	Fracture resistance	
	Mean	SD
Group I	79.86	6.19
Group II	105.71	5.02
p-value	<0.001*	

*; significant (p<0.05)

Effect among subgroups regardless of the groups:
No statistically significant difference was noted between (Subgroup A) and (Subgroup B) where (p=0.347). The highest mean value noted was found in (Subgroup A), in contrast with the lowest mean value that was found in (Subgroup B).

Table 3. Mean and standard deviation (SD) values for the fracture resistance among groups regardless of the groups.

Variables	Fracture resistance	
	Mean	SD
Subgroup A	95.05	3.59
Subgroup B	90.52	3.11
p-value	0.347ns	

ns; non-significant (p>0.

DISCUSSION

In contrast, the conventional freehand technique depends solely on the operator' s tactile sensation and visual magnification. Even under a dental microscope, it is difficult to differentiate between the resin matrix of the post, cement layer, and surrounding dentin, especially when anatomical variations or limited visibility are present. This increases the likelihood of iatrogenic dentin loss, external stripping, or internal notching all factors that reduce root strength and predispose to vertical root fractures. The significantly lower fracture resistance values observed in the conventional groups reflect these limitations. [29,30]

Across both techniques, ultrasonic tips yielded higher fracture resistance values than Endo Tracer burs. Ultrasonic tips (ET18D) exhibit selective cutting efficiency, focusing more on the composite post material rather than aggressively removing dentin. (31) The fine diamond coating and slender design produce vibration-based abrasion that gradually degrades the post while enabling the operator to maintain controlled instrument contact. This selective removal reduces the risk of dentin over-preparation during post removal.

Endo Tracer burs, although precise and commonly used in endodontic retreatment, possess a higher cutting aggressiveness due to their rotary action and diamond-coated surfaces. [32] When used freehand, this may lead to unintentional over-preparation of the apical extension or enlargement of the post space, especially in narrower or anatomically curved roots. This can weaken the remaining radicular dentin and consequently lower the fracture resistance. [32]

However, the effect of instrument type was significant only within the guided technique. This indicates that when the instrument' s path is tightly controlled as in guided navigation the intrinsic properties of the tool (e.g., abrasiveness, precision, vibration pattern) become more influential. In contrast, within the freehand technique, human variability and difficulty in maintaining an accurate trajectory overshadow the differences between instruments, leading to generally lower and more comparable fracture resistance values. [33,34]

CONCLUSION

The results suggested that guided navigation plays a dominant role in structural preservation. Even the bur subgroup within the guided technique performed significantly better than both subgroups in the freehand technique. This underscores that precision of instrument path is more important than the instrument itself in determining mechanical outcomes.

Given that vertical root fractures are a leading cause of tooth loss in retreatment cases, the ability to maintain high fracture resistance is essential for long-term success. Thus, the results of this study carried significant clinical relevance regarding using Guided endodontics for fiber-post removal, especially in cases of deep posts, calcified canals, or thin roots. Also, the Ultrasonic tipsmay be preferred over burs, particularly when combined with guided navigation, to enhance precision andminimize radicular dentin loss. [30]

DECLARATIONS .

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Competing Interests

The no competing interests .

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ORIGINAL RESEARCH

ENHANCING SURGICAL HEALING WITH OZONE GEL IN GRAFTLESS CLOSED SINUS LIFT PROCEDURES FOR DENTAL IMPLANTS: A RANDOMIZED CONTROLLED STUDY

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Abstract

Objective: This study aims to provide comprehensive evaluation of ozone gel's effects alongside standard postoperative care in effectively reducing pain and improving soft tissue healing after dental implant procedures with closed sinus lifting done simultaneously.

Materials and Methods: A total of 30 sinuses with an average residual alveolar bone height ranging from 4-7 mm participated in this clinical trial. Following a closed sinus lift procedure, patients were randomized into two groups: one for the ozone gel recipient group and the other for control group. Pain was rated based on the visual analog scale at 24, 48 hours and one week postoperative; soft tissue healing was rated according to the Landry healing index at seven and 14 days. Data were analyzed using appropriate statistical methods, with a significance value considered at $p < 0.05$.

Results: The ozone therapy group showed a statistically significant reduction in pain scores specifically at 24 hours and 48 hours compared to the control group ($p < 0.05$). In terms of soft tissue healing, the ozone group demonstrated improved soft tissue healing rates 7 days postoperatively.However at 14 days postoperatively , it was insignificant .

Conclusion: Ozone therapy has demonstrated considerable potential as an adjunctive treatment following dental implant surgery, effectively mitigating postoperative pain and facilitating soft tissue healing.

Keywords**:** biomaterials, closed sinus lifting, implants, osteotomes, transcrestal sinus floor elevation.

INTRODUCTION

Deficiency in bone volume in the posterior maxilla is one of the most common problems to the implantologist to plan an implant supported prosthesis. This is because the maxillary sinus “MS” in the absence of teeth tends to be pneumatized reducing the height of alveolar ridge, thus hindering the process of installation and/or initial stability of the implant required to the proceed for the prosthetic support sophisticated. Against this problem, authors have created a procedure to increase bone volume of atrophic jaws through the maxillary sinus lifting.[1] The osteotome-mediated transcrestal sinus lift technique was first introduced by Tatum in 1986.

In the original approach, surgeons created a controlled fracture of the sinus floor, placed the implants, and then submerged them during healing.[2] Later, in 1994, Summers refined the method by using a crestal approach—eliminating the need for a window—with specialized osteotomes to elevate the sinus floor, enabling simultaneous implant placement.[3] This technique involves preparing the implant site with tapered osteotomes, which compact the bone laterally, particularly useful in the posterior maxilla.[4]

The effectiveness of dental implants in atrophied posterior maxillae hinges significantly on the success of sinus augmentation. Although surgical methods have

improved, postoperative complications still arise in 9-24% of cases, largely due to bacterial contamination. The sinus membrane's anatomical closeness to the nasal cavity forms a distinct microenvironment where native microbial flora—such as Streptococcus, Staphylococcus, and anaerobic bacteria—can potentially infect graft materials and implant surfaces.[5]

Several strategies have been proposed to reduce postoperative complications, including local or systemic corticosteroid administration, nonsteroidal anti-inflammatory drugs (NSAIDs) and modified incision techniques to reduce tissue trauma. Recently, ozone therapy has been explored alongside these methods to assess its effectiveness in controlling inflammation, alleviating discomfort, and promoting wound healing.[6]

Ozone therapy is a form of bio-oxidative treatment that involves administering a mixture of oxygen and ozone—either as a gas or dissolved in water or oil—to produce therapeutic effects. Recognized as an alternative medicine in the U.S. since the 1880s, it has been widely used across the globe for over a century.[7-8] E. A. Fisch in the 1930's was the first dentist to use ozone therapy in his practice to aid in disinfection and wound healing.It presents great advantages when used as an adjunct to conventional treatments.[9-10] Ozone can be administered in three primary forms: ozonated water, ozonated oil/gel, and oxygen-ozone gas mixtures. When applied to wounds, ozone-infused oils or gels release their active ions upon contact [11].Medical ozone generators precisely control the mixture of medical-grade oxygen and ozone to create therapeutic concentrations[12].

As a powerful oxygenating agent, ozone enhances tissue oxygenation and activates the body's natural healing processes. It works by stimulating growth factor production and supporting hemostasis while improving circulation and immune function [13-14]. Its clinical effectiveness stems from potent antimicrobial activity against bacterial, fungal, and viral pathogens, combined with immune system modulation [15-16].The therapeutic benefits of ozone treatment stem from several key mechanisms: its direct antibacterial and antiseptic effects, ability to improve blood flow and oxygenation, anti-inflammatory properties, and capacity to stimulate wound healing.[17-18]

Oleozon is ozonated pure olive oil, created by infusing a 5% ozone-95% oxygen mixture until the oil transforms from its original greenish liquid state into a whitish gel. This ozonized gel formulation was preferred over ozonated water for oral applications due to its superior retention time in the mouth, enhanced drug penetration capabilities, greater therapeutic efficacy, and better patient acceptability.[19]However, current evidence supporting ozone therapy in oral and maxillofacial surgery remains limited. While research suggests ozone treatment may enhance blood flow, stimulate growth factors, accelerate wound healing, and potentially improve bone regeneration [20],more robust clinical studies are needed to confirm these benefits. Therefore ,this study aims to provide comprehensive evaluation of ozone gel's effects alongside standard postoperative care, in effectively reducing pain and improving soft tissue healing after dental implant procedures with closed sinus lifting done simultaneously.

2.MATERIALS AND METHOD

A total of 19 patients participated in this randomized controlled clinical trial. The patients were selected from the outpatient clinic of the Oral and Maxillofacial Department at Suez Canal University's Faculty of Dentistry. All participants had sinus pneumatization and were seeking fixed prosthetic rehabilitation in the maxillary posterior region.The study was approved by the ethics committee of Suez Canal University's Faculty of Dentistry (Ethical Approval No.: 417/2021)., and all patients were informed of the study's purpose and methodology by their treating dentists. Enrollment took place between December 2021 and December 2023, and written informed consent was obtained from each participant. This study protocol was retrospectively registered on the trial registry "Clinical trials.gov PRS". ClinicalTrials.gov ID is : NCT06604819 and the registration date is 20/9/2024.

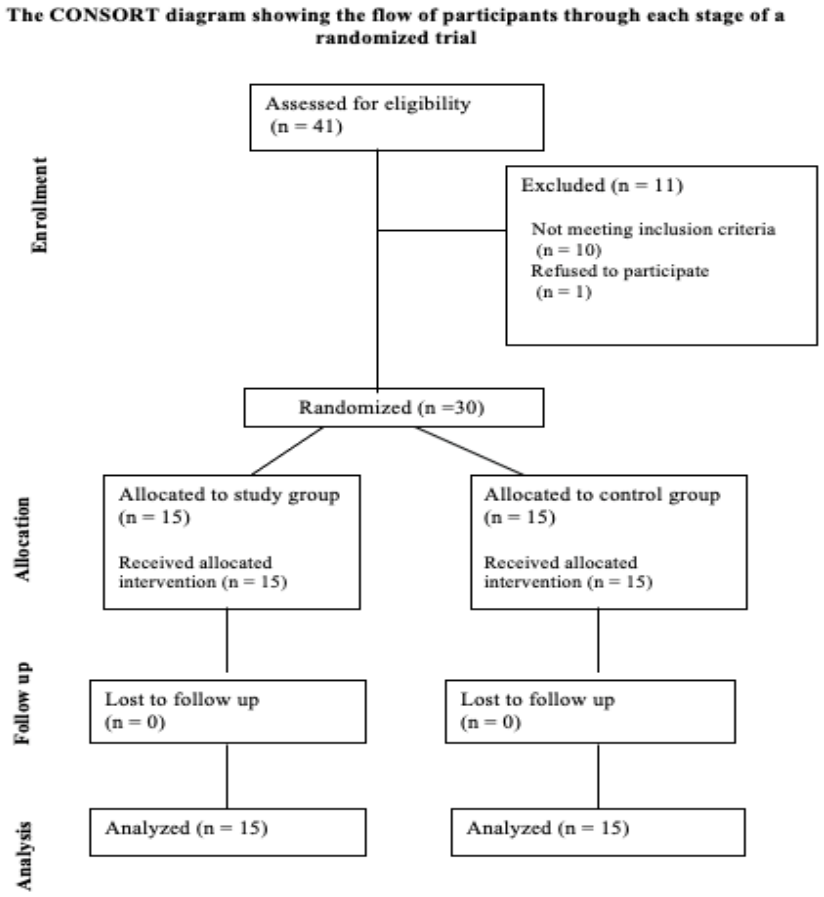
2.1 Sample size calculation

The sample size was calculated using G*Power version 3.1.9.4, based on previous research. To account for potential loss to follow-up, we adjusted the sample size to 30 (15 per group), using a two-sided hypothesis test with an effect size of 1.10 and a power (1-β) of 0.8. The significance level (alpha error) was set at 0.05.[21]Patients were recruited by the outpatient clinic supervisor at the Oral and Maxillofacial Department. After enrollment by the principal investigator, the trial's primary supervisor assigned participants to the intervention. Outcome assessments were conducted by two co-supervisors.

Eligible patients had multiple tooth defects with residual alveolar bone heights between 4 and 7 mm (Table 1) and no systemic conditions or medications that could interfere with bone healing or implant osseointegration. Exclusion criteria included smoking more than 20 cigarettes per day, adjacent tooth pathology, residual roots displaced into the sinus, or maxillary sinus pathosis.This study follows CONSORT guidelines(F. 1).

Table 1. Measurements of amount of preoperative residual bone height .

Sinus no.	Residual bone height (ozone group)	Residual bone height (control group)
1	4mm	7
2	5mm	7
3	6	6.9
4	6.1	5.81
5	6.73	4.69
6	5.16	5.7
7	6.1	6.7
8	5.2	6.5
9	6.7	5
10	6.7	7
11	5	6.5
12	6	4.2
13	5	6.6
14	5.5	7
15	5.6	6.9



Figiura 1. The consort flowchart

Preoperative evaluation

Every enrolled patient underwent radiographic analysis after an initial clinical evaluation. A cone beam computed tomography (CBCT) scan of the maxilla was taken for each participant to accurately measure residual alveolar bone height and assess for any sinus pathology. The CBCT's reconstructed images were then used to determine the appropriate implant dimensions (length and width) for placement (Fig. 2). Additionally, both intraoral and extraoral photographs were obtained for all patients.

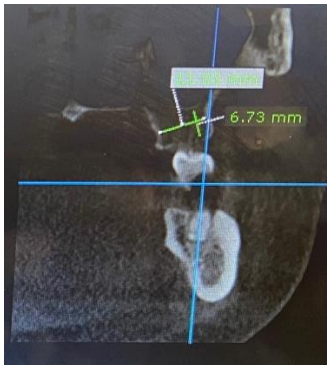


Figure 2. Sections of reformatted sagittal cut from the preoperative CBCT to assess presence of any sinus pathosis and toaccurately measure the residual alveolar bone height

2.1 Surgical Procedure

The study included two groups, each consisting of 30 sinuses (15 sinuses per group). Randomization was performed using *Randomizer.org*, an open online tool, to generate the allocation sequence. This ensured that each participant had an equal chance of being assigned to either the control group or the study group.

- Group A received ozone gel application during implant placement, following sinus membrane elevation via osteotomes.
- Group B underwent graftless osteotome-mediated sinus membrane elevation with simultaneous implant placement.

All patients followed the same surgical protocol. Preoperatively, they were instructed to rinse twice daily for one week with 0.2% chlorhexidine antiseptic mouthwash (*Orovex Mouthwash, Macro Group, Egypt*), including a final rinse approximately two minutes before surgery.

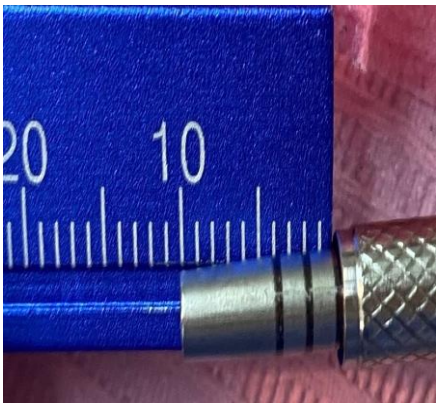
Local anesthesia was administered using 4% articaine with 1:100,000 adrenaline. A full-thickness mucoperiosteal flap was then raised, beginning with a mid-crestal incision (No. 15 blade) and a mesial vertical releasing incision (*Fig. 3*)

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Figure 3. Full thickness mucoperiosteal flap

The osteotomy was initiated using the implant system's pilot drill (Nebiotech, Seoul, South Korea), stopping 1 mm short of the subantral floor. Drilling was carefully performed in an apical direction through the cancellous bone until resistance from the sinus floor's cortical bone was encountered.To prevent accidental sinus penetration, a metal stopper was placed on the osteotome prior to use .The osteotome was then gently advanced with minimal pressure, employing slight rotation and occasional light malleting when necessary to elevate the sinus membrane apically. This membrane elevation process was repeated as needed to achieve the desired lift .Finally, an osteotome matching the diameter of the final drill (which was slightly smaller than the planned implant) was used to complete the sinus floor infracture (Fig. 4- 6)



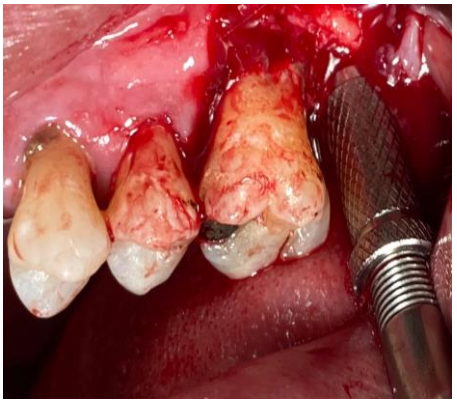
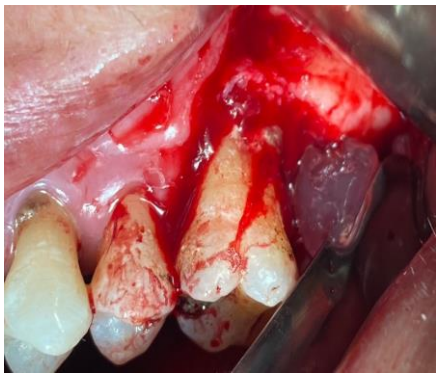



Figure. 4 Penetration height of the osteotome was determined
Figura 5 Sequential use of osteotome s
Figure 6 The last osteotome corresponding in size to the last drill that should be use

For Group A, ozone gel was administered into the osteotomy site prior to implant placement (Fig. 7). The ozone gel was prepared by saturating pure olive oil with 25 µg/ml O_3 gas using the Longevity EXT 120 ozone generator. This process continued for two days or until the oil transformed from its initial greenish hue to a whitish gel consistency. Following gel application, the implant was placed.In contrast, Group B received implant placement without any additional grafting material in the sinus cavity, following the graftless tenting technique (Fig. 8). In each group, a healing abutment was positioned (Fig. 9).primary closure was carried out, and the flap was interruptedly sutured with 4/0 prolene suture .



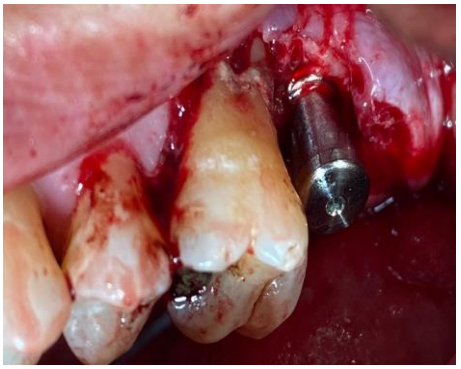


Figure 7 Ozone gel delivered into the osteotomy
Figure 8 Implant placement done
Figure 9 Healing abutment over the implant fixture

2.2| Postoperative instructions and medication

All patients were prescribed a standard postoperative regimen consisting of amoxicillin/clavulanic acid (875 mg/125 mg) twice daily for seven days, with clindamycin 300 mg three times daily as an alternative for penicillin-allergic patients. For pain management, ibuprofen 600 mg was administered every eight hours as needed for three days. Additionally, patients were instructed to use oxymetazoline 0.25% nasal decongestant (two drops per nostril every six hours) for four days.

To protect the surgical site, patients received strict instructions to avoid nose blowing, sneeze with their mouths open, and refrain from any activities that might increase nasal or oral pressure, including heavy lifting, playing wind instruments, balloon inflation, or other actions requiring Valsalva maneuvers during the initial healing period.

2.3| Postoperative follow-up and assessment

2.3.1| Clinical assessment

Pain assessment Postoperative pain was assessed using a 100 mm visual analog scale (VAS) (Fig. 10), with scores categorized as no pain (0-4 mm), mild pain (5-44 mm), moderate pain (45-74 mm), or severe pain (75-100 mm). Participants documented their pain levels at 24- , 48-hour and one week intervals following surgery to evaluate discomfort progression.

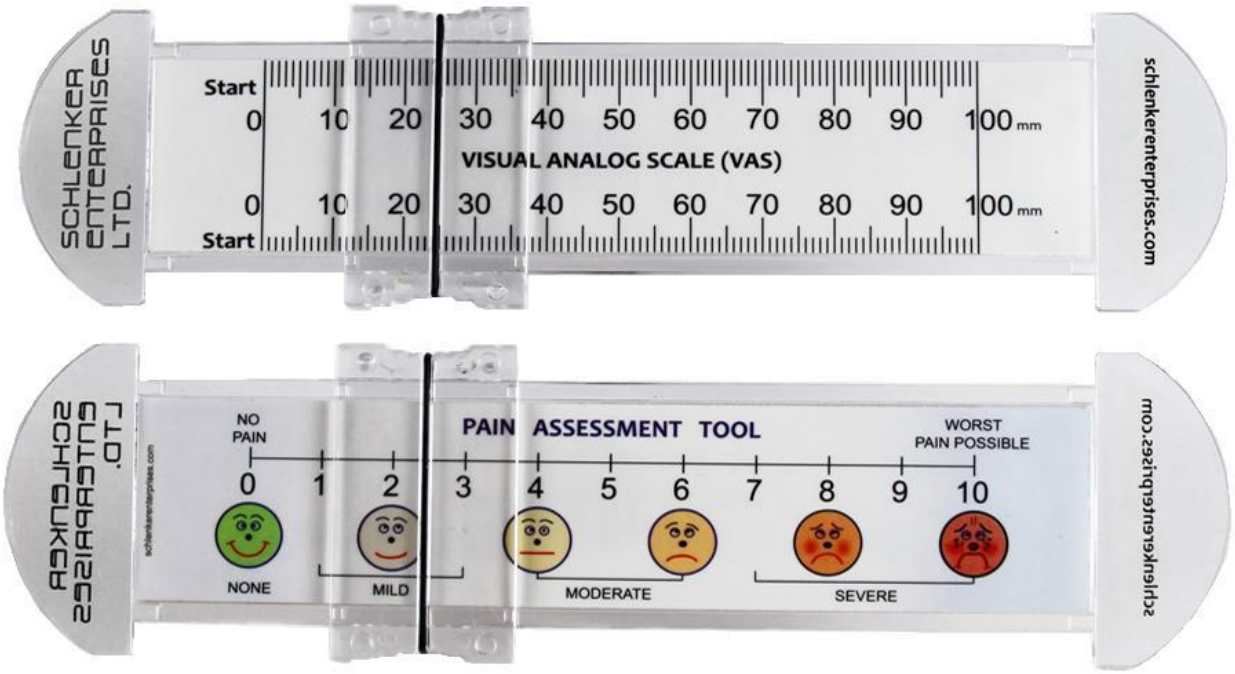


Figure 10. Showing pain visual analogue scale

Soft tissue healing assessment

Soft tissue healing was clinically assessed using standardized criteria: tissue color, bleeding on palpation, granulation tissue formation, epithelialization status, and presence of suppuration. Concurrently, soft tissue healing was objectively measured using the Landry-Turnbull-Howley index at 7- and 14-day postoperative timepoints, allowing for comprehensive monitoring of both acute pain response and longer-term wound recovery.Healing outcomes were graded according to this index (scores 1–5), where:
Score 1 (Very poor): ≥50% redness, bleeding, granulation tissue, non-epithelialized margins, suppuration
Score 2 (Poor): ≥50% redness, bleeding, granulation tissue, non-epithelialized margins, exposed connective tissue
Score 3 (Good): 25–50% redness, no bleeding/granulation/exposed connective tissue
Score 4 (Very good): <25% redness, no bleeding/granulation/exposed connective tissue
Score 5 (Excellent): Complete pink tissue, no bleeding/granulation/exposed connective tissue
Assessments were conducted at scheduled follow-up visits to compare healing progression between study groups.

3 | Statistical analysis

By examining the distribution of the data and applying normalcy tests (Kolmogorov-
By examining the distribution of the data and applying normalcy tests (Kolmogorov-Smirnov and Shapiro-Wilk tests), numerical data were examined for normality. With the exception of VAS scores, the repeated measures ANOVA test was employed for parametric data in order to examine changes over time within each group and to compare the two groups. When the ANOVA test is significant, pairwise comparisons were performed using Bonferroni's post-hoc test. The mean ages of the two groups were compared using the student's t-test. which are non-parametric data, all data displayed a normal (parametric) distribution. The values of the mean, standard deviation (SD), median, and range were displayed for the data.

4 RESULTS

The 19 patients in the study ranged in age from 24 to 59 years old (average 42.9± 4.9 years), with 17 females and 2 males. Both groups received thirty implants. The implants that were inserted ranged in widths from 3.7 to 4.8 mm and in height from 10 to 12 mm (table 2). There was no statistically significant difference found between these two groups.

Table 2.Descriptive statistics and results of Fisher's Exact test and Student's t-test for comparisons between base line characteristics in the two groups

Baseline characteristics	Study (n = 15)	Control (n = 15)	P-value
Gender [n, (%)]			
Male	1 (6.7%)	2 (13.3%)	1
Female	14 (93.3%)	13 (86.7%)	
Age [Mean, SD]	42.9 (4.9)	43.1 (4.5)	0.907
Tooth [n, (%)]			
Premolar	3 (20%)	4 (26.7%)	1
Molar	12 (80%)	11 (73.3%)	

4.1 Clinical Results

All patient data were included for analysis, and no patients were lost for follow-up. During the follow-up period, no implants were lost, and all the implants placed in both groups were successfully loaded and clinically stable at the prosthetic stage.

Effect of ozone gel on pain at 24 hrs. postoperatively

The Median and mean value of VAS pain score after 24 hours was greater in control group than study group. Mann-Whitney test revealed that the difference between control and study groups was statistically significant (U=0, P<0.00001) (Table 3, Fig.11).

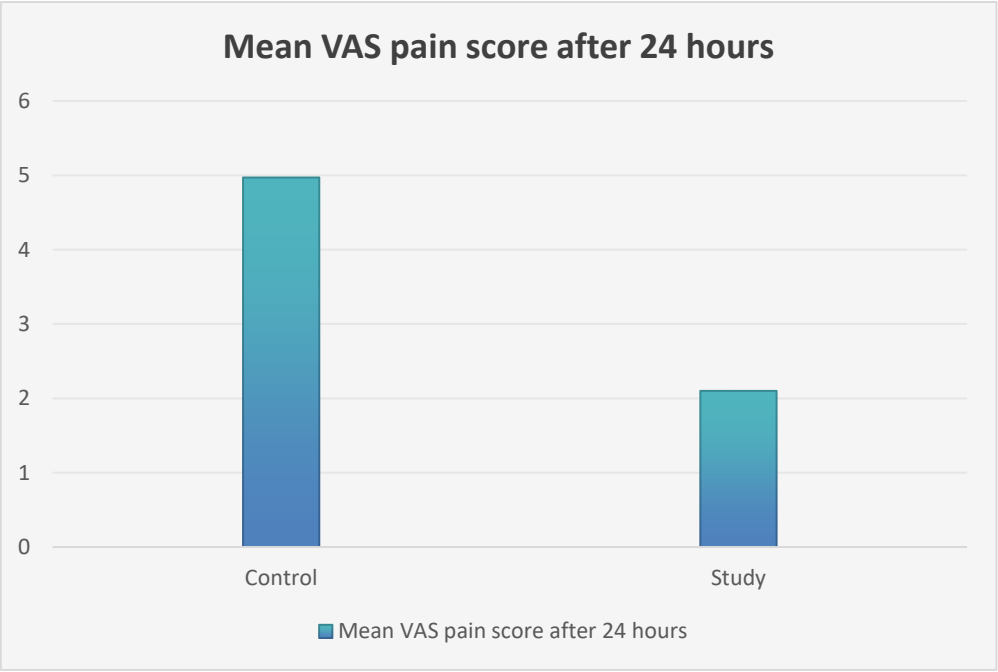


Figure 11. Column chart showing mean value of VAS pain score after 24 hours in studied groups

Table 3. Comparison of VAS pain score after 24 hours between control and study group using Mann-Whitney test

POC	Control	Study
Median	4.8	2
Mean ± SD	4.97±0.86	2.1±0.796
Minimum	3.8	0.6
Maximum	5.8	3.5
U value	**0***	
Z value	**4.64554**	
P value	**< 0.00001***	

*significant at U< 72, p<0.05

Effect of ozone gel on pain at 48 hrs. postoperatively

VAS scores were recorded at 48 hours postoperatively and the values obtained are presented in Table 4 and Fig. 12. The VAS scores for the control group after 48 hours were 3.12±0.84 and for the study group after 48 hours were 0.6±0.455"Thus, the mean values in the study group were significantly lower compared to those in the control group.There was statistically significant difference between pain scores in the two groups.

Table 4. Comparison of VAS pain score after 48 hours between control and study group using Mann-Whitney test

POC	Control	Study
Median	3.4	0.6
Mean ± SD	3.12±0.84	0.6±0.455
Minimum	1.3	0
Maximum	4.2	1.6
U value	**1***	
Z value		**4.60407**
P value		**< 0.00001***

*significant at U< 72, p<0.05

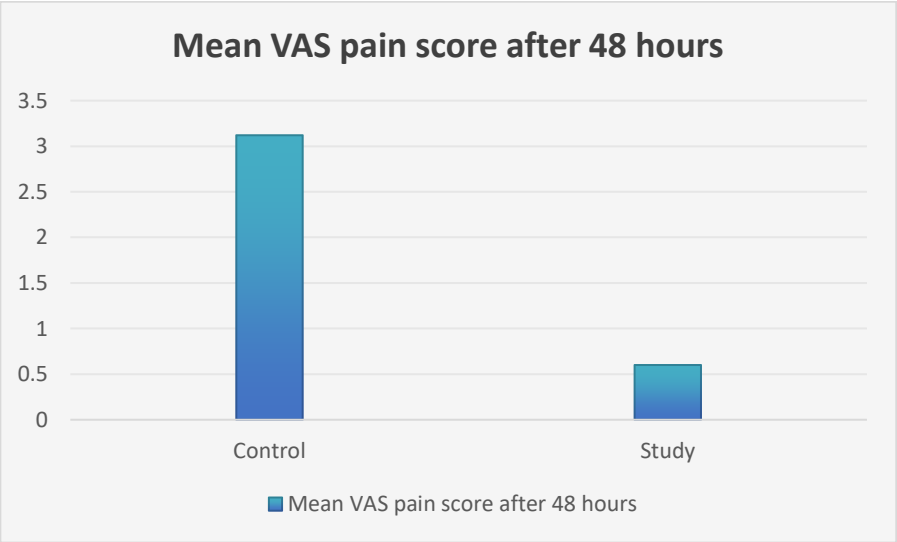


Figure 12. Column chart showing mean value of VAS pain score after 48 hours in studied groups.

Effect of ozone gel on pain at 7 days postoperatively

I. Pain (VAS scores)

There was no statistically significant difference between pain scores in the two groups (*P*-value = 0.763, Effect size = 0.106).

Table 5. Descriptive statistics and results of Mann-Whitney U test for comparison between pain (VAS scores) in the two groups after 7 days.

Study (n = 15)		**Control (n = 15)**		***P*-value**	***Effect size (d)***
Median (Range)	**Mean (SD)**	**Median (Range)**	**Mean (SD)**		
4 (2, 6)	**4 (1.3)**	**4 (2, 6)**	**4.1 (1.4)**	**0.763**	**0.106**

**: Significant at P ≤ 0.05*

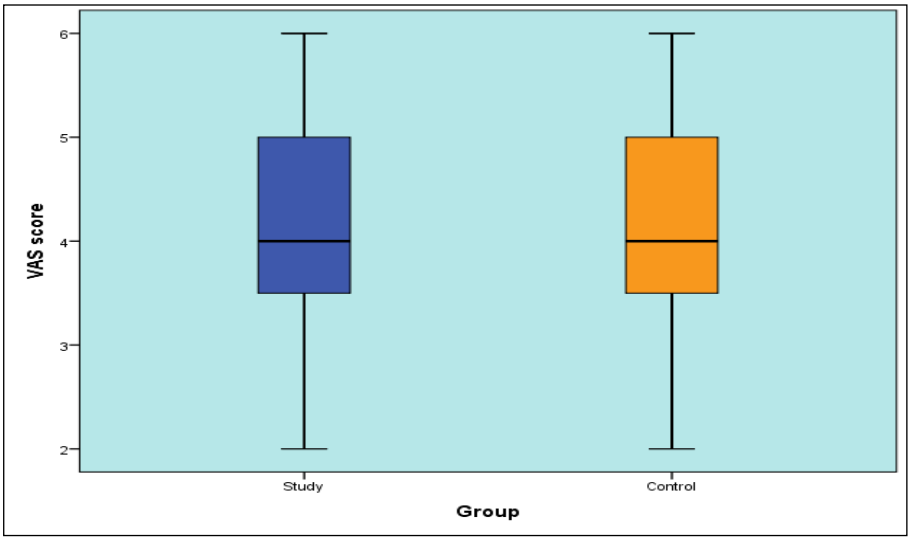


Figure 13. Box plot representing median and range values for pain scores in the two groups at 7 days

Effect of ozone gel on soft tissue healing at 7 days postoperatively

Soft tissue healing was evaluated after seven days by using the tissue healing index. The mean healing index scores are presented in Table 6 and Fig. 14. The mean healing index score for the control group was 7.94±0.135 and the mean healing index score for the study group was 8.79±0.175. Thus, the mean values of the tissue healing index in the study group were significantly higher compared to those in the control group (U=0, P<0.00001) (Table 6 , Fig.14).

Table 6. Comparison of soft tissue healing score after 7 days between control and study group using Mann-Whitney test

POC	**Control**	**Study**
Median	7.9	8.8
Mean ± SD	7.94±0.135	8.79±0.175
Minimum	7.7	8.5
Maximum	8.2	9.1
U value	**0***	
Z value		**-4.64554**
P value		**< 0.00001***

*significant at U< 72, p<0.05

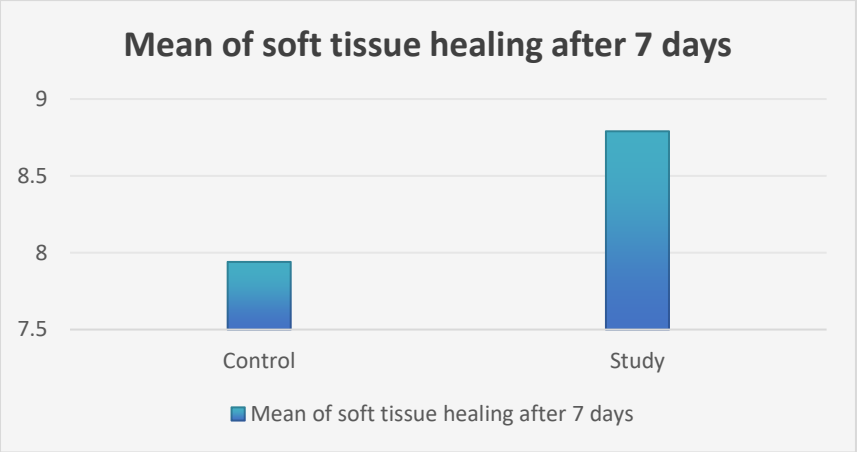


Figure 14. Column chart showing mean value of soft tissue healing score after 7 days in studied groups.

Effect of ozone gel on soft tissue healing at 14 days postoperatively

Soft tissue healing was evaluated after fourteen days by using the tissue healing index. The mean healing index scores are presented in Table 7 and Fig. 15. The mean healing index score for the control group was 9.53±0.07 and the mean healing index score for the study group was 9.64±0.082. The Median and mean value of soft tissue healing score after 14 days was greater in study group than control group. However, Mann-Whitney test revealed that the difference between control and study groups was statistically insignificant (U=77, P<0.0735) (Table 7, Fig.15).

Table.7 Comparison of soft tissue healing score after 14 days between control and study group using Mann-Whitney test

POC	Control	Study
Median	9.6	9.6
Mean ± SD	9.53±0.07	9.64±0.082
Minimum	9.5	9.5
Maximum	9.7	9.8
U value	**77***	
Z value	**-1.45173**	
P value	**< 0.0735***	

*significant at U< 72, p<0.05

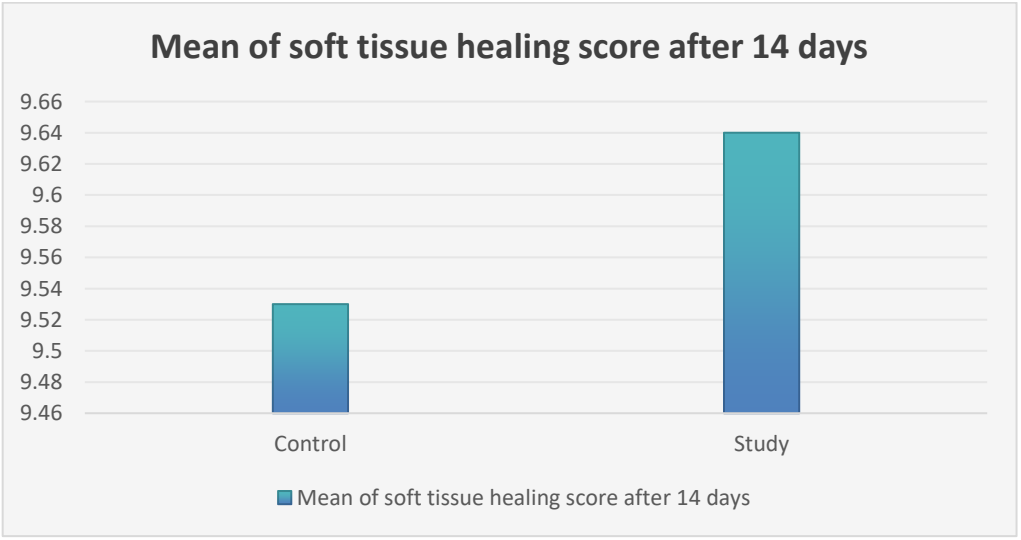


Figure 15. Column chart showing mean value of soft tissue healing score after 14 days in studied groups.

Effect of ozone gel on clinical infection parameters

There were no signs of postoperative infection including sinusitis and purulent discharge, dehiscence, or oroantral communications in any of the patients, who all healed without incident. The findings of this study suggest that the application of ozone gel significantly contributes to the reduction of postoperative pain, and improved wound healing outcomes.

5 DISCUSSION

The osteotome-mediated sinus floor elevation technique, whether performed with or without graft material, demonstrates favorable clinical outcomes including high implant survival rates, significant intrasinus bone formation, and low complication rates. Nevertheless, there remains a paucity of reported data regarding patients' subjective experiences, including postoperative recovery perceptions and satisfaction levels with the surgical procedure [22].

Ozone therapy has emerged as a promising therapeutic modality, demonstrating clinically significant antimicrobial, anti-inflammatory, and biostimulatory properties with applications across medical and dental disciplines. The therapeutic efficacy of ozone is mediated through two primary biological mechanisms: the generation of reactive oxygen species (ROS) and the formation of lipid oxidation products (LOPs). These molecular agents function as signaling mediators that regulate three key physiological processes: wound healing cascades, modulation of inflammatory responses, and controlled release of growth factors. The observed acceleration in tissue repair may be attributed to ozone's dual capacity to simultaneously reduce excessive inflammation while promoting neovascularization and immune cell activation [23].

Thus, this study aims to provide comprehensive evaluation of ozone gel's effects alongside standard postoperative care in effectively reducing pain and improving soft tissue healing after dental implant procedures with closed sinus lifting done simultaneously.y.In the present research, patient's age was above 18 years old. There was no statistically significant difference between gender, tooth distributions in the two groups. Regarding gender, proportion of females was higher than males by 90% versus 10 % with a ratio 10:1, this may be attributed to that females are keener about teeth replacement for the sake of esthetic and functional purposes.

Surgical trauma induces upregulation of key biochemical mediators of inflammation and pain, including serotonin, prostaglandins, bradykinin, and histamine [24].Our findings demonstrate the clinical utility of the Visual analogue score "VAS" for pain assessment due to its cross-cultural applicability and patient comprehension advantages which indicates the presence of postoperative pain . While conventional management of postoperative pain relies on analgesic medications with potential systemic adverse effects [25] ,Notably Velio Bocci's theory elucidated ozone's intrinsic analgesic mechanism through vasodilator induction, particularly via nitric oxide (NO) secretion , providing a scientific basis for its pain-modulating effects [26].

There was no statistically significant difference between pain scores in the two groups (P-value = 0.763, Effect size = 0.106).This result was in accordance with several studies published by Taschieri et al. in 2017 and 2018 where they confirmed that the crestal sinus lift approach had less patient morbidity as smaller mucoperiosteal flaps are required when compared with the lateral window procedure resulting in a significantly better postoperative healing (e.g., less inflammation, less pain and faster recovery including normal daily activities) [27]. The effect of ozone on the stimulation of fibroblasts during oral surgery, and less postoperative pain, agrees with our results of faster recovery and better pain control of patients [28].

Ozone demonstrates significant therapeutic effects on peri-implant tissues through its dual capacity to regulate microbial colonization and enhance tissue oxygenation [29]. These combined mechanisms create an optimal microenvironment for wound healing. The observed improvements in our ozone-treated cohort align with ozone's established biological properties, including its ability to potentiate oxygen metabolism and modulate immune responses, which collectively contribute to enhanced tissue regeneration.These systemic effects complement its well-established antimicrobial and wound healing properties, as confirmed by Reedy et al. [30] and Patel et al. [32], making it particularly valuable for managing oral ulcerations and herpetic lesions. These results are in accordance with our Current research results which demonstrates ozone's multifaceted biological effects.

6 CONCLUSION

Within the limitations of this study, Current evidence consistently supports the potential of ozone therapy to enhance postoperative outcomes in implant and sinus lifting surgeries. The dual therapeutic mechanisms—combining antimicrobial efficacy with tissue regenerative properties—suggest its value as an adjunct to standard treatment protocols. However, further randomized controlled trials with extended follow-up periods and larger patient cohorts are required to substantiate these preliminary findings and strengthen their clinical applicability. These additional

investigations would help elucidate the precise mechanisms by which ozone enhances wound healing while providing more robust clinical evidence for its use as an adjunctive therapy.

Abbreviations

MS: Maxillary Sinus

CBCT: Cone beam computed tomography

Acknowledgments

We would like to thank all the patients who participated in this study.

Authors' contributions

The authors' responsibilities were as follows: Study design: DY and ME; data collection: DY; analysis and interpretation of the data: DY, RR, RS and ME; drafting of the manuscript: DY; critical revision of the manuscript: RS and ME; study supervision: RR and ME. All authors read and approved the final manuscript.

DECLARATION

Funding: The authors affirm that no funding, money, or other assistance was obtained in order to prepare this study.

Availability of data and materials: The datasets generated during and analyzed during the current study are available from the corresponding author upon request.

Ethics approval and consent to participate: The study and the confidentiality procedures were explained to each participant. All participants provided written informed consent. The study's morality and ethics were validated by the Suez Canal University Faculty of Dentistry's Ethics Committee (Ethical Approval No.: 417/2021).

Consent for publication: Not applicable as all the patients signed a written informed consent stating their approval to participate in a research project. Additionally, no details on individuals are reported within the manuscript.

Competing interests: The authors declare that they have no competing interests.

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ORIGINAL RESEARCH

EXPLORING THE KNOWLEDGE AND ATTITUDE OF DENTAL STUDENTS AND PROFESSIONALS TOWARDS CORRELATION BETWEEN POLYCYSTIC OVARY SYNDROME (PCOS) AND DENTAL CARIES-A QUESTIONNAIRE STUDY.

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Abstract

Background: Polycystic Ovary Syndrome (PCOS) is a prevalent endocrine disorder among women of reproductive age, characterized by metabolic disturbances and chronic low-grade inflammation. Recent studies suggest a possible association between PCOS and oral health, particularly dental caries, potentially linked to elevated pro-inflammatory cytokines. However, the awareness and perspectives of dental students and professionals regarding this connection remain underexplored. This study aims to evaluate their knowledge and perceptions of the PCOS–dental caries relationship.

Methods: A validated, self-administered online questionnaire was used to assess awareness among dental professionals and students. The survey was distributed via Google Forms. Data were analyzed using SPSS, applying descriptive statistics and chi-square tests ($p \leq 0.05$) to identify knowledge gaps.

Results: Of 153 respondents, 92.81% identified PCOS as a hormonal disorder, yet only 49.67% recognized its oral health implications. Over 60% were unaware of the PCOS–dental caries link, and 34.64% lacked confidence in managing affected patients. Just 10.46% had received PCOS-related training. Awareness was higher among younger participants ($p=0.010$) and postgraduates ($p=0.031$). Nearly half (48.37%) considered PCOS "somewhat important" in treatment planning.

Conclusion: Despite recognizing PCOS as a hormonal disorder, its oral health relevance is poorly understood. Targeted education and curriculum inclusion are essential to enhance clinical awareness and patient care.

Keywords: Polycystic Ovary Syndrome, Oral health, Dental caries, Periodontal diseases, dental students and professionals.dental education, competence, formative, summative, student support

INTRODUCTION

Polycystic Ovary Syndrome (PCOS) is a common endocrine disorder affecting 4% to 20% of women of reproductive age, often marked by menstrual irregularities, hyperandrogenism, and polycystic ovaries.(1) Despite its prevalence, up to 70% of cases may go undiagnosed. PCOS is a multifactorial metabolic condition linked to insulin resistance, cardiovascular risk, dyslipidaemia, and chronic inflammation.(2) Contributing factors include hormonal imbalance, genetic predisposition, gut microbiota changes, and lifestyle elements such as obesity, poor diet, and stress.(3) Emerging research highlights a significant association between PCOS and oral health, particularly periodontal disease and xerostomia.(4) Chronic infections like gingivitis, frequently observed in PCOS patients, may exacerbate systemic inflammation.(5) Hormonal dysregulation and reduced salivary flow can complicate periodontal treatment and increase susceptibility to dental caries and other oral pathologies.(6)

Despite growing evidence, awareness among dental students and professionals regarding this link remains limited. Understanding the oral implications of PCOS is crucial for effective dental care and management. This study aims to bridge the knowledge gap by evaluating the awareness and attitudes of dental students and practitioners toward the relationship between PCOS and dental caries through a structured questionnaire survey.

Materials and Methods: According to available literature studying gingival health and oral complications, this questionnaire survey was designed to assess the knowledge and attitudes of dental professionals and students about the possible link between dental caries and Polycystic Ovary Syndrome (PCOS).[7] The questionnaire was divided into two sections: the first part elicited demographic information like age, gender, and educational level; the second part measured participants' awareness and knowledge of PCOS and how it relates to dental caries.[8]

A close-ended, self-administered, structured electronic questionnaire was created. The questionnaire was content validated and suggested changes were taken into consideration. The form was distributed through WhatsApp to achieve the highest possible reach and response rate.

Data thus collected from the responses were fed into a computerized system and analyzed on SPSS software (version 16.0). Descriptive and inferential statistics were utilized. Continuous variables were presented as mean and standard deviation, and the categorical variables as frequency and percentage. A significance level of $p \leq 0.05$ was fixed. The chi-square test was utilized to evaluate associations between the categorical variables and to determine statistical significance of the study parameters.

Results

A total of 153 individuals participated in the study. The demographic distribution revealed that the majority of respondents were between 18 and 25 years of age (81.70%), followed by those aged 26–35 years (10.46%) and those above 36 years (7.84%). In terms of gender, females constituted the majority (75.82%), while males accounted for 24.18% (Table 1).

In terms of professional category, undergraduate dental students formed the largest category (80.39%), followed by postgraduate students (11.11%), practitioners (4.58%), and teachers (3.92%). The results indicate that the sample was largely made up of female, young undergraduate dental students, which could be indicative of contemporary demographic trends in institutions of dental education. The lower rates of response from postgraduates, teachers, and practitioners emphasize the possible demand for more extensive outreach and continuing dental education programs on the oral health aspects of PCOS.

Awareness and Knowledge of PCOS:

The majority (89.54%) of the participants claimed to know about Polycystic Ovary Syndrome (PCOS) and correctly identified it as a hormonal disorder of women in 92.81% (Table 2) . There was comparatively lesser awareness about its effects on oral health, with only half (50.33%) confirming there was a relationship between PCOS and oral health (Table 3).

When questioned as to the particular impact of hormonal changes associated with PCOS on oral health, replies were divergent. While 35.29% acknowledged a risk of dental caries, a considerable percentage (37.91%) was unsure. These results indicate differing levels of knowledge and imply that gaps in knowledge about the systemic and oral health relationship in PCOS exists (Table 4)

Oral Manifestations of PCOS:

Out of the described oral conditions among women with PCOS, the most commonly identified was periodontal disease (47.71%), followed by dental caries (39.22%) and dry mouth or xerostomia (20.26%). The least common identified manifestation was enamel erosion (9.15%). Interestingly, more than one-third of the participants (37.25%) were not sure about the respective oral manifestations of PCOS, reflecting lack of knowledge in this respect (figure 1).

Knowledge of the Link Between PCOS and Dental Caries:

While overall awareness of PCOS was high, knowledge of its particular relationship to dental caries was reported by only 39.87% of respondents. When asked where they had heard about this, 22.22% mentioned social media, 21.57% attributed knowledge to healthcare practitioners, and 9.80% cited scientific literature. Yet a very significant number of respondents (44.44%) were not aware of any relation between PCOS and dental caries, indicating the restricted communication of this issue through formal as well as informal communication channels (Table 5).

Confidence and Clinical Practices Around PCOS Patients:

The investigation showed differing degrees of confidence in the care of PCOS dental patients. Less than a tenth (11.11%) of those surveyed—mostly undergraduates—were very confident, while 34.64% had no confidence at all (Table 6). As shown in (Table 7) almost half (47.06%) reported that they do take PCOS into account in clinical practice, e.g., considering endocrine or reproductive history when assessing patients to enhance diagnosis and treatment planning. Not withstanding this, fewer than one in ten (10.46%; again, mostly undergraduates) had received any training in oral health management in PCOS.

For clinical referral, 46.41% of the respondents said they would refer PCOS patients to specialists, and 41.18% were uncertain, implying a confusion with interprofessional collaboration practices.

Table 1. Demographic profile of respondents.

Demographic profile	No of respondents	% of respondents
Age groups		
18-25yrs	125	81.70
26-35yrs	16	10.46
36+yrs	12	7.84
Gender		
Male	37	24.18
Female	116	75.82
Qualifications		
UG	123	80.39
Postgraduates	17	11.11
Faculty members	6	3.92
Practitioner	7	4.58
Total	153	100.00

*p<0.05

Table 2 Awareness and knowledge of the respondents.

Items	No of respondents	% of respondents
Have you heard about Polycystic Ovary Syndrome (PCOS)?		

No	**16**	**10.46**
Yes	**137**	**89.54**
What is PCOS?		
Hormonal disorder affecting females	**142**	**92.81**
Genetic disorder	**2**	**1.31**
Uncertain	**9**	**5.88**
Are you aware of any PCOS health implications associated with oral health?		
No	**77**	**50.33**
Yes	**76**	**49.67**
How do hormonal fluctuations in PCOS impact on oral health ?		
Increased risk of dental caries	**54**	**35.29**
Altered salivary composition	**26**	**16.99**
Affect gingival health	**51**	**33.33**
Not sure	**58**	**37.91**
Are you aware of PCOS and its association with dental caries?		
No	**92**	**60.13**
Yes	**61**	**39.87**

***p<0.05**

Table 3. Knowledge , Confidence and Practice of the respondents

17. Are you confident in managing dental patients with PCOS?		
Very confident	**17**	**11.11**
Somewhat confident	**83**	**54.25**
Not at all confident	**53**	**34.64**
18.Do you incorporate PCOS considerations into clinical practice?		
No	**81**	**52.94**
Yes	**72**	**47.06**
19. Do you refer PCOS patients to specialists?		
Yes	**71**	**46.41**
No	**19**	**12.42**
Uncertain	**63**	**41.18**
Total	**153**	**100.00**

***p<0.05**

Table 4:Association between Age of respondents and awareness of PCOS.

Items	18-25	%	26-35	%	36+	%	Total	Chi-square	p-value
Have you heard about Polycystic Ovary Syndrome (PCOS)?						Type your text			
No	**11**	**68.75**	**5**	**31.25**	**0**	**0.00**	**16**	**9.1550**	**.010***
Yes	**114**	**83.21**	**11**	**8.03**	**12**	**8.76**	**137**		
What is PCOS?									
Hormonal disorder affecting females	**120**	**84.51**	**11**	**7.75**	**11**	**7.75**	**142**	**25.8620**	**.000***
Genetic disorder	**1**	**50.00**	**0**	**0.00**	**1**	**50.00**	**2**		
Uncertain	**4**	**44.44**	**5**	**55.56**	**0**	**0.00**	**9**		
Are you aware of any PCOS health implications associated with oral health?									
No	**64**	**83.12**	**8**	**10.39**	**5**	**6.49**	**77**	**0.3990**	**0.8190**
Yes	**61**	**80.26**	**8**	**10.53**	**7**	**9.21**	**76**		
Are you aware of PCOS and its association with dental caries?									

No	**75**	**81.52**	**9**	**9.78**	**8**	**8.70**	**92**	**0.3150**	**0.8540**
Yes	**50**	**81.97**	**7**	**11.48**	**4**	**6.56**	**61**		

***p<0.05**

Table 5. Association of age and understanding of PCOS as hormonal disorders.

Do you inquire about PCOS in patients' medical history?									
No	**68**	**80.95**	**10**	**11.90**	**6**	**7.14**	**84**	**0.5020**	**0.7780**
Yes	**57**	**82.61**	**6**	**8.70**	**6**	**8.70**	**69**		
Do you think it's important to consider PCOS in dental treatment planning?									
Very important	**39**	**82.98**	**5**	**10.64**	**3**	**6.38**	**47**	**7.5420**	**0.2740**
Somewhat important	**64**	**86.49**	**5**	**6.76**	**5**	**6.76**	**74**		
Not at all important	**3**	**75.00**	**0**	**0.00**	**1**	**25.00**	**4**		
Uncertain	**19**	**67.86**	**6**	**21.43**	**3**	**10.71**	**28**		
Are you confident in managing dental patients with PCOS?									
Very confident	**13**	**76.47**	**0**	**0.00**	**4**	**23.53**	**17**	**13.0120**	**.011***

Somewhat confident	**71**	**85.54**	**6**	**7.23**	**6**	**7.23**	**83**		
Not at all confident	**41**	**77.36**	**10**	**18.87**	**2**	**3.77**	**53**		

***p<0.05**

Table 6. Association of Age and Confidence in managing PCOS patients.

8. How do hormonal fluctuations in PCOS impact on oral health ?									
Increased risk of dental caries	**46**	**85.19**	**4**	**7.41**	**4**	**7.41**	**54**	**5.9985**	**0.4233**
Altered salivary composition	**18**	**69.23**	**5**	**19.23**	**3**	**11.54**	**26**		
Affect gingival health	**37**	**72.55**	**7**	**13.73**	**7**	**13.73**	**51**		
Not sure	**49**	**84.48**	**6**	**10.34**	**3**	**5.17**	**58**		

Table 7. Association of age and incorporation of PCOS consideration in practice

Do you incorporate PCOS considerations into clinical practice?									
No	**63**	**77.78**	**13**	**16.05**	**5**	**6.17**	**81**	**6.0830**	**.048***
Yes	**62**	**86.11**	**3**	**4.17**	**7**	**9.72**	**72**		

***p<0.05**

Statistical Associations:

Chi-square testing identified a number of statistically significant correlations. Knowledge of PCOS was significantly correlated with level of qualification (p = 0.010) and confidence in treating PCOS patients (p = 0.011). Further, consideration of PCOS in dental practice was also significantly correlated with educational level and other demographic factors (p = 0.048). These results highlight the role of academic exposure and professional standing on knowledge, attitudes, and clinical practice concerning oral health related to PCOS.

DISCUSSION

The results of this study corroborate those of Azziz et al., reaffirming that Polycystic Ovary Syndrome (PCOS) is a common though not infrequently underdiagnosed endocrine-metabolic disorder. It is marked by systemic sequelae like insulin resistance, chronic inflammation, and hormonal imbalance, all of which could affect oral health, specifically the incidence of periodontal disease and dental caries. In the presence of well-documented diagnostic criteria and established clinical phenotypes, this study demonstrates limited dental professional awareness of the oral implications of PCOS. The findings highlight the necessity of enhanced interdisciplinary knowledge that has been previously indicated within the literature. Incorporation of PCOS-related issues into dental education curricula could promote earlier detection and broader management of affected patients.[9]

The most frequent sources of information on the association of PCOS with dental caries, as identified through our data, were healthcare workers (21.57%) and social media (22.22%). Yet, nearly half (44.44%) of the participants identified no previous knowledge of the existence of such a relationship. This indicates an important knowledge deficit and underscores conclusions by Nivedha et al., who stressed the need for public health campaigns and professional education to raise awareness of oral health risks associated with PCOS.[10]

While respondents generally were highly aware of PCOS overall, knowledge regarding its association with oral diseases was still lacking. Most lacked any formal education on this subject, and fewer than half felt adequately trained to handle dental patients with PCOS. This result is consistent with the findings of Gomula et al., who have described women with PCOS as often seeking information online because they feel there is inadequate clinical support.[11] The incompatibility between professional readiness and patient requirements established by both of these studies indicates a critical need for more vigorous educational paradigms and better clinical practices.

Together, the findings underscore the need for an important gap in dental education and practice. Addressing this will require the integration of PCOS-related modules in dental education and the development of a multidisciplinary, patient-focused approach. This would serve not only to enhance clinicians' skills in the management of patients with PCOS but also to underpin wider initiatives in addressing the systemic oral–reproductive interface.

Derya S. et al. showed a high correlation between DMFT index values and both Streptococcus mutans counts and resting salivary flow rate/pH in PCOS patients ($p < 0.05$), which proves a microbiological and biochemical etiology for enhanced caries risk in these patients.[6] Contrarily, however, our investigation found that a large percentage of dental students and practitioners were not aware of any relationship between PCOS and dental caries. This knowledge disparity was also reflected in the channels through which participants initially became aware of the association—mainly social media sites. Based on Naroji S. et al., PCOS content is actually widespread on social media, demarcating how non-clinical information pathways increasingly influence public and professional knowledge through new forms of health communication.[12]

Subbiah et al.'s results and our own findings indicate a wide gap between available clinical evidence and the knowledge of healthcare providers on the oral health effects of PCOS. Subbiah et al. reported that newly diagnosed PCOS patients had significantly worse periodontal parameters—higher gingival and plaque indices, increased probing depths, and clinical attachment loss—than treated PCOS patients ($p < 0.001$). Even with this, a very limited 47.71% of our survey respondents identified periodontal disease as an oral presentation of PCOS, and a significant 57.52% were unclear about its contribution to caries risk.

This disparity continues despite high general knowledge of PCOS (89.54%). The youngest respondents (18–25 years), who made up the majority of the sample, showed a markedly lower level of knowledge (p = 0.010), as expressed in their answers. In addition, only 10.46% had received any official training in the oral health impact of PCOS, and only 46.41% reported referring PCOS patients for further management to specialists.

These results highlight an urgent need for more rigorous educational programs that incorporate the systemic–oral health correlation of PCOS into undergraduate and postgraduate dental teaching. Uniform screening protocols and interprofessional collaboration should be emphasized in order to bridge the gap between new scientific evidence and actual clinical practice. Due to the complex etiology of PCOS and its dental health effect, dental practitioners need to be armed not only with knowledge but also with clinical resources that

address the total care of this high-risk patient group.[13]

Our investigation found that there was a considerable awareness of Polycystic Ovary Syndrome (PCOS), with 89.54% of the interviewees stating they had heard of the condition. Nevertheless, an astonishingly low 49.67% knew about its oral implications, meaning there is a huge knowledge gap in interdisciplinary understanding. Even though the sample consisted primarily of female undergraduate students between 18 and 25, only 1.96% claimed their PCOS-related knowledge was excellent, and merely 11.11% were confident handling patients with PCOS. Although oral manifestations like dental caries and periodontal disease were recognized by some, 37.25% of the respondents were still uncertain, indicating a lack of proper incorporation of systemic concepts in dental education.

Statistical analysis demonstrated that awareness levels, clinical adoption, and confidence in treating PCOS cases were significantly affected by age. These findings are consistent with those by Khan et al., who outlined the genetic determinants of PCOS—i.e., gene variations in CYP, SHBG, and INS—as major players in its endocrine and metabolic phenotype. This systemic information, however, seems poorly translated into dental practice. With a mere 10.46% of the respondents citing any formal training in the oral health properties of PCOS, augmenting interdisciplinary education that includes genetic, hormonal, and environmental factors is critical to enhance clinical proficiency and patient outcomes.[14]

Subbiah et al. reported elevated levels of pro-inflammatory cytokines—such as interleukin-6, interleukin-17, and tumor necrosis factor—in women with PCOS compared to healthy individuals, emphasizing its systemic inflammatory burden.[13] Similarly, Wendland et al. found correlations between metabolic and hormonal profiles, salivary cytokine levels, and gingival health among adolescent females with PCOS.[15] Marcinkiewicz et al. further suggested a potential link between oral microbiota and female reproductive health, reinforcing the need for cross-disciplinary collaboration.[16]

Results of Varghese S.R. et al. indicate that while most healthcare providers know the clinical and oral manifestations of PCOS, less than 10% can diagnose the condition early in careers. Our findings mirror similar trends as the majority of respondents did not routinely ask about PCOS during patient histories and include it in clinical considerations.[17] Even though they identified PCOS as a hormonal condition, most had no formal education and expressed low confidence in the clinic. These findings are consistent with Lobo et al., who highlighted the systemic role of PCOS—inflammation and insulin resistance, for example—which can give rise to periodontal disease and caries.[18]

As a whole, our results highlight a fundamental lack of awareness and readiness among dental practitioners of the oral-systemic connections of PCOS. While overall knowledge of the condition was good, less than half knew of its relevance to oral health, and only a minority had specifically been trained or felt competent dealing with such cases. This is consistent with the findings of Singh et al., who emphasized the link between PCOS and periodontal disease by virtue of common inflammatory and hormonal mechanisms.[19] The strong relationships identified between confidence and age ($p < 0.05$) support the need to include education regarding PCOS as part of the early stages of dental education. Complementing interdisciplinary and evidence-based educational programs will be critical to enhancing overall patient care and cooperation between the dental and medical communities.

Both Rathi N. et al. and our study highlight a significant bidirectional relationship between PCOS and periodontal disease, connected through common mechanisms like chronic inflammation, hormonal imbalance, and oral microbiome dysbiosis.[20] Yet, our results also show significant gaps in awareness among dental professionals and students. Just 49.67% recognized oral health risks of PCOS, and 60.13% did not know the association with dental caries. These deficits were most glaring among younger participants and those without specialized education, highlighting the imperative for specific educational interventions.

In order to close this divide, it is necessary to incorporate PCOS screening into standardized dental check-ups, encourage interdisciplinary cooperation, and leverage commonly used platforms—like social media—to both professional and public health education. Such a multi-pronged strategy could enhance early detection and reduce the oral-systemic risks to women with PCOS.

Augmenting this, Cai et al. further emphasized the systemic nature of PCOS, which encompasses inflammation and immune dysfunction and leads to enhanced oral health susceptibility. Although the majority of our participants were familiar with PCOS as a hormonal disorder, formal training and confidence in clinical practice were significantly low. Statistically significant age differences in awareness and practice behavior further emphasize the need to introduce PCOS-related materials early in dental education to facilitate holistic care provision.[21]

Our study demographics—predominantly female participants (75.82%)—should suggest higher awareness of women's health issues. However, as also seen in K. Nivedha et al.'s study, only 39.87% of respondents in our sample recognized the association between PCOS and dental caries, and just 49.67% acknowledged any oral implications.[10] Chi-square analysis indicated lower awareness in young professionals ($p = 0.010$, Q5), and qualification

differences in identifying oral manifestations (p = 0.0108, Q9). Though 89.54% were familiar with PCOS, only 11.11% felt "very confident" managing affected patients (Q17), the gap between theoretical understanding and clinical preparedness.

Considering that the most frequent sources of information (Q11) were social media (22.22%) and healthcare professionals (21.57%), the use of these sources must be strategically planned for awareness campaigns. The strong association between age and confidence (p = 0.011, Q17) supports the necessity of early-stage professional training programs.

The implications of this educational deficit are severe—less than optimal care for PCOS patients and lost opportunities for early intervention. Our results echo those of S.C. Tanguturi et al., who labeled PCOS as a complex, multisystem disorder with metabolic, inflammatory, and changed salivary biochemistry implications, all of which make persons susceptible to oral diseases like caries and periodontal disease. Tanguturi et al. also recommended early multidisciplinary treatment—reiterated in our call for coordinated medical-dental collaboration.[22]

Chi-square testing in our research further revealed the following associations with age: and overall awareness (p = 0.010), and the knowledge of PCOS as a hormonal disorder (p = 0.000). These findings are reflective of the variance in knowledge levels among age groups and emphasize the need to make younger dental professionals more aware about systemic–oral health relationships.

Conclusion: Despite the high prevalence of Polycystic Ovary Syndrome (PCOS) among women, this study reveals a notable gap in awareness regarding its oral health implications among dental professionals. This knowledge deficit not only impacts clinical decision-making but also limits the delivery of comprehensive care to patients with PCOS. The study reveals a critical gap in the understanding and integration of Polycystic Ovary Syndrome (PCOS)-related oral health considerations among dental professionals. While a majority of respondents are aware of PCOS as a hormonal disorder, there is insufficient recognition of its oral health implications, such as increased risks of dental caries and periodontal diseases. The lack of targeted training further compounds this challenge, with many respondents feeling uncertain or ill-equipped to address the unique oral health needs of patients with PCOS. It is imperative that dental education programs emphasize the connection between systemic conditions like PCOS and oral health. Specialized training and workshops can empower practitioners to incorporate PCOS considerations into patient care, fostering improved clinical outcomes and interdisciplinary collaboration. By addressing these gaps, the dental community can lead the way in promoting holistic, patient-centered care, ensuring that no health aspect is overlooked**.**

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ORIGINAL RESEARCH

FEEDBACK IN DENTAL EDUCATION: A NARRATIVE REVIEW OF PRINCIPLES, MODALITIES, AND IMPLEMENTATION STRATEGIES

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Abstract

Feedback, an essential tool in dental education, is vital for students to shape their clinical competence. Consistent, on-time, and well-structured feedback is a good recipe for ensuring that learning outcomes are met. In-depth clinical training without proper feedback cannot ensure either the effectiveness of teaching methods or the appropriateness of assessments. This narrative review articulates current evidence on feedback methods in dental education and highlights various strategies to enhance student learning and clinical competence. It would help educators and students improve the application of feedback methods, thereby fostering student growth and clinical success.

Keywords: dental education, competence, formative, summative, student support

INTRODUCTION

Feedback helps students assess their academic performance and focus more effectively on learning in dental education. Inadequate feedback practices or a lack of structured formative assessment can lead to significant risks, including compromised patient safety due to inaccurately developed clinical skills or incomplete competence in essential procedures. Feedback offers advantages such as timely guidance, highlighting strengths in teaching and learning, and identifying areas for improvement.[1] This approach facilitates the development of clinical competence, attainment of required standards, and readiness for independent practice. Evidence indicates that effective feedback improves academic outcomes, self-confidence, and adaptability, all of which are critical for success in the health professions. [2, 3]

Effective feedback encourages students to provide their reflections, engage in continuous improvement, and maintain sustained motivation. The supervising faculty can utilize this to refine teaching methods and update curricula.[4] Although it can be challenging, effective feedback results in meaningful and enduring learning experiences. Instructors should provide unbiased feedback for every clinical procedure they supervise, highlighting their strengths and areas for improvement. When students engage in reflective practice and draw their own interpretations from feedback, they achieve deeper learning and lasting behavioral change, rather than simply following instructions. [5]

This narrative review aims to: (i) synthesize current evidence on feedback practices in dental education; (ii) compare the effectiveness of formative, summative, verbal, written, peer, and self-assessment feedback; (iii) outline faculty- and system-level strategies to enhance feedback quality; and (iv) identify gaps to plan future research and curricular design.

A narrative search of PubMed, Scopus, and ERIC from January 2000 to October 2024 focusing on original and review articles was performed using the terms: ‘dental education’, ‘feedback’, ‘formative assessment’, ‘summative assessment’, ‘peer feedback’, ‘self-assessment’, ‘OSCE’, ‘haptic’, and ‘AI’. Short communications or commentaries without primary data were excluded. A formal risk-of-bias assessment was not performed; rather, emphasis was placed on study method and educational relevance.

Principles of Effective Feedback

Effective feedback can transform even low-achieving students, thereby improving their competence and self-confidence. Evidence from a prompt feedback obtained in a dental hospital suggests it promotes reflective self-evaluation and the development of clinical competencies.[1] A supervisor who routinely engages students immediately after observing a procedure to provide focused guidance, observational reports suggest that addressing minor technical modifications at the exact moment enables students to acquire clinical skills more efficiently.

Feedback should be performance-specific and action-oriented, recognizing strengths and areas for improvement. For instance, faculty should proactively recommend procedural modifications, rather than simply stating that a procedure or technique is unsatisfactory.[6] Educators are also encouraged to reflect on which feedback strategies have most effectively enhanced student engagement or motivation. A balanced feedback model addressing both strengths and areas needing refinement helps maintain engagement and motivation.[7] When constructive guidance is combined with positive reinforcement, it enhances confidence and clinical competence. Research consistently shows that feedback that is both supportive and candid is most effective for learning.[8] Ongoing use of these strategies promotes the development of competent, reflective dental professionals.

Types of Feedback in Dental Education:

Formative Vs. Summative assessments: These two assessments differ in timing, purpose, and learner involvement. Formative feedback is part of the instructional process to improve understanding of concepts, emphasizing immediate guidance and encouraging reflective learning, rather than just determining grades. It identifies learning gaps, reduces anxiety among beginners, and enables timely error correction.[9] In contrast, summative feedback is a comprehensive evaluation of achieved outcomes, often contributing to final grades. It is learning outcome-oriented and focuses primarily on their achievability of outcomes rather than the journey of learning. However, in a 2008 study, Anziani reported that students' performance on formative assessments in oral surgery did not consistently translate into higher grades on their final examinations.[10] In another study on postgraduate dental training, specific, focused feedback was found to be essential for accurately evaluating clinical skills, as relying on final grades may obscure individual progress and fail to reflect true competence.[11] Hence, it becomes essential for curriculum developers and educators to adopt appropriate assessment and feedback strategies that enhance clinical judgment, performance, and self-regulatory skills. Examining instances where formative performance does not correspond with summative outcomes emphasizes the need for targeted interventions and flexible teaching methods, which are central to promoting excellence in dental education.[12] Divergence between formative and summative performance underscores construct alignment issues and the need for programmatic assessment.

Verbal Vs. Written feedback: Verbal feedback enables real-time interaction, fostering a motivational learning environment. However, to improve retention of information in students' minds, proper documentation is helpful, as verbal feedback may be forgotten over time.[13] However, well-constructed written feedback can be maintained by students and reviewed at a later, convenient date for reflection and self-assessment. Hence, a combination of both written and verbal feedback facilitates better comprehension and prepares students for real-world practice (Table 1).

Table 1. Feedback Modalities and Key Characteristics

Feedback modality	Key features	Advantages	Limitations	Typical context & references
Formative feedback	Ongoing, performance-specific, dialogic	Promotes reflection, early error correction	Time-intensive, variable uptake	Preclinical labs; chairside teaching [9,12]
Summative feedback	Outcome-focused, grade-oriented	Certifies competence, benchmarks learning	Limited learning impact if isolated	End-of-course/OSCEs [10,11]
Verbal feedback	Immediate, interactive	Motivating, contextual	May be forgotten	Chairside supervision [14,15]
Written feedback	Documented, structured	Supports reflection & tracking	Variable engagement	Assignments, portfolios [16]
Peer & self-feedback	Collaborative, reflective	Builds critical thinking	Requires calibration	Case presentations [20–22]

DISCUSSION

Teaching students how to use feedback may be more helpful than focusing on learning styles, since some students want to keep improving, while others focus mainly on passing. Carless (2018) reported that final-year dentistry students preferred verbal feedback on their theory and clinical skills, as they felt there was insufficient time after sessions for written feedback.[14] Hence, the good inter-professional relationship between the supervisor and the student is vital for proper feedback assessment.[15] It is observed that low-achieving students need regular feedback, whereas targeted strategies are well-suited for high-achieving students. One approach involves assigning faculty mentors to each student to ensure consistent, balanced feedback. In addition, data analytics can be used to track feedback practices, helping identify and correct inconsistencies. However, findings by Glover and Brown indicate that the depth of written feedback is not necessarily associated with students' academic performance.[16] Both verbal and written feedback contribute to continuous improvement and goal attainment. Overall, integrating multiple feedback approaches supports the development of all learners, regardless of their level of achievement.

Teachers should provide feedback soon after an assignment so students can identify and correct mistakes quickly. Immediate feedback activates the basal ganglia, especially the striatum, which helps with habit and reinforcement learning. Fast feedback helps students change their behavior and rewards good habits, leading to better learning and adaptability.[17] Feedback given after a pause helps students think more deeply. It helps them internalize criticism. The hippocampus supports contextual memory and learning in this process. Studies show that the hippocampus processes delayed feedback, while the basal ganglia process instant feedback. Delayed feedback enhances long-term understanding of content.[18] Peer feedback lets students give each other helpful comments about their work or assignments. This creates an active learning environment, enhances learning, and builds skills such as critical thinking, self-reflection, and communication. Peer feedback also helps students see things from different viewpoints.[19] Over time, students tend to appreciate peer assessment more, recognizing its importance in learning how to evaluate performance and engage constructively in feedback.

Research clearly shows that peer feedback is valuable in dental education. A study at King's College London Dental Institute found that students who regularly took part in peer assessment and feedback improved both their grades and their ability to reflect.[20]Those who attended 10 or more peer assessment sessions performed better on important exams and demonstrated stronger critical thinking than those who did not. Peer review encourages students to take charge of their learning and think critically, making it a key strategy for training skilled and confident dental professionals. Self-evaluation improves critical thinking and problem-solving skills by allowing students to review their own work and identify areas for improvement. This also helps students take responsibility for their learning.[21] Self-evaluation has been shown to increase dental hygiene students' awareness of their strengths and weaknesses, thereby improving their clinical performance. Even though students may rate themselves higher than teachers do, self-assessment has led to encouraging real reflection and better learning results.[22]

Reflective feedback prompts students to evaluate their learning experiences and translate reflections into improved future performance, thereby strengthening lifelong learning and clinical understanding. A study by Jonas-Dwyer in 2013 showed that third-year dental students' reflective abilities led to their professional development.[23] Reflective portfolios also enhance clinical competence by promoting structured reflection and self-evaluation. Hence, to enhance students' educational experiences, encourage self-directed learning, and ultimately develop competent and self-assured dental professionals, it becomes important that both self-assessment and reflective feedback are delivered.[24]

Methods and Strategies for Providing Feedback

(i) Individualized Feedback: Active clinical practice necessitates individualized feedback as it facilitates targeted improvement of therapeutic abilities, fosters professional development, and improves patient communication. Best practices involve timely post-procedure feedback, clear identification of areas for improvement, balanced reinforcement and correction, actionable guidance, promotion of self-reflection, and longitudinal progress tracking. For example, a student receiving immediate feedback on the dental procedure clearly understood the adjustment to the bur's angulation, emphasizing the importance of timely feedback. Although this approach is more demanding for the faculty in terms of effort and time, it is rewarding.[4]

(ii) Group Feedback: Students actively share their constructive criticism, their viewpoints, and the learning experiences with peers in small-group pre-clinical or clinical tasks. Such cooperative methods promote confidence and can play a key role in peer-assisted learning and reflective group discussions, leading to deeper understanding of concepts and skill development.[25] For example, students can critically analyze the Class II restoration experience, focus on

technique, ergonomics, and communication with patients. Students can similarly receive feedback from their faculty and colleagues when they review and present clinical cases related to diagnosis, treatment planning, and presentation skills. Students gain a well-rounded perspective that enables them to identify and address areas for development by gathering feedback from peers, teachers, and even patients.[26]

Student performance can be objectively evaluated using rubrics and structured assessment tools that are transparent and consistent. The performance criteria of the rubrics must be clearly defined in line with the expectations and intended learning outcomes. This was demonstrated in a study at Beirut Arab University, which showed that student performance improved when standardized rubrics were used, as they increased transparency, consistency, and opportunities for self-assessment.[27] Similarly, clinical competence can be appropriately evaluated in a controlled, standardized setting using an Objective Structured Clinical Examination (OSCE). It helps to assess students' ability to integrate theoretical knowledge, perform diagnostic tasks, and apply sound clinical judgment. They are more accurate and reliable than traditional evaluation methods. They also successfully pinpoint students' strengths and areas for growth and offer insightful, practice-focused feedback. Dental graduates are better prepared for clinical practice when such assessment techniques are used.[28]

Feedback can be further strengthened through rubric-based digital dashboards that deliver real-time performance indicators. By combining technology-enhanced feedback with structured assessment frameworks, these systems offer immediate insights into learner progress. The faculty and their students can easily make informed decisions using real-time data visualization that supports active learning and continuous improvement. Educators need to evaluate available platforms and select tools aligned with curricular objectives to ensure effective implementation. Faculty should be encouraged to pilot test within selected courses to generate valuable insights for refinement. A phased institutional rollout can therefore facilitate systematic enhancement of feedback and assessment practices.

(iii) Technology-Assisted Feedback: Technologies such as Haptic and force-feedback are reshaping dental education by delivering immediate tactile cues to improve precision, performance, and overall clinical competency.[29] Recent evidence indicates that this strengthens skill acquisition and helps minimize subjectivity, thereby improving students' preparedness for clinical practice.[30]

Role of Feedback in Clinical Training

(i) Preclinical vs. Clinical Feedback: During the preclinical phase, students focus on improving their technical skills in simulated environments to enhance manual dexterity.[31] Feedback advances toward real patient work in a clinical setting, combining psychomotor and communicative skills. The question "What metrics will ensure haptic-gained proficiency translates to patient care?" serves as a guiding point for narrowing the gap between simulation and the required clinical competence. This question prompted teachers and students to assess how preclinical simulations enhance clinical preparedness.

(ii) Hands-on Skill Assessment: In dentistry, mastering clinical skills is vital. Feedback methods, especially self-assessment and teacher evaluation, are key to skill development. Encouraging self-evaluation helps students think critically, become more independent, spot their weaknesses, track their progress, and gain confidence in their abilities.[31]

(iii) Patient Interaction and Communication Skills Feedback: Research shows that educational programs that use role-playing and simulations are highly effective because they strengthen these skills, ultimately leading to better patient outcomes.[32]

(iv) Ethical and Professionalism Feedback: A great dental practice relies on professionalism and strong ethics. Helpful feedback in this area covers topics like patient privacy, informed consent, and professional behavior. It is important to include this kind of feedback in dental education. Training programs that focus on these values through regular teaching and mentoring help build trust and integrity in patient care. In the end, a culture of self-evaluation and ongoing growth, supported by clear and timely feedback on skills, communication, and ethics, produces skilled, caring dental professionals.[33]

Challenges in Providing Feedback in Dental Education

(i) Student Resistance to Feedback: Feedback may be resisted by learners because they lack confidence, are afraid of receiving a poor grade, or don't fully comprehend its purpose. According to studies, many dental students take constructive criticism personally, which can impede their ability to learn and grow as professionals.[1] Reframing feedback as a chance for growth rather than a judgment is a useful strategy to allay this worry. This change can be aided by encouraging students to view criticism as instructive advice. Students are better able to appreciate the value of feedback when reflective questions are used, such as those that highlight strengths or provide detailed instructions for growth. Feedback thus shifts the focus from perceived personal flaws to useful, practical insights.

(ii) Faculty Training and Capacity Constraints: Educators lack formal training in delivering feedback and hence struggle to deliver it with quality. Introducing practical strategies, such as the ask–tell–ask approach and feedforward language, can lead to improvement. Institutions may support this through workshops, online training, and the integration of AI-based tools to provide a personalized feedback experience among faculty.[34]

(iii) Time Limitations: Although individualized feedback is proven to be effective, time constraints among faculty and students during clinical years often restrict its frequency and depth. Its outcomes vary with learners' educational backgrounds and anxiety levels. A multimodal approach is needed to address these issues.[1]

Strategies to Enhance Feedback Effectiveness

(i)Training Faculty on Effective Feedback Techniques: Teachers must receive formal training in evidence-based feedback techniques. Ramani et al.[35] emphasized the importance of structured feedback techniques using the Pendleton model in preclinical restorative dentistry, thereby encouraging students to self-reflect before receiving reflections from their faculty. Another model, the Sandwich Method, makes students more receptive to feedback by combining encouragement, helpful criticism, and positive comments. Focusing on what students do rather than on personal traits and giving clear, practical advice makes feedback even more effective and improves learning.

(ii)Encouraging a Growth Mindset Among Students: It is highly useful to adopt a development mentality, which is the conviction that abilities can be acquired with hard work and perseverance. This mindset encourages dental students to grow and helps them take constructive criticism. According to research, students' clinical performance increases significantly when they view criticism as an opportunity to grow rather than as an assessment of their skills.[36]

(iii)Developing a Feedback-Rich Learning Culture: To make feedback most effective, it is important to create an environment where feedback is regular, expected, and valued. A culture that embraces criticism makes it a natural aspect of learning and lessens the anxiety that often accompanies it. The University of Michigan School of Dentistry has developed a robust feedback culture by integrating self-evaluation into clinical training, peer review, and enhancing students' evaluative abilities.[37] One effective way to model this culture is through a consistent, recognizable routine that reinforces feedback as a shared responsibility. A brief daily practice can serve this purpose—for example, dedicating the first five minutes of each session to rapid reflections and practical feedback. At the University of Michigan, this simple routine has proven effective in sustaining an ongoing cycle of feedback and growth, making feedback a natural and integral part of the learning experience.

(iv)Implementing Regular Feedback Mechanisms: Timely feedback is essential for student growth and preventing the formation of bad habits. Digital tools and weekly reviews are effective ways to ensure feedback is given regularly. Al-Jewair et al.[38] used a tablet app for delivering instant feedback following orthodontic training and found that technical skills improved after wire-bending exercises. However, it is important that regular feedback sessions be held after clinical work and that they combine both formative and summative assessments to track progress.

(i) Role of Technology in Feedback Delivery: Technology has significantly transformed feedback delivery in dental education by enabling advanced tools and platforms that enhance learning. E-portfolios, for example, support ongoing assessment and reflection through self-evaluation, systematic feedback, and progress tracking. The e-portfolio system used at Harvard School of Dental Medicine effectively supports monitoring of clinical program progress.[39]

(ii) AI-Based Feedback Systems: AI's ability to provide prompt, personalized feedback is transforming dentistry education. AI-powered tools assess students' performance in simulations and offer precise insights regarding technique and procedural accuracy. For example, the DenTeach system is a cloud-based platform that offers high-precision, haptic-enabled training using state-of-the-art hardware and software.[40] Furthermore, by accurately segmenting anatomical structures and recognizing pathological changes (such as caries and periapical lesions), AI-driven software significantly improves students' diagnostic skills.[41]

(iii) Online Peer Review Platforms: Students can use digital peer review systems for feedback, which promote critical thinking and reflective learning. The COVID-19 pandemic's quick shift to online learning further demonstrated the need for these resources[42]. Despite fewer difficulties, these technologies have facilitated the sharing of feedback in clinical training, increasing student motivation and academic achievement[43] These developments enhance education and help produce knowledgeable, competent dental practitioners.

Assessing Feedback Effectiveness on Student Learning

(i) Assessing improvement in Knowledge and Skills: In dental education, feedback is crucial for students' skill development. Debates and discussions would improve reasoning, problem-solving, and critical thinking, while Objective Structured Clinical Examinations (OSCEs) effectively test clinical skills, knowledge, and decision-making.[44] In a study of a dental materials course, students assessed the sandwich feedback models favorably, with a slight preference for the latter.[45]

(iii) Faculty Perspectives on Feedback Effectiveness: To improve teaching, it is important to know how faculty view feedback (Figure 1). Teachers, too, should value reliable, timely, and relevant feedback to help ensure student learning.[46]

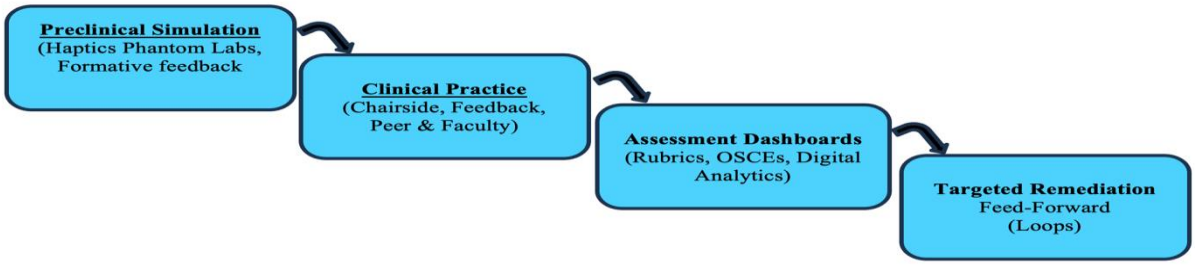


Figure 1. Programmatic Feedback Flow in Dental Education

CONCLUSION

Feedback is basic to the professional development of dental students and shapes their clinical competence. Its effectiveness relies on faculty training and efforts, as well as a strong feedback culture adopted in the institution. However, challenges need to be addressed, such as time constraints and learner resistance. Educators should adopt and implement at least one strategy described in this review to improve professional standards among their students. A collective commitment to these educational practices is key to improving standards of dental education.

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CASE REPORT

COLLISION TUMOR OF BASAL CELL CARCINOMA AND SQUAMOUS CELL CARCINOMA OF THE NASAL SKIN; A CASE REPORT

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Abstract

Collision tumors of two or more histologically separated neoplasms coexisting at the same anatomical site are rare pathological entities. We report a case of a 74-year-old female living in a rural resource-limited area who presented with a slowly growing, asymptomatic ulcerated lesion on the nasal skin. Excisional biopsy was performed with a 5 mm free margin, revealing a collision tumor comprising of basal cell carcinoma (BCC) and well-differentiated squamous cell carcinoma (SCC). The lesion showed clear separation with no evidence of transitional zones between the two components, differentiating it from basosquamous carcinoma. The patient underwent surgical excision, with no evidence of recurrence or metastasis observed during a six-month follow-up. Collision tumors, including both BCC and SCC, are exceptionally rare, and this represents, according to our knowledge, the first documented case in Iraq. Management should be tailored to the most aggressive histologic component, in this case, SCC. This case emphasized the importance of accurate histopathological diagnosis and highlights the need for increased clinical awareness in underserved regions.

Keywords: *collision tumors, basal cell carcinoma, squamous cell carcinoma*

INTRODUCTION

Concurrent appearance of distinct tumor types localized to the same region can be grouped into four major forms: collision, colonization, combination, and biphenotypic tumors[1]. Various hypotheses have been proposed to interpret this phenomenon, including random coexistence, tumor-induced microenvironmental changes, field cancerization, and stem cell transformation resulting in dual differentiatio[2-4]. In the context of collision tumors, two or more independent neoplasms develop in close anatomical proximity but retain clear histological boundaries, without intermixing of cellular components[5]. Documented cases of collision tumors containing basal cell carcinoma (BCC) and squamous cell carcinoma (SCC) are limited in the scientific literature [6,7].

CASE REPORT DESCRIPTION

An elderly female patient aged 74 residing in an economically disadvantaged rural area presented with a slowly enlarging, painless nasal skin mass of eight months' duration. The patient reported no relevant family history. Clinically, the lesion was well demarcated and red in color with a centrally ulcerated area (Figure 1).



Figure 1. The patient presented with a large ulcerated

mass on the nasal skin

The patient was diabetic and hypertensive. On clinical examination, there were no other skin lesions and no palpable lymphadenopathy. An excisional biopsy was performed with a 5 mm free surgical margin (Figure 2).



Figure 2. the lesion removed with 5 mm free surgical margin

Histopathological analysis revealed a well-differentiated squamous cell carcinoma (SCC) with keratin pearl formation, in conjunction with basal cell carcinoma (BCC) displaying basaloid epithelial cells arranged in peripheral palisading. The two neoplastic components were distinctly demarcated without histological intermixing or evidence of gradual differentiation (Figure 3).

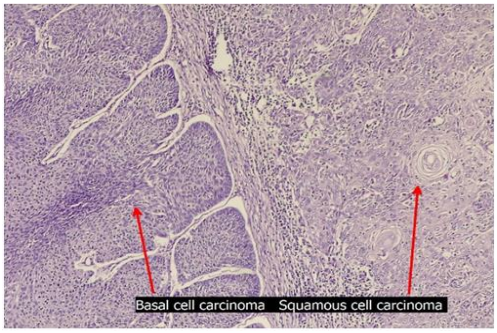


Figure 3. BCC and SCC are juxtaposed and well separated in the H&E-stained section

The patient has been under regular surveillance, with no signs of local recurrence or metastatic disease observed over a 6-month follow-up period (Figure 4).



Figure 4. complete healing of lesion with no signs of recurrence following 6 months period

DISCUSSION

Collision tumors arising in the skin area are rare pathological phenomena, with the head and neck region considered the second most prevalent anatomical site, accounting for 24.7% of cases. Among these, tumors composed of two malignant components—specifically the co-occurrence of basal cell carcinoma (BCC) and squamous cell carcinoma (SCC)—remain exceptionally rare[8]. This report details a rare and clinically significant case of a collision tumor exhibiting both BCC and SCC components, which was successfully managed via wide local excision. Surgical excision remains the most widely accepted and efficacious modality for the management of both BCC and SCC, particularly when histopathologic clearance is a primary goal[9]. Despite the shared utility of surgical excision, BCC and SCC vary in terms of their biological behavior, risk of recurrence, and possibility for metastasis, thereby necessitating distinct approaches to surgical margin determination[10]. Current guidelines recommend a margin of at least 3 mm for the excision of small, well-defined primary BCCs, as this has been shown to achieve high rates of complete excision while minimizing unnecessary removal of surrounding healthy tissue. However, the British Association of Dermatologists recommends slightly wider peripheral margins of 4–5 mm to achieve complete tumor removal in about 95% of cases[11]. In contrast, the management of SCC necessitates a more extensive approach reflecting its higher tendency for local invasion and metastasis[12]. Surgical excision of SCC required a rim of clinically normal-appearing skin as well as underlying subcutaneous tissue to confirm clearance. The determination of the appropriate free surgical margins for SCC differs according to the lesion's risk stratification: low-risk SCCs should be removed with a minimum free margin of 4 mm, whereas high-risk SCCs determined by features like tumor dimension, perineural invasion, depth of invasion, poor differentiation, and immunosuppression necessitate at least 6 mm free margin to mitigate the possibility of residual disease and recurrence[13-17]. Due to the rarity of lesions exhibiting both BCC and SCC components, standardized management guidelines have yet to be established. Consequently, therapeutic strategies must be individualized, with clinical decision-making guided by the most histologically aggressive component of the lesion. It is important to recognize that basal cell carcinoma–squamous cell carcinoma (BCC-SCC) collision tumors possess metastatic potential, mostly reported to axillary lymph nodes and lungs [18]. To the best of our knowledge, this is the first collision tumor of BCC and SCC documented in Iraq. It is essential to differentiate BCC-SCC collision tumors from basosquamous carcinoma (BSC), which displays features suggestive of transitional tumor phenotypes.

Muhannad Kareem Shumran Al-Ghanimi , Osama Mohammed Ghazi, Ali Hamid Jasim Khekan. COLLISION TUMOR OF BASAL CELL CARCINOMA AND SQUAMOUS CELL CARCINOMA OF THE NASAL SKIN; A CASE REPORT.Bulletin of Stomatology and Maxillofacial Surgery. 2025;21(12)200-203
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BSC demonstrates a histologic continuum between BCC and SCC, with areas of BCC or metatypical basal cell carcinoma gradually transitioning into regions showing squamous differentiation. Within BSC, the transition zones contain metatypical cells, which are cytologically distinct: they appear larger and paler than the basaloid cells found in classic BCC, yet smaller and less eosinophilic than the keratinizing squamous cells observed in SCC [19,20].

CONCLUSION

This case highlights a rare and significant example of basal cell carcinoma (BCC) and squamous cell carcinoma (SCC) collision tumor arising in the nasal skin of an elderly patient from a resource-limited rural area. The distinct histopathological demarcation between the two neoplastic components confirms the diagnosis of a true collision tumor rather than a basosquamous carcinoma. Surgical removal with free margins proved curative, with no recurrence or metastasis observed during three years of follow-up. Given the rarity of such tumors and the absence of standardized treatment protocols, clinical management should be guided by the more aggressive histological component, in this case, SCC. This report also represents the first documented case of a BCC-SCC collision tumor in Iraq, emphasizing the need for increased awareness, accurate histopathological differentiation, and individualized treatment strategies in such uncommon presentations.

DECLARATIOM

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REVIEW ARTICLE

EXPLORING THE CURRENT STATE OF MENTAL HEALTH LITERATURE: A BIBLIOMETRIC REVIEW OF SCHOLAR-FOCUSED RESEARCH AND FUTURE RESEARCH DIRECTIONS

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Abstract

This study explores the current state of mental health literature with a focus on scholar-centered research in higher education. A comprehensive bibliometric review was conducted using a range of tools, including VOSviewer, Biblioshiny (R-package), and Publish or Perish, analyzing data from the Scopus database. A total of 1.935 journal articles, spanning publications from 1919 to 2026, were systematically reviewed, with a steady increase in annual publications, particularly in the last decade. The analysis reveals that mental health in higher education settings has become a prominent research area, with key themes such as student well-being, depression, stress, and academic pressure frequently emerging in the literature. The leading countries contributing to this research include the United States, the United Kingdom, and Australia, with major institutions driving the scholarly output. The study also identifies prominent journals like Journal of American College Health and Educational Psychology Review, which have significantly shaped the field. Additionally, the research emphasizes the critical role of higher education policies in supporting student mental health, particularly post-COVID-19, while highlighting the increasing relevance of digital mental health tools and online interventions. Despite the growing body of literature, gaps remain in addressing intersectional mental health issues, particularly concerning marginalized student populations. The findings suggest that future research should focus on innovative interventions and the broader societal factors influencing student mental health, providing key insights into the evolving landscape of academic and student mental health research.

Keywords: Mental Health, Higher Education, Student Well-being, Bibliometric Analysis

INTRODUCTION

Mental health of students has become an increasingly urgent global issue, especially in the face of rising mental health challenges among the youth[1]. With increasing academic pressures, economic anxieties, and uncertainties about the future, students are now more vulnerable to mental health issues such as depression, anxiety, and stress, which can disrupt their overall well-being[2]. In addition to the factors mentioned, the widespread use of social media has also become a significant factor affecting the mental health of the younger generation. Research shows that excessive interaction on social media platforms can worsen feelings of low self-esteem, increase social anxiety, and exacerbate feelings of isolation[3,4]. The COVID-19 pandemic has further exacerbated this situation, leading to increased stress levels among students, caused by both remote learning and uncertainty about the future[5].

In response to this phenomenon, studies related to student mental health have rapidly developed in recent decades. Previous research has highlighted various mental health issues faced by students, including anxiety disorders, depression, and stress, which have become more prevalent due to high academic demands, social changes, and the impacts of globalization and digitalization[2]. One area that is now drawing attention is the impact of technology and social media use, which can serve both as a tool and a trigger for mental health issues. A study by Zhang [6] revealed that the phenomenon of digital dependency could exacerbate students' mental

health disorders, with different effects depending on the type and intensity of usage.

Furthermore, as technology advances, digital-based interventions to address mental health issues are gaining more attention. Psychological therapy applications (e-therapy), telemedicine, and other internet-based programs are now widely used to support students' mental health, providing easier access and reducing the stigma that often prevents students from seeking help[7]. On the other hand, research also indicates that while digital interventions offer more accessible solutions, their effectiveness and impact on students' mental health still require further study[8].

However, despite the increasing number of studies on student mental health, there are still various gaps in the literature, both in terms of geographic and thematic focus. Research on student mental health varies greatly across countries and cultures, with some countries focusing on physical health and diet, while others prioritize the role of social media and its impact on mental well-being (Altassan, 2025; Zhang et al., 2026). Therefore, this study aims to fill these gaps by conducting a bibliometric analysis of existing literature to explore research trends, recurring themes, and identify opportunities and challenges for future research. This study aims to answer three main questions:

1. What are the trends in student mental health literature over time, including the most frequently cited journals, countries, institutions, and most productive authors?
2. What are the main themes and keywords that frequently appear in literature related to student mental health?

RESEARCH METHODOLOGY

Research design.

This study adopts a quantitative approach using bibliometric analysis from the Scopus database. Bibliometrics is an optimal technique for examining the conceptual structure of a research domain and identifying potential future research directions. To conduct a more comprehensive bibliometric analysis, this study integrates bibliometric and content analysis to synthesise research streams from various journals indexed in Scopus, spanning from 1919 to 2026. The primary reason for selecting the Scopus database is that it provides broader citation coverage compared to other databases, including Web of Science (WoS), which is relatively limited and often overlaps with Scopus or includes journals indexed by both[9]. Furthermore, the Scopus database grants access to a more comprehensive range of journals and provides a wider citation network.

Search Strategy, Criteria, and Data Collection

In our data search strategy, we adapted the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) model to ensure transparency and consistency in the data collection process. Figure 1 presents the detailed flowchart of the PRISMA protocol employed in this study's search strategy. Data were collected from the Scopus database on December 25, 2025, using the search query: ("psychology" OR "mental health") AND ("scholarship" OR "financial aid" OR "grants" OR "funding") AND ("students" OR "learners" OR "scholars"). This search query was designed to capture documents focusing on mental health, funding (e.g., scholarships, grants), and student populations.

To guarantee the inclusiveness of the bibliometric review and content analysis, we followed a structured screening process. This included screening literature relevant to the research topic, evaluating documents based on their eligibility criteria (including full-text search), and cross-verifying citations and relevance to the subject, which were not directly included in the data search query.

The initial records screened in the Scopus database (n = 45,214) were based on article titles, abstracts, and keywords from journals, proceedings, book chapters, and reviews. Three key search criteria were used to ensure article quality and review validity: article universality, publication quality, and relevance. Universality was ensured by including only English-language journal articles. Therefore, we applied the following filters: LIMIT-TO (DOCTYPE, "ar"), LIMIT-TO (SRCTYPE, "j"), LIMIT-TO (LANGUAGE, "English").

Subsequently, we excluded documents that did not meet the inclusion criteria, including irrelevant studies, non-article document types, non-journal sources, and documents not written in English (n = 43.279). The remaining records deemed eligible (n = 1.935) were included for further descriptive analysis, bibliometric analysis, and content analysis.

Tools and Data Analysis

Various tools were used to conduct this research. For frequency analysis and chart generation, R-Biblioshiny and Excel were employed to perform calculations and visualise the results. VOSviewer was used to construct and visualise bibliometric networks, examine abstract keywords and authorship, and explore relationships and collaborations across authors, countries, and publications. Harzing's Publish or Perish software was utilised to compute citation metrics and identify highly cited documents, providing insight into the most influential research in the domain [10]. This research adopted a comprehensive methodology, combining bibliometric analysis with content and network analysis

to uncover insights into various facets of the research field. These include publication years, contributing countries and institutions, prominent journals, influential authors, keyword associations among authors, document citations, author citations and co-citations, international collaborations, and emerging research streams.

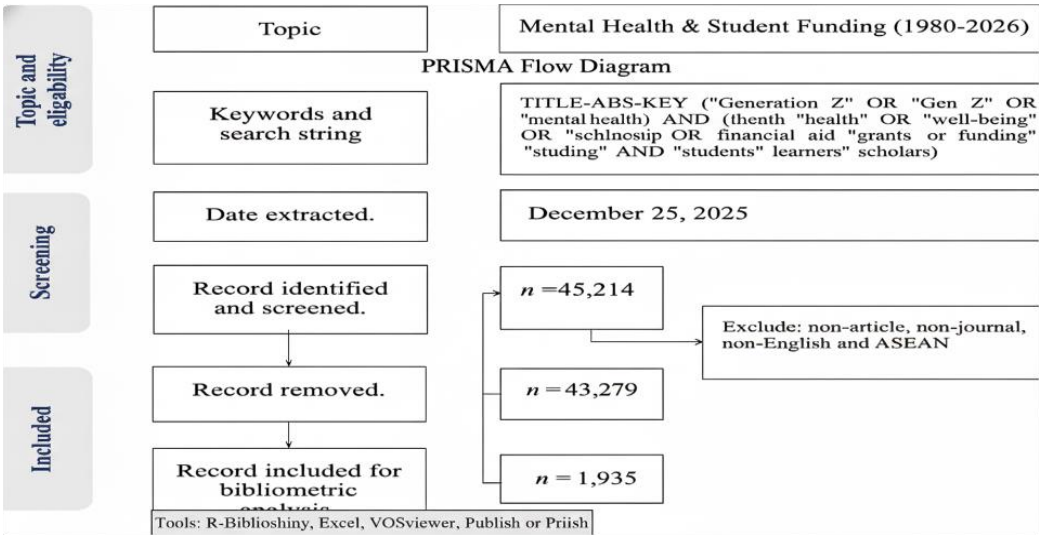


Figure 1. Diagram PRISMA

RESEARCH FINDINGS AND DISCUSSION

Descriptive analysis

The author examined a collection of 1,935 journal articles published between 1919 and 2026 for this study, sourced from a total of 963 different publications. These articles were authored by 6,637 authors, with only one article being single-authored. On average, each article had 8.43 co-authors, and 13.59% of the publications had international co-authorship, indicating substantial global collaboration. The annual growth rate of publications was 1.3%, reflecting steady scholarly activity in this area. The average age of the documents was 11 years, and there were 15,353 references across all publications. Each document had an average of 21.53 citations, demonstrating their significant impact on the academic community. Additionally, the authors used 4,392 different keywords, showing the broad range of topics covered. This overall picture suggests that the field is experiencing steady growth, with increasing international collaboration, and is contributing significantly to the academic landscape, as evidenced by the rising citation rates.



Figure 2. Dataset

Figure 3 In this study, the author examined journal articles published between 1919 and 2026, focusing on the development of scholarly work during this period. The first article was published in 1919, and there were several years with no publications, particularly in the early years. However, the number of publications started to rise gradually, with notable growth after the 1980s. The most significant increase in publications occurred after 2017, with a sharp rise in the number of articles in the following years. The highest number of publications was recorded in 2025, with 223 articles published, followed by 210 articles in 2024. A total of 1,935 articles were identified from the Scopus database. The analysis of the publication trends showed an annual growth rate of 1.3%. On average, each article received 21.53 citations per document, with 8.43 co-authors

per document. The total number of references across all articles amounted to 15,353. This upward trend highlights the growing academic interest and research activity in the field, particularly in recent years.

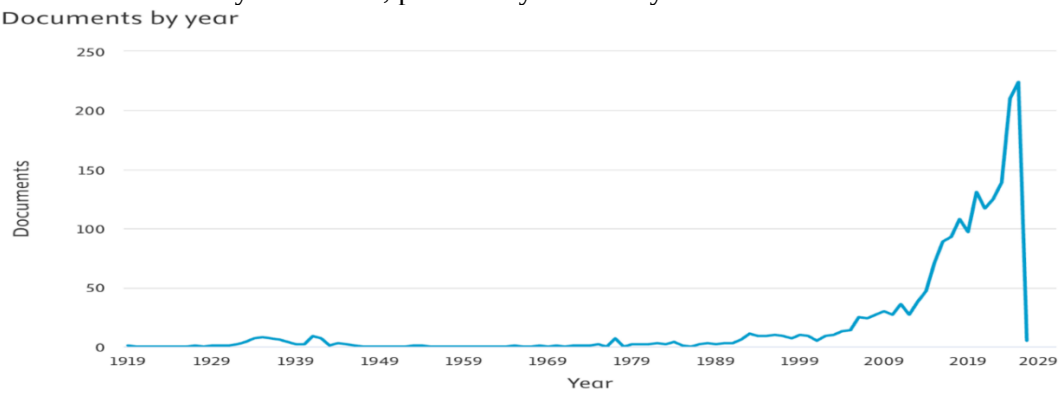


Figure 3. Number of publications per year

Research trend analysis

The chart illustrates the various subject areas relevant to Generation Z health research. The largest portion of the research focuses on Social Sciences, accounting for 27.9% of the total, highlighting the significant interest in understanding the societal factors that influence Generation Z's health. Medicine follows closely behind, contributing 25.4%, indicating that physical health remains a major focus of academic inquiry. Psychology also plays a central role, with 19.7% of the publications dedicated to understanding the mental health of Generation Z, reflecting the growing attention to mental health issues in this demographic. Smaller but still significant portions of research cover fields such as Nursing (6.1%), Arts and Humanities (5.7%), and Health Professions (2.5%), indicating an interdisciplinary approach to understanding Generation Z's health. Other subject areas, including Business and Management (2.6%), Neuroscience (1.3%), and Biochemistry (1.1%), show a more specialized focus, suggesting that research is not limited to traditional health disciplines but spans a wide range of topics related to the well-being of Generation Z.

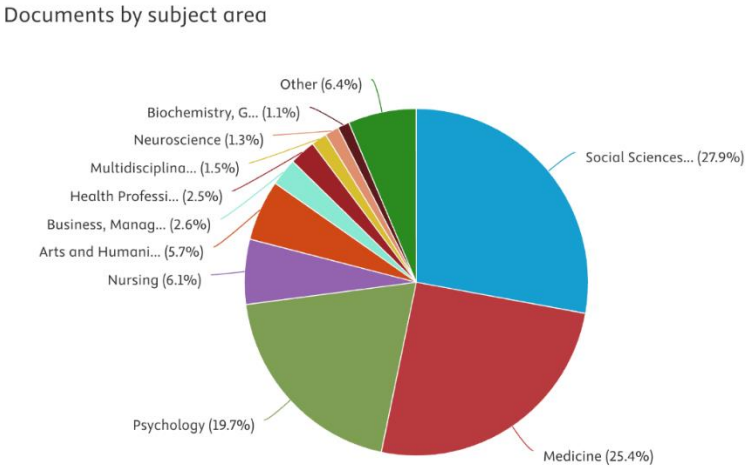


Figure 4. Subject Area

The chart presents the most relevant sources in Generation Z health research based on the number of documents published. The American Psychologist leads with 47 documents, followed by BMC Medical Education with 37 documents, reflecting significant contributions to psychology and medical education. PLOS ONE ranks third with 35 documents, showcasing its broad interdisciplinary focus. Other notable sources include the Journal of Educational Psychology and the Journal of Applied Psychology, contributing 31 and 30 documents, respectively, highlighting their influence in the fields of education and psychology. Teaching of Psychology follows with 29 documents, emphasizing psychological education, while Academic Medicine (22 documents), International Journal of Environmental Research and Public Health (18 documents), Academic Psychiatry (16 documents), and Currents in Pharmacy Teaching and Learning (14 documents) contribute to research across medical, environmental, psychiatric, and pharmacy-related fields. This distribution underscores the interdisciplinary nature of Generation Z health research, with a prominent focus on psychology, education, and medical disciplines.

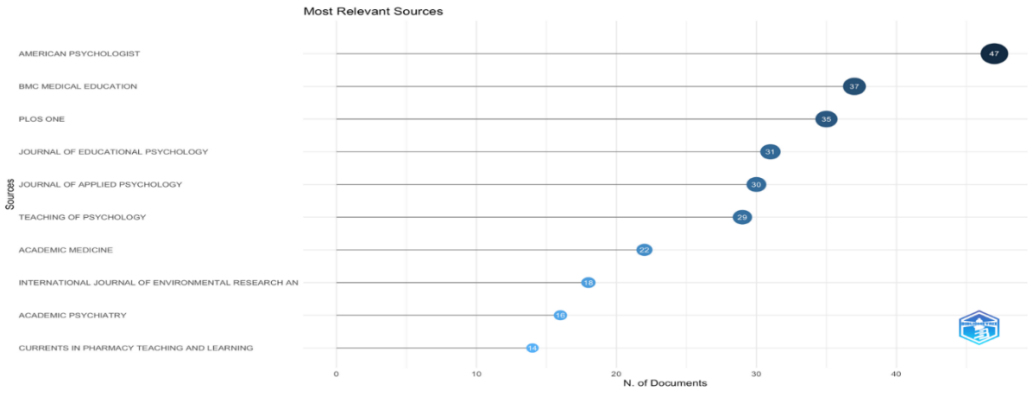


Figure 5. Most Relevant Sources

The figure above shows the local impact of the sources in Generation Z health research based on the H-index. The sources with the highest H-index, reflecting their impact within the research community, are Academic Medicine and The Lancet Psychiatry, both of which have a H-index of 12. These sources are followed by BMC Medical Education and Teaching of Psychology, both with a H-index of 11, indicating their strong influence in the field. The International Journal of Environmental Research and Public Health and Academic Psychiatry each have a H-index of 10, further demonstrating their significant contribution to Generation Z health research. Other notable sources such as American Psychologist, Journal of Professional Nursing, eClinicalMedicine, and Nurse Education Today have a H-index of 9, while other journals with a lower impact, such as the Journal of Clinical Psychology and Nursing Education Today, have an H-index of 8. These results highlight the key sources that are shaping the current landscape of Generation Z health research and their respective impact in the academic community.

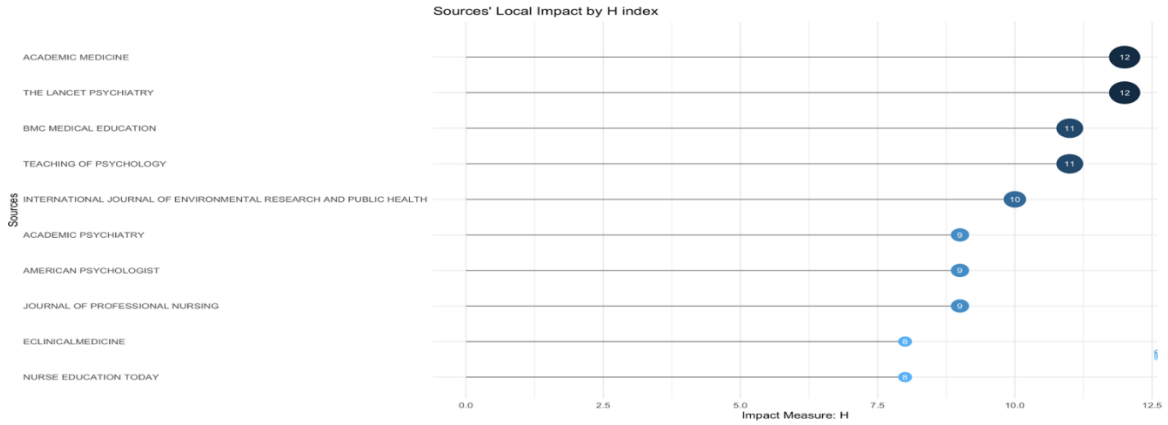


Figure 6. Journal local impact related to the topic

Most influential countries, affiliates, and productive author

Table 3 shows the distribution of health research on Generation Z by country. The United States leads the list with 1,076 publications (55.61%), followed by the United Kingdom with 193 publications (9.97%). The United States significantly contributes to the research in this area, and the United Kingdom also has a strong presence. Undefined sources represent 162 publications (8.37%), with a lower citation rate compared to the others. Australia follows with 145 publications (7.49%), showing a substantial interest in the topic. Canada ranks fifth with 133 publications (6.87%), while China has 54 publications (2.79%), but it leads in total citations, with 3,496 citations and a high 64.74 citations per publication, reflecting a significant global impact. South Africa contributes 42 publications (2.17%), and Germany has 36 publications (1.86%). Spain and the Netherlands contribute fewer publications, with 27 (1.40%) and 26 (1.34%), respectively, but still make valuable contributions in this field. This distribution indicates that countries like the United States and the United Kingdom dominate the field, while others, like China, stand out for their impact despite fewer publications. The variation in citation rates highlights the global nature of Generation Z health research, suggesting that partnerships between these countries could help bridge research gaps and amplify the global impact of this important area of study. The figure above shows the most relevant affiliations based on the number of articles published about mental health research focused on scholars, as part of the bibliometric review titled "Exploring the Current State of Mental Health Literature: A Bibliometric Review of Scholar-Focused Research and Future Research Directions." The University of California leads with 79 articles, showcasing its significant contribution to the field. Next, London School of Hygiene and Tropical Medicine published 61 articles, reflecting its strong focus on mental health

research. The University of Oxford Medical Sciences Division follows with 55 articles, further reinforcing its role in advancing mental health studies. The University of Queensland and The University of Sydney both published 45 articles, indicating their active participation in the research. King's College London comes in with 44 articles, and University of Toronto with 42 articles, both institutions making substantial contributions. Other notable institutions include The Ohio State University, The University of Hong Kong, and University College London, with 39 and 37 articles respectively, demonstrating their important roles in the academic landscape. This distribution highlights the key academic institutions that are driving forward the research on mental health, particularly in scholar-focused contexts, and underscores the global collaboration in this field.

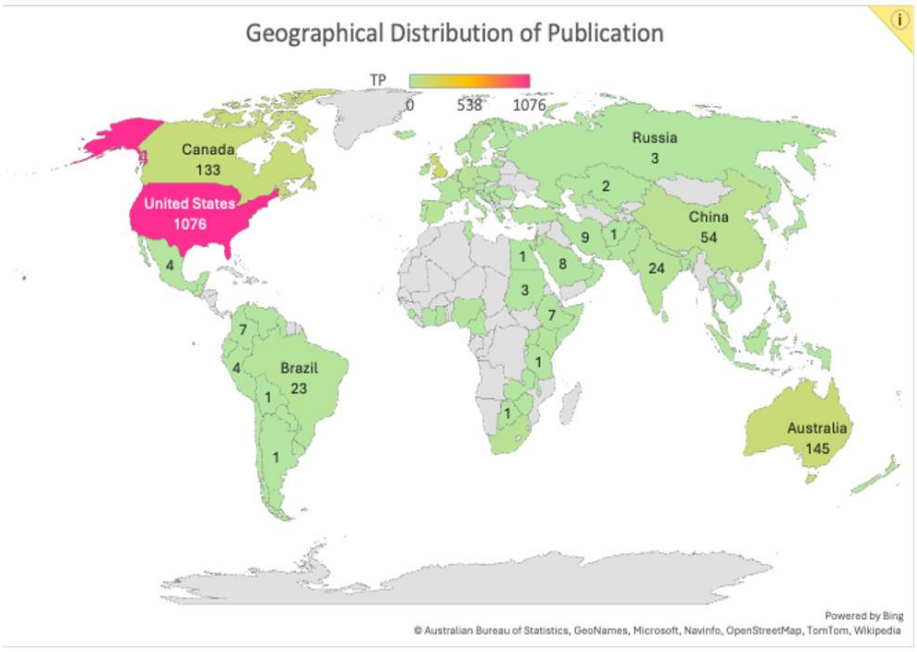


Figure 7. Most influential countries

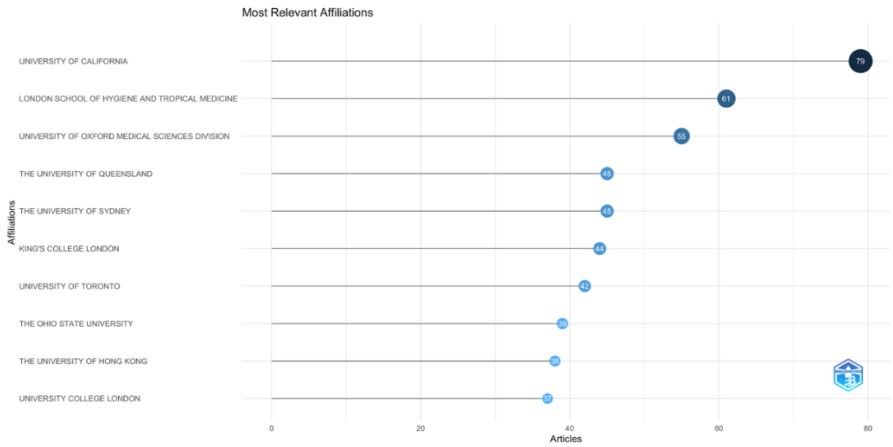


Figure 8. The top 10 Relevant Affiliations

Table 4 shows the top authors who have contributed to Generation Z health research, along with their key publications and citation impact. [No Author ID found] leads with 17 publications, making up 55.61% of the total. This indicates a strong influence in the field, although no specific author ID is provided for this contributor. Jimerson, S.R. follows with 7 publications, accounting for 9.97% of the research, showcasing his significant role in the field, while Williamson, E.G. has 5 publications. Other contributors such as Birrell, L., Bonell, C., Espelage, D.L., Evans-Lacko, S., Hill, G., and Mannix, D. each have 4 publications, making valuable contributions to the research landscape. These authors demonstrate a mix of contributions with varying citation impacts. This distribution shows the diverse range of experts contributing to the field, and underscores the importance of their work in the expanding area of Generation Z health research.

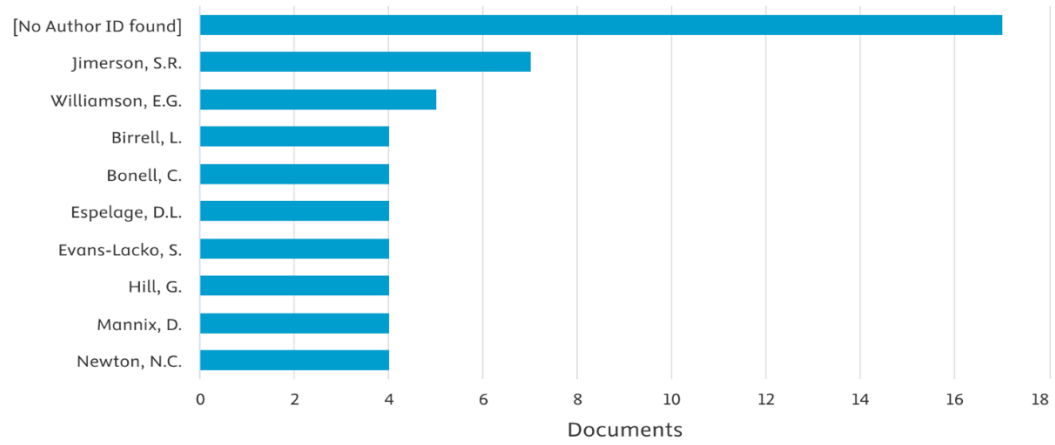


Figure 9. Most Productive Authors

Citation analysis

Several key studies have made significant contributions to the field of mental health research. Santomauro (2021) leads with 4,045 citations, reflecting the wide-reaching impact of his work, particularly with a high normalized citation rate of 77.53. West (2016) follows closely with 1,695 citations and a normalized citation rate of 34.25, focusing on psychological aspects. Lai (2019), with 1,272 citations and a normalized citation rate of 36.57, also contributes substantially to mental health research. Other important studies include Freeman (2017), Nomaguchi (2020), and Wasserman (2015), with citation counts ranging from 467 to 543, offering insights into mental health interventions, stress, and social factors. Ajzen (2004), with 457 citations, significantly advances understanding of behavioral aspects, while Bleiker (2008) and Galante (2018), with 426 and 374 citations, respectively, focus on psychological stress and coping mechanisms. Finally, Payne-Sturges (2018), with 303 citations, examines the environmental factors affecting mental health. These studies highlight the growing academic focus on mental health, showcasing diverse areas of research that contribute to understanding the complex nature of mental well-being.

Table 1. The top ten most cited documents

Paper	DOI	T C	TC/Y	Normalized TC
Santomauro, 2021.	10.1016/S0140-6736(21)02143-7	4045	809,00	77,53
West, 2016.	10.1016/S0140-6736(16)31279-X	1695	169,50	34,25
Lai, 2019.	10.1016/S2215-0366(19)30289-5	1272	181,71	36,57
Freeman, 2017.	10.1016/S2215-0366(17)30328-0	543	60,33	23,42
Nomaguchi, 2020.	10.1111/jomf.12646	526	87,67	24,57
Wasserman, 2015.	10.1016/S0140-6736(14)61213-7	467	42,45	14,57
Ajzen, 2004.	10.1177/0146167204264079	457	20,77	5,74
Bleiker, 2008.	10.1017/S0260210508007821	426	23,67	8,29
Galante, 2018.	10.1016/S2468-2667(17)30231-1	374	46,75	12,44
Payne-Sturges, 2018.	10.1177/0890117117719620	303	37,88	10,08

Note(s): TC=total citations; C/Y=average citations per years

Keyword analysis

Table 6 shows the frequency of keywords related to mental health research in the Scopus database. "Mental health" emerges as the most common keyword, appearing in 135 articles, indicating its central role in health research. "Education" follows with 56 occurrences, highlighting the importance of educational contexts in mental health research, while "Higher education" appears in 48 articles, further supporting the link between mental health and academic settings. Keywords like "educational psychology" (41), "students" (37), and "educational psychology (including vocational guidance)" (35) show the strong association between education and mental health, especially in academic and career guidance contexts. Other frequent

keywords include "COVID-19" , reflecting the pandemic's impact on mental health, and "medical education", indicating the intersection of health education and mental well-being.

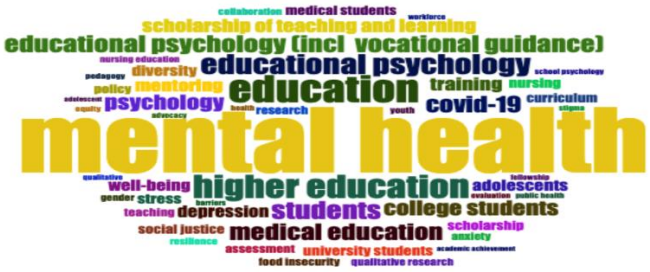


Figure. 10 Top Keywords

The figure presents a keyword co-occurrence network that plots the development degree (density) against the relevance degree (centrality) of various research themes in mental health. In the Motor Themes category, located in the top-right corner, "mental health," "education," and "higher education" are central themes with high relevance and growth. These themes highlight the growing importance of mental health research in educational settings, demonstrating that this area is becoming a significant and influential part of the field. In the Basic Themes section (bottom-right), "college students," "depression," and "well-being" are key themes, foundational in understanding mental health, particularly for young adults. These topics, though essential, may not be as interdisciplinary as other themes. Moving to the Niche Themes section (top-left), keywords like "academic achievement" and "school mental health" represent more specialized areas, related to performance and mental well-being in academic contexts. While these themes are impactful, they are more specific and still developing. The Emerging or Declining Themes section (bottom-left) shows "educational psychology (including vocational guidance)", suggesting that it is either emerging or in decline in terms of research focus. Lastly, Other Themes like "medical education," "medical students," and "stigmas" are in the middle, indicating their growing relevance but with a more specific focus. Overall, this visualization demonstrates that research on mental health in educational contexts is expanding, with a focus on student well-being, depression, and the role of higher education institutions in shaping the research landscape.

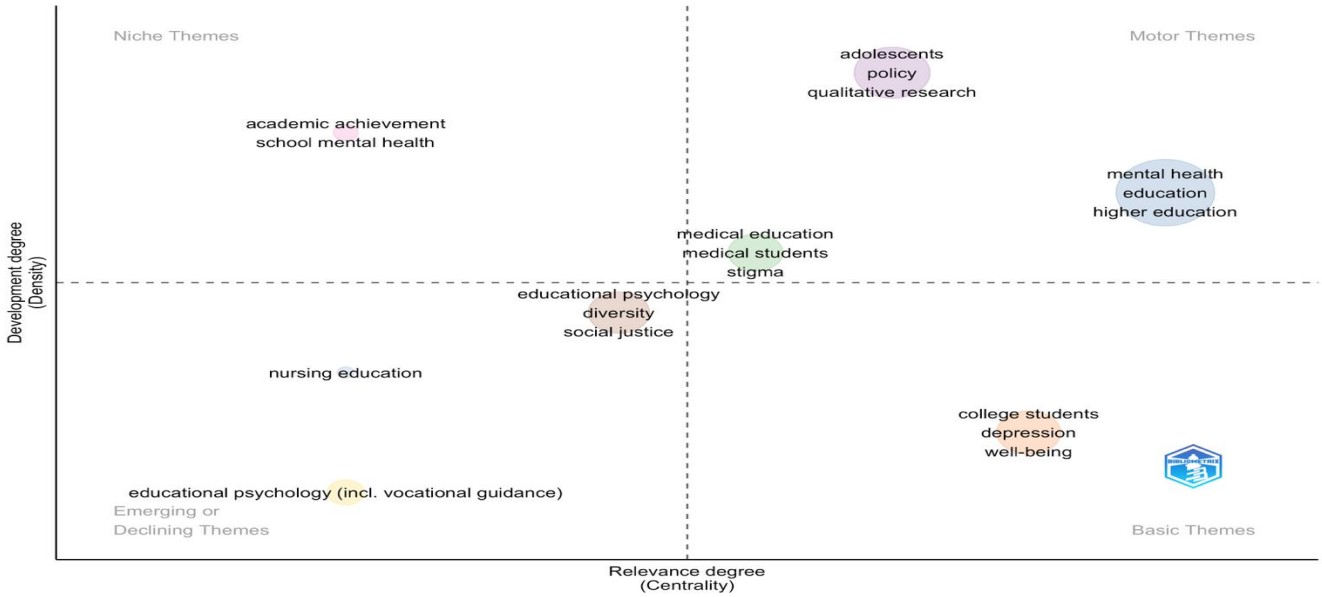


Figure. 11 Thematic Maps

DISCUSSION

Educational Framework and Student Development

Cluster 1 emphasizes the integration of mental health strategies within the educational framework, which is essential for addressing the increasing mental health challenges in higher education. The role of educational psychology has expanded as researchers acknowledge its impact on student development, particularly in promoting emotional resilience. Many universities have started to incorporate mental health services directly into the curriculum to support students' psychological well-being[2]. Educational programs that offer a balance between academics and mental health are essential for fostering a more holistic student experience. Notably, universities that adopt proactive mental health policies improve not only academic outcomes but also the overall life satisfaction of their students[11]. This comprehensive approach to education highlights the growing recognition of the importance of emotional well-being in academic success.

Furthermore, the adoption of mental health services within the academic environment has seen positive results in enhancing students' ability to manage stress and thrive in a competitive educational system[12]. By integrating peer mentoring programs, counseling services, and stress management techniques, universities provide much-needed support for students, especially those facing academic and personal challenges. These systems have proven effective in mitigating the pressures of academia, providing students with the tools to handle emotional and academic stressors more effectively[13]. The expansion of mental health support within education systems not only improves students' well-being but also leads to better academic outcomes and higher retention rates in higher education.

Mental Health Challenges in Students

Cluster 2 highlights the mental health challenges faced by college students, with a particular focus on the effects of food insecurity, financial stress, and academic pressures. Food insecurity is increasingly recognized as a significant contributor to students' emotional distress, including heightened levels of depression and anxiety[14]. A study on Bangladeshi students revealed that food insecurity negatively impacts both academic performance and psychological well-being[15]. Addressing this issue requires targeted interventions that provide nutritional support alongside mental health resources, which would help alleviate the stressors that exacerbate students' mental health challenges[16]. Given the strong link between food insecurity and mental health, universities must prioritize food security initiatives to improve student outcomes.

Moreover, financial stress is another pressing issue that affects students' mental health, especially in the context of rising tuition fees and living costs[17]. Studies suggest that students experiencing significant financial strain are more likely to report symptoms of anxiety and depression. Mental health interventions that address both financial and psychological challenges are essential for promoting well-being and academic success. Furthermore, universities can play a crucial role by offering financial aid and support programs, which not only reduce financial stress but also positively impact students' emotional health[14]. These findings emphasize the importance of a comprehensive approach that integrates financial, academic, and mental health support for students.

Well-being and Mental Health Policy in Higher Education

Cluster 3 examines the role of mental health policies in supporting students' well-being within higher education institutions, particularly in the aftermath of the COVID-19 pandemic. The pandemic intensified the mental health challenges for students, including stress, anxiety, and depression, leading universities to implement more robust mental health policies[18]. Many institutions have expanded their mental health services to include virtual counseling, wellness apps, and peer support groups, which have been critical in providing support during periods of social distancing[5]. These initiatives demonstrate the importance of institutional policies that adapt to evolving needs and focus on accessible, scalable solutions for student well-being[19].

Additionally, the integration of mental health education into university curricula is an essential strategy for promoting well-being among students. Programs designed to enhance students' mental health literacy can help them recognize signs of distress in themselves and others, encouraging early intervention and reducing the stigma associated with mental health challenges[5]. The importance of these initiatives is underscored by research showing that students who receive mental health education are more likely to seek help when needed. As universities continue to prioritize mental health, the evidence supports the need for continued investment in both preventive and responsive mental health services to safeguard students' well-being[20].

Medical Education and Mental Health in Healthcare Students

Cluster 4 focuses on medical students and the mental health challenges they face due to the rigorous nature of their education. Medical students often experience high levels of burnout, stress, and depression, which are exacerbated by the demands of their coursework, long hours, and patient interactions[21]. These students face unique mental health risks, as the stress they endure during training can carry over into their professional lives. Research suggests that medical humanities programs, which include components such as emotional intelligence training and empathy exercises, can help students develop better coping mechanisms and reduce the psychological toll of their education[22]. These programs aim to foster well-being while preparing students for the emotional demands of a healthcare career.

To address these challenges, medical schools are increasingly integrating resilience training and mental health support into their curricula[23]. Universities have adopted various strategies, including mindfulness workshops, peer support systems, and access to counseling services, to reduce burnout and support students' mental health. Studies show that students who participate in these programs report improved emotional well-being, better stress management, and a greater sense of connectedness with their peers[24]. By focusing on both the academic and emotional needs of medical students, institutions can reduce mental health issues and better prepare future healthcare professionals to care for others while maintaining their own well-being.

CONCLUSION

This study provides a comprehensive overview of the development of mental health literature among students, particularly in the context of the growing use of technology and social media. Through bibliometric analysis, it was found that, although there has been a significant increase in research on student mental health in recent years, many gaps remain that need attention. Most of the existing studies focus on the negative impacts of social media and digitalization on students' psychological well-being, as well as the rising issues of anxiety, depression, and stress due to academic and social factors. However, research related to the use of technology as a digital intervention, such as psychological therapy apps and telemedicine, still requires further investigation to ensure their effectiveness and accessibility in diverse cultural and social contexts. This study also highlights significant regional variations in the focus and approach of student mental health research, with some countries emphasizing social and cultural issues affecting mental health, while others focus more on technology-based interventions. Therefore, to address these gaps, more research is needed that takes local contexts into consideration and develops more affordable and accessible technology-based interventions for students worldwide. Furthermore, integrating mental health into higher education policies and university programs is crucial to ensure students' overall well-being. In light of these findings, this study makes an important contribution to the development of policies and practices that are more inclusive in supporting student mental health. Moving forward, developing policies that integrate psychological support with the appropriate use of technology, as well as raising awareness about the importance of mental health, will be critical in creating a healthier academic environment and supporting students' well-being globally.

DECLARATIOM

Conflict of Interest

None to declare.

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ORIGINAL RESEARCH

HEALTH COMMUNICATION AND GENERATION Z:A BIBLIOMETRIC MAPPING OF KEY ISSUES AND FUTURE RESEARCH DIRECTIONS

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Abstract

This study investigates the phenomenon of health communication in the context of Generation Z in the digital era, focusing on digital health literacy and the influence of social media on their health behaviour. Generation Z, who grew up with digital technology, more often seek health information through the internet, but their level of health empowerment is relatively lower than previous generations. The purpose of this study is to analyse publication trends, author collaborations, and emerging topics in the literature related to Generation Z health communication using bibliometric analysis methods. The data was analysed by mapping the number of publications, citations, main sources, and comparing global and local trends. The findings of this study show a significant surge in publications in 2020, triggered by the COVID-19 pandemic, with the USA being the largest contributor to publications. However, despite an increase in the number of publications, citations per article tended to decline after peaking in 2019, indicating saturation or a shift in topic focus. In addition, these findings also identified disparities in author collaboration and research influence, with several leading journals such as the International Journal of Environmental Research and Public Health becoming major centres of publication. This study enriches the literature by providing insights into the dynamics of Generation Z's health communication and revealing the need for better digital health literacy education. The practical implication of this study is the importance of digital-based education to improve Generation Z's health empowerment.

Keywords: Health Communication, Bibliometric Review, Generation Z

INTRODUCTION

Generation Z, comprising individuals born between 1995 and 2010[1-3], is the first group to grow up in a highly connected digital era[4,5]. They have unique habits in accessing and sharing information, particularly in the context of health, which differ significantly from previous generation[6,7]. Digital technology, especially the internet and social media, has changed the way they search for, understand, and manage health information. This phenomenon presents new challenges in health communication, where information delivery must be adapted to their highly integrated digital habits. Meanwhile, although Generation Z accesses health information more frequently online, research shows that their health empowerment levels are lower than previous generations, despite their high digital health literacy. Furthermore, the importance of research that understands the relationship between digital health literacy and information-seeking behaviour among Generation Z is becoming increasingly urgent. As a generation that is more dependent on technology, they not only search for health information online, but also interact with various digital platforms that offer various forms of health information. Thus, understanding Generation Z's preferences and habits in searching for health information is key to designing effective and relevant health communication strategies. However, there is a significant gap in research linking digital health literacy theory with real-world practice, as well as a deeper understanding of how Generation Z utilises digital media in managing their health.

Recent research on health communication involving Generation Z indicates a significant gap in digital health literacy and health information search behaviour among this group. Several studies, such as those conducted by[8,9], identify that although Generation Z uses the internet more often to search for health information than previous generations, they demonstrate lower levels of health empowerment. This behaviour is influenced by digital health literacy, which in some cases, although

higher among Generation Z, does not always correlate with their ability to manage their health independently. Additionally, research by[10,11] indicates that although Generation Z possesses high technological capabilities, they tend to rarely use mobile health applications or wearable devices to monitor their health, influenced by variables such as social interactions and healthy living habits that are already ingrained in their lives.

On the other hand, studies by[12,13] show how the COVID-19 pandemic has accelerated changes in Generation Z's lifestyle, with an increased interest in health and health management, although there are still challenges in adopting new technologies in health management. The dependent variables in these studies include health empowerment, technology adoption, and the utilisation of digital health resources, with research designs varying from cross-sectoral surveys to qualitative interview-based studies. Overall, this research highlights the importance of a deeper understanding of how Generation Z manages their health in the digital world, with important implications for more effective health communication strategies.

Although many studies related to health communication and Generation Z have been conducted, most studies use qualitative approaches or primary data-based surveys. However, bibliometric analyses that map global and local research trends, as well as inter-topic relationships and major influences in this field, are still very limited. The use of bibliometrics to identify publication patterns, author collaborations, and emerging topic shifts is crucial for comprehensively understanding the dynamics of this research. There is a lack of global and local bibliometric analysis that maps research trends, leading authors, and emerging topics in the field of Generation Z health communication. Based on the identified gaps, there is a significant lack of application of bibliometric methods in analysing health communication for Generation Z. The main gaps include a lack of mapping of global and local trends, analysis of author collaboration , identification of emerging topics, and the use of citations to measure policy impact. In addition, multidisciplinary approaches and long-term analysis are also areas that require more attention in using bibliometric methods to understand research developments in this field.

This study offers a unique contribution by utilising a bibliometric approach to provide a comprehensive overview of research trends, author collaboration, emerging topics, and the impact of policies on health communication for Generation Z. By mapping emerging topics and distinguishing between global and local research trends, this study not only fills a gap in the current literature but also introduces a new methodology that can strengthen future health communication strategies for Generation Z.

This study aims to conduct a bibliometric analysis of research related to Generation Z health communication, focusing on mapping global and local trends, author collaboration, and the development of relevant topics. The main focus of this study is to identify how these research trends have developed over time and to understand the relationships between emerging topics, particularly those related to digital health literacy and health empowerment. In addition, this study also aims to explore the differences between research conducted at the global and local levels and to examine how this research influences health policy and health communication practices, especially in an increasingly digitalised world. Using a bibliometric approach, this research will provide a clearer picture of publication patterns, key authors, and existing research networks in this field, as well as make an important contribution to the development of more effective health communication strategies for Generation Z.

RESEARCH METHODOLOGY

Research design.

This study applies a quantitative approach through bibliometric analysis using the Scopus databas[14,15] . Bibliometric analysis was chosen as the optimal technique for mapping the conceptual structure in the domain of health communication and identifying future research directions related to Generation Z. To produce a more comprehensive synthesis, this study integrates bibliometric mapping with content analysi[16,17] to examine various research trends from 2013 to 2026.

Data were extracted on 23 December 2025 using specific keywords *(Health AND Communication AND Generation Z)*. The use of the Scopus database was based on its broader coverage and more comprehensive citation metadata compared to Web of Science (WoS), particularly in social science and communication literature. Unlike previous studies on Generation Z health that tended to focus on the WoS database, this study explored the *Health Communication* niche in Scopus to obtain a more inclusive global perspective. From the search results, 91 documents were obtained and then analysed thoroughly without applying exclusion criteria (document type or language) to ensure complete and in-depth data representation of key issues in Generation Z health communication.

Search strategy, criteria, and data collection

In the data search strategy, this study adapted the *Preferred Reporting Items for Systematic Reviews and Meta-Analyses* (PRISMA) model, which has been modified for bibliometric studies. Figure 1 presents a detailed flow chart of the PRISMA protocol applied. Data were collected on 23 December 2025 from the Scopus database using a specific search query: ("Health" AND "Communication" AND "Generation Z"). These keywords were selected to capture literature that explicitly discusses the intersection of communication practices and health behaviour in Generation Z.

To ensure the inclusivity of this bibliometric review and content analysis, this study adopted a comprehensive review approach. After conducting an initial screening of relevant literature, we evaluated documents based on eligibility criteria that included subject relevance and citation structure. Unlike most bibliometric studies, which often limit results to English-language journal articles, this study did not apply exclusion criteria based on document type or language. This strategy was adopted to ensure that the entire spectrum of literature—including conference proceedings, book chapters, and reviews in various languages—was fully represented, given that the topic of Gen Z health communication is a rapidly developing field in various geographical regions.

The initial search in the Scopus database yielded 91 documents based on titles, abstracts, and keywords. All of these records (n=91) were deemed eligible and qualified for inclusion in descriptive analysis, bibliometric mapping, and further content analysis. The use of the entire database without reduction allowed researchers to capture the research landscape holistically without losing important information from non-article document types.

Tools and data analysis

This study utilised R-Biblioshiny software, a *web-interface-based* application for bibliometrics operated in the RStudio environment, as the main tool for data analysis and visualisation. The use of R-Biblioshiny allows researchers to perform integrated data processing, from data *cleaning*, bibliometric metric calculations, to the creation of complex network maps in one robust workflow. Through this platform, we constructed and visualised bibliometric networks to examine keyword correlations, authorship patterns, and cross-country collaboration and publications in the domain of Generation Z health communication.

This comprehensive methodology combines quantitative bibliometric analysis with *network* analysis to uncover in-depth insights from various aspects of the research field. The analysis covers annual publication growth trends, identification of the most contributing journals and institutions, mapping of the most influential authors, and keyword *co-occurrence* analysis to identify major theme clusters. With this approach, this study aims to synthesise current research flows and map *future* research directions that are crucial for the development of health communication studies on Generation Z.

Peer & self-feedback	Collaborative, reflective	Builds critical thinking	Requires calibration	Case presentations [20–22]

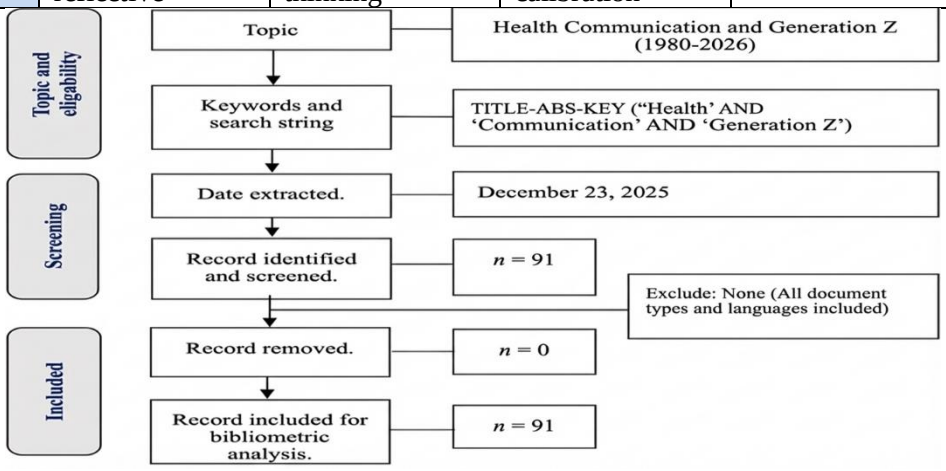


Figure 1. PRISMA Diagram
Source: Researcher's Data Analysis Results, 2025

RESEARCH FINDINGS AND DISCUSSION

Descriptive analysis

Based on the bibliometric data analysis presented, this study covers publications produced between 2013 and 2026, with an annual growth rate of 8.82%, indicating rapid development in this field. During this period, 91 documents were published through 68 different sources, indicating a concentration on several major research platforms. Author collaboration was a dominant factor in this research, with a total of 324 authors, but only 12 authors contributed as sole authors. Most of the research involved team collaboration, with an average of 3.75 co-authors per document. International collaboration was recorded at 17.58%, indicating a global dimension to this research. A total of 386 keywords were used, enabling a more in-depth mapping of topics, while 790 references were used to support the validity of the research. The average age of the

documents was 2.76 years, indicating that most of this research is still highly relevant to current developments. In addition, this research also received significant attention with an average of 10.38 citations per document, indicating that this research has had a considerable impact on the academic community. (Figure 2).



Figure 2. Dataset Overview

Based on the graph in Figure 3, there is a significant fluctuation in the average citations per year in the publications studied. In 2019, there was a large spike in the number of citations, reaching more than 7 citations per document, reflecting a peak of interest or relevance to publications in that year. However, after 2019, citations per year declined sharply and tended to stabilise at around 2 to 3 citations per document in subsequent years. This decline may indicate that although research in 2019 received a high level of attention, interest in the topic has begun to wane in recent years, possibly due to shifts in research focus, the novelty of the topic, or newer publications capturing the attention of the academic community. This graph provides an overview of how citation trends in this literature can be influenced by external or internal factors, including thematic relevance and academic context outside the peak period.

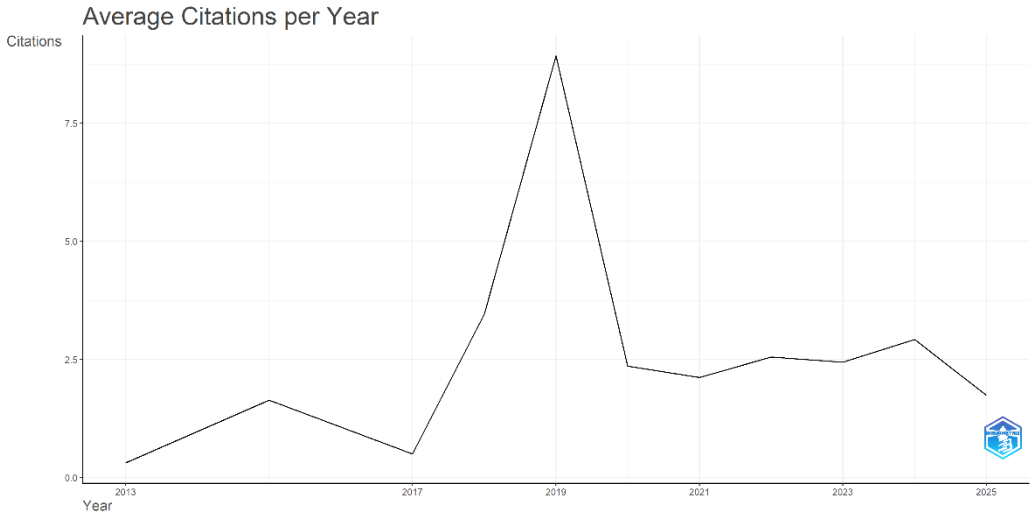


Figure 3. Average Citations Per Year

Research trend analysis

Based on the attached graph, the production of research sources from 2013 to 2026 can be seen, showing the accumulation of sources from various journals or related publications. At the beginning of the period (2013-2017), source production was relatively stagnant, with only a few journals appearing, as indicated by the flat line. However, since 2019, there has been a significant surge in the number of publications, with a sharp increase in the line, reflecting rapid growth in contributions from various research sources.

Certain journals or sources, such as the International Journal of Environmental Research and Public Health (green) and Sustainability (blue), show more consistent and significant growth from 2020 to 2025, indicating that topics related to health and sustainability are gaining greater attention. On the other hand, some sources, such as the European Journal of Business and Economics (purple), show sharper fluctuations with a surge in 2021 before reaching stability. Overall, this graph illustrates a clear trend, where certain topics in the fields of health communication, the environment, and sustainability have been growing since 2020, with the highest peak expected to occur between 2023 and 2025. This reflects a shift or increase in academic interest in these fields, with a strong possibility of a connection to global developments or significant events that influence attention to these topics.

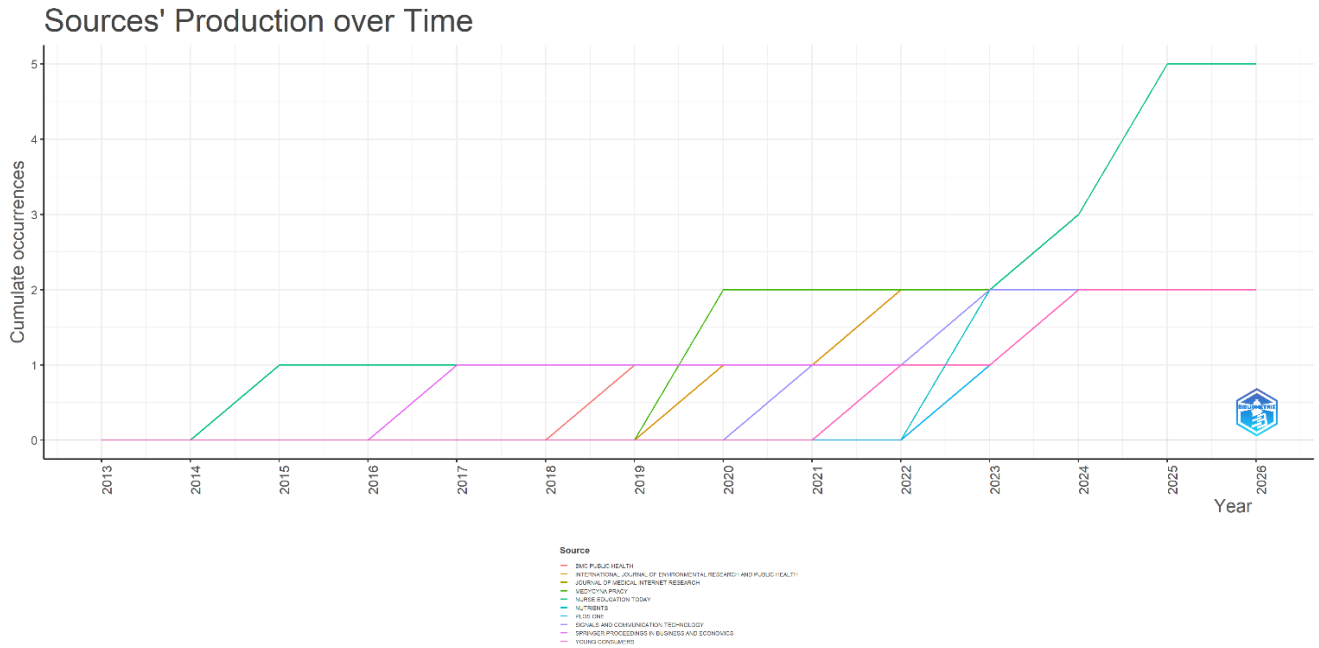


Figure 4. Sources' Production over Time

Most influential countries, affiliates, and productive authors

Based on the table presented in Table 3, it can be seen that the USA dominates in terms of publications related to this topic, with a total of 40 publications. Indonesia is in second place with 28 publications, indicating a significant contribution in this field. This is followed by Poland with 19 publications and Australia with 17 publications. Other countries such as South Korea, Greece, and Portugal have smaller contributions, with 14, 9, and 9 publications respectively. Meanwhile, the UK, China, and India are at the bottom with 7 publications each. These findings indicate that the USA has the greatest influence in research related to health communication and topics related to Generation Z, while other countries outside America and Indonesia have more limited but still significant contributions.

Table 1. Top Countries' Scientific Production

Country	Freq
USA	40
Indonesia	28
Poland	19
Australia	17
South Korea	14
Greece	9
Portugal	9
UK	8
China	7
India	7

Source: Author Data Processing from Scopus Database

Based on Figure 5, there is a list of the most relevant authors in this study based on the number of documents they produced. The most dominant authors, each with three documents, are Kamenidou I, Mamalis S, Mylon I, and Stavriane A. This shows that they have made a significant contribution to the total number of publications on this research topic.

Several other authors, such as Bieńkowski P, Bortkiewicz A, Fahmy HMA, Karpowicz J, Kieliszek J, and Lukman S, have only 1 or 2 documents, indicating that although they are involved in this research, their contributions are relatively smaller than those of the authors mentioned earlier. This graph provides insight into the main authors who have played a role in producing relevant literature on the topic of Generation Z health communication, with some authors showing greater involvement in this research.

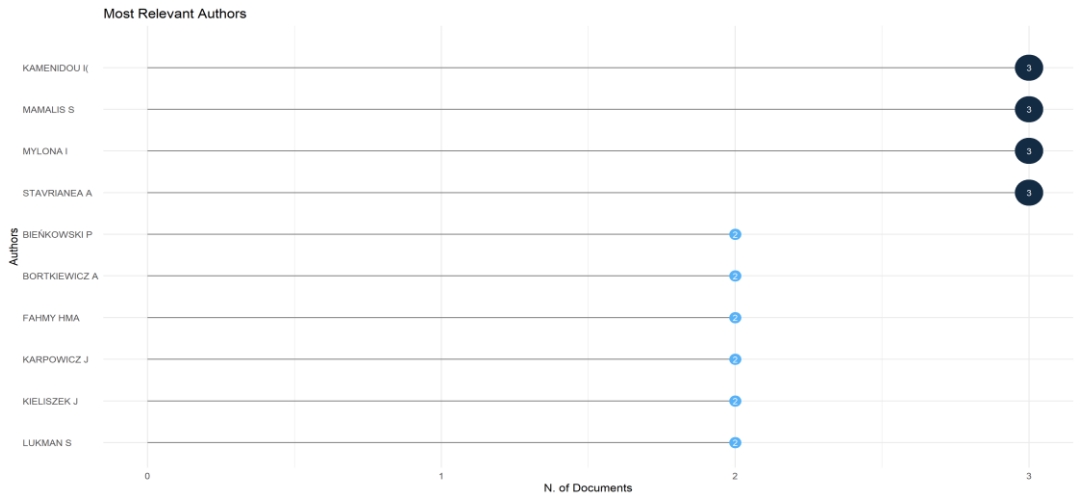


Figure 5. Most Relevant Authors

Based on the graph in Figure 4, the local H-index of several authors involved in this study can be seen. All authors listed, namely Bieńkowski P[18,19]Bortkiewicz A [20,21], Kamenidou I[12,22,23], Karpowicz J[24,25], Keiszek J, Lukman S, Mamalis S[26,27], Mylon I, Politański P[28,29], and Rydzyński K[30], have the same H-index, which is 2. This H-index indicates the local impact of these authors based on the number of publications that have been cited, which means that each author has at least two publications that have received two or more citations. This shows that although no author has a higher score, all authors in this graph have made a significant contribution to research, with an equal level of influence in the local context.

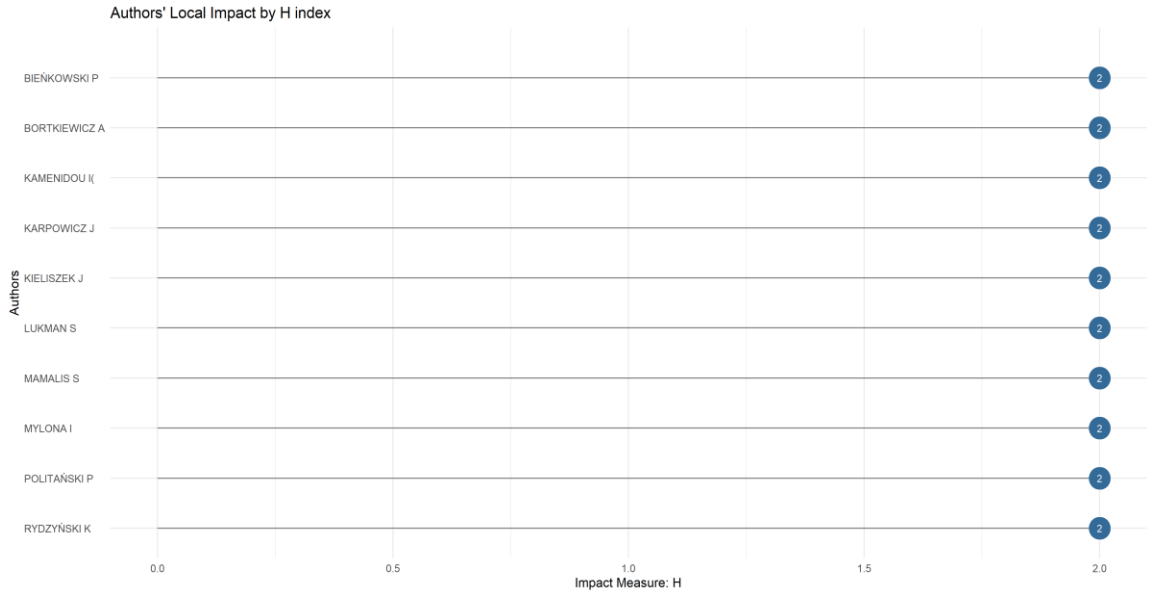


Figure 6. Author Local Impact H-Index

Citation analysis

Based on the graph in Figure 5, there is a significant fluctuation in the average citations per year from the publications studied. In 2019, there was a sharp increase in the number of citations, reaching more than 7 citations per document. This surge indicates a peak of interest or relevance to publications in that year. However, after 2019, citations per year declined dramatically and tended to stabilise at around 2 to 3 citations per document in subsequent years. This decline may indicate that although publications in 2019 received a great deal of attention, interest in the topic began to wane, possibly influenced by a large number of new publications focusing on fresher or more developing topics. This graph provides insight into changes in citation trends that may be related to the relevance or novelty of topics in the academic community.

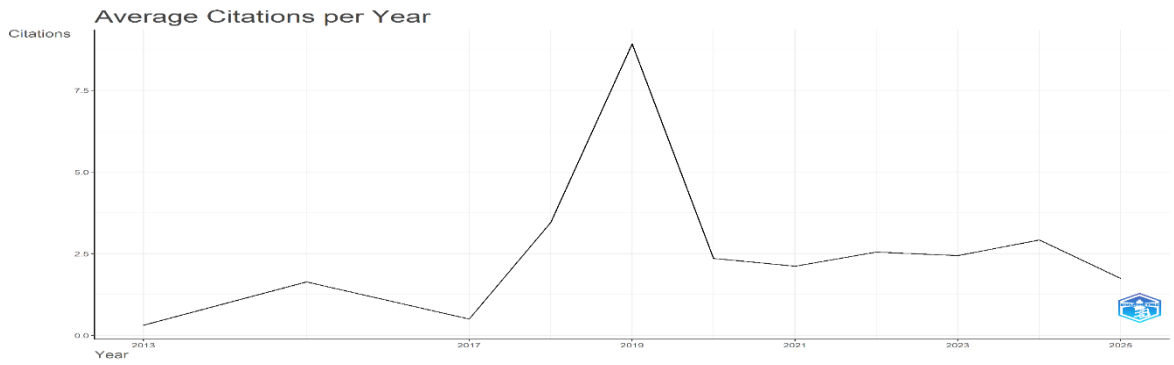


Figure 7. The top ten most cited documents

Based on Table 3, the USA recorded the highest number of TC (Total Citations) at 283, with an average of 23.60 citations per article. This shows that although the number of publications from the USA is higher, the average citation from these publications is relatively lower than that of Germany, which has the highest average citation of 67.30 despite having fewer publications, namely 202 TC. Other countries such as Australia (15.00 average citations), Greece (9.00), and Indonesia (4.20) also have lower average citations, reflecting differences in the impact or acceptance of their research at the international level. Countries with smaller contributions in terms of citation numbers, such as Korea and Pakistan, also show lower average citations (5.30 and 19.00, respectively). These findings show that Germany is the leader in terms of citation impact per article, despite having fewer publications than other countries such as the USA.

Table 2. Top Most Cited Countries

Country	TC	Average Article Citations	Freq
United States	283	23.60	16
Germany	202	67.30	16
Australia	45	15.00	16
Greece	36	9:00	16
Indonesia	34	4.20	16
Malaysia	25	12.50	16
Hungary	23	11.50	16
Pakistan	19	19:00	16
Korea	16	5:30	16

Topic analysis

Table 6 shows how often keywords related to Generation Z health research appear in the Scopus database. "Human" is the most common keyword, appearing in 53.20% of the articles. "Adolescent" comes in second with 45.78%, and "Female" comes in third with 43.90%. "Male" (43.31%), "Article" (42.59%), and "Humans" (37.50%) are some of the other most common keywords. This shows that there is a strong focus on studies centred on humans, especially those dealing with teenagers and health issues related to gender. Mental health is a significant part of this field, with the term "Mental Health" appearing in 31.83% of articles. Additionally, words such as "Psychology" (17.44%), "Depression" (16.28%), and "Youth" (12.21%) indicate growing concern about mental health in young people. The distribution also shows that study designs are a major focus, with terms such as "Major Clinical Study," "Controlled Study," and "Cross-sectional Study" appearing in many articles. This indicates that there is a great deal of research on Generation Z health, with a focus on mental health and the well-being of teenagers and young adults.

Table 3. Topic Trends

Term	Frequency	Year (Q1)	Year (Median)	Year (Q3)
Attitude of Health Personnel	7	2018	2018	2022
Health Personnel Attitude	7	2018	2018	2022
Baby Boomers	6	2020	2020	2022
Public Health	5	2020	2020	2022
Medical Education	6	2020	2020	2024
Education	5	2018	2018	2021
Article	25	2020	2020	2024
Interpersonal Communication	14	2020	2022	2024
Human Experiment	7	2018	2022	2024
Human	41	2020	2023	2024

Source: Author's data processing from the Scopus database

Based on Figure 6, there is a word cloud that illustrates the main keywords that frequently appear in research related to health communication and Generation Z. The words "human" and "humans" appear in very large sizes, indicating that topics related to human studies are the main focus of this research. "Generation Z" also appears as a dominant keyword, emphasising the importance of research focusing on this age group in the context of health communication. In addition, terms related to interpersonal communication, attitude of health personnel, public health, COVID-19, and survey/questionnaire also appear frequently, indicating that this research focuses heavily on individual behaviour, perceptions of medical personnel, and the use of survey methods to collect data. Other topics that emerged included social media, education, procedures, and human experiments, indicating that social media, education, and human experiments are important aspects of this research. Overall, this word cloud provides an overview of the topics that dominate health communication studies focusing on Generation Z, with an emphasis on behavioural, educational, and interpersonal communication aspects in the context of public health.

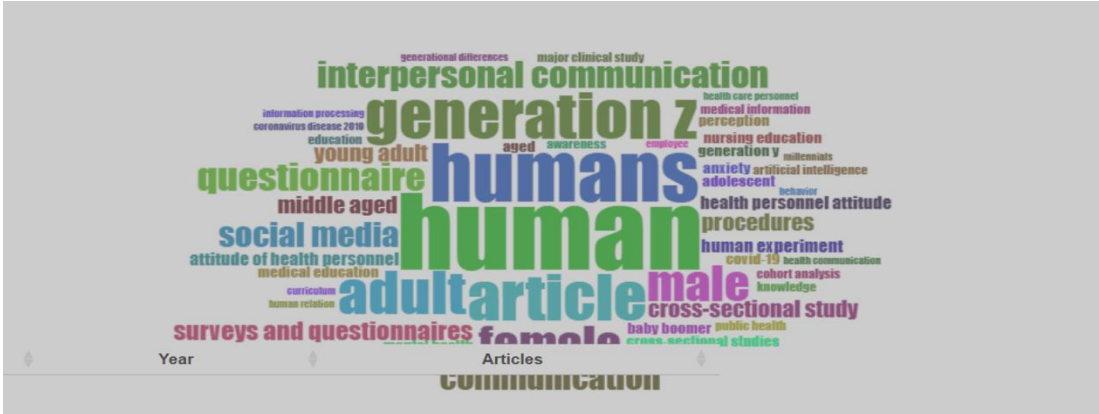


Figure 8. Word Cloud

Based on Figure 7, it can be seen that the most relevant keywords in this study are "human" and "humans", with 41 and 31 occurrences respectively, indicating that human-related topics are the main focus of this study. Furthermore, the term "article" appears 23 times, indicating that publications or articles related to this topic also receive significant attention. "Generation Z" appears 23 times, indicating that this age group is one of the main focuses in health communication studies. Other words that appear quite significantly are "adult" and "female", each with 23 occurrences, which shows the importance of the role of adult age groups and gender in this study. In addition, words such as "male," "questionnaire," "interpersonal communication," and "communication" were also recorded quite frequently, each with 11 to 18 occurrences. These findings illustrate that the focus of this study is on interpersonal communication, as well as studies of specific human groups, including gender and age groups, in the context of health communication.

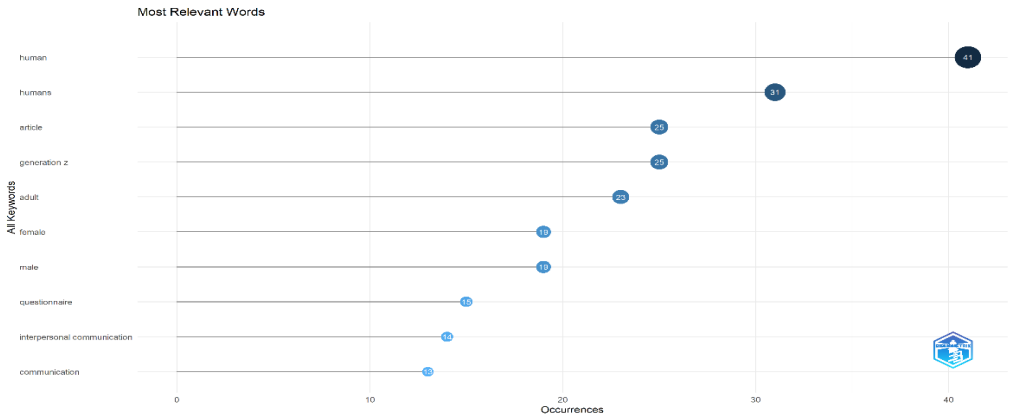


Figure 9. Most Relevant Words

DISCUSSION

This study reveals that health communication for Generation Z has undergone significant transformation in recent years, reflected in the rapid increase in publications and citations since 2020. One of the main patterns that emerged was the dominance of publications from the USA, with 40 publications, indicating this country's dominance in research related to Generation Z and health communication. However, although the USA had the highest number of publications, Germany had a higher average number of citations, indicating the greater quality and impact of its publications. This study also shows that 2020 was a major turning point, with a large number of publications emerging, possibly in response to the urgent need for health communication amid the COVID-19 pandemic. However, despite a surge in 2019, there was a subsequent decline in citations per document. This indicates saturation in certain topics or a shift in research focus towards topics that are more relevant to global changes and faster technological developments. This decline mayalso reflect a lack of sustainability of previously popular themes or the emergence of new topics that are more attractive to researchers and the academic community.

A more interesting finding is the concentration on several key sources such as the International Journal of Environmental Research and Public Health, which shows that although many publications have been produced, there are several key sources that are the focus of research in Generation Z health communication. This reflects that, although this research is growing rapidly, there is an imbalance in the distribution of publications across various journals or platforms. This opens up opportunities to disseminate more research to more diverse sources in order to reach a wider audience and increase the impact of future research.

search for health information than previous generations. However, our findings also reveal that despite greater access to information, Generation Z's level of health empowerment tends to be lower. This confirms the results of previous studies showing that digital health literacy and the ability to manage health information independently are determining factors in the successful adoption of health information by Generation Z. These findings add to the insight that even though they are more digitally connected, Generation Z still needs more training in digital health literacy to improve personal health management.

This study also expands on existing findings, such as the research by Kamenidou et al. (2020) which highlights the importance of social media in health communication. Social media is recognised as the main platform for Generation Z to obtain health information, and our research deepens this understanding by identifying how their interaction with health information on digital platforms shapes the way they respond to and manage their health. Overall, this study broadens our understanding of the role of digital media in disseminating health information, as well as the challenges faced by Generation Z in using this information for personal health.

The results of this study support the Digital Health Communication theory, which states that although digital technology provides greater access to health information, this is not always matched by a high level of empowerment. These findings confirm that greater access to health information through digital platforms does not necessarily improve individuals' ability to use that information effectively. Our research adds a new dimension to this theory by showing that although Generation Z is more exposed to technology and digital health information, they tend to lack the ability to assess the quality or relevance of this information, which impacts their health decisions.

Theoretically, these findings also enrich the Technology Adoption Theory in the context of digital health, by showing that although Generation Z has extraordinary technological capabilities, they have not yet fully adopted technology for personal health management. This shows that technology adoption in health communication does not only depend on individuals' ability to access information, but also on the availability of educational

support, the development of digital health literacy skills, and critical understanding of existing health information. This study also challenges the theory by showing that habitual factors and technological limitations can hinder the wider acceptance of health technology among Generation Z.

Practically, these findings have important implications for the development of more effective health communication strategies for Generation Z. To improve health empowerment, communication strategies must emphasise the development of digital health literacy, particularly in relation to the ability to assess and use health information found on digital platforms. Practices in the field should include digital-based education that helps Generation Z identify valid and relevant information, as well as provide them with better tools to manage their personal health. In this context, the results of this study provide a basis for designing digital health education campaigns that are more adaptive and based on the digital habits of Generation Z.

From a theoretical perspective, these findings enrich the health communication literature by providing insights into how existing theories, such as interpersonal communication theory and technology adoption theory, can be expanded and updated. This study shows that although these theories are quite relevant in explaining digital health communication, changes in digital dynamics require theoretical adjustments to better reflect the challenges and opportunities that exist in the use of technology for personal health. Thus, these findings open the door to the development of digital health communication theories that are more integrated with the needs and characteristics of Generation Z.

One limitation of this study is the limited data, which only covers literature indexed in large databases such as Scopus and Web of Science, which may not cover all relevant studies, especially those published in local journals or unindexed platforms. Furthermore, this study is also limited to secondary data and bibliometric analysis, which does not allow for a deeper exploration of social, cultural, or policy factors that may influence digital health communication for Generation Z in various regions. Therefore, further research that includes primary data and more in-depth field studies can provide richer insights into the contextual factors that influence the adoption of health communication among Generation Z.

CONCLUSION

This study examines Generation Z's health communication with a focus on digital health literacy and the use of social media in obtaining health information. The findings show that although the USA dominates in terms of the number of publications, Germany has the greatest influence in terms of citations per article, indicating the higher quality and impact of their publications. There was also a significant surge in publications in 2020, suggesting that the COVID-19 pandemic influenced academic interest in this topic. However, despite the increase in the number of publications, the average citations per article declined after peaking in 2019, indicating topic saturation or a shift in research interests. This anomaly illustrates that although the topic of Generation Z health communication is highly relevant, a new approach is needed in managing and publishing future research. This study enriches the literature by identifying new trends in author collaboration and research influence, and shows that digital health literacy is essential for improving Generation Z's health empowerment. However, there are several limitations, including a lack of field research and reliance on bibliometric data, which only covers indexed publications. Further research with primary data in various cultural contexts could deepen our understanding of the factors that influence technology adoption in health communication among Generation Z. Recommendations for future research include digital health literacy education and studies that combine social and cultural factors in health technology adoption.

DECLARATIOM

Conflict of Interest

None to declare.

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ORIGINAL RESEARCH

HISTAMINE RECEPTORS IN ORAL CANCER: MECHANISMS, CARCINOGENESIS, AND THERAPEUTIC POSSIBILITIES – A SYSTEMATIC REVIEW

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Abstract

Mast cells and their degranulation products play a key role in the pathogenesis of cancer, with histamine, being a key factor in carcinogenesis through its four distinct receptors. Research has shown that the expression of these receptors in malignant tissues triggers a variety of effects that modulate cancer cell behavior. However, there is lack of definitive evidence elucidating the precise mechanisms behind their involvement. This review aims to provide an overview of the current understanding of histamine receptors in oral carcinogenesis and highlight potential directions for future research in this field.

A literature search in Medline provided 27 articles for key terms, histamine receptors and oral cancer. Eight articles relevant to the search terms conducted studies on expression of histamine receptors in oral cancer.

The present review indicated a strong role of histamine receptors in oral carcinogenesis and suggests to generate new evidence on high scales. Therapeutic interventions employed in the form of inhibitors for these receptors may provide a promising breakthrough in cancer management.

Key words: Histamine receptors, oral cancer, carcinogenesis, therapeutic outcome

INTRODUCTION

Oral cancer, the most common form in the head and neck region, has high mortality and early metastasis due to late detection and diagnosis. Younger population being at higher risk of oral cancer, it has become a serious public health concern ranking at number six in global cancer burden. The percentage of 5-year survival varies from 40-50% in oral malignancies. Currently, it is revealed that not only tumor cell itself, but also the tumor microenvironment plays a role in growth and survival of cancer cells. Immune cells like mast cells and macrophages found in tumor microenvironment, can secrete several cytokines, chemokines, growth factors and enzymes.[1,2]

Expressions of mast cells in the tumor microenvironment of oral cancer have underlined their role as a principal player in the pathogenesis of oral cancer.[3,4] Various enzymes and bioactive molecules in mast cells are found to be participating in the pathophysiology of oral cancer. Histamine, one of the active cellular molecules, has been studied over a few decades for its role in various physiological and pathological processes, including immune responses, inflammation, and regulation of gastric acid secretion. It can modulate cell proliferation and modulation of different normal and tumorous tissues.[5,6] Its effects are mediated through four distinct receptors labelled as H1R through H4R, each playing a role in different cellular and tissue responses. Moreover, histamine has highly drawn the attention due to its implications in cancer development and metastasis. Recent studies have highlighted the significance of histamine and its receptors in carcinogenesis of various cancers including oral squamous cell carcinoma (OSCC).[7,8]

The literature reveals that the H1 receptor has been associated with advanced stages of tumor and may be implicated in the promotion of oral carcinogenesis while H2 receptor shows overexpression.[9] Nonetheless, little is known about the role of histamine and its receptors in

OSCC, although few studies with limited sample sizes and a lack of animal studies to generate evidence for expression of histamine receptors in oral cancer.[8, 10] This review explores the literature contemplating objectives like molecular mechanisms of histamine receptor signaling, their interactions with carcinogens, and potential therapeutic implications, elucidating the findings from the published data on oral cancer.

MATERIAL AND METHODS

This systematic review refers to PRISMA guideline following searches from Medline/PubMed, ScienceDirect, and EBSCOhost using advanced search features with keywords based on Medical Subject Headings (MeSH) guideline with predetermined screening and eligibility criteria.

Search strategy

A research question was formulated as follows: do histamine receptors play potential role in the pathogenesis of oral cancer? To address the research question, an extensive search was conducted on Medline/PubMed, ScienceDirect and EBSCOhost using the terms “histamine receptors” and “oral cancer.” The search, guided by MeSH terms, revealed a comprehensive set of search words: ("receptors, histamine"[MeSH Terms] OR ("receptors"[All Fields] AND "histamine"[All Fields]) OR "histamine receptors"[All Fields] OR ("histamine"[All Fields] AND "receptors"[All Fields])) AND ("mouth neoplasms"[MeSH Terms] OR ("mouth"[All Fields] AND "neoplasms"[All Fields]) OR "mouth neoplasms"[All Fields] OR ("oral"[All Fields] AND "cancer"[All Fields]) OR "oral cancer"[All Fields]). A total of 27 articles were initially identified in Medline while two articles appeared in EBSCOhost.

Screening process

All the 27 articles were read carefully for language, full-text availability and specific for the research question. After thoroughly reviewing the abstracts to recognize the relevance of the search terms, eight articles were ultimately selected for inclusion in the review. The excluded articles comprised of three reviews, 16 studies were regarding other malignancies (e. g. colorectal, bladder and pancreatic cancers) and on allergic and inflammatory responses towards the histamine receptors (Figure 1).

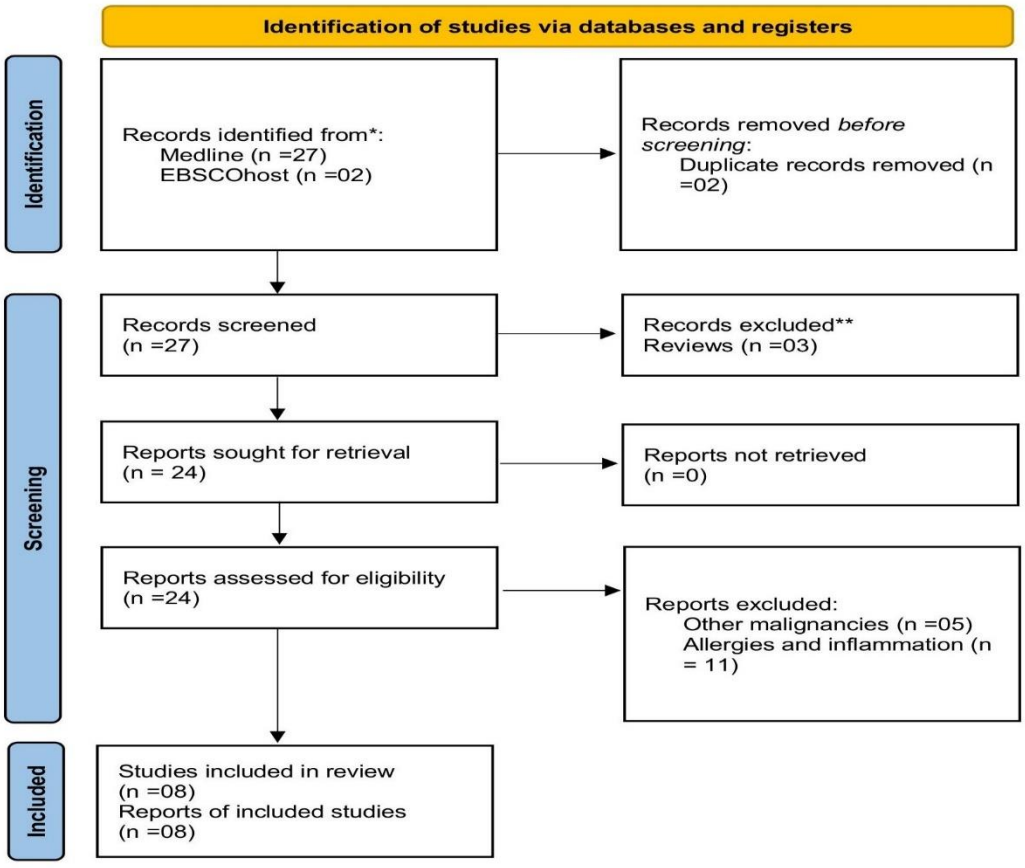


Figure 1 Flowchart illustrating the sequence of article selections for the review

RESULTS

The selected eight articles were read carefully to identify the details about the studies conducted on various histamine receptors in oral cancer. Five studies included oral squamous cell carcinoma [11-15] while one study was particularly about OSCC involving tongue.[16] Two studies were conducted on evaluation of photodynamic treatment in context to histamine receptors. [17, 18] The main objectives, findings, and inferences from each study to provide a clear overview of the Histamine receptors related oral cancer research and/or treatment were summarized (Table 1).

Table 1: Summary of the key inferences from the studies included in the review

Author	Key Findings	Inference
Ding et al. (2022)[11]	H1R gene polymorphism is associated with lower risk of developing advanced tumor stages in betel-quid-chewing patients.	H1R genetic variants may influence tumor progression, with gene morphism linked to the tumor size and clinical staging.
Kimura et al. (2022)[12]	Histamine receptors co-expressed with chemokine ligands. Tumor depth invasion affected histamine expression	Histamine influenced tongue SCC through histamine receptors and chemokines affecting tumor microenvironment.
Kon et al. (2022)[13]	Effect of epigallocatechin gallate on histamine receptors in four oral cancer cell lines.	There was stimulation of histamine production and decreased H1R expression in those cell line.
Salem et al. (2017)[16]	H4R expression was reduced in tongue SCC and oral epithelial dysplasia.	Possible association between HR and oral carcinogenesis through histamine-mediated factors in the regulation of oncogenes.
Parihar et al. (2013)[18]	Confirmation of histamine receptor over-expression in tumor mass. Photodynamic treatment led to regression of tumors up to 1000 mm^3.	Conjugating histamine to chlorin can improve tumor targeting and enhance Photodynamic treatment efficacy in oral cancer.
Grimm et al. (2013)[14]	H1R expression was rare in OSCC but associated with advanced tumor stages. Patients with H1R expression had poorer disease-free survival.	H1R may serve as a prognostic marker for OSCC, with higher expression linked to poorer survival outcomes. Activation of H1R may promote carcinogenesis in OSCC.
Parihar et al. (2011)[17]	Cp6-histamine showed 10x higher cellular uptake than Cp6, with higher phototoxicity in oral cancer cell lines.	Conjugating Cp6 with histamine enhances its uptake and phototoxicity, making it a promising approach for improving PDT in oral cancer.
Arai et al. (2002)[15]	Both bradykinin and histamine enhanced calcium ion influx, but only histamine's effect was inhibited by H1 receptor antagonists.	Histamine activates calcium influx in oral cancer cells through H1 receptors, which may play a role in tumor progression.

DISCUSSION

Histamine is a biogenic amine that plays a crucial role in various physiological processes, including immune responses, allergic reactions, and neurotransmission. It exerts its effects through binding to four types of receptors: H1, H2, H3, and H4. These receptors are G protein-coupled receptors found on various cell types, including those within the oral cavity. Recent research highlights the involvement of histamine receptors in the pathophysiology of oral cancer, especially OSCC, with significant implications for cancer development, progression, and potential therapeutic strategies.[6,8,9]

Molecular Mechanisms of Histamine Receptor Signalling:

The key aspects of molecular mechanisms of these receptors in cancer, specifically in relevance to OSCC, are as following:

H1 Receptor is principally involved in mediating allergic responses but also plays a significant role in cell proliferation, migration, and inflammation in cancer. Histamine activation of the H1 receptor has been linked to the regulation of signaling pathways such as PI3K/Akt and MAPK, both of which are involved in promoting tumor growth and metastasis.[14] H1 receptor activation has been associated with increased vascular permeability and immune cell infiltration, which can facilitate tumor progression.[8,16] In OSCC, H1 receptor expression has been correlated with poor prognosis, suggesting its potential as a prognostic marker.[14]

H2 Receptor is known for its role in gastric acid secretion, but in cancer, it has been implicated in immune modulation and cell survival. Histamine

signaling through the H2 receptor can inhibit apoptosis and promote tumor cell survival through activation of the cAMP-PKA pathway.[8,10] Studies suggest that the H2 receptor contributes to immune evasion by modulating the activity of immune cells, such as T-cells and macrophages, within the tumor microenvironment.[12]

H3 Receptors are primarily involved in the regulation of neurotransmitter release and regulates the synthesis and release of histamine, have also been found to play a role in tumor biology. Although not studied in the context of OSCC, evidences suggest that H3 receptor is expressed in numerous types of tumors and is associated with tumor cell proliferation, migration and invasion. [19,20]

H4 Receptor is expressed on immune cells, has emerged as a critical regulator in inflammation and immune responses within the tumor microenvironment. In OSCC, H4 receptor signaling has been shown to promote tumor progression by facilitating immune cell recruitment and influencing angiogenesis. To be precise, H4R signaling enhances the inflammatory milieu, which may facilitate the development and progression of OSCC.[16]

Interactions Between Histamine Receptors and Carcinogens

Histamine receptors, especially the H1 and H4 subtypes, are involved in the cellular response to carcinogenic agents, particularly environmental and chemical carcinogens. One of the key factors influencing oral carcinogenesis is the exposure to environmental carcinogens, such as tobacco smoke, alcohol, and certain occupational chemicals.

Histamine and Environmental Carcinogens*:* Ding et al.[11] examined the combined effects of histamine receptor H1 gene polymorphisms and exposure to environmental carcinogens on OSCC susceptibility. Their findings indicate that genetic variations in the H1 receptor may modulate the response to carcinogen exposure, thereby influencing tumor development. This suggests that histamine receptor genetic polymorphisms may serve as potential biomarkers for OSCC risk and progression, particularly in individuals exposed to carcinogens.[11]

Histamine and Tumor Microenvironment*:* Kimura et al.[12] explored the role of histamine in modulating the chemokine balance in the tumor microenvironment of squamous cell carcinoma of the tongue. Histamine released in response to tumor-induced inflammation may alter the immune cell composition within the tumor, enhancing tumor cell survival and metastasis. Histamine's ability to influence chemokine production and immune responses underscores its potential as a therapeutic target in managing OSCC progression.[12]

Epigallocatechin Gallate (EGCG) and Histamine: Kon et al.[13] studied the effects of EGCG, a compound found in green tea, on histamine production and histamine receptor expression in oral cancer cell lines. EGCG was found to stimulate histamine production and downregulate the H1 receptor, which could alter the response of OSCC cells to external stimuli. This finding suggests that dietary compounds such as EGCG might modulate histamine receptor expression and contribute to oral cancer prevention or therapy.[13]

Therapeutic Implications of Histamine Receptor Modulation

The involvement of histamine receptors in OSCC may provide novel opportunities for therapeutic interventions. Both receptor antagonists and agonists have potential roles in the treatment of OSCC.

Histamine Receptor Antagonists*:* Targeting histamine receptors with specific antagonists could mitigate tumor growth and metastasis. For instance, H1 receptor antagonists could reduce tumor-associated inflammation and prevent immune cell infiltration, potentially improving the therapeutic outcomes in OSCC patients. H2 receptor antagonists, commonly used for gastric acid disorders, might be repurposed to target immune modulation in the tumor microenvironment, enhancing anti-tumor immunity.[8,16]

Photodynamic Therapy with Histamine Conjugates: Parihar et al. explored the use of chlorin p6-histamine conjugates in photodynamic therapy (PDT) for OSCC. By enhancing cellular uptake and phototoxicity, these conjugates may offer a novel therapeutic strategy. The conjugation of histamine to a photosensitizer could increase the selectivity and efficacy of PDT, particularly in targeting cancer cells that overexpress histamine receptors.[17,18]

Histamine and Immune Modulation*:* The potential of histamine receptor modulation in enhancing anti-cancer immune responses is another promising avenue for OSCC therapy. Perhaps, H4 receptor antagonists may offer a strategy for controlling inflammation and modulating the tumor immune scenario, making it more responsive to immunotherapies.[16]

In summary, histamine receptors, predominantly H1, H2, and H4, play multifaceted roles in oral cancer progression. They influence tumor cell behavior, immune cell modulation, and therapeutic efficacy. Genetic variations in histamine receptor genes, histamine receptor expression in the tumor microenvironment, and receptor-targeted therapies offer promising strategies for improving the management of oral cancers, highlighting the importance of histamine signaling in the pathogenesis and treatment of OSCC and possibly head and neck related malignancies.

CONCLUSION

Histamine receptors play a crucial role in the molecular mechanisms in pathogenesis of OSCC, particularly in the regulation of tumor growth, immune and environmental carcinogenic responses. It was found that H1, H2, and H4 receptors are involved in various signaling pathways that influence tumor progression,

making them potential therapeutic targets. Further research into histamine receptor genetics, their interactions with various carcinogens, and the development of receptor-specific therapies will be essential in advancing the treatment and prevention of OSCC. The modulation of histamine receptors, either through their antagonists, agonists, or coupled therapies, embraces promise for improvement in patient outcomes and providing novel treatment opportunities in the fight against oral cancer.

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Authors declare that there is no conflict of interest

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ORIGINAL RESEARCH

COMPARATIVE ASSESSMENT OF THE EFFICACY OF TWO TECHNIQUES OF INDIRECT BRACKET POSITIONING ON TREATMENT OUTCOME IN EXTRACTION CASES OF CLASS I MALOCCLUSION

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Abstract

Background: Accurate bracket positioning is crucial in orthodontics to achieve desired tooth movement. Two primary techniques exist: direct bonding, where brackets are attached directly to teeth, and indirect bonding, which utilizes a transfer tray. There is limited evidence comparing the clinical efficacy of conventional indirect bonding (CIB) versus digital indirect bonding (DIB), particularly in Class I malocclusion cases requiring extraction treatments.

Aim: To compare the efficacy of CIB and DIB in patients with Class I malocclusion undergoing extraction orthodontic treatment.

Methods: In a randomized controlled trial, 28 patients with Class I malocclusion scheduled for extraction orthodontic treatment were randomly assigned to either the CIB or DIB group. Both groups underwent initial impressions to create plaster models. In the CIB group, brackets were positioned on the plaster models and transferred to the teeth using a vacuum-formed transfer tray. In the DIB group, plaster models were scanned to create 3D digital models, and brackets were positioned and transferred using a 3D-printed tray. Baseline assessments included the discrepancy index, and treatment outcomes were evaluated using the Objective Grading System (OGS).

Results: The CIB and DIB groups were comparable in terms of median age (20 vs. 21, P=1.000) and gender distribution (71.4% vs. 57.1% male, P=0.695). Baseline discrepancy index scores were similar between groups (22 vs. 30, P=0.653). There was no significant difference in median total OGS scores between the CIB and DIB groups (14 vs. 12, P=1.000).

Conclusion: Both conventional and digital indirect bonding techniques are effective for bracket positioning in the extraction orthodontic treatment of patients with Class I malocclusion**.**

Keywords: extraction orthodontic treatment, Class I malocclusion, indirect bracket positioning, conventional indirect bonding, digital indirect bonding

INTRODUCTION

Orthodontics aims to achieve optimal functional occlusion, facial harmony, and long-term stability while enhancing aesthetics and supporting overall oral health; this is achieved through positioning the teeth into the best functional balance.

To reach that, Orthodontists continually look for new products and procedures that can simplify their practice, increase clinical effectiveness, and improve patient experience. By far the most commonly used appliance in fixed orthodontic treatment is the orthodontic brackets1.

From the advent of pre-adjusted edgewise appliances, researchers and clinicians have focused on improving the efficiency of aligning malpositioned teeth with minimal wire bending. Pre-adjusted edgewise appliances have provided orthodontists the ability to achieve a gradual progression towards finishing, rather than an abrupt stage of wire bending as in the standard edgewise technique[2].

The use of pre-adjusted bracket systems is based on the concept that ideal bracket placement will correct tooth positions in all the three planes of space during treatment with placement of straight archwires. As regards efficient finishing, ideal bracket placement from the onset of treatment should be the goal for every practicing orthodontist[3].

There are numerous techniques regarding the bonding of the brackets, including direct and indirect bonding techniques. Indirect bonding method became very popular after it was first described by Silverman and Cohen in 1972[4].

There are various techniques of indirect bonding, according to bracket base preparation (standard or

customized), transfer mask type (single jigs or full arch) and transfer tray material (acrylic resin, silicone, thermo-printed material)[5-7].

In terms of utilization, Gorelick reported that only 17 percent of orthodontists used indirect bonding in their practice. Although the technique of indirect bonding has become more accepted in recent years due to advances in materials and development of new techniques, the majority of orthodontists still utilize the direct bonding method[8].

The uncertainties inherent in the transfer could present a problem for clinicians using the indirect method because bracket positioning has a direct influence on both the magnitude and direction of tooth movement. Improperly positioned brackets lead to inefficiencies in initial bracket leveling, alignment and, ultimately, longer treatment times. This is especially true when the clinician assumes that each bracket has been transferred precisely as originally placed on the stone or digital models. When the clinician later recognizes malpositioned brackets, they must either be repositioned or archwire adjustments need to be made, which often negate the efficiencies gained by bonding indirectly at the onset of treatment [7-9].

The evolution of imaging techniques has opened new horizons for both diagnosis and treatment. Recent imaging techniques have allowed complete visualization of the tissues in 3 dimensions[10]. Cone-beam computed tomography (CBCT) has proven to have great diagnostic value, with the ability to produce accurate images of the patient's soft and hard tissues [10–12].

Recently, computer-aided design and computer- aided manufacturing (CAD/CAM) systems have been used for indirect bonding. This process involves designing a virtual model in a CAD/CAM program to produce a transfer jig. The CAD/CAM transfer jig facilitates bonding of the bracket to the target tooth[13-15]. For instance, 3-dimensional (3-D) modeling of the maxilla and the mandible has been used for the ideal setup and the rapid production of prototype transfer jigs. These would, subsequently, be involved in the transfer of brackets with individualized custom resin bases.

Over the years, several in-vitro and in-vivo studies have compared direct and indirect bonding techniques.

To the best of our knowledge, no studies compared the digitally positioned brackets to the conventionally manual indirect bonding technique. Thus, it seems important to compare the effect of digital and conventional indirect bonding techniques on the outcome of orthodontic treatment. Studying the clinical variables, which are affected by these different bonding techniques in orthodontic treatment, might help clinicians choose the best method for bracket bonding.

The present work will therefore aim to compare efficiency of bracket positioning in extraction orthodontic treatment of Class I malocclusion patients with two techniques of indirect bonding.

METHODS

This was an interventional prospective randomized controlled study. A total of 28 patients with Class I malocclusion who were scheduled for extraction orthodontic treatment were included. The patients were randomly assigned to receive either CIB or DIB.

Before commencing the study, the approval of the Research Ethics Committee (REC) of the faculty of Dentistry, Suez Canal University was obtained, and a written informed consent was signed by all the included subjects.

No prior studies have compared OGS outcomes between these specific digital and conventional indirect bonding techniques. Therefore, an a priori sample size calculation was conducted using variability estimates from a previous study evaluating OGS scores [16]. Based on a standard deviation of approximately 2.5, a significance level (α) of 0.05, and a power of 80%, it was determined that 14 subjects per group (28 total) were required to detect a clinically significant difference.

Patients were included in the study if they fulfilled the following criteria: age between 18 and 40 years, with permanent dentition (excluding third molars), bilateral Angle's Class I molar relationships, without skeletal discrepancy or history of previous orthodontic treatment.

Impressions of the patient's teeth were obtained and used to create plaster models in both groups. In the CIB group, the brackets were then positioned on the plaster models and transferred to the patient's teeth using 1 mm vacuum formed transfer tray as shown in **Figure 1**. In the DIB group, digital scans of the plaster models were scanned using a laboratory scanner 3Shape R500 to create 3D digital models. The brackets were then positioned virtually on the 3D models using 3Shape OrthoAnalyzer, and transferred to the patient's teeth using a 3D-printed transfer tray with biocompatible resin, as shown in **Figure 2**. Treatment outcomes were assessed using the Objective Grading System (OGS) on post-bonding dental casts. The assessed OGS parameters included alignment, marginal ridges, buccolingual inclination, occlusal contacts, occlusal relationships, overjet, interproximal contacts, and root angulation[17].



A



B



C

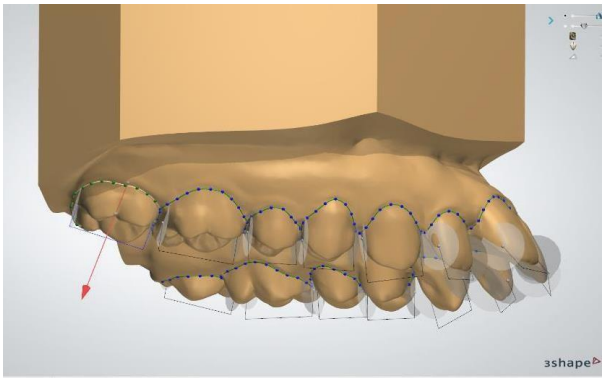


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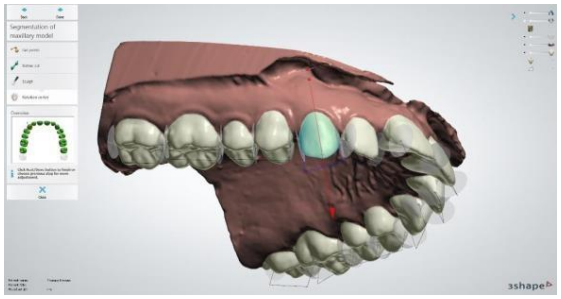
Figure 1. Conventional indirect bonding technique: positioning of the brackets on dental cast according to positioning guidelines; B, transfer tray formation; C, transfer tray; D, intra-oral view of indirect bonding.



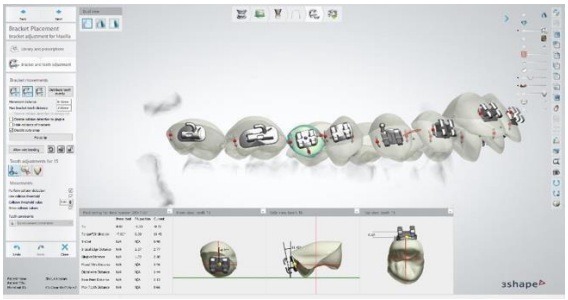
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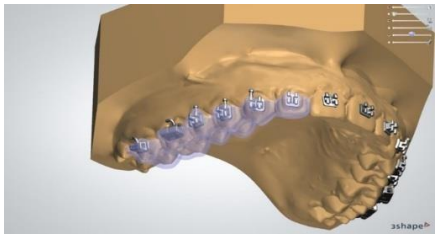
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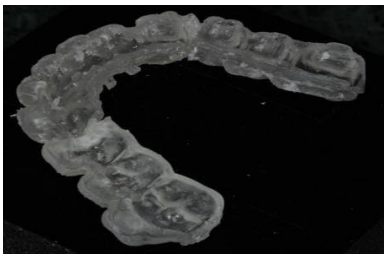


C



D


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Figure 2. Digital indirect bonding technique: A, Lab scanner 3Shape R500; 3Shape OrthoAnalyzer software defining the gingival margins (B), long axes (C); D, bracket adjustment on software; E, Constructed virtual transfer tray ready for printing; F, transfer tray; G, loading the brackets; H, intra-oral teeth etching; transfer trays installed in patient's upper (I) and lower (J) arches; K, intra-oral brackets after removal of trays.

Fixed appliances consisted of 0.022-inch slot brackets with an MBT prescription (Rocky Mountain Orthodontics, Denver, CO, USA). To minimize bias, all patients were bonded by a single operator to ensure consistency, the OGS scores were evaluated by an independent examiner blinded to the group allocation. Data were analyzed using the IBM SPSS Statistics for Macintosh, Version 26.0 (IBM Corp, Armonk, NY, USA). Qualitative data were presented as frequency and percentage, while qualitative data were presented as median and interquartile range (IQR). The non-parametric Mann-Whitney U test (Wilcoxon rank-sum test) was used to compare the distributions of the studied variable between the conventional and digital groups. The association between categorical variables was assessed using the chi-square test. The Fisher's exact test was used if any of the observed or expected values is less than 5. A two-sided P (probability) value less than 0.05 was considered significant in all analyses.

RESULTS

The results of this study highlight the comparative effectiveness of CIB) and DIB techniques in orthodontic treatment, specifically focusing on key treatment outcomes assessed using the OGS.

Demographic and Baseline Characteristics

The study included 28 patients diagnosed with Class I malocclusion, randomly assigned to either the CIB or DIB group. The demographic characteristics were well-balanced between the two groups, with median ages of 20 years (CIB) and 21 years (DIB), showing no statistically significant difference (P=1.000). Gender distribution was also comparable, with males comprising 71.4% of the CIB group and 57.1% of the DIB group (P=0.695). Baseline discrepancy index scores, which reflect the initial complexity of malocclusion, were similar between the groups, with median scores of 22 for CIB and 30 for DIB (P=0.653) **(Table 1)**.

Table 1. Comparison of baseline and outcome characteristics between the studied groups

	Conventional	Digital	P
Males*	10 (71.4)	8 (57.1)	0.695
Age	20 (3.5)	21 (4)	1.000
Discrepancy index	22 (5.5)	30 (15.5)	0.653
OGS			
Alignment	2 (1.5)	2 (1.5)	0.462
Marginal ridge	2 (2.5)	2 (1)	1.000
Buccolingual inclination	2 (1.5)	2 (1)	0.192
Occlusal contacts	3 (2)	2 (0)	0.266
Occlusal relationship	0 (1)	0 (0.5)	1.000
Overjet	2 (1.5)	2 (2)	1.000
Interproximal contacts	0 (1)	0 (0.5)	1.000
Root angulation	1 (1)	2 (1)	0.266
Total OGS	14 (6.5)	12 (3)	1.000

*Data are presented as number and (percentage), while other data are median and (interquartile range).

Objective Grading System (OGS) Scores

The primary outcome measure, the total OGS score, was used to evaluate the effectiveness of both bonding techniques in achieving desirable orthodontic results. The median total OGS score was 14 for the CIB group and 12 for the DIB group, with no statistically significant difference observed between the two (P=1.000) **(Table 1, Figure 3)**. This suggests that both techniques are equally effective in achieving high-quality orthodontic outcomes.

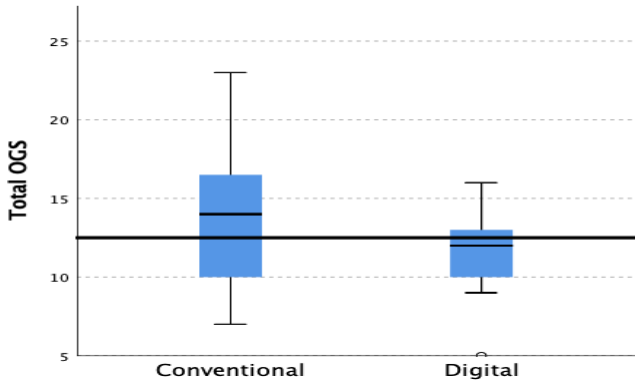


Figure 3. Total OGS in conventional and digital indirect bonding group

Component Analysis of OGS Scores

To gain deeper insights into the performance of CIB and DIB, we analyzed the individual components of the OGS as detailed in **Table 2**. The following sections discuss the results for each component.

Table 2. Outcome assessment of orthodontic treatment in the studied groups using the Objective Grading System

	Conventional	Digital	P
Alignment	2 (1.5)	2 (1.5)	0.462
Marginal ridge	2 (2.5)	2 (1)	1.000
Buccolingual inclination	2 (1.5)	2 (1)	0.192
Occlusal contacts	3 (2)	2 (0)	0.266
Occlusal relationship	0 (1)	0 (0.5)	1.000
Overjet	2 (1.5)	2 (2)	1.000
Interproximal contacts	0 (1)	0 (0.5)	1.000
Root angulation	1 (1)	2 (1)	0.266
Total OGS	14 (6.5)	12 (3)	1.000

Data are median and (interquartile range).

1. **Alignment**: Both groups achieved similar outcomes in terms of alignment, with median scores of 2 for both CIB and DIB groups (P=0.462).
2. **Marginal Ridge**: Both techniques demonstrated similar effectiveness regarding the marginal ridge scores were also comparable, with median values of 2 for both groups (P=1.000).
3. **Buccolingual Inclination**: Buccolingual inclination, which assesses the angular position of the teeth in the buccolingual direction, showed no significant difference between the groups, with median scores of 2 for both (P=0.192).
4. **Occlusal Contacts**: The occlusal contact scores, which evaluate the precision of tooth contacts in the occlusal plane, were slightly better in the DIB group (median score of 2) compared to the CIB group (median score of 3), though this difference was not statistically significant (P=0.266).
5. **Occlusal Relationship**: Both groups achieved near-perfect occlusal relationships, with median scores of 0 in both groups (P=1.000).
6. **Overjet**: The overjet, which measures the horizontal overlap of the front teeth, showed identical outcomes in both groups, with median scores of 2 (P=1.000).
7. **Interproximal Contacts**: The integrity of interproximal contacts was well-maintained in both groups, with median scores of 0, indicating no gaps or discrepancies between teeth (P=1.000).
8. **Root Angulation**: Lastly, the root angulation scores, which assess the positioning of the tooth roots, were similar between the groups, with a median score of 1 for CIB and 2 for DIB (P=0.266).

DISCUSSION

Currently, the accuracy of bracket bonding is a key and difficult component to achieve successful and efficient orthodontic treatment outcomes. To achieve more exact and precise bracket insertion, the indirect bonding process has been devised. Indirect bonding has been researched over time to strengthen the bonding of fixed orthodontic equipment[18].

The indirect bonding procedure was developed to achieve more exact and precise bracket insertion. Over time, indirect bonding has been studied to improve the accuracy of the bonding of fixed orthodontic appliance[18].

Digital technology has, as is widely known, invaded all elements of orthodontics, including diagnostic tools, treatment planning, appliance production, and 3D printing; Botsford et al. asserted that intraoral scanning-based software and virtual 3D occlusal records in biting registration provided clinically adequate precision when obtaining contact size and location[19].

Furthermore, developments in digital technology have enabled the combination of tomographic scan data with digital models to visualize tooth roots in scanned casts and enable correct bracket location[20]. Digital process combining intraoral scanners and CAD-CAM software enabled virtual setup, printing of 3D models, and digital transfer trays for indirect bonding[21,22].

To our knowledge, no studies have directly compared digitally positioned indirect bonding to conventional manual bonding. Examining the clinical outcomes of these techniques could guide clinicians in choosing the best bracket bonding method.

Regarding demographic data, there was comparable data between both groups for gender and age. All patients in each group were treated by the same operator using the same kind of brackets and the same treatment protocol.

This allowed us to maintain consistency while determining the effects of these bonding methods in orthodontic treatment.

Both techniques have demonstrated their effectiveness in achieving desirable clinical outcomes, as evidenced by comparable OGS scores across key parameters such as alignment, marginal ridges, and occlusal relationships. According to the ABO's standard, a total OGS score of less than 20 points indicated a successful orthodontic treatment[17]. In this study, the median OGS scores were 14 for the CIB group and 12 for the DIB group, with no statistically significant difference ($P > 0.05$), both comfortably below the threshold of 20. This is consistent with the findings of Yıldırım and Saglam-Aydinatay, who compared direct and indirect bonding techniques in non-extraction orthodontic treatment for Class I malocclusion patients, reporting median OGS scores of 14 for indirect bonding and 17 for direct bonding[23].

Based on our data and the findings of Yıldırım and Saglam-Aydinatay[23], successful clinical outcomes were achieved with both techniques. However, patients who underwent indirect bonding had lower total OGS scores due to lower marginal ridge scores, which were linked to better treatment outcomes. In our study, there was no statistically significant difference in marginal ridge scores between the two indirect techniques, with both groups having a median score of 2. This aligns with the findings of Soares Ueno et al., who reported no significant difference between conventional and digital indirect bonding techniques regarding marginal ridge scores, with both methods scoring 1.4[24]. This is also consistent with Yıldırım and Saglam-Aydinatay[23], where the indirect bonding group also had a marginal ridge score of 2.

This suggests that the indirect bonding technique is more effective in leveling the marginal ridges, which is crucial for achieving proper occlusal contacts and maintaining a flat bone level between adjacent teeth in periodontally healthy patients[17]. The low marginal ridge scores observed in both techniques in our study may indicate better vertical positioning of brackets with the indirect bonding technique. The vertical height of brackets is key to determining marginal ridge levels and contact points, and correct vertical positioning promotes appropriate occlusal contacts[2].

In line with our study findings, Brown et al. compared the clinical effectiveness and efficiency of CAD/CAM customized orthodontic appliances with direct and indirect bonded stock brackets [25]. The study included three treatment groups: group 1 with direct-bonded self-ligating appliances, group 2 with indirect-bonded self-ligating appliances, and group 3 with CAD/CAM indirect-bonded self-ligating appliances. The study found no statistically significant differences in the discrepancy index or ABO Cast-Radiograph Evaluation across the groups.

Theoretically, indirect bonding could reduce the need for compensatory archwire bends and repositioning of brackets by increasing accuracy in bracket positioning.

The comparable outcomes across multiple OGS components suggest that both CIB and DIB are versatile and reliable options. For practices with access to advanced digital tools, DIB offers advantages in integration with other digital workflows, potentially enhancing precision, overall treatment efficiency and patient experience.

While the findings of this study are robust, it is important to acknowledge certain limitations. The single-center design and relatively small sample size may limit the generalizability of the results. However, the strict selection criteria (extraction cases only) and standardization (single operator) reduced confounding variables.

Future research should focus on multi-center trials with larger cohorts to validate these findings and explore the long-term outcomes of CIB and DIB techniques.

Additionally, exploring patient-centered outcomes, such as comfort, satisfaction, and overall treatment experience, could provide valuable insights into the practical benefits of digital orthodontics. Investigating the cost-effectiveness of digital versus conventional methods would also be beneficial for clinicians considering the adoption of new technologies.

CONCLUSION

In summary, both conventional and digital indirect bonding are effective in achieving accurate bracket positioning and desirable orthodontic outcomes in extraction cases of Class I malocclusion.

DECLARATIOM

Conflict of Interest
None to declare.
Funding
None to declare.

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REVIEW ARTICLE

EXPLORING THE CURRENT STATE OF HEALTH IMPACT ANALYSIS IN TOXIC RELATIONSHIPS: A BIBLIOMETRIC REVIEW

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Abstract

This study explores the current state of health impact analysis in toxic relationships, focusing on a bibliometric review of scholarly research. A comprehensive review was conducted using tools such as VOSviewer, Biblioshiny (R-package), and Publish or Perish, analyzing data from the Scopus database. A total of 622 journal articles published between 1985 and 2025 were systematically reviewed, showing a steady increase in annual publications, particularly in the last decade. The analysis reveals that the study of toxic relationships and their health impacts has become a significant area of research, with key themes such as intimate partner violence, mental health, stress, and trauma consistently emerging in the literature. The United States, the United Kingdom, and Canada are the leading countries contributing to this research, with major institutions like Johns Hopkins University and the University of California significantly driving the scholarly output. Prominent journals, including the *Journal of Interpersonal Violence* and *Violence Against Women*, have had a major impact on the field. Additionally, the study highlights the critical role of mental health policies and support systems in mitigating the effects of toxic relationships, emphasizing the need for accessible interventions and support for affected individuals. Despite the expanding literature, gaps remain in addressing intersectional health issues related to marginalized populations. The findings suggest that future research should focus on comprehensive interventions, social factors, and the long-term mental and physical health consequences of toxic relationships, offering valuable insights into the evolving landscape of health impact research in toxic relationships.

Keywords: Bibliometric Analysis, Health Impact, Toxic Relationships, Bibliometric Analysis

INTRODUCTION

The mental health impact of toxic relationships has become an increasingly significant area of research, particularly as awareness of the psychological consequences of such relationships grows [1,2]. Toxic relationships whether romantic, familial, or professional have been linked to a variety of mental health issues, including anxiety, depression, and emotional trauma[3]. Research suggests that these relationships can have long-lasting negative effects on an individual's emotional and psychological well-being, especially in high-stress environments such as academia, where students are particularly vulnerable to mental health challenges due to academic and social pressures[4]. These toxic environments can lead to detrimental effects on students' overall mental health, making it more challenging to cope with day-to-day responsibilities[5].

The rise of social media has complicated the landscape of toxic relationships by providing a platform where harmful behaviors, such as cyberbullying, emotional manipulation, and unhealthy comparisons, are often perpetuated[6]. These behaviors have been shown to contribute to increased feelings of anxiety, stress, and low self-esteem, ultimately affecting individuals' mental health[2,7]. The COVID-19 pandemic further exacerbated these issues, as students faced social isolation, increased academic uncertainty, and a shift to remote learning, all

of which amplified the mental health challenges related to toxic relationships[8].

In response to these growing concerns, the academic literature has increasingly focused on the mental health impacts of toxic relationships. Bibliometric analyses have highlighted the rising number of studies exploring these issues, but there remain significant gaps in the research. Much of the existing literature is fragmented, with some studies focusing on physical health outcomes and others concentrating on specific types of toxic relationships without addressing the broader mental health implications. Additionally, there is a lack of research examining the role of digital technologies in the perpetuation of toxic relationships and their impact on mental health[9].

The current study, Exploring the Current State of Health Impact Analysis in Toxic Relationships: A Bibliometric Review, aims to address these gaps by conducting a bibliometric analysis of the literature. This analysis will explore trends in research, recurring themes, and the most influential authors, journals, and institutions. Furthermore, this review seeks to identify key challenges and opportunities for future research in the field, with particular attention to how digital platforms contribute to toxic dynamics and their subsequent effects on mental health. The study aims to answer the following questions:

1. What are the key trends in the research on the health impacts of toxic relationships, including the most frequently cited journals, institutions, countries, and productive authors?
2. What are the dominant themes and keywords in the literature, and how have they evolved over time?

RESEARCH METHODOLOGY

Research design.

This study adopts a quantitative approach using bibliometric analysis, which is an effective technique for evaluating the conceptual structure of a research domain and identifying future research directions. The objective of this study is to synthesize research streams from various journals indexed in Scopus, covering the period from 1985 to 2025. The bibliometric analysis will be integrated with content analysis to provide a more comprehensive understanding of the topic being researched. The choice of Scopus as the data source is based on its broader citation coverage compared to other databases such as Web of Science (WoS), which is more limited and often overlaps with Scopus. Furthermore, Scopus provides access to a wider range of journals and offers a more extensive citation network[10].

Search Strategy, Criteria, and Data Collection

For our data search strategy, we adapted the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) model to ensure transparency and consistency in the data collection process. The detailed flowchart below outlines the PRISMA protocol employed in this study's search strategy. Data were collected from the Scopus database on December 25, 2025, using the search query: ("toxic relationship" OR "abusive relationship") AND ("health impact" OR "well-being" OR "mental health" OR "stress" OR "anxiety" OR "depression" OR "trauma"). This search query was designed to capture documents focusing on toxic relationships and their impact on mental health. To ensure the inclusiveness of the bibliometric review and content analysis, a structured screening process was followed. This process included screening literature relevant to the research topic, evaluating documents based on eligibility criteria (including full-text search), and cross-verifying citations and relevance to the subject, even if not directly included in the data search query. The initial records screened from the Scopus database (n = 811) were based on article titles, abstracts, and keywords. Filters were applied to ensure the inclusion of only journal articles in English. The following criteria were applied: LIMIT-TO (DOCTYPE, "ar"), LIMIT-TO (SRCTYPE, "j"), LIMIT-TO (LANGUAGE, "English"). Subsequently, we excluded documents that did not meet the inclusion criteria, such as irrelevant studies, non-article document types, non-journal sources, and documents not written in English or Indonesian (n = 189). The remaining records deemed eligible (n = 622) were included for further descriptive analysis, bibliometric analysis, and content analysis.

Tools and Data Analysis

Various tools were employed to conduct this research. For frequency analysis and chart generation, R-Biblioshiny and Excel were used to perform calculations and visualize the results. VOSviewer was used to construct and visualize bibliometric networks, examine abstract keywords and authorship, and explore relationships and collaborations across authors, countries, and publications. Harzing's Publish or Perish software was utilized to compute citation metrics and identify highly cited documents, providing insights into the most influential research in the domain[11,12]. This research adopts comprehensive methodology, combining bibliometric analysis with content and network analysis to uncover insights into various facets of the research field. These include publication years, contributing countries and institutions, prominent journals, influential authors, keyword associations among authors, document citations, author citations and co-citations, international collaborations, and emerging research streams.

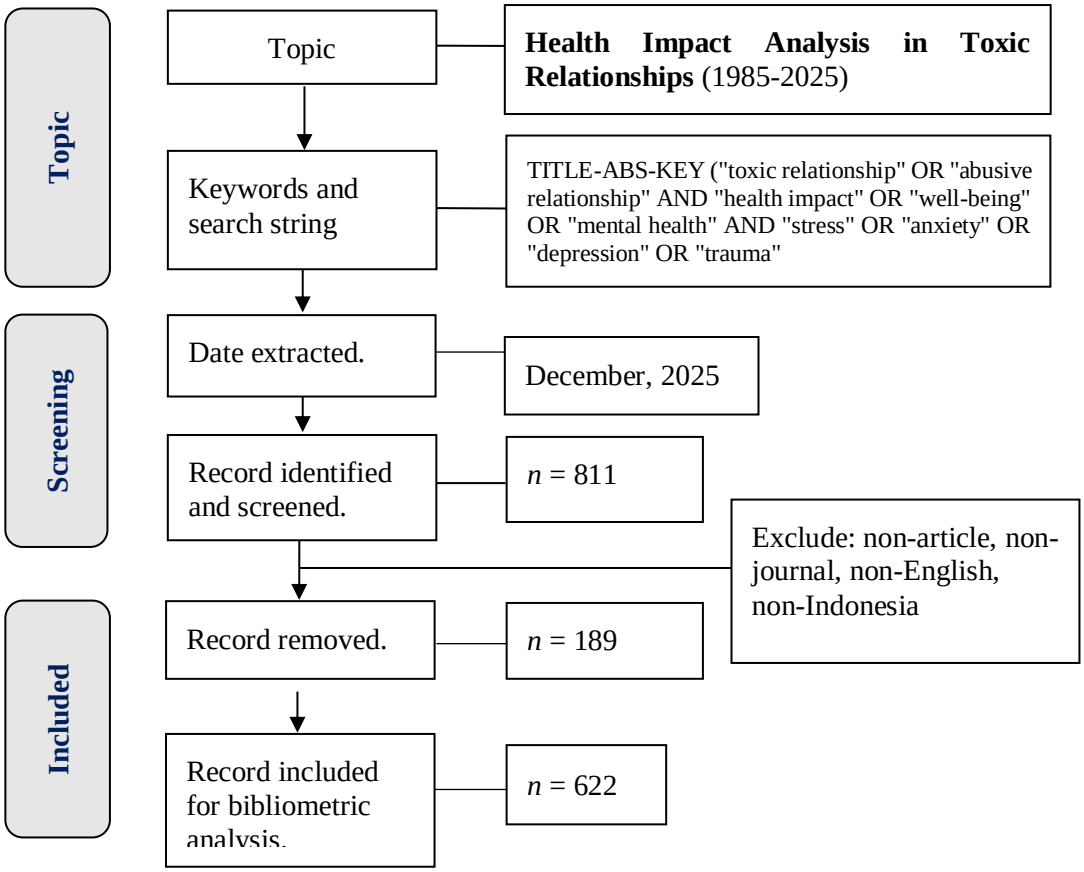


Figure 1. Diagram PRISMA

RESEARCH FINDINGS AND DISCUSSION

Descriptive analysis

The author examined a collection of 622 journal articles published between 1985 and 2025 for this study, sourced from a total of 336 different publications. These articles were authored by 2,085 authors, with 0 single-authored documents. On average, each article had 6.99 co-authors, and 14.63% of the publications featured international co-authorship, indicating significant global collaboration. The annual growth rate of publications was 7.84%, reflecting a strong and accelerating scholarly activity in this area. The average age of the documents was 9.5 years, and there were 4,753 references across all publications. Each document had an average of 27.91 citations, demonstrating a significant impact on the academic community. Additionally, the authors used 1,452 different keywords, showing the broad range of topics covered. This overall picture suggests that the field is experiencing rapid growth, with increasing international collaboration, and is contributing significantly to the academic landscape, as evidenced by the rising citation rates.

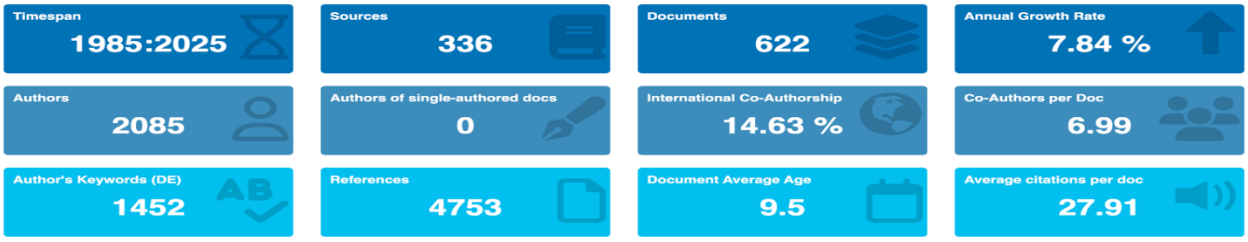


Figure 2. Dataset

In this study, the author examined journal articles published between 1985 and 2025, focusing on the development of scholarly work during this period. The first article was published in 1985, with a few years having very few or no publications, particularly in the early years. However, the number of publications started to increase gradually, with noticeable growth occurring after the early 2000s. The most significant increase in publications happened after 2011, with a sharp rise in the number of articles in the following years. The highest number of publications was recorded in 2023, with **53** articles published, followed by **50** articles in 2022. A total of 622 articles were identified from the Scopus database. The

analysis of the publication trends shows an annual growth rate of 7.84%. On average, each article had 6.99 co-authors per document, and the total number of references across all articles amounted to 4,753. This upward trend highlights the growing academic interest and research activity in the field, particularly in recent years.

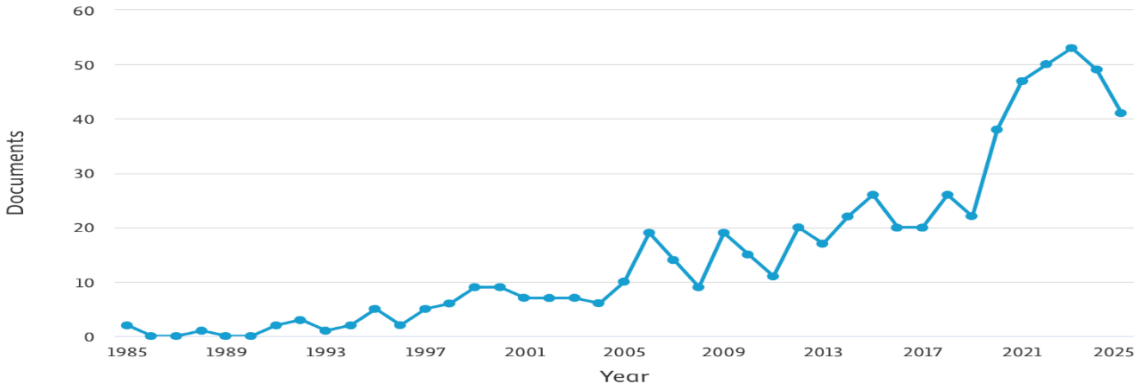


Figure 3. Number of publications per year

Research trend analysis

The chart illustrates the distribution of research across various subject areas related to toxic relationships and their health impact. The largest portion of the research focuses on Psychology, accounting for 31.0% of the total publications, reflecting the significant interest in understanding the psychological effects of toxic relationships. Medicine follows closely behind with 24.6%, indicating that physical health and the medical consequences of toxic relationships remain major areas of academic inquiry. Social Sciences contribute 24.4%, highlighting the importance of societal and cultural factors in shaping the experiences and health impacts of toxic relationships. Other notable areas include Nursing (6.5%), focusing on healthcare aspects, and Arts and Humanities (3.8%), suggesting an exploration of the broader social and cultural impacts. Health Professions (2.8%) represent an important area that links healthcare professions with toxic relationship-related health issues. Smaller portions of research in specialized areas such as Neuroscience (1.5%), Business and Management (1.0%), and Environmental Studies (1.5%) suggest that there is also exploration into the impact of toxic relationships on the brain, workplace dynamics, and environmental factors. Other subject areas, accounting for 2.2%, contribute to the overall discourse on toxic relationships and health, rounding out the interdisciplinary nature of the research in this field.

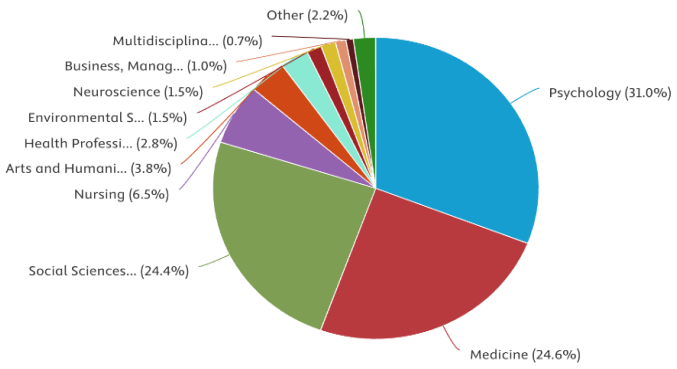


Figure 4. Subject Area

The chart presents the most relevant sources in the field of toxic relationships and health impact research based on the number of documents published. The Journal of Interpersonal Violence leads with 79 documents, followed by the Journal of Family Violence with 27 documents, reflecting significant contributions to understanding violence in relationships. Violence Against Women ranks third with 16 documents, highlighting the focus on gender-based violence. Other notable sources include Issues in Mental Health Nursing and Violence and Victims, contributing 12 and 11 documents, respectively, indicating a focus on the intersection of violence, mental health, and nursing. The International Journal of Environmental Research and Public Health follows with 10 documents, reflecting its interdisciplinary approach to public health and toxic relationships. Frontiers in Psychology contributes 9 documents,

showcasing its relevance to the psychological aspects of toxic relationships, while Health Care for Women International and Affilia - Feminist Inquiry in Social Work each contribute 9 and 8 documents, respectively, emphasizing healthcare and social work perspectives. The Journal of Aggression, Maltreatment and Trauma rounds out the list with 8 documents, focusing on trauma and maltreatment in relationships. This distribution highlights the interdisciplinary nature of research on toxic relationships and their health impacts, with a significant focus on psychology, violence studies, nursing, and public health.

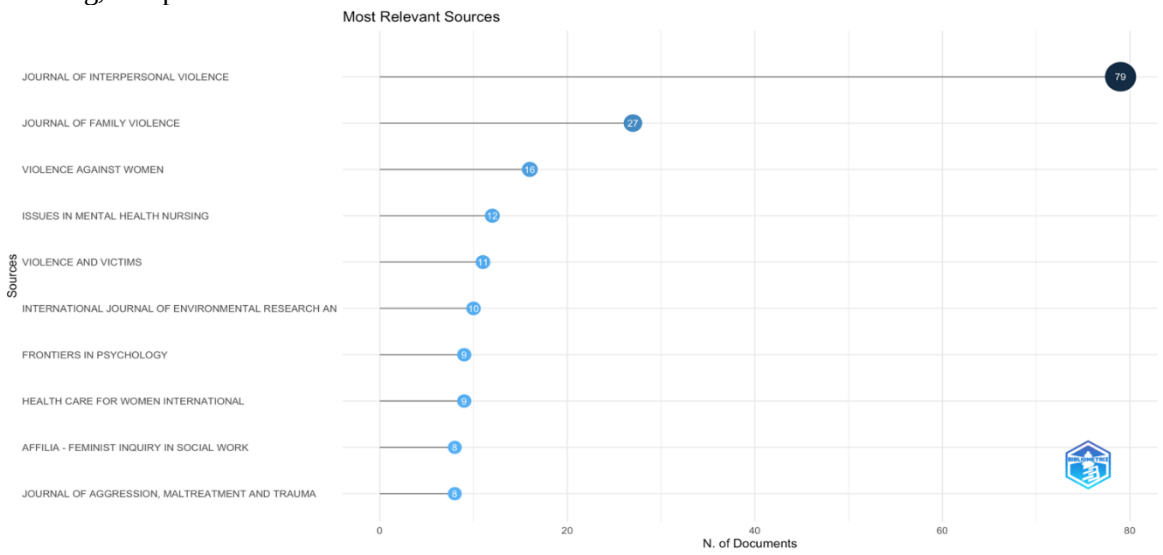


Figure 5. Most Relevant Sources

The figure above shows the local impact of the sources in toxic relationships and health impact research based on the H-index. The source with the highest H-index, reflecting its impact within the research community, is the Journal of Interpersonal Violence, with an H-index of 29. This is followed by the Journal of Family Violence with an H-index of 13, demonstrating its significant influence. Violence Against Women ranks third with an H-index of 10, indicating its considerable impact in the field. Issues in Mental Health Nursing, Violence and Victims, and Frontiers in Psychology each have an H-index of 9, further showing their importance in shaping research in this area. Health Care for Women International, International Journal of Environmental Research and Public Health, and Affilia - Feminist Inquiry in Social Work all have an H-index of 6, reflecting their moderate influence in the field. Finally, BMC Public Health has an H-index of 5, indicating a lesser but still relevant impact. These results highlight the key sources that are shaping the current landscape of toxic relationship research and their respective impact within the academic community.

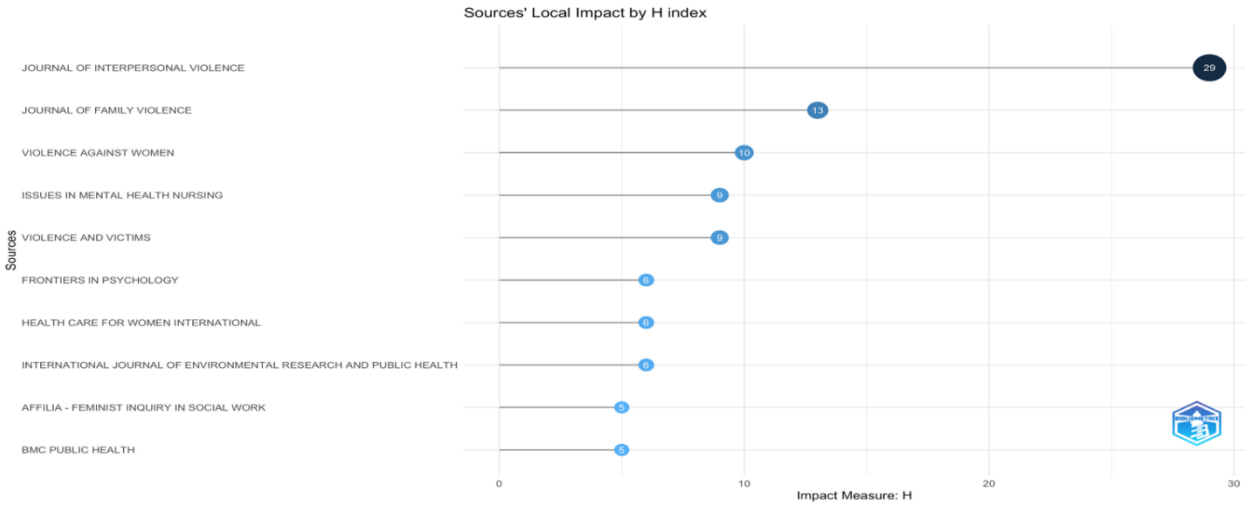


Figure 6. Journal local impact related to the topicMost influential countries, affiliates, and productive author

Table 3 shows the distribution of toxic relationships and health impact research by country. The United States leads the list with 335 publications (53.86%), followed by the United Kingdom with 60 publications (9.65%). The United States

significantly contributes to the research in this area, and the United Kingdom also has a strong presence. Canada ranks third with 57 publications (9.16%), demonstrating a considerable interest in the topic. Australia follows with 29 publications (4.66%), showing some engagement in the research, while Spain contributes 21 publications (3.38%). India and South Africa each contribute 15 publications (2.41%), representing regions with growing research on toxic relationships and health impact. Germany, Israel, and Italy each contribute 11 publications (1.77%), indicating their involvement in the field, while other countries and regions contribute smaller portions of research. This distribution indicates that North America and Europe are dominant in this area of research, with the United States and the United Kingdom leading the way. The variation in publication numbers also highlights the global nature of this research, suggesting that increased international collaboration could enhance the overall impact of this important area of study.

Country	TP	%	Continent
United States	335	53,86%	North America
United Kingdom	60	9,65%	Europe
Canada	57	9,16%	North America
Australia	29	4,66%	Oceania
Spain	21	3,38%	Europe
India	15	2,41%	Asia
South Africa	15	2,41%	Africa
Germany	11	1,77%	Europe
Israel	11	1,77%	Asia
Italy	11	1,77%	Europe

Figure 7. Most influential countries

The figure above shows the most relevant affiliations based on the number of articles published about toxic relationships and their health impact, as part of the bibliometric review titled "Exploring the Current State of Health Impact Analysis in Toxic Relationships: A Bibliometric Review." Johns Hopkins School of Nursing leads with 47 articles, showcasing its significant contribution to the field. University of California follows with 36 articles, reflecting its strong focus on research in this area. Johns Hopkins Bloomberg School of Public Health ranks third with 28 articles, reinforcing its role in advancing research on health impacts related to toxic relationships. Western University and University of Washington each published 25 and 24 articles, respectively, indicating their active participation in this research area. University of Toronto published 20 articles, contributing notably to the field, while other institutions like The University of Texas Health Science Center at San Antonio, Carleton University, Islamic Azad University, and Michigan State University contributed 19, 16, 16, and 15 articles, respectively, demonstrating their important roles in the academic landscape. This distribution highlights the key academic institutions driving forward research on toxic relationships and their health impacts, underscoring the global collaboration in this field.

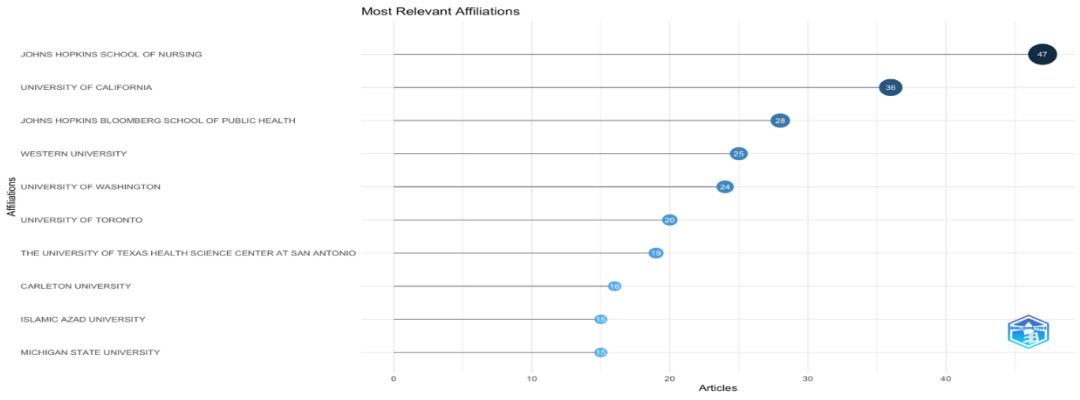


Figure 8. The top 10 Relevant Affiliations

Table 4 shows the top authors who have contributed to toxic relationships and health impact research, along with their key publications. Campbell, J.C. leads with 12 publications, indicating a significant contribution to the field. Sabri, B. follows

with 5 publications, demonstrating a strong influence in this area, while Glass, N. has contributed 4 publications, marking a notable presence in the research. Other contributors such as Edwards, K.M., Bloom, T.L., Clough, A., Grace, K.T., Anisman, H., Decker, M.R., and Gidycz, C.A. each have 3 to 4 publications, showcasing their valuable contributions to the research landscape. These authors reflect a diverse range of expertise in the field of toxic relationships and health impacts, highlighting their collective role in advancing research on this important topic.

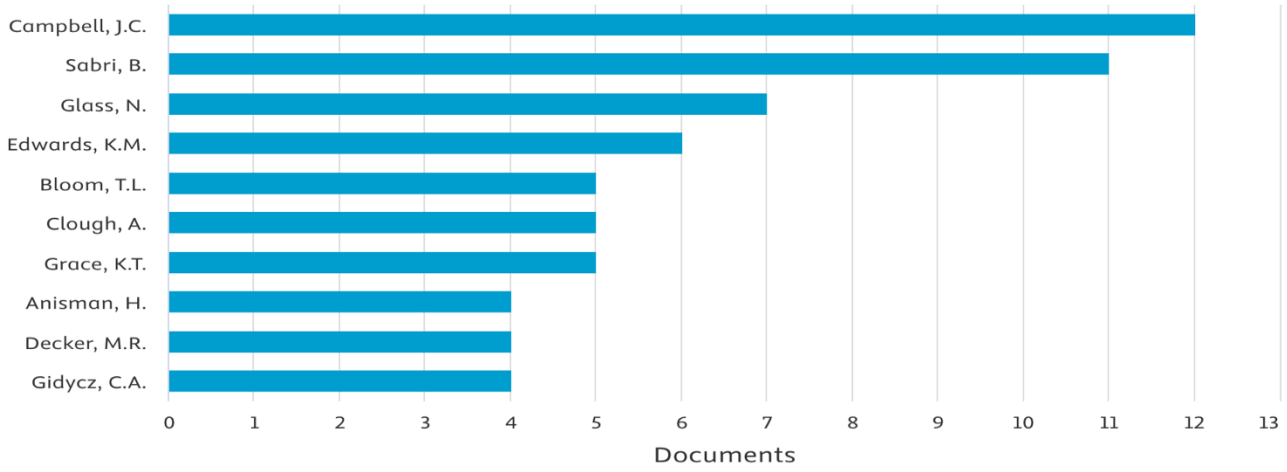


Figure 9. Most Productive Authors

Citation analysis

Several key studies have made significant contributions to the field of toxic relationships and their health impact. Podsakoff (2007) leads with 1,531 citations, reflecting the wide-reaching impact of his work, particularly in understanding stressor relationships and job-related behaviors, with a high normalized citation rate of 9.03. Anderson (2003) follows with 377 citations and a normalized citation rate of 2.91, focusing on the process of leaving abusive relationships and its psychological effects. Wolfe (2003) contributed 317 citations with a normalized citation rate of 2.45, concentrating on dating violence prevention in at-risk youth. Other important studies include Zlotnick (2006), Fanslow (2010), and Ellsberg (2000), with citation counts ranging from 230 to 297. These studies provide significant insights into intimate partner violence and the long-term psychosocial effects, with normalized citation rates ranging from 2.43 to 4.78. Ehrensaft (2004) and Rolland (1994), with 203 and 193 citations, respectively, further expand our understanding of abusive relationships and the impacts on mental health. Kemp (1995) and Pallitto (2005), with 177 and 174 citations, contribute important findings regarding post-traumatic stress disorder in battered women and unintended pregnancies linked to intimate partner violence, respectively. These studies highlight the growing academic focus on toxic relationships and their health impacts, underscoring diverse areas of research in understanding the long-term consequences of intimate partner violence.

Table 1. The top ten most cited documents

Author	Paper	T C	C/Y	Normalized TC
Podsakoff, 2007.	Differential challenge stressor-hindrance stressor relationships with job attitudes, turnover intentions, turnover, and withdrawal behavior: A meta-analysis.	1531	80,58	9,03
Anderson, 2003.	Leaving An Abusive Partner: An Empirical Review of Predictors, the Process of Leaving, and Psychological Well-Being	377	16,39	2,91
Wolfe, 2003.	Dating violence prevention with at-risk youth: A controlled outcome evaluation.	317	13,78	2,45
Zlotnick, 2006.	Intimate Partner Violence and Long Term Psychosocial Functioning in a National Sample of American	297	14,85	4,45

	Women			
Fanslow, 2010.	Help-Seeking Behaviors and Reasons for Help Seeking Reported by a Representative Sample of Women Victims of Intimate Partner Violence in New Zealand	255	15,94	4,78
Ellsberg, 2000.	Candies in hell: women's experiences of violence in Nicaragua	230	8,85	2,96
Ehrensaft, 2004.	Clinically Abusive Relationships in an Unselected Birth Cohort: Men's and Women's Participation and Developmental Antecedents.	203	9,23	2,43
Rolland, 1994.	In Sickness And In Health: The Impact Of Illness On Couples' Relationships	193	6,03	1,79
Kemp, 1995.	Incidence and Correlates of Posttraumatic Stress Disorder in Battered Women: Shelter and Community Samples	177	5,71	2,36
Pallitto, 2005.	Is Intimate Partner Violence Associated with Unintended Pregnancy? A Review of the Literature	174	8,29	4,33

Note(s): TC=total citations; C/Y=average citations per years

Keyword analysis

Table 6 shows the frequency of keywords related to toxic relationships and their health impact in the Scopus database. "Intimate partner violence" emerges as the most common keyword, appearing in 155 articles (20%), indicating its central role in research on toxic relationships. "Domestic violence" follows with 107 occurrences (14%), highlighting its significant connection to the health impact of abusive relationships. Other notable keywords include "battered women" and "partner abuse", both appearing 27 times (3%) each, reflecting a strong focus on gender-based violence and its consequences. "Mental health" appears in 22 articles (3%), indicating its importance in understanding the psychological effects of toxic relationships. Keywords like "coping" and "help-seeking" appear 13 times (2%) each, reflecting the focus on strategies and interventions for those affected by abuse. Additionally, "adolescents", "sexual abuse", and "trauma" each appear in 12 to 18 articles, emphasizing the intersection between violence and mental health issues in younger populations. Other relevant keywords, such as "violence", "relationships", and "resilience", highlight the broader scope of research on the personal, emotional, and social impact of toxic relationships. This distribution underscores the diverse areas of focus in toxic relationship research, with a strong emphasis on intimate partner violence and its effects on both mental and physical health.

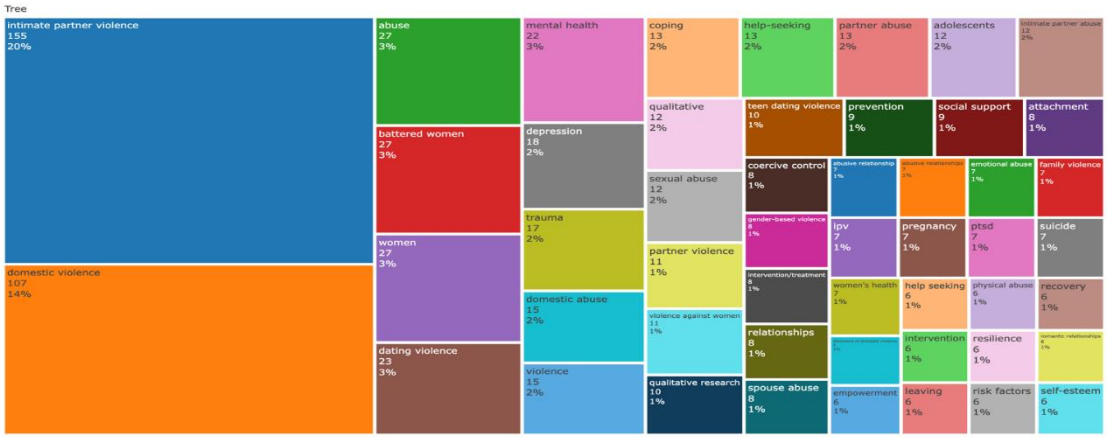


Figure. 10 Top Keywords

The figure presents a keyword co-occurrence network that plots the development degree (density) against the relevance degree (centrality) of various themes in toxic relationships and health impact research. In the Motor Themes (top-right),

central themes like "intimate partner violence," "domestic violence," and "mental health" show high relevance and growth, indicating their importance in the field. In the Basic Themes (bottom-right), "battered women" and "depression" are foundational themes, essential but not as interdisciplinary. The Niche Themes (top-left) include specific topics like "sexual abuse" and "partner violence," which are still developing in the research landscape. Emerging or Declining Themes (bottom-left) include "stress" and "family," suggesting these areas are either emerging or declining. Finally, themes like "coping" and "resilience" are in the middle, showing growing relevance with a focus on intervention strategies. Overall, the chart illustrates the expanding research on toxic relationships, focusing on violence, mental health, and interventions.

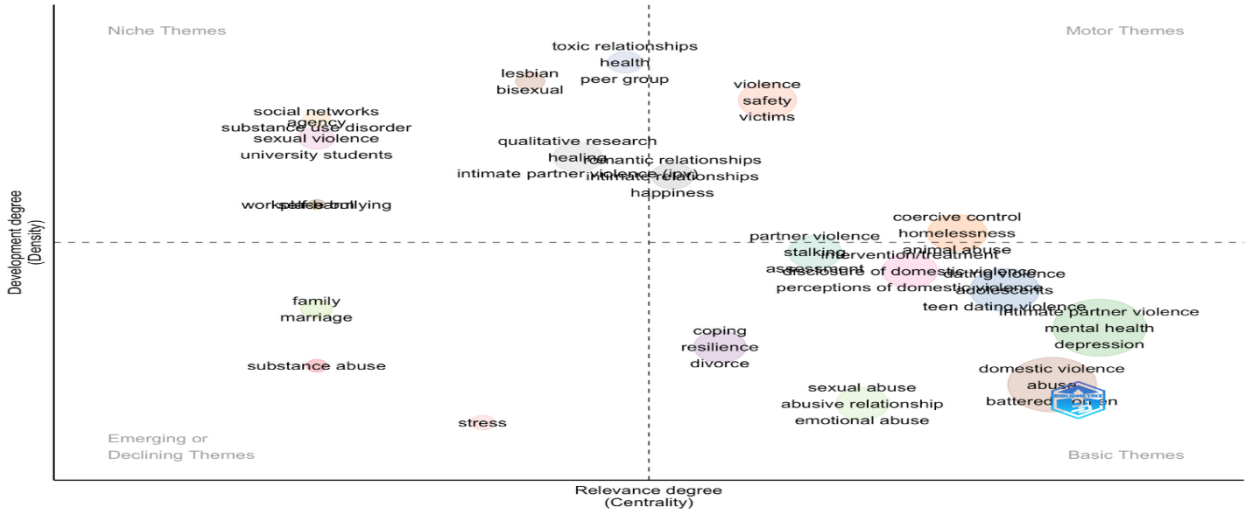


Figure. 11 Thematic Maps

DISCUSSION

Integration of Mental Health Strategies in Education

Cluster 1 highlights the growing importance of integrating mental health strategies within educational frameworks to address the increasing mental health challenges faced by students, particularly in higher education[13]. The role of educational psychology has expanded, as researchers recognize its impact on student development, focusing on emotional resilience and well-being. Many universities have started to incorporate mental health services into their curricula, supporting students' psychological health while enhancing their academic experience[14]. This holistic approach has been shown to improve both academic outcomes and students' overall life satisfaction, making it clear that fostering emotional well-being is crucial to academic success. Additionally, mental health programs that include peer mentoring, counseling services, and stress management techniques help students manage academic and personal challenges, mitigating the pressures of academia and enabling students to thrive. As universities increasingly adopt these comprehensive mental health support systems, they not only improve students' well-being but also contribute to higher retention rates and better academic performance[15].

Mental Health Challenges in Students

Cluster 2 addresses the mental health challenges faced by college students, with a focus on factors like food insecurity, financial stress, and academic pressures. Food insecurity has been recognized as a significant contributor to students' emotional distress, leading to heightened levels of depression and anxiety[16]. Research shows that addressing food insecurity, alongside providing mental health resources, can reduce stress and improve academic performance. Furthermore, financial stress exacerbates mental health issues, particularly as students face rising tuition fees and living costs. Students experiencing significant financial strain are more likely to report symptoms of anxiety and depression. Universities can support students by offering financial aid programs, which not only ease financial burden but also improve students' emotional health. This highlights the importance of an integrated approach that addresses financial, academic, and mental health needs to ensure students' well-being and academic success[17].

Mental Health Policy in Higher Education

Cluster 3 examines the role of mental health policies within higher education, particularly in response to the increased challenges posed by the COVID-19 pandemic[18]. The pandemic has exacerbated students' mental health issues, including stress, anxiety, and depression, prompting universities to implement more robust mental health policies. Many institutions have expanded their services to

include virtual counseling, wellness apps, and peer support groups, which have proven effective in supporting students during periods of social distancing. These initiatives underscore the importance of adaptable, accessible, and scalable solutions for student well-being. Additionally, integrating mental health education into university curricula helps raise awareness about mental health, encouraging early intervention and reducing stigma. Research supports the continued investment in preventive and responsive mental health services, emphasizing that these programs are vital for safeguarding students' well-being in a rapidly changing world[19,20].

Medical Education and Mental Health in Healthcare Students

Cluster 4 focuses on the unique mental health challenges faced by medical students, who often experience high levels of burnout, stress, and depression due to the demanding nature of their education and training. These students are at risk of long-term mental health consequences, as the stress they endure during their studies can affect their professional lives. Medical humanities programs, which include emotional intelligence and empathy training, have been shown to help students develop coping mechanisms and reduce the psychological toll of their education[21,22]. Medical schools are increasingly incorporating resilience training and mental health support into their curricula to combat burnout. Strategies such as mindfulness workshops, peer support systems, and counseling services help students manage stress and maintain their emotional well-being. By focusing on the academic and emotional needs of medical students, institutions can reduce mental health issues and better prepare future healthcare professionals to care for others while preserving their own well-being[23].

CONCLUSION

This study provides a comprehensive overview of the development of mental health literature among students, particularly in the context of the growing use of technology and social media. Through bibliometric analysis, it was found that, although there has been a significant increase in research on student mental health in recent years, many gaps remain that need attention. Most of the existing studies focus on the negative impacts of social media and digitalization on students' psychological well-being, as well as the rising issues of anxiety, depression, and stress due to academic and social factors. However, research related to the use of technology as a digital intervention, such as psychological therapy apps and telemedicine, still requires further investigation to ensure their effectiveness and accessibility in diverse cultural and social contexts. This study also highlights significant regional variations in the focus and approach of student mental health research, with some countries emphasizing social and cultural issues affecting mental health, while others focus more on technology-based interventions. Therefore, to address these gaps, more research is needed that takes local contexts into consideration and develops more affordable and accessible technology-based interventions for students worldwide. Furthermore, integrating mental health into higher education policies and university programs is crucial to ensure students' overall well-being. In light of these findings, this study makes an important contribution to the development of policies and practices that are more inclusive in supporting student mental health. Moving forward, developing policies that integrate psychological support with the appropriate use of technology, as well as raising awareness about the importance of mental health, will be critical in creating a healthier academic environment and supporting students' well-being globally.

DECLARATION

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Conflict of Interest

None to declare.

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ORIGINAL RESEARCH

COST AND CLINICAL IMPACT OF DIGITAL VS. CONVENTIONAL INDIRECT BONDING IN EXTRACTION ORTHODONTIC TREATMENT OF CLASS I MALOCCLUSION

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Abstract

Background:Orthodontic treatment advancements aim to improve clinical outcomes, efficiency, and patient satisfaction. Indirect bonding techniques, both conventional (CIB) and digital (DIB), are innovations that enhance bracket placement accuracy, reduce chairside time, and potentially minimize the number of visits. However, while digital methods offer increased precision and efficiency, they incur higher laboratory costs and require advanced technology.

Methods: This prospective, randomized controlled trial included 28 patients with Class I malocclusion requiring orthodontic extraction. Participants were randomized into CIB or DIB groups. Brackets in the CIB group were manually positioned on plaster models and transferred using vacuum-formed trays, while the DIB group used digitally scanned models with 3D-printed transfer trays. Treatment outcomes were assessed using the Objective Grading System (OGS). Cost, treatment time, number of visits, and bracket failure rates were also evaluated.

Results: Both techniques yielded comparable OGS scores (CIB median: 14; DIB median: 12; P=1.000), indicating similar treatment quality. Laboratory costs were significantly higher for DIB ($100.54) than CIB ($16.30; P<0.001). However, the DIB group demonstrated significant advantages, including shorter treatment times (20 months vs. 24 months; P=0.021) and fewer visits (23 vs. 27; P=0.003). Initial bracket failure rates were lower in the DIB group (2 vs. 4; P=0.018).

Conclusion: Both techniques provide similar treatment quality, but DIB represents a promising advancement in orthodontics, balancing initial costs with improved clinical efficiency and patient satisfaction. Further research with larger, diverse populations is necessary to validate these findings and assess long-term cost-effectiveness.

Keywords: extraction orthodontic treatment, Class I malocclusion, indirect bracket positioning, conventional indirect bonding, digital indirect bonding

INTRODUCTION

Orthodontic treatment continues to evolve, with a strong focus on improving clinical outcomes, efficiency, and patient satisfaction. As demand for orthodontic care rises, optimizing treatment efficiency and reducing costs have become critical goals. Indirect bonding techniques, both conventional and digital, are key innovations in addressing these challenges by minimizing chairside time, enhancing bracket placement accuracy, and potentially reducing the number of required visits.

Conventional indirect bonding, introduced by Silverman and Cohen in the 1970s, was initially praised for its ability to reduce chairside time by allowing brackets to be positioned on a model outside the mouth and then transferred to the patient using a bonding tray[1].

This method improved visibility and precision compared to direct bonding but required time-intensive laboratory steps that increased total treatment time and costs[2]. Since then, the technique has undergone numerous refinements, as summarized in a comprehensive review by Kalange and Thomas[3]. Bozelli et al. noted that while indirect bonding could reduce clinical time, its labor-intensive nature in the laboratory limited its overall efficiency[4].

In recent years, digital technologies have transformed orthodontics, offering significant improvements in workflow precision and efficiency. Digital indirect bonding (DIB), powered by computer-aided design and manufacturing (CAD/CAM), involves virtual bracket placement on 3D models and the fabrication of bonding

trays using 3D printing technology. Early adopters such as Redmond et al. and Garino and Garino highlighted how CAD/CAM workflows could enhance efficiency and reduce errors[5,6].Ciuffolo et al. demonstrated the potential of rapid prototyping to simplify tray preparation further [7].

Studies suggest that digital indirect bonding may reduce the number of visits and total treatment time due to its enhanced precision and fewer required follow-up adjustments. For example, Christensen and Cope highlighted how digital workflows using intraoral scanning and 3D printing streamline the process, potentially leading to shorter treatment durations[8]. Similarly, Rosti et al. described how digital methods improve bracket placement accuracy, reducing mid-course corrections and the overall number of visits [9].

However, the initial costs of CAD/CAM systems, including 3D scanners and software, remain significant, which can offset long-term savings in materials and labor[10]. Conventional indirect bonding, while more labor-intensive, involves lower upfront costs, making it more appealing in settings with limited access to advanced technologies.

Comparative studies have demonstrated the advantages of digital techniques over conventional methods. For example, Czolgosz et al. found that digital bonding significantly reduced chairside time while offering comparable bracket placement accuracy and lower failure rates[11]. Furthermore, Kono et al. reported that digital techniques, despite higher initial costs, improved overall treatment efficiency by reducing manual errors and enhancing bracket placement precision[12].

However, the higher laboratory costs of digital workflows remain a challenge. Plattner et al. highlighted that digital bonding requires significant investment in equipment, software, and materials, which may offset the time savings [13]. Sollenius et al. emphasized the need for economic evaluations to assess the cost-effectiveness of new orthodontic technologies[10].

Despite these considerations, digital indirect bonding shows immense promise. Haeger noted its potential for improving clinical metrics, particularly in achieving consistent outcomes with self-ligating brackets[14]. Additionally, Soares Ueno et al. recently demonstrated the accuracy of digital techniques, suggesting their suitability as a reliable alternative to conventional methods [15].

Despite its potential, digital indirect bonding's impact on treatment efficiency and cost requires further study. As far as we know, there have been no direct comparisons between digitally positioned brackets and the conventional manual indirect bonding technique. This study aims to address this gap by systematically evaluating both methods' clinical and financial aspects, focusing on total treatment time, laboratory costs, bracket placement accuracy, and overall efficiency. By analyzing these factors, this research seeks to guide practitioners in determining the most effective approach to indirect bonding in orthodontic treatment.

METHODS

This study was a prospective, randomized controlled trial involving 28 patients with Class I malocclusion who were scheduled for orthodontic extraction treatment. Participants were randomly assigned to either the conventional indirect bonding (CIB) group or the digital indirect bonding (DIB) group. Prior to the study, approval was obtained from the Institutional Review Board (IRB) of the Faculty of Dentistry at Suez Canal University, and all participants provided written informed consent.

To date, no studies have directly compared OGS outcomes between these specific digital and conventional indirect bonding approaches. Consequently, an a priori sample size calculation was performed using variability estimates from a previous investigation of OGS scores[16]. Assuming a standard deviation of approximately 2.5, a significance level of 0.05, and 80% statistical power, the analysis indicated that 14 participants per group (28 in total) would be necessary to detect a clinically meaningful difference.

Eligible patients were between 18 and 40 years old, had permanent dentition (excluding third molars), bilateral Angle's Class I molar relationships, no skeletal discrepancies, and no history of prior orthodontic treatment.

Dental impressions were taken to create plaster models for both groups. In the CIB group, brackets were positioned on the plaster models and transferred to the patients' teeth using a 1 mm vacuum-formed transfer tray **(Figure 1)**.

In the DIB group, digital scans of the plaster models were used to create 3D models, with the brackets positioned on the 3D models and transferred to the patients' teeth using a 3D-printed transfer tray **(Figure 2)**.

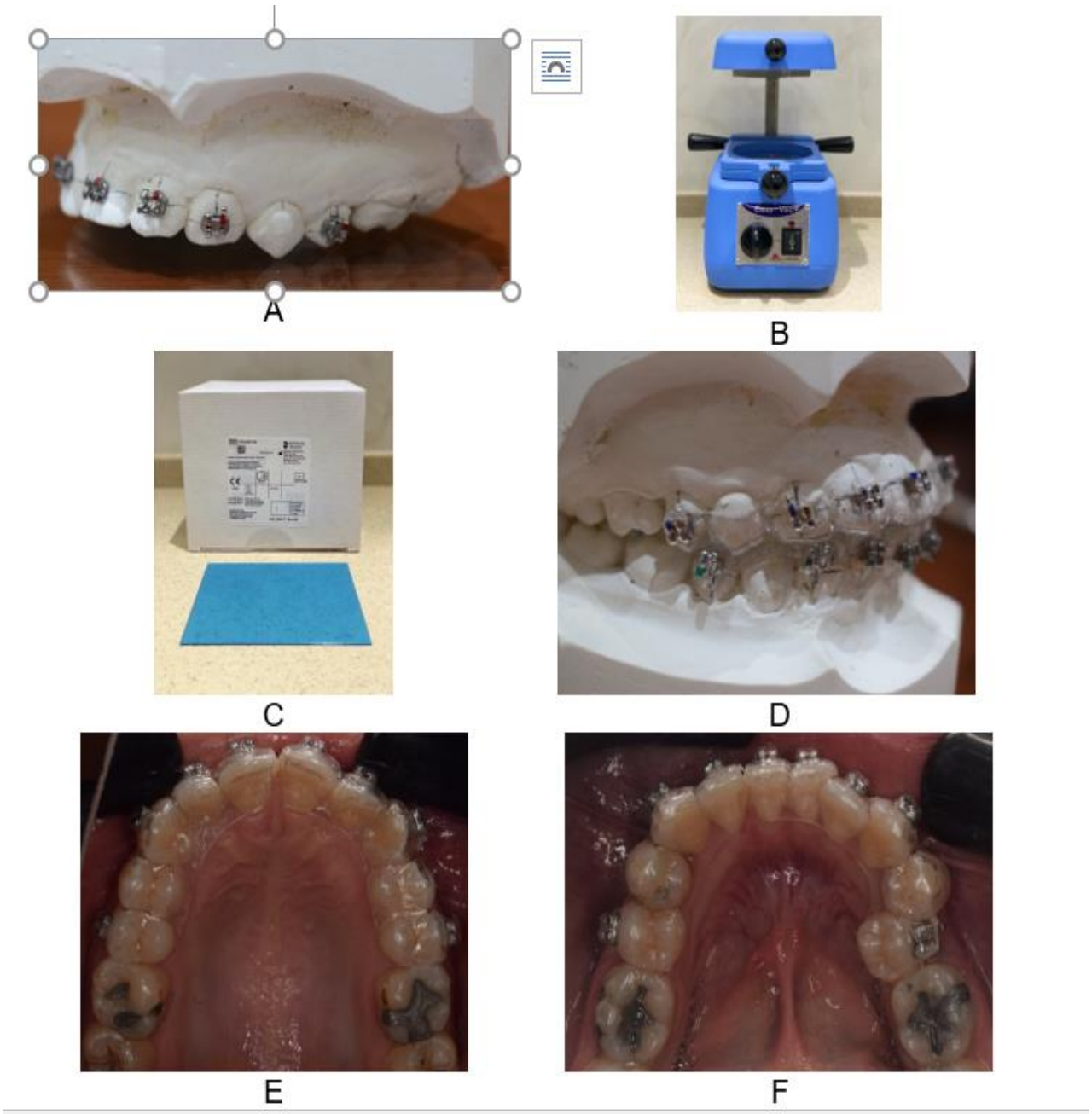


Figure 1. Conventional indirect bonding technique: A, positioning of the brackets on dental cast according to positioning guidelines; B, Vacuum former used in the study; C: Sheets used in the Conventional group; D: transfer tray after installation of the casts; Occlusal view showing trasnfer trays, upper (E) and lower (F) arches.

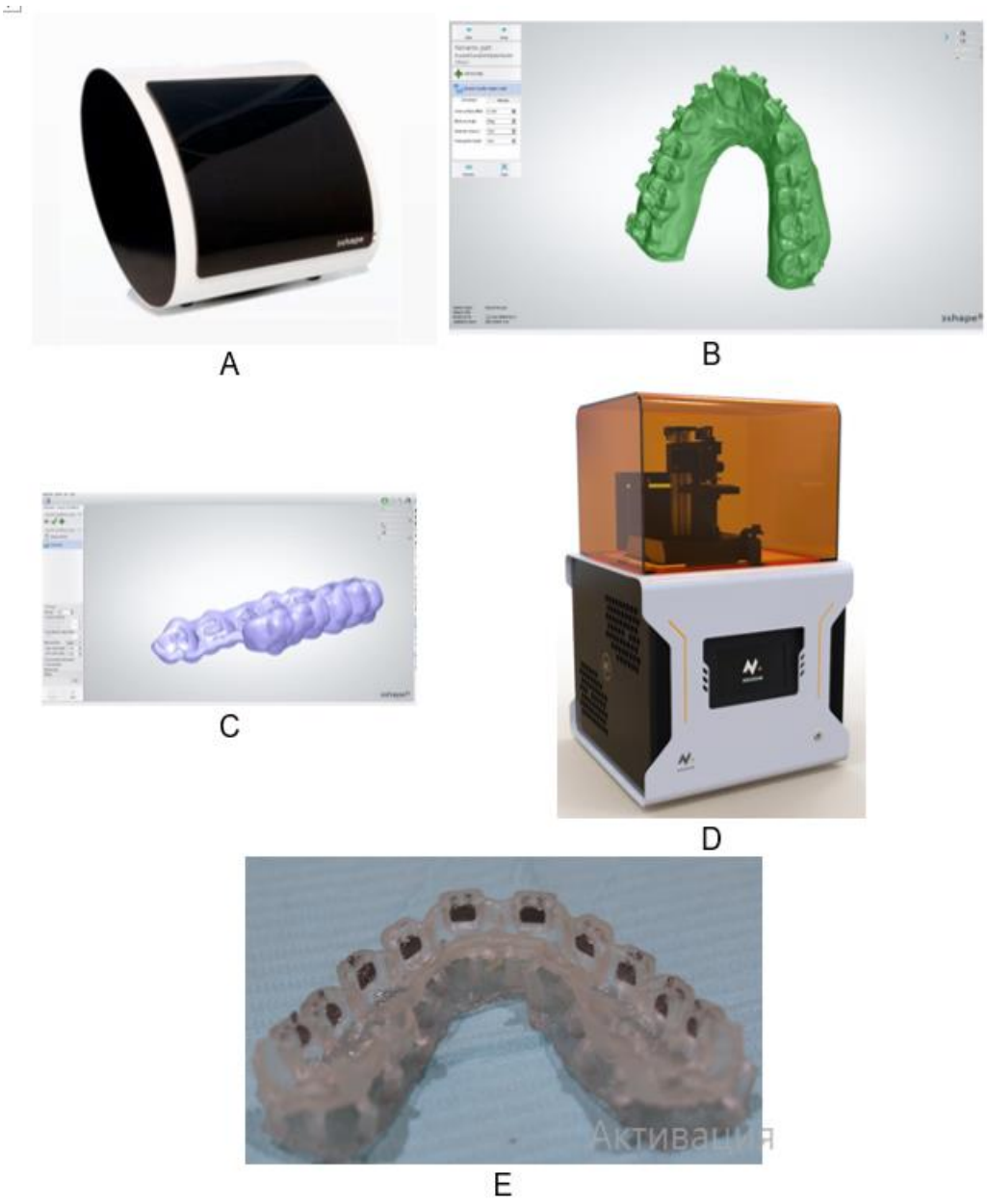


Figure 2. Digital indirect bonding technique: A, Lab scanner 3Shape R500; B, 3Shape OrthoAnalyzer software defining digital bracket adjustment; C, Constructed virtual transfer tray ready for printing; D, DLP printer Mogassam Dent 2; E, transfer tray loaded with brackets.

Treatment outcomes were evaluated using the Objective Grading System (OGS), which assesses factors such as alignment, marginal ridges, buccolingual inclination, occlusal contacts, occlusal relationships, overjet, interproximal contacts, and root angulation [17]. A total OGS score of less than 20 points was considered to meet the ABO's standard for orthodontic treatment. All patients were bonded by a single operator to ensure consistency, and a single evaluator assessed the OGS scores and was blinded to group assignments to minimize the risk of detection bias.

Data analysis was performed using IBM SPSS Statistics for Macintosh, Version 26.0. Qualitative data were expressed as frequencies and percentages, while quantitative data were presented as medians and interquartile ranges (IQR).

The Mann-Whitney U test (Wilcoxon rank-sum test) was used to compare the distribution of variables between the CIB and DIB groups. Associations between categorical variables were examined using the chi-square test, and Fisher's exact test was applied when observed or expected values were less than five. A two-sided p-value of less than 0.05 was considered statistically significant.

RESULTS

The study compares conventional and digital indirect bonding techniques in orthodontics, examining both patient characteristics and treatment outcomes. Table 1 presents the baseline characteristics of the studied patients, showing a balanced distribution between the two groups. Each group consisted of 14 patients, with no statistically significant differences in gender distribution, age, or discrepancy index. The conventional group had a slightly higher proportion of males (71.4% vs 57.1% in the digital group), but this difference was not significant (P=0.695). The median ages were similar (20 years for conventional, 21 years for digital) with a narrow interquartile range. The discrepancy index showed a higher median in the DIB compared to the CIB (22 vs 30, respectively), though this difference was not statistically significant (P=0.653).

Table 1. Baseline characteristics of the studied groups

	Conventional	Digital	P
Gender			0.695
Males, n (%)	10 (71.4)	8 (57.1)	
Females, n (%)	4 (28.6)	6 (42.9)	
Age, median (IQR)	20 (3.5)	21 (4)	1.000
Discrepancy index, median (IQR)	22 (5.5)	30 (15.5)	0.653

IQR, interquartile range.

Table 2 presents the detailed cost breakdown. The total bonding cost for the conventional group was calculated at $16.30, comprising $10.00 in materials and approximately $6.30 in estimated labor costs. In contrast, the digital indirect bonding incurred a significantly higher total cost of $100.54, which consisted primarily of the fixed laboratory service fee (P < 0.001).

Table 2. Direct cost analysis of both techniques

	Time (Average)	Unit Cost (USD)	Total Cost (USD)
A. Conventional indirect bonding			
1. Clinical steps (bonding)			
Orthodontist (clinic time)	16 min 47 s	6.00 / hr	1.68
Dental assistant (assisting)	16 min 47 s	1.60 / hr	0.45
2. Laboratory steps (manual)			
Materials (alginate, stone, sheets)	N/A	Flat rate	10.00
Laboratory technician (pouring/trimming)	20 min	2.00 / hr	0.67
Orthodontist (bracket positioning)	30 min	6.00 / hr	3.00
Laboratory technician (tray fabrication)	15 min	2.00 / hr	0.50
Total cost			16.30
B. Digital indirect bonding			
1. Clinical steps (bonding)			
Dental assistant (bonding/assisting)	12 min 52 s	1.60 / hr	0.34
Orthodontist (supervision/check)	2 min	6.00 / hr	0.20
2. Laboratory steps (digital)			
3D Laboratory service fee (scan/design/print)	N/A	Flat rate	100.00
Total cost			100.54

The treatment outcomes are presented in Table 3. The total OGS scores were similar between the two groups (14 for conventional, 12 for digital; P=1.000), suggesting comparable overall treatment quality. Although the laboratory costs were significantly higher for the digital technique ($100.54 compared to $16.30 for conventional; P<0.001), the digital technique demonstrated several advantages in other metrics. Treatment time was significantly reduced with the digital technique (20 months vs 24 months; P=0.021), as was the number of required visits (23 vs 27; P=0.003). Additionally, the digital technique showed a significantly lower rate of initial bracket failure (2 vs 4; P=0.018).

Table 3. Outcomes and associated costs of the studied groups

	Conventional	Digital	P
Total OGS	14 (6.5)	12 (3)	1.000
Total bonding cost ($)	16.30 (2.06)	100.54 (0.61)	0.001
Treatment time (months)	24 (2)	20 (2)	0.021
Number of visits	27 (2)	23 (1.5)	0.003
Initial bracket failure	4 (1)	2 (1)	0.018

Data are median (IQR).
OGS, Objective Grading System.

DISCUSSION

The results of this study comparing conventional indirect bonding and digital indirect bonding techniques in orthodontics provide valuable insights into both treatment efficiency and patient outcomes. The baseline characteristics of the two groups, as shown in Table 1, indicate a balanced distribution between the CIB and DIB groups, with no significant differences in gender, age, or discrepancy index. This balance ensures that patient characteristics were unlikely to have influenced the outcomes.

In terms of treatment quality, the overall OGS scores were comparable between the groups, with no significant difference between the conventional and digital methods (medians of 14 and 12, respectively, P=1.000). This suggests that both techniques can achieve similar clinical outcomes in terms of the precision of bracket placement and treatment effectiveness. This is consistent with the findings of Yıldırım and Saglam-Aydinatay, who compared direct and indirect bonding techniques in non-extraction orthodontic treatment for Class I malocclusion patients, reporting median OGS scores of 14 for indirect bonding and 17 for direct bonding [18].

The laboratory cost of DIB was significantly higher ($100.54) compared to CIB ($16.30, P<0.001). The cost of the digital technique in our study aligns with the findings of Czolgosz *et al.*,[11] who reported that the direct cost of digital indirect bonding trays was approximately 84 euros, closely matching our observed cost. However, our analysis highlights a distinct economic reality compared to such studies conducted in Europe or North America. While previous research often employs cost-minimization analyses where high clinician salaries narrow the gap between digital and conventional methods, our findings reflect the Egyptian economic context. Due to significantly lower local labor rates, the time-intensive manual steps of conventional indirect bonding—relying on affordable plaster and thermoplastic materials—added only a minimal financial burden (~$6.30). Consequently, the conventional method remained approximately six times cheaper than the digital alternative, as the latter is driven by fixed hardware and software costs that are less sensitive to local economic variations.

However, the digital technique offered distinct advantages. The DIB group experienced significantly shorter treatment times (20 months vs. 24 months; P=0.021) and fewer required visits (23 vs. 27; P=0.003). These findings are consistent with Brown et al. study[19], as treatment times for the 3 groups were significantly different; the CAD/CAM group was the shortest at 13.8 ± 3.4 months, compared with 21.9 ± 5.0 and 16.9 ± 4.1 months for the direct bonded and indirect bonded groups, respectively. The distinction is made between class 1 and class 2 malocclusions. In the case of class 1 malocclusions, traditional indirect bonding required less time on average (15 months) than direct bonding (17 months), while in class 2 malocclusions, direct bonding took less time (22 months) than indirect bonding (22.5 months). The number of treatment appointments for the CAD/CAM group was significantly fewer than for the direct bonded group.

Similarly, the findings of Yıldırım and Saglam-Aydinatay align with our results, demonstrating no significant difference in total treatment time between direct bonding (12.0 ± 3.1 months) and conventional indirect bonding (11.4 ± 2.4 months)[18].

It should be highlighted that most of the total working time for indirect bonding is spent in the laboratory stage, resulting in time savings for the clinician such a reduction in chair-side time could be advantageous in busy clinics and make the treatment more comfortable for the patient[4]. To the best of our knowledge, no other studies have specifically included patients requiring extractions, as was done in our study.

This reduction in treatment duration and appointments directly benefits both patients and practitioners. Shorter treatment times reduce the burden on patients, improving their overall experience, while fewer visits lower the

clinic's workload, increasing operational efficiency. The time savings associated with the digital technique are likely due to the increased precision in bracket placement, leading to fewer adjustments and corrections throughout the treatment.

Moreover, the digital method showed a significantly lower rate of initial bracket failure (2 in the DIB group vs. 4 in the CIB group; P= 0.018). Multiple studies assessed the bracket failure following different bonding techniques. However, we could not find any direct comparisons between the digital indirect bonding and conventional indirect bonding using hard splint transfer tray. Nevertheless, our numbers are comparable to that of the literature regarding the DIB method, as shown by Pottier et al., who observed a 2.5% bracket failure rate [20]. Regarding, bracket failure following conventional indirect bonding, the meta-analysis by Li et al. showed a pooled bracket failure rate of 7.5% which again aligns with our findings[21].

The significantly lower initial bracket failure rate associated with the DIB highlights the potential reliability of digital methods in improving treatment stability early on, which may further contribute to the reduction in treatment time and visits. Fewer bracket failures translate into fewer emergency visits and less need for re-bonding, adding to the efficiency of the digital workflow.

While the results are promising for the digital technique, further research with larger and more diverse patient populations would be beneficial to confirm these findings and explore their applicability across different orthodontic scenarios. Long-term follow-up studies would also be valuable to assess the stability of treatment outcomes and any differences in relapse rates between the two techniques.

Adopting digital indirect bonding in orthodontics faces barriers, including high laboratory costs for 3D scanners, CAD/CAM software, and 3D printers, which can be prohibitive for smaller practices [13,22]. The workflow's complexity and learning curve for virtual bracket positioning and tray design further hinder adoption8.

However, while the upfront laboratory costs of digital bonding are higher, they must be evaluated in the broader context of overall treatment efficiency. Digital methods can reduce chairside time, improve precision in bracket placement, and lower the risk of bracket failures or errors, potentially leading to fewer adjustments and follow-up visits. Over time, these efficiencies might offset the higher initial laboratory costs, particularly in high-volume practices where streamlined workflows and reduced treatment times can translate into cost savings and improved patient throughput.

Future research should focus on a comprehensive cost-effectiveness analysis, considering not just laboratory costs but also long-term savings in clinical time and improved outcomes associated with digital methods.

The technique's sensitivity demands precise scanning, tray production, and adhesive application, with errors potentially compromising outcomes6,2. Additionally, the setup, including scanning and 3D printing, is more time-consuming than traditional methods, deterring adoption[9,21].

Discrepancies in bracket placement during transfer raise concerns about digital systems' ability to replicate virtual setups clinically [23,24].

Addressing these barriers through technological advancements, clinician training, and additional research could facilitate broader adoption of digital indirect bonding in orthodontic practice. Finally, it is important to acknowledge the limitations of this study. First, although the sample size was adequate to detect significant differences in key metrics, it remains relatively small, which may reduce the power to identify more subtle distinctions between the bonding techniques. Additionally, the single-center design might limit the generalizability of the findings, as the results may not fully represent diverse clinical settings or patient populations. Furthermore, the study focused exclusively on patients with Class I malocclusion undergoing extraction, meaning the outcomes may not directly translate to other types of malocclusion or non-extraction cases. Despite these constraints, this research provides valuable insights into the potential benefits of digital indirect bonding techniques, highlighting their role in improving efficiency and precision in orthodontic practice. In summary, while both the conventional and digital indirect bonding techniques produce similar treatment quality, the digital approach offers several significant advantages, particularly in terms of reduced treatment time, fewer visits, and lower bracket failure rates. These findings suggest that digital indirect bonding could be an attractive alternative to conventional techniques for both orthodontists and patients. As digital technologies continue to evolve, further improvements in orthodontic care may be possible.

CONCLUSION

Both techniques provide similar treatment quality, but DIB represents a promising advancement in orthodontics, balancing initial costs with improved clinical efficiency and patient satisfaction. Further research with larger, diverse populations is necessary to validate these findings and assess long-term cost-effectiveness.

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Authors declare that there is no conflict of interest
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ORIGINAL RESEARCH

INTERPERSONAL COMMUNICATION AND PATIENT BEHAVIORAL UNDERSTANDING IN HEALTH SERVICES: A SOCIOPSYCHOLOGICAL STUDY IN INDONESIA

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Abstract

The phenomenon of low patient understanding of medication use and treatment procedures remains a challenge in healthcare services, especially in outpatient services where interactions are brief. This problem can hinder treatment compliance and impact the effectiveness of treatment. This study aims to analyze the effectiveness of interpersonal communication by pharmaceutical personnel and its relationship with the level of patient understanding based on the Elaboration Likelihood Model (ELM) framework, which explains how the quality of messages and communicative relationships influence the process of elaborating health information. The study used a quantitative method with a cross-sectional survey design, involving outpatient patients who received medication information services. Data were collected through questionnaires and analyzed using descriptive and inferential statistics. The results showed that the effectiveness of interpersonal communication by pharmaceutical personnel was in the good to very good category, especially in terms of empathy, openness, support, and clarity of message. The level of patient understanding was also in the good category, as reflected in their ability to translate, interpret, and relate drug information to their daily conditions. Correlation analysis showed a significant positive relationship with moderate strength between interpersonal communication and patient understanding, while demographic variables did not show a significant influence except for consultation frequency. These findings reinforce the ELM assumption that high-quality communication promotes cognitive elaboration through central pathways, thereby strengthening patient understanding. Practically, this study confirms the importance of improving the interpersonal communication competence of pharmaceutical personnel as an effort to improve the quality of drug education and patient safety. The benefits of these findings can be used as a basis for developing communication training, formulating drug information service policies, and conducting further research related to therapy compliance and the quality of patient experience.

Key words: Pharmacists, Interpersonal Communication, Patient Understanding, Healthcare Services, Empathy, Communication Effectiveness.

INTRODUCTION

Interpersonal communication between healthcare professionals, especially pharmacists, and patients is an important aspect of healthcare that contributes to patients' understanding of medical information[1,2]. Effective communication plays an important role in improving patients' understanding of the treatment they receive, which in turn affects their adherence to treatment and the expected therapeutic outcomes[3-5]. In Indonesia, although healthcare services are increasingly patient-centered, communication based solely on the delivery of accurate medical information often neglects patients' deep understanding of that information, which

can affect the quality of care received[6.7].

Previous studies have shown that communication based on empathy, openness, support, positive attitudes, and equality can improve patients' understanding of the treatment provided[8]. Communication that emphasizes these socio-emotional aspects has the potential to improve the patient's experience of undergoing treatment and strengthen the relationship between patients and health workers[7-9]. However, in Indonesia, although families and communities play a major role in health decision-making, pharmacist-patient communication still tends to focus on biomedical aspects, while the social-emotional dimension is still neglected[12]. This leads to an imbalance in communication, which has the potential to reduce patients' understanding of treatment.

Although there are studies that highlight communication in the context of health and its influence on patient understanding, a major gap in the literature is the lack of studies examining the influence of interpersonal communication dimensions in improving patient understanding in the context of outpatient care in Indonesia. Most existing studies focus more on analyzing pharmacist communication patterns or biomedical communication in care, while socio-emotional factors such as empathy and openness are still rarely discussed in health research in Indonesia. This gap creates a need for more in-depth research on the dimensions of interpersonal communication and how it affects patient understanding, especially in outpatient services.

The novelty of this study lies in the integration of interpersonal communication theory with a sociopsychological perspective, which introduces a new analysis of the influence of pharmacist-patient communication on patient understanding of medication. This study also presents a new contribution to health communication studies by exploring communication dimensions such as empathy, support, and equality, which are rarely discussed in depth in the existing literature. In addition, this study will consider Indonesian social and cultural factors that influence communication between pharmacists and patients, which provide a unique context for this study.

This study aims to measure the level of effectiveness of pharmacists' interpersonal communication in outpatient services and analyze its influence on patients' understanding of medication. The specific objectives of this study are to: (1) assess the quality of pharmacists' interpersonal communication, which includes the dimensions of openness, empathy, support, positive attitude, and equality, in influencing patients' understanding of medication; (2) analyze the relationship between pharmacist communication and patient behavior understanding; and (3) identify factors that strengthen or weaken this relationship, such as the frequency of pharmacist consultations with patients.

The main argument of this study is that effective interpersonal communication, with an emphasis on socio-emotional dimensions such as empathy and openness, can improve patients' understanding of their medication[13]. Improved patient understanding of medication will not only affect medication adherence but can also improve overall therapeutic outcomes[11,12]. Therefore, more humanistic and empathy-baseds interpersonal communication has great potential to improve the quality of health services in Indonesia.

In addition, this study argues that pharmacists, as part of the medical team, need to strengthen their interpersonal communication skills to create a more open and supportive environment for patients. With a more open and empathetic approach, pharmacists can build stronger relationships with patients, which in turn can improve patients' understanding of treatment and improve their adherence to therapy[16,17]. This study not only contributes theoretically to the understanding of pharmacist-patient communication but also provides practical implications for improving communication training for pharmacists in Indonesia.

METHODOLOGY

This study adopted a descriptive quantitative research design to assess the effectiveness of pharmacists' interpersonal communication in outpatient services and analyze its impact on patients' understanding of medication-related information [18]. The study used a survey approach, with a questionnaire as the main instrument to gather data from patients receiving pharmaceutical services at Batara Siang Regional General Hospital, Pangkajene and Kepulauan Regency, Indonesia.

Research Design

This study used a cross-sectional design, employing a quantitative descriptive approach to assess the relationship between pharmacists interpersonal communication and patients understanding of medication. The sample for this research was determined using the Slovin formula and purposive sampling, selecting 386 outpatient patients who met the inclusion criteria. The study employed a questionnaire based on DeVito's theory of interpersonal communication, which includes five key dimensions: openness, empathy, support, positive attitude, and equality[9]. The questionnaire was designed to measure patients perceptions of pharmacist communication quality and their understanding of medication, using Bloom's taxonomy[19].

Population and Sample: The population of this study consisted of outpatient patients registered at Batara Siang Regional General Hospital, totaling 10,821 patients. The sample size of 386 patients was selected using the Slovin formula, with the criteria focusing on

patients who had received services from pharmacists and interacted with them during outpatient visits. The sample was selected to represent various demographic categories, including gender, age group, highest level of education, occupation, and frequency of consultation with a pharmacist [20,21].

Data Collection Technique: Data were collected in two phases. The first phase involved administering a questionnaire to assess pharmacist interpersonal communication, focusing on dimensions such as openness, empathy, support, positive attitude, and equality. A 4-point Likert scale was used to measure patient perceptions (1 = strongly disagree, 4 = strongly agree)[22]. In the second phase, respondents were asked to complete a questionnaire evaluating their understanding of medication-related information, using the cognitive dimensions of Bloom's taxonomy (Translation, Interpretation, Extrapolation)[19].

Research Instrument: The research instrument was a structured questionnaire based on DeVito's interpersonal communication theory and Bloom's taxonomy[9],[19]. The questionnaire was designed in two parts: the first part assessed the quality of pharmacist-patient communication, and the second part measured patient understanding of medication-related information. The instrument was tested for validity by experts and methodologists, and reliability was assessed using Cronbach's Alpha, which showed a reliability value above 0.7, considered satisfactory for this study[23].

Data Analysis: Data analysis was performed using JAPS software. The analysis techniques included Pearson's correlation to assess the linear relationship between pharmacist communication quality and patient understanding, Spearman's Rho correlation for ordinal data, and multiple linear regression to identify the influence of independent variables on patient behavioral understanding [24-27]. Descriptive statistics were used to summarize the demographic characteristics of the sample and the distribution of responses.

RESULTS

Level of Interpersonal Communication Effectiveness

Based on research data, Table 1 illustrates the effectiveness of interpersonal communication between pharmacists and outpatients at Batara Siang Regional General Hospital. This table analyzes communication indicators such as openness, empathy, support, positive attitude, and equality. In addition, the research data for each element of communication effectiveness is explained in detail below.

Table 1. Total Frequency Distribution of Respondents

Question Item	Response Frequency				Total
	Strongly disagree	Disagree	Agree	Strongly agree	
Openness Item 1	2 (0.5%)	8 (2.1%)	139 (36.0%)	237 (61.4%)	386 (100%)
Openness Item 2	13 (3.4%)	25 (6.5%)	163 (42.2%)	185 (47.9%)	386 (100%)
Openness Item 3	4 (1.0%)	22 (5.7%)	169 (43.8%)	191 (49.5%)	386 (100%)
Empathy Item 1	2 (0.5%)	10 (2.6%)	144 (37.3)	230 (59.6%)	386 (100%)
Empathy Item 2	2 (0.5%)	13 (3.4%)	180 (46.6%)	191 (49.5%)	386 (100%)
Empathy Item 3	2 (0.5)	27 (7.0%)	177 (45.9%)	180 (46.6%)	386 (100%)
Empathy Item 4	11 (2.8%)	33 (8.5%)	152 (39.4%)	190 (49.2%)	386 (100%)
Support Item 1	3 (0.8%)	23 (6.0%)	177 (45.9%)	185 (47.4%)	386 (100%)
Support Item 2	4 (1.0%)	23 (6.0%)	156 (40.4%)	203 (52.6%)	386 (100%)
Support Item 3	4 (1.0%)	12 (3.1%)	171 (44.3%)	199 (51.6%)	386 (100%)
Positive Item 1	2 (0.5%)	11 (2.8%)	141 (36.5%)	232 (60.1%)	386 (100%)

Positive Item 2	3 (0.8%)	12 (3.1%)	158 (40.9%)	213 (55.2%)	386 (100%)
Positive Item 3	2 (0.5%)	25 (6.5%)	168 (43.5%)	191 (49.5%)	386 (100%)
Equality Item 14	1 (0.3%)	11 (2.8%)	176 (45.6%)	198 (51.3%)	386 (100%)
Equality Item 15	1 (0.3%)	10 (2.6%)	170 (44.0%)	205 (53.1%)	386 (100%)

Source: Researcher Data Analysis Results, 2025

Upon analyzing the communication indicators, Table 1 shows that: For Openness, Item 1 has an overall score of 61.4% Strongly Agree and 36.0% Agree. Item 2 shows 47.9% Strongly Agree and 42.2% Agree. Item 3 has 43.8% Agree and 49.5% Strongly Agree. The respondents' views on openness reflect high levels of agreement.

For Empathy, Item 1 shows 59.6% Strongly Agree and 37.3% Agree. Item 2 has 49.5% Strongly Agree and 46.6% Agree. Item 3 shows 46.6% Strongly Agree and 45.9% Agree, while Item 4 has 49.2% Strongly Agree and 39.4% Agree. The findings indicate strong support for the importance of empathy in communication.

For Support, Item 1 has 47.4% Strongly Agree and 45.9% Agree. Item 2 shows 52.6% Strongly Agree and 40.4% Agree. Item 3 has 51.6% Strongly Agree and 44.3% Agree. The majority of respondents agree on the importance of support in communication.

For Positive Communication, Item 1 has 60.1% Strongly Agree and 36.5% Agree. Item 2 shows 55.2% Strongly Agree and 40.9% Agree, while Item 3 has 49.5% Strongly Agree and 43.5% Agree. This highlights the respondents' strong inclination towards maintaining a positive communication attitude.

For Equality, Item 14 shows 51.3% Strongly Agree and 45.6% Agree. Item 15 has 53.1% Strongly Agree and 44.0% Agree. The data reflect strong agreement on the importance of equality in communication.

Level of Understanding of Outpatients

Based on the research data, Table 2 shows the frequency distribution of the level of understanding of outpatients at Batara Siang Regional General Hospital. This table analyzes the indicators of understanding, namely Translation, Interpretation, and Extrapolation. In addition, the research data for each element of patient understanding is described in detail below.

Table 2. Total Frequency Distribution of Respondents

Question Item	Response Frequency				Total
	Strongly Disagree	Disagree	Agree	Strongly agree	
Translators Item 1	1 (0.3%)	18 (4.7%)	155 (40.2%)	212 (54.9%)	386 (100%)
Translators Item 2	1 (0.3%)	29 (7.5%)	146 (37.8%)	210 (54.4%)	386 (100%)
Translators Item 3	21 (5.4%)	93 (24.1%)	187 (48.4%)	85 (22.0%)	386 (100%)
Translators Item 4	15 (3.9%)	30 (7.8%)	195 (50.5%)	146 (37.8%)	386 (100%)
Interpretation Item 1	66 (17.1%)	103 (26.7%)	142 (36.8%)	75 (19.4%)	386 (100%)
Interpretation Item 2	8 (2.1%)	58 (15.0%)	215 (55.7%)	105 (27.2%)	386 (100%)
Interpretation Item 3	5 (1.3%)	27 (7.0%)	189 (49.0%)	165 (42.7%)	386 (100%)
Extrapolation Item 1	5 (1.3%)	51 (13.2%)	194 (50.3%)	136 (35.2%)	386 (100%)
Extrapolation Item 2	39 (10 .1%)	98 (25.4%)	152 (39.4%)	97 (25.1%)	386 (100%)
Extrapolation Item 3	8 (2.1%)	49 (12.7%)	214 (55.4%)	115 (29.8%)	386 (100%)

Source: Researcher Data Analysis Results, 2025

Upon analyzing the patient comprehension indicators, Table 2 shows that: For Translation, Item 1 has an overall score of 54.9% Strongly Agree and 40.2% Agree. Item 2 shows 54.4% Strongly Agree and 37.8% Agree. Item 3 has 22.0% Strongly Agree and 48.4% Agree. Item 4 has 37.8% Strongly Agree and 50.5% Agree. Respondents' views on translation show strong agreement on the importance of translation in facilitating communication.
For Interpretation, Item 1 shows 19.4% Strongly Agree and 36.8% Agree. Item 2 had 27.2% Strongly Agree and 55.7% Agree. Item 3 showed 42.7% Strongly Agree and 49.0% Agree. These findings indicate that despite a moderate level of agreement, interpretation is still considered crucial in ensuring effective communication.
For Extrapolation, Item 1 shows 35.2% Strongly Agree and 50.3% Agree. Item 2 shows 25.1% Strongly Agree and 39.4% Agree. Item 3 shows 29.8% Strongly Agree and 55.4% Agree. These results show that the majority of respondents agree on the importance of extrapolation in communication, highlighting its relevance in understanding and applying information in a broader context.

The Relationship Between Communication Effectiveness and Outpatient Understanding Levels

Based on research data, Table 3 illustrates the Relationship Between Communication Effectiveness and the Level of Understanding of Outpatients at Bsatara Siang Regional General Hospital. This table explores how various communication indicators, such as openness, empathy, support, positive attitude, and equality, correlate with patient comprehension levels, such as Translation, Interpretation, and Extrapolation of medical information. Detailed research data on the influence of each communication element on comprehension is presented below.

Table 3. Relationship between Communication Effectiveness and Level of Understanding

Variable	Variable	Communication Effectiveness	Level of Understanding
Communication Effectiveness	Pearson's r	-	
	p-value	-	
	Spearman's	-	
	p-value	-	
Level of Understanding	Pearson's r	0.301	-
	p-value	< .001	-
	Spearman's	0.328	-
	p-value	< .001	-

Source: Researcher Data Analysis Results, 2025

Upon analyzing the relationship between communication effectiveness and patient understanding, Table 3 shows that. For Communication Effectiveness, the Pearson correlation coefficient is not applicable (marked with "-"), while the Spearman correlation coefficient is also not calculated. However, the p-values for both measures are not available in this table, as the relationship was not evaluated directly with these variables.
For the Level of Understanding, the Pearson correlation coefficient is 0.301, with a p-value of less than <0.001, indicating a moderate positive relationship between communication effectiveness and the level of understanding. These results show that as communication effectiveness increases, patients' understanding of medical information also increases. Additionally, the Spearman correlation coefficient is 0.328, with a p-value also less than <0.001, confirming a similar moderate positive correlation.
These findings indicate that effective communication significantly contributes to increased levels of understanding among outpatients, and this relationship is statistically significant, as evidenced by the low p-value.

Factors Affecting the Effectiveness of Interpersonal Communication Between Pharmaceutical Staff and Outpatients

Based on research data, Table 4 shows the Factors Affecting the Effectiveness of Interpersonal Communication between Pharmacists and Outpatients at Batara Siang Regional General Hospital. This table displays regression coefficients for various factors such as openness, empathy, support, positive attitude, and equality. This table highlights the strength and significance of each factor's influence on overall communication effectiveness. This data provides a deeper understanding of how each factor contributes to improving communication effectiveness in a healthcare settings.

Table 4. Coefficients

Model		Unstandardized	Standard Error	Standardized	t	p
M_0	(Intercept)	51.868	0.318		163.192	< .001
M_1	(Intercept)	50.500	2.163		23.345	< .001
	Gender	0.705	0.644	0.056	1.095	.274
	Age	0.081	0.279	0.017	0.291	.771
	Highest Level of Education	-0.105	0.251	-0.025	-0.418	.677
	Employment	-0.225	0.148	-0.091	-1.524	.128
	Total Consultations	0.700	0.324	0.112	2,162	0.31

Source: Researcher Data Processing Results, 2025

Table 4 presents the unstandardized coefficients and p-values for the regression models M_0 and M_1, providing insights into the statistical significance of each variable included in the analysis.

In Model M_0, the Intercept has an unstandardized coefficient of 51.868, with a p-value less than 0.001, indicating a highly significant intercept. This suggests that, when all predictors are held constant at zero, the baseline value of the dependent variable is estimated to be 51.868, serving as a crucial reference point for the model. These findings are consistent with previous research, which has emphasized the significant impact of intercept values in predicting outcomes[28].

In Model M_1, the Intercept coefficient is 50.500, with a p-value less than 0.001, further reinforcing the strong statistical significance of the intercept. This result underscores the foundational role of the intercept in the model's prediction [29].

When examining the predictors in Model M_1, the coefficient for Gender is 0.705, with a p-value of 0.274. This p-value exceeds the conventional threshold of 0.05, indicating that Gender does not have a statistically significant impact on the dependent variable in the context of this model. This aligns with findings from prior studies, which suggest that demographic factors, such as gender, often do not significantly influence outcomes in healthcare models [30]. Similarly, Age shows a coefficient of 0.081, with a p-value of 0.771, suggesting that age does not significantly influence the dependent variable. These findings align with studies indicating that age does not always have a significant effect in pharmaceutical communication [31].The coefficient for Highest Level of Education is -0.105, with a p-value of 0.677, further supporting the lack of statistical significance for this variable. This suggests that the highest level of education may not significantly affect communication effectiveness, as corroborated by similar research[32]. Similarly, Employment has an unstandardized coefficient of -0.225, with a p-value of 0.128, indicating that employment status does not significantly affect the dependent variable. Although the coefficient is negative, the lack of statistical significance suggests that employment status is not a determining factor in this context[28].

Finally, Total Consultations exhibits a coefficient of 0.700, with a p-value of 0.31. Although the p-value does not reach the conventional significance threshold of 0.05, the positive coefficient suggests that total consultations may have a positive, albeit marginal, impact on the dependent variable. However, further analysis may be required to establish a clearer understanding of this relationship. This finding is consistent with research suggesting that service-related factors, such as the number of consultations, may influence patient satisfaction.

In conclusion, the results from Model M_1 suggest that while the intercept plays a crucial role, most of the demographic variables tested do not significantly influence the dependent variable in this context. The positive coefficient for Total Consultations warrants further exploration, as it may offer valuable insights for future studies aimed at enhancing the explanatory power of the model. These findings reinforce the literature that emphasizes the role of communication structure and service processes over demographic background in improving healthcare outcomes.

DISCUSSION

The findings show that, in general, the effectiveness of pharmacists' interpersonal communication is in the "very good" category, especially in terms of openness, empathy, support, positive attitude, and equality. This is evident from the percentage of "agree" and "strongly agree" responses that consistently dominate each statement item, with a proportion above 80% for most indicators. This condition indicates that pharmacist-

patient interactions in outpatient facilities are not only transactional and oriented towards the delivery of drug information, but also contain strong relational elements: pharmacists are willing to listen to complaints, explain in easy-to-understand language, show a supportive attitude, and treat patients equally. From the perspective of DeVito's interpersonal communication theory, the combination of openness, empathy, support, positive attitude, and equality is an important prerequisite for effective communication, as it creates a safe psychological climate in which patients feel valued and dare to express their needs[9]. These findings are also in line with the basic assumptions of the Elaboration Likelihood Model (ELM), which states that when the source of a message is perceived as credible, warm, and empathetic, patients tend to pay more attention and are encouraged to engage in cognitive elaboration of the message being conveyed.

On the other hand, patients' level of understanding of health service information was also in the "good" to "very good" category for all three understanding indicators, namely translation, interpretation, and extrapolation. The high percentage of respondents who stated that they were able to translate drug information into their own language, understand the meaning and purpose of treatment, and relate the information received to their daily situations shows that patients not only receive information passively but also process it at a higher cognitive level as classified in Bloom's Taxonomy. From an ELM perspective, this condition reflects the dominance of the "central route" processing pathway, in which patients with high involvement in their health and treatment are encouraged to examine the arguments presented by pharmacists in greater depth. The pharmacist's empathy and openness serve as initial triggers that reduce psychological barriers, while the clarity of the drug explanation provides "strong arguments" that support the formation of stable understanding. Thus, the quality of interpersonal communication acts as a relational context that facilitates the patient's cognitive elaboration of drug information.

The relationship between communication effectiveness and moderate but significant patient comprehension levels (Pearson $r = 0.301$; Spearman $r = 0.328$; $p < 0.001$) indicates that the better the quality of pharmacists' interpersonal communication, the higher the patients' comprehension of medication information. This positive correlation reinforces the ELM assumption that message elaboration is influenced by both message characteristics and the way the message is packaged and delivered. Interestingly, the regression analysis results show that demographic variables such as gender, age, education, and occupation do not have a significant effect on communication effectiveness, while the frequency of consultation with pharmacists has a significant positive coefficient. This means that it is not the patient's demographic background that is most decisive, but rather the intensity and quality of the communication encounter itself. Within a sociopsychological framework, these findings confirm that repeated pharmacist–patient relationships with consistent patterns of empathetic and equal communication will strengthen patients' cognitive engagement, so that the messages conveyed are processed more through central pathways, leading to increased understanding and the potential for better treatment compliance.

The application of the Elaboration Likelihood Model (ELM) theory in the findings of this study can be seen from the way patients process persuasive messages conveyed by pharmaceutical personnel. In this context, pharmaceutical personnel act as *the source* that conveys messages in the form of drug information, usage procedures, side effects, and the importance of therapy compliance, while patients become *receivers* who assess, elaborate, and respond to these messages. The results show that most patients stated that they understood the information provided, were able to explain it back in their own words, and relate it to their daily lives. This indicates that many patients process messages through the *central route*, which is characterized by motivation and the ability to think critically, weigh arguments, and evaluate the content of messages in depth. Warm, empathetic, clear, and equal interpersonal communication creates psychological conditions conducive to cognitive elaboration, so that health messages are not only received superficially but are processed into more meaningful understanding.

However, the finding that the relationship between interpersonal communication effectiveness and patient understanding is moderate also indicates that *the peripheral route* still plays a role in the message processing process. This means that some patients rely more on peripheral cues, such as the friendliness of pharmaceutical staff, professional credibility, institutional authority, and previous positive experiences, rather than examining medical arguments in detail. Within the ELM framework, this condition commonly occurs when the patient's motivation, opportunity, or cognitive ability to elaborate on the message is not optimal, for example, due to time constraints, low health literacy, or emotional burden during treatment. Therefore, the findings of this study confirm that the effectiveness of interpersonal communication by pharmaceutical personnel must combine two aspects simultaneously: presenting strong and easily understood arguments to encourage *central route* processing, while maintaining credibility, empathy, and support as positive *peripheral cues*. The combination of these two aspects explains why improving the quality of communication contributes to improving patient

understanding, although it does not automatically guarantee a change in attitude and therapy compliance in all individuals.

This study found that interpersonal communication among pharmaceutical personnel was rated as good to very good and contributed positively to patient understanding, in line with the latest discourse on psychological safety and patient-centered communication. [33] Emphasized that *psychological safety* in health services is characterized by strong interpersonal relationships, a work environment that is safe for taking interpersonal risks, and a non-punitive culture. in the context of this study, high scores on the dimensions of empathy, support, and equality indicate that patients feel safe enough to ask questions, express ignorance, and discuss concerns related to medication without fear of blame, thus supporting message elaboration through *the central route* in the ELM framework. This intersects with the study by [34], which places patient-centered communication at the core of service quality and highlights institutional, environmental, and behavioral barriers. Our findings show that when these barriers are relatively overcome at the micro-interaction level (pharmacist–patient), perceptions of communication quality and patient understanding tend to increase. On the other hand, the study by [35] on online medical consultations during Covid-19 showed that the quality of communication and technical comfort in teleconsultations can be equivalent to face-to-face consultations; this reinforces the interpretation that it is not merely the medium (offline or online), but the quality of the relationship, comfort, and clarity of the message that determines the path of health information elaboration by patients as described in ELM.

Dialogue with other studies also shows consistency that the interpersonal competence of health workers needs to be viewed as the result of a continuous process of education, training, and leadership. [36] Found that various educational interventions were able to improve medical students' interpersonal communication and empathy skills, albeit with small effects; this is in line with the moderate correlation in this study, which indicates that improving the communication skills of pharmaceutical personnel contributes significantly, but is not the only determinant, to patient understanding. [37] In rural primary care in China showed that the better the doctors' communication skills, the higher the quality of service and patient satisfaction; this pattern parallels our finding that communication effectiveness is positively related to patient understanding. In terms of cultural sensitivity, the study by [38] on the cultural competence of community pharmacists in the UAE showed that cultural diversity training was associated with increased *self-perceived competence* and more patient-centered caregiving behaviors; although this study did not explicitly measure cultural competence, high scores on empathy and support indicate the presence of communication practices that are sensitive to the patient's context. Furthermore, the studies by [39] on *transformative learning* and [40] on *health leadership* emphasize the importance of critical reflection, emotional support, and healthy leadership styles in shaping a humanistic communication culture in healthcare facilities. This implies that the quality of interpersonal communication identified in this study is likely supported by a supportive organizational climate and leadership, and opens up space for further research agendas linking pharmacist communication, organizational support, and clinical outcomes and patient compliance behavior within the ELM framework.

The finding that interpersonal communication among pharmaceutical personnel is in the good to very good category and is positively related to the level of patient understanding has important theoretical and practical implications. Theoretically, these results reinforce the main assumption of the Elaboration Likelihood Model (ELM) that the quality of communicative relationships and the strength of message arguments will determine the extent to which patients process health information through *the central route*, resulting in deeper and more stable understanding. Practically, this study emphasizes the need for hospitals and health education institutions to make interpersonal communication training (empathy, support, clarity of explanation, and equality) a core component of pharmaceutical personnel competency development, for example through *patient-centered communication* modules, medication counseling simulations, and structured performance-based feedback. However, this study has several limitations, including a cross-sectional design that does not allow causal conclusions to be drawn, the use of self-report questionnaires that have the potential for social bias, a limited scope of location to one facility/area, thus limiting generalizability, and the failure to measure other important variables such as medication adherence, patient psychological safety, cultural competence, and the context of digital services (tele-pharmacy). Based on these limitations, future research could be directed toward longitudinal or quasi-experimental designs to test the impact of communication training on patient understanding and compliance, expansion of the context to various types of health facilities and more diverse regions, combining objective data (e.g., prescription adherence profiles, revisit rates, or *medication error* indicators), and mixed (quantitative–qualitative) approaches to further explore how psychological, cultural, and organizational factors interact in shaping the persuasive message processing pathway as formulated in ELM.

CONCLUSION

This study was motivated by the question of how effective interpersonal communication by pharmaceutical personnel is in shaping outpatient understanding of medication use and treatment procedures. Amidst the complexity of the healthcare system, it is still common to find patients who lack understanding of the therapy they are undergoing, which has the potential to reduce compliance and clinical outcomes. Based on the Elaboration Likelihood Model (ELM) framework, this study seeks to analyze the extent to which the quality of interpersonal communication by pharmaceutical personnel is related to the level of patient understanding of the healthcare information they receive.

The results of the study show that the effectiveness of interpersonal communication by pharmaceutical personnel is in the good to very good category, especially in terms of openness, empathy, support, positive attitude, and equality. The level of patient understanding regarding the use of medication and treatment procedures is also in the good category, as reflected in the ability of patients to translate, interpret, and relate information to everyday situations. Statistical analysis shows a significant positive relationship with a moderate correlation between communication effectiveness and patient understanding, while demographic variables tend to have no significant effect, except for the frequency of consultation with pharmaceutical personnel. Theoretically, these findings reinforce the ELM assumption that empathetic, clear, and equal communication encourages patients to process information through the central pathway, resulting in deeper understanding. Practically, these results emphasize the importance of strengthening interpersonal communication competencies as an integral part of the professional standards of pharmaceutical personnel.

However, this study has limitations, including a cross-sectional design that does not allow for causality to be drawn, the use of self-report instruments that are prone to social bias, and a limited scope of locations, thereby limiting the power of generalization. Recommendations for future research include the use of longitudinal or quasi-experimental designs to test the impact of communication training on patient understanding and compliance, expansion of settings to various types of facilities and regions, measurement of additional variables such as medication adherence, psychological safety, and cultural competence, and the application of a mixed-methods approach to further explore the dynamics of persuasive message processing in the context of pharmaceutical services.

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ORIGINAL RESEARCH

CORRECTION OF LEDGE FORMATION IN SIMULATED ROOT CANALS USING MANUAL AND ROTARY NICKEL–TITANIUM INSTRUMENTS WITH VARIED KINEMATICS

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Abstract

Background: The aim of this study was to evaluate and compare the effectiveness of manual files and rotary nickel–titanium instruments operating in continuous rotation, reciprocation, and optimum torque reverse (OTR) motion for correction of ledge formation in simulated curved root canals.

Materials and Methods: Eighty standardized acrylic blocks with curved canals were used. Ledges were artificially created at a standardized level. Specimens were randomly divided into four groups (n = 20): manual stainless-steel files, continuous rotary NiTi, reciprocating NiTi, and OTR NiTi systems. Ledge correction was attempted using standardized protocols. Outcomes included success rate of ledge correction, time required to regain working length, and change in canal curvature. The significance level was set at $P \leq 0.05$. Statistical analysis was performed with IBM® SPSS® Statistics Version 25 for Windows.

Results: Manual files demonstrated the highest success rate in bypassing ledges, while reciprocating and OTR systems showed significantly reduced correction time. Continuous rotary instruments exhibited greater change in canal curvature compared with other groups.

Conclusion: Manual files remain the most reliable instruments for initial ledge bypassing, whereas rotary systems particularly those using OTR and reciprocation can efficiently refine canal shaping after correction. Instrument kinematics significantly influence ledge management outcomes.

Keywords: Ledge formation; Acrylic blocks; Rotary instrumentation; Reciprocation; Optimum torque reverse; Canal transportation.

1.INTRODUCTION

Ledge formation is a common procedural error encountered during root canal instrumentation, particularly in curved canals, and is often associated with improper file selection, inadequate glide path establishment, failing to use the instrument in sequential order, inadequate irrigation during shaping, and excessive apical pressure. A ledge may prevent instruments from reaching the full working length, resulting in inadequate cleaning of the apical portion of the canal and potentially compromising the long-term success of endodontic treatment.[1, 2]

Traditionally, manual stainless-steel files, especially when pre-curved, have been advocated for bypassing ledges due to their rigidity and enhanced tactile feedback.[3, 4] However, these instruments are associated with an increased risk of canal transportation and further procedural errors when used improperly in curved canals.[5, 6] The introduction of nickel–titanium (NiTi) rotary instruments has significantly improved the efficiency and safety of root canal preparation owing to their superior flexibility and shape memory.[7, 8] Contemporary rotary systems operate using different kinematics, including continuous forward rotation, reciprocation, and optimum torque reverse (OTR) motion. Continuous rotation allows efficient dentin

removal but may increase torsional stress, while reciprocating motion has been shown to reduce cyclic fatigue and instrument separation.[9, 10] OTR motion represents a hybrid kinematic approach that alternates between clockwise and counterclockwise rotation in response to torque load, potentially enhancing canal centering and instrument safety.[11, 12] Despite advances in instrumentation systems, limited data are available regarding the effectiveness of these different kinematics in correcting ledge formation once it has occurred.[13, 14] Therefore, the present study aimed to compare manual files and rotary NiTi instruments operating in continuous rotation, reciprocation, and OTR motion for the correction of ledge formation in simulated curved root canals with artificial ledges. [9, 10]

2. MATERIALS AND METHODS

2.1 Study Design

This experimental in vitro study compared four instrumentation techniques for the correction of artificial ledge formation using standardized simulated root canals in acrylic resin blocks.[9, 14]

2.2 Sample Size Determination

Sample size was calculated a priori based on previous studies on ledge correction and canal shaping. Assuming a medium-to-large effect size (f = 0.40), α = 0.05, and 80% power, 18 specimens per group were required. To ensure robustness and account for potential specimen loss, 20 specimens were included per group, resulting in a total of 80 root canal blocks, sufficient to detect significant differences across all parameters

2.3 Sample Selection

Eighty transparent acrylic resin blocks (Endo Training Blocks; Dentsply Sirona) were used. All blocks had standardized canal characteristics, including a curvature of 30° a curvature radius of 5 mm, canal length of 16 mm and apical diameter 0.15 mm. Figure (1)

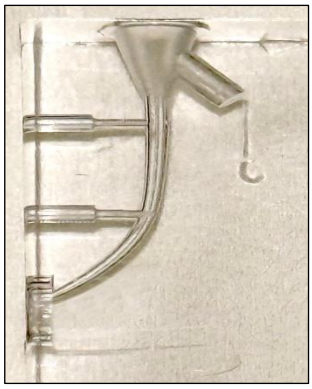


Figure 1. Simulated canal before ledge formation under x8 magnification

2.4 Artificial Ledge Creation

Artificial ledges were created at the beginning of the canal curvature by advancing size #35 and #40 stainless-steel K-files with excessive apical pressure and without respecting the canal curvature.[15, 16] Figure (2)

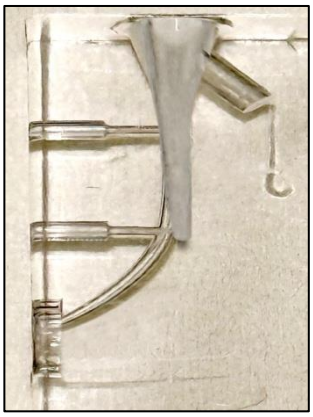


Figure 2. Simulated canal after ledge formation under x8 magnification

Ledge formation was confirmed when a #10 K-file could no longer reach the original working length. This method replicates clinical ledge formation in curved canals.[6,17]

2.5 Ledge Correction Protocol

All procedures were performed by a single experienced operator under dental operating microscope (DOM) Zumax OMS2350 (Zumax Medical Co., Ltd., Suzhoi, China) ×8 magnification to minimize variability.[14] Throughout instrumentation, canals were irrigated with distilled water to remove debris and prevent heat-related resin distortion. No chemical irrigants were used.[9] Prior to ledge correction, patency up to the ledge level was verified using a #10 K-file.

2.5.1 Group Allocation

Specimens were randomly assigned into four groups (n = 20 each):

Group I – Manual Instrumentation:

In this group after bypassing the ledge using precurved K-files (#08–#15), files #20, and #25 were pre-curved at the apical 2–3 mm and introduced using gentle watch-winding and short push–pull motions with minimal apical pressure.[3, 4] Once the #10 K-file reached the original WL, enlargement was cautiously completed up to size #30 and step back instrumentation upto #45.

In all rotary groups, ledge correction was initiated only after patency beyond the ledge was regained with a #10 K-file after bypassing was done as in group I.[9, 10] Instrumentation was performed using gentle 2–3 mm pecking motions with minimal apical pressure. After each insertion, instruments were withdrawn, cleaned, and the canal irrigated. Patency was reconfirmed after each cycle using a #10 K-file.[11, 18] All rotary groups were operated using Wismy Endo Motor (Black Edition; Bomedent, Changzhou, China).

Group II – Continuous Rotary Motion :
After coronal flaring Protaper next file (PTN) X2 (25/.06) was operated at a speed of 300 rpm and 2.5 Ncm of torque, according to the manufacturer's instructions.

Group III – Reciprocating Motion:
After coronal flaring WaveOne Gold: WOG Primary (25/.07) variable taper was operated at a speed of 300 rpm and 2.5 Ncm of torque (30° clockwise and 150° counterclockwise) , according to the manufacturer's instructions.

Group IV –(OTR) Motion:
After coronal flaring Protaper next file (PTN) X2 (25/.06) was operated using at a speed of 300 rpm and 2.5 Ncm of torque, according to the manufacturer's instructions.

Each instrument was used according to manufacturer guidelines and discarded to avoid fatigue-related bias.

A maximum time of 5 minutes was allowed for ledge correction per specimen. Failure to regain the original WL within this time was recorded as unsuccessful.[15, 17]

2.6 Evaluation Parameters

2.6.1 Success of Ledge Correction

Defined as the ability to regain the original working length with a #10 K-file without resistance. Outcomes were recorded as successful or unsuccessful.[4, 14]

2.6.2 Change in Canal Curvature (Schneider's Method)

Change in canal curvature was evaluated before and after ledge correction using Schneider's method.[19] in combination with digital image analysis. Standardized digital images of each acrylic resin block were obtained before and after instrumentation using Zumax OMS2350 (Zumax Medical Co., Ltd., Suzhoi, China) DOM equipped with a digital camera at a fixed magnification of ×8. During image acquisition, each specimen was positioned on a flat, stable white surface and aligned parallel to the microscope optical axis to ensure consistent orientation, magnification, and illumination for all images. The captured images were imported into AutoCAD software (Autodesk Inc., USA) and calibrated using the known reference dimension of the resin block to ensure measurement accuracy. Canal curvature was measured according to Schneider's method as follows; a straight reference line was drawn parallel to the long axis of the canal from the canal orifice to the point where the canal began to deviate (A); a second line was drawn from this point of deviation to the apical foramen (B). The angle formed between the two lines represented the degree of canal curvature (α). Figure (3)

Curvature angles were recorded before instrumentation and after ledge correction. The percentage change in canal curvature was calculated using the following formula:

$$\text{Curvature Change (\%)} = \frac{\text{pre-instrumentation angle} - \text{post-instrumentation angle}}{\text{pre-instrumentation angle}} \times 100$$

Higher percentage values indicated greater canal straightening, whereas lower values reflected better preservation of the original canal curvature. [8, 20]

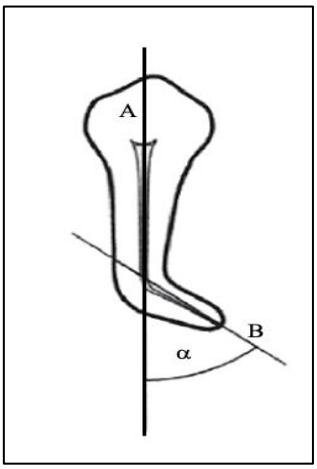


Figure 3. Angle of curvature by Schneider

2.6.3 Time Required for Ledge Correction

Measured in seconds using a digital stopwatch, starting from initial file insertion until the #10 K-file smoothly reached the original WL. [10, 18]

2.7 Statistical Analysis

Normality of the data was assessed using the Kolmogorov–Smirnov and Shapiro–Wilk tests. Parametric variables were analyzed using one-way or two-way ANOVA, while non-parametric success rate data were evaluated with the Chi-square test. Statistical significance was set at $P \leq 0.05$. All analyses were performed using IBM® SPSS® Statistics Version 25 for Windows.

3. RESULTS

A significant difference was observed among the four instrumentation groups for ledge correction success ($p = 0.041$). Manual and reciprocating instrumentation achieved the highest success rates, continuous rotation showed intermediate performance, and OTR motion had the lowest success. No significant difference was found between manual and reciprocating groups ($p > 0.05$), whereas OTR differed significantly from both ($p < 0.05$) (Table 1).

Table 1. The frequencies of Success Rate of Ledge Correction of different groups.

Variables	Success Rate of Ledge Correction		
	Total canals	n	Success rate %
Manual	20	19	95%
Continuous Rotation (PTN)	20	17	85%
OTR (PTN)	20	16	80%
Reciprocation (WOG)	20	19	95%
p-value	**0.041***		

*; significant (p<0.05)

Table 2. The mean and SD of change in canal curvature of different groups.

Variables	Change in canal curvature	
	Mean	SD
Manual	2	0.7
Continuous Rotation (PTN)	5.6	1.3
OTR (PTN)	3.8	1
Reciprocation (WOG)	3.1	0.9
p-value	**<0.001***	

*; significant (p<0.05)

Table 3. The mean and SD of Time Required for Ledge Correction of different groups.

Variables	Time Required for Ledge Correction	
	Mean	SD
Manual	182	36
Continuous Rotation (PTN)	96	22
OTR (PTN)	108	25
Reciprocation (WOG)	88	20
p-value	**<0.001***	

*; significant (p<0.05)

4. DISCUSSION

Ledge formation represents a challenging procedural error that compromises canal negotiation, working length control, and treatment outcome.[6,15] The present study evaluated manual stainless-steel instrumentation and rotary nickel–titanium systems operating under continuous rotation, reciprocation, and optimum torque reverse (OTR) motion for ledge correction in standardized simulated root canals.[7, 10] The findings demonstrate that instrument kinematics significantly influence ledge correction success, curvature preservation, and procedural efficiency, often outweighing similarities in instrument design and taper.[13, 20]

Acrylic blocks were used to provide a standardized and reproducible experimental model, eliminating anatomical variability inherent in extracted teeth and allowing precise evaluation of canal transportation and curvature changes.[1,14] Manual stainless-steel K-files were included as a reference technique, as they represent the traditional and widely accepted method for negotiating and bypassing ledges due to their superior tactile feedback, pre-curving capability, and controlled hand movements.[3,4]

The inclusion of continuous rotation, reciprocation, and optimum torque reverse (OTR) motion allowed a comprehensive assessment of how different rotary behaviors influence ledge correction efficiency and canal preservation. By integrating manual instrumentation and three distinct rotary kinematics, the present protocol enabled a precise evaluation of how tactile control versus engine-driven motion dynamics influence ledge correction success, curvature preservation, and procedural efficiency.

Glide path confirmation using **a** #10 K-file was performed in all specimens prior to further instrumentation to establish a reproducible and safe pathway beyond the ledge. This step reflects standard clinical practice and ensured that subsequent manual or rotary instruments were guided along the original canal trajectory, minimizing the risk of secondary procedural errors such as ledge deepening or canal transportation.[9]

WaveOne Gold and ProTaper Next were chosen because they represent different kinematic approaches; WaveOne Gold is reciprocating, ProTaper Next is continuous rotation, and it can also be used in OTR motion.[21] WaveOne Gold has a parallelogram/offset cross-section, whereas ProTaper Next has a rectangular off-centered cross-section.[7, 10] This influences cutting efficiency, debris removal, and canal centering ability. Both systems include instruments with similar apical sizes and variable taper, allowing a fair comparison and reducing the confounding effect of instrument dimensions while focusing on kinematics and design.[2] Both instruments are made from heat-treated NiTi alloys, which improve flexibility and cyclic fatigue resistance compared to conventional NiTi.[3,7] This makes them suitable for shaping curved canals and for safe ledge bypassing experiments.

Manual instrumentation and reciprocating rotary motion demonstrated the highest ledge bypass success rates (95%), whereas OTR motion showed the lowest success among rotary systems, followed by continuous rotation. The high success of manual files is attributed to their pre-curving capability, superior tactile feedback, and controlled watch-winding movements, which allow precise redirection of the file toward the original canal path.[3,4]

Reciprocating instrumentation matched manual success despite being engine-driven. This can be explained by its alternating clockwise and counterclockwise motion, which limits continuous engagement at the ledge site, reduces the screw-in effect, and promotes frequent disengagement and re-centering of the instrument.[7, 18] In contrast, continuous rotation allows uninterrupted cutting at the ledge, increasing the risk of deviation and reducing bypass success.[20] OTR motion, although safer than continuous rotation, remains predominantly forward-rotating, and torque reversal may occur too late to prevent dentin removal at the ledge, explaining its reduced success rate.[11]

Preservation of the original canal curvature is a critical objective during ledge correction, as excessive straightening may compromise apical anatomy, increase the risk of further procedural errors, and negatively affect long-term treatment outcomes.[13, 14] In the present study, significant differences were observed among the tested instrumentation techniques with respect to the degree of canal curvature alteration following ledge correction, underscoring the influence of instrument kinematics and mode of operation on shaping behavior.[7,8] Manual stainless-steel instrumentation resulted in the lowest percentage change in canal curvature, indicating superior preservation of the original canal anatomy.[3,4] This finding can be attributed to the ability to pre-curve manual files and to the enhanced tactile feedback they provide, allowing the operator to carefully redirect the file along the original canal path. The use of controlled watch-winding and short push–pull motions enables incremental negotiation of the ledge while minimizing uncontrolled dentin removal along the outer curvature, particularly important in curved canals.[6]

Continuous rotary instrumentation demonstrated the greatest degree of canal straightening among all groups,

consistent with the tendency of nickel–titanium instruments operating in uninterrupted clockwise rotation to return to their straight configuration under load.[7] Sustained rotational motion generates continuous lateral forces against the canal walls at the point of maximum curvature, promoting progressive straightening. During ledge correction, repeated engagement at the ledge site can exacerbate this effect. [9]

Reciprocating motion showed significantly lower curvature change compared with continuous rotation and OTR motion, indicating better preservation of canal anatomy.[9,10] The alternating clockwise and counterclockwise movements characteristic of reciprocation limit continuous dentin engagement and reduce sustained lateral pressure on the canal walls. This repeated disengagement allows the instrument to re-center within the canal and follow the existing curvature more closely, even during the challenging process of ledge correction.[20] Despite being engine-driven, reciprocating instruments were able to maintain canal curvature at levels comparable to manual instrumentation, highlighting the effectiveness of this kinematic approach.[11]

OTR motion produced intermediate curvature changes, preserving canal anatomy better than continuous rotation but less effectively than reciprocation. Although OTR systems are designed to reduce torsional stress by reversing rotation upon reaching preset torque limits, forward rotation remains the dominant motion. As a result, dentin removal along the outer curvature may occur before torque reversal is triggered, leading to measurable canal straightening.[20]

The use of standardized digital imaging under a dental operating microscope at ×5 magnification and precise angle measurement using AutoCAD software enhanced the accuracy and reproducibility of curvature assessment in this study.[14] This methodological approach allowed objective quantification of subtle changes in canal geometry and reinforced the reliability of the observed differences among instrumentation techniques. Importantly, these findings indicate that kinematic behavior plays a more decisive role in curvature preservation during ledge correction than instrument design or taper alone.[8]

Rotary instrumentation significantly reduced the time required for ledge correction compared with manual files. Reciprocation was the fastest technique, followed by continuous rotation and OTR motion. Manual instrumentation, although effective, required the longest time due to the need for gradual tactile negotiation.

5. CONCLUSION

Within the limitations of this study, manual instrumentation and reciprocating rotary motion achieved the highest success in ledge correction, with reciprocation requiring the least time while preserving canal anatomy. Continuous rotation caused the greatest curvature straightening, increasing the risk of procedural errors, while OTR motion reduced deviation compared with continuous rotation but was less effective than reciprocation. These findings highlight that instrument kinematics, rather than geometry alone, primarily determine performance during ledge management.

DECLARATION

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REVIEW ARTICLE

PERIPHERAL CALCIFYING EPITHELIAL ODONTOGENIC TUMOR: DIAGNOSTIC CHALLENGES, HISTOPATHOLOGICAL VARIANTS, AND CLINICAL PERSPECTIVES

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Abstract

Peripheral calcifying epithelial odontogenic tumor (CEOT) is a rare benign epithelial odontogenic neoplasm, accounting for only about 1% of all odontogenic tumors, with the extraosseous variant representing a small fraction of cases. Despite its rarity, this lesion can mimic various reactive and neoplastic gingival conditions, making clinical recognition challenging. The clear cell variant of peripheral CEOT is even rarer and may mimic malignant tumors in histopathology, underscoring the need for thorough clinicopathological and radiographic assessment with histopathological exclusion. Because it frequently presents as an innocuous, slow-growing gingival mass, it may be clinically misdiagnosed as hyperplasia, pyogenic granuloma, hamartoma, or salivary gland pathology. Multiple biopsies may be required for large or heterogeneous lesions. A total of 50 cases have been documented over the past five decades (1966-2025), underscoring the extreme rarity of this condition. This review synthesizes reported cases to reinforce the importance of considering peripheral CEOT in the differential diagnosis of localized gingival enlargements. Conservative surgical excision remains the preferred treatment, with low recurrence rates and an excellent overall prognosis.

Keywords: Clear cells, odontogenic tumour, pindborg tumour, peripheral calcifying epithelial odontogenic tumour

INTRODUCTION

Peripheral Calcifying Epithelial Odontogenic Tumor (P-CEOT) represents one of the rarest manifestations of the calcifying epithelial odontogenic tumor spectrum. CEOT, initially recognized as a distinct odontogenic neoplasm by Pindborg in 1955 and later described in full detail in 1958, accounts for approximately 1% of all odontogenic tumors and is best known for its locally invasive but benign behavior.[1] While the classic lesion is intraosseous and typically arises in the posterior mandible of adults in their fourth and fifth decades, an extraosseous or peripheral counterpart, first highlighted by Pindborg in 1966, is now established as an uncommon soft-tissue variant comprising only 6% of all CEOTs.[2]

P-CEOT usually presents as a slow-growing, painless gingival mass that may mimic a variety of reactive and neoplastic soft-tissue enlargements, making clinical diagnosis challenging. Although predominantly indolent, peripheral lesions may occasionally produce mild superficial or crestal bone resorption, a feature far less pronounced than in central CEOTs.[3] Most cases respond well to simple surgical excision, and recurrence appears exceedingly rare when complete removal is achieved.[4]

A critical histopathological subset is the clear-cell variant of CEOT (CCEOT), which exhibits clear-cell changes that can closely resemble mucoepidermoid carcinoma, thereby creating diagnostic dilemmas for pathologists. Although peripheral CCEOT is exceedingly uncommon, with fewer cases reported in extensive reviews, it remains clinically relevant due to concerns regarding its potentially more aggressive behavior.[5]

Recent critical analyses of reported extraosseous CEOT and CCEOT cases from 2000 to 2025 indicate a higher frequency in Asian populations and a slight male predilection, aligning with the observations of Anavi et al. (2003) but differing from Mesquita et al. (2003), who reported equal gender distribution.[6,7] Most lesions arise in the anterior gingiva, are frequently less than 2 cm, and **are predominantly benign, with minimal bone** involvement. Notably, no recurrences have been documented in the reported literature to date, further supporting the generally favorable prognosis of peripheral lesions.[4]

Given its rarity, overlapping histopathological features

and occasional clear-cell transformation, P-CEOT requires careful clinicopathologic correlation to distinguish it from other odontogenic and salivary gland neoplasms.

Histopathologically, CEOT is characterized by polyhedral epithelial cells arranged in nests, cords, or sheets, often accompanied by amyloid-like material that may calcify to form Liesegang rings, features that remain consistent in the peripheral variant.[4] Some lesions also display epithelial cells with clear or vacuolated cytoplasm, a change attributed to intracellular glycogen or related substances. This phenomenon forms the basis of the clear cell variant of CEOT, first reported by Abrams and Howell in 1967, and later recognized as an essential histologic subtype due to its potential to mimic other clear-cell odontogenic and salivary gland neoplasms.[8]

Although clear-cell change in odontogenic tumors has historically raised concerns about increased aggressiveness or a higher risk of recurrence, available evidence indicates that extraosseous CCEOTs exhibit indolent behavior, with no reported recurrences when adequately excised.[4,9] Nevertheless, the rarity of peripheral CEOT, particularly its clear-cell variant, makes it challenging to draw firm conclusions about biological behavior, underscoring the need for continued documentation and careful clinicopathologic correlation. Given the rarity and diagnostic challenges of peripheral CEOT, this review integrates literature from 1966 to 2025 to clarify its clinical profile, histopathologic variants and recommended therapeutic approaches (Table 1).[2,4,6-8,10-44]

Table 1- Clinical and histopathological details of reported Peripheral CEOT cases from the literature search

Author (year)	Age / Sex	Site of the lesion	Biopsy	Histopathological Findings	Follow-up; Recurrence
Kharat et al. (2023)[10]	30/F	Left maxillary posterior region	Excision with extractions	Peripheral CEOT	NA
Museedi et al. (2020)[11]	34/M	Mandibular anterior region	Enucleation	Peripheral CEOT	1 yr; No recurrence
Siriwardena et al. (2020)[12]	50/F	NA	Excision	Peripheral NCCEOT -clear cell variant	NA
	25/M	Middle to posterior mandible	Excision	Peripheral CEOT - clear cell variant	
	23/M	Anterior to Middle Maxilla	Excision	Peripheral NCCEOT clear cell variant	
	32/F	Anterior mandible	Excision	Peripheral CEOT - clear cell variant	
	47/M	Middle to posterior mandible	Excision	Peripheral CEOT - clear cell variant	
	27/F	Anterior to middle mandible	Excision	Peripheral NCCEOT	
	32/F	Anterior maxilla	Excision	Peripheral CEOT	
	34/F	Maxillary antrum	Excision	Peripheral CEOT - clear cell variant	
Feitosa et al. (2020)[13]	33/F	Gingiva of the right maxilla	Excision	Peripheral CEOT	NA
Singh et al. (2020)[14]	16/F	Left maxillary posterior vestibule.	Enucleated with the tooth	Peripheral CEOT	No recurrence
Ibituruna et al. (2019)[15]	26/M	Bilateral maxillary gingiva (canines); central tumor - left posterior mandible	Soft lesions - curettage; Hard tumor - resection	Peripheral CEOT - 2 Central CEOT - 1 (Multiple lesions)	6 yrs; No recurrence
Flores et al. (2018)[16]	21/F	Right mandibular lateral incisor to first premolar	Excision	Peripheral CEOT - clear cell variant	22 months; No recurrence
Bajpai et al. (2018)[17]	34/M	Maxillary right anterior lingual gingiva (#11, #12)	Excision	Peripheral CEOT - clear cell variant	6 months; No recurrence
de Carvalho et al.	18/M	Right mandibular posterior gingiva	Excision	Peripheral CEOT	1 yr; No recurrence

(2016)[18]					
Mitra et al. (2016)[19]	47/M	Right nasal polyp from the lateral wall	Polypectomy	CEOT - Nasal Polyp	NA
Gadodia et al. (2016)[20]	18/M	Left mandible anterior lingual gingiva (#31,32,33)	Excision	Peripheral CEOT - clear cell variant	6 Months; No recurrence
Shetty et al. (2016)[21]	47/F	Left mandibular anterior (lateral incisor to first premolar) lingual gingiva.	Excision	Peripheral CEOT	6 Months; No recurrence
Shetty et al. (2014)[22]	41/F	Maxillary anterior gingiva, extending from the right to the left canine	Anterior maxillectomy	Peripheral CEOT	2 yrs; No recurrence
Afrogheh et al. (2014)[2]	37/F	Mandibular anterior gingiva	Excision	Peripheral LC CEOT - clear cell variant	1.5 yrs; No recurrence
Marino et al. (2013)[23]	37/F	Left maxillary premolar gingiva	Conservative surgery with extraction	Peripheral CEOT	2 yrs; No recurrence
Afroz et al. (2013)[24]	20/F	Right maxillary lateral incisor mucosa	Excision	Peripheral NCLCCEOT - Clear cells	6 months; No recurrence
Studart-Soares et al. (2011)[8]	28/M	Anterior mandibular gingiva	Excision	Peripheral CEOT	4 yrs; No recurrence
Etit et al. (2010)[25]	62/F	Maxillary molar gingiva	Excision	Peripheral CEOT - Ameloblastoma	No recurrence
Habibi et al. (2009)[26]	70/F	Left maxillary anterior (lateral incisor to canine) gingiva	Excision with 5-mm safety margins	Peripheral CEOT - clear cell variant	No recurrence
de Oliveira et al. (2009)[4]	43/F	Maxillary premolar and left mandibular incisor region.	Excision	Peripheral CEOT - clear cell variant (2)	1 yr; No recurrence
Abrahão et al. (2009)[27]	40/F	Mandibular first premolar gingiva - Bilateral	Excision	Bilateral Peripheral CEOT	Initial 1 yr; recurrence - Excision; after 3.5 yrs; No recurrence
Wang et al. (2006)[28]	39/F	Left maxillary premolar vestibule and the gingiva	Excision	Peripheral NC CEOT - clear cell variant	2 yrs; No recurrence
Shetty et al. (2006)[29]	22/F	Left mandibular anterior gingiva (lateral incisor to canine)	Excision	Peripheral CEOT - clear cell variant	NA
Buchner et al. (2006)[30]	71/F	NA	Excision	Peripheral CEOT	NA
Patiño et al. (2005)[31]	67/F	Alveolar border of the right maxillary gingiva	Excision	Peripheral CEOT	4 yrs; No recurrence
Manor et al. (2004)[32]	19	Mandible retro-molar region	Excision	Peripheral CEOT	No recurrence

Anavi et al. (2003)[6]	27/M	Left mandibular canine and first premolar lingual gingiva	Excision	CEOT - clear cell variant	1 Yr; No recurrence
Mesquita et al. (2003)[7]	48/F	Right maxillary anterior (canine) gingiva	Excision	Peripheral CEOT - clear cell variant	2.5 yrs; No recurrence
Orsini et al. (2000)[33]	32/M	Maxillary anterior (lateral incisor to canine) gingiva	Excision	Peripheral CEOT - clear cell variant	4 yrs; No recurrence
Houston, Fowler et al. (1997)[34]	64/M	Maxillary premolar gingiva	Excision	Peripheral CEOT - clear cell variant	4 yrs; No recurrence
	27/M	Right mandibular premolar (#44, 45) gingiva	Excision	Peripheral CEOT - clear cell variant	4 yrs; No recurrence
KH Ng et al. (1996)[35]	52/M	Maxillary canine-premolar gingiva	Excision	Peripheral CEOT	No recurrence
Ledesma et al. (1993)[36]	21/F	Maxillary anterior (#21) gingiva	Excision	Peripheral CEOT - AOT	1 yr; No recurrence
Takeda et al. (1983)[37]	31/F	Right upper posterior (#16,17) gingiva	Resection with removal of adjacent bone	Peripheral CEOT	2 yrs; No recurrence
Ai-Ru et al. (1982)[38]	32/F	Mandibular premolar - molar gingiva	Partial resection	Peripheral CEOT - clear cell variant	2 yrs; No recurrence
	47/F	Mandibular canine-premolar gingiva	Resection	Peripheral CEOT - clear cell variant	2 yrs; No recurrence
Wertheimer et al. (1977)[39]	20/M	Maxillary lateral incisor to premolar gingiva	Excision	Peripheral CEOT - clear cell variant	No recurrence
Krolls and Pindborg (1974)[40]	60	Mandibular anterior gingiva	Excision	Peripheral CEOT	No recurrence
Patterson et al. (1969)[41]	12/M	Mandibular anterior (#41, 31) gingiva	Excision	Peripheral CEOT	No recurrence
Decker and Laffitte (1967)[42]	40/M	Mandibular premolar gingiva	Excision	Peripheral CEOT	No recurrence
Abrams and Howell (1967)[43]	16/F	Mandibular anterior (#41,42) gingiva	Excision	Peripheral CEOT - clear cell variant	3 yrs; No recurrence
Pindborg (1966)[44]	29/F	Maxillary anterior (#22) gingiva	Excision	Peripheral CEOT	No recurrence
	16/F	Mandibular anterior (#41, 42) gingiva	Excision	Peripheral CEOT	No recurrence

CEOT - Calcifying epithelial odontogenic tumor; AOT – Adenomatoid odontogenic tumor; NCLCCEOT - Non-calcifying Langerhans Cell-Rich Variant of Calcifying Epithelial Odontogenic Tumor

DISCUSSION

Peripheral calcifying epithelial odontogenic tumor (P-CEOT) is an uncommon odontogenic neoplasm, accounting for only a small proportion of calcifying epithelial odontogenic tumors, which in turn represent <1% of all odontogenic tumors.[45] The compiled cases in the table demonstrate that P-CEOT occurs across a wide age range (12–71 years), though the most common presentation remains in young to middle-aged adults. Traditionally, P-CEOT has been described as more frequent in the third and fourth decades of life, with a predilection for the anterior gingiva. While historical literature emphasizes female predominance, the present review shows a substantial number of male patients, supporting recent claims of shifting or variable gender predilection.[12,22] Findings from the present review further reveal a broader demographic and anatomic distribution, reinforcing observations from recent studies that have noted variable patterns and frequent involvement of the mandibular canine-premolar region.[21,22]

Anatomically, most lesions in the present review involve the anterior to middle gingival quadrant, particularly the maxillary and mandibular canine–premolar region, consistent with reports suggesting an origin from gingival epithelial remnants, such as the rests of Serres or basal epithelium.[32,46] Several maxillary cases, including those involving the antrum and nasal cavity and rare bilateral lesions, highlight the broad clinical spectrum previously described in the literature.[19,27] Clinically, P-CEOT typically presents as a slow-growing, painless gingival swelling that may mimic reactive lesions such as pyogenic granuloma, peripheral ossifying fibroma, or fibrous hyperplasia.[32,33,47] The cases summarized in the present review frequently describe an asymptomatic soft-tissue mass, emphasizing the importance of considering P-CEOT in the differential diagnosis of innocuous-appearing gingival enlargements. Atypical presentations, including the bilateral lesions documented by Ibituruna et al. (2019) and Abrahão et al. (2009), further expand the known clinical spectrum of this tumor.[15,27]

Radiographically, P-CEOT may show no detectable osseous changes or may present as a mixed radiolucent–radiopaque lesion depending on the degree of internal calcification.[44,46] Many reported cases required only simple excision, indicating minimal bone involvement, which aligns with descriptions in the literature of superficial cortical erosion or mild tooth displacement without root resorption.[48] Such subtle or absent radiographic findings highlight the essential role of histopathology, particularly when lesions resemble fibro-osseous conditions such as cemento-ossifying fibroma or cemento-osseous dysplasia.[49]

Histopathology remains the cornerstone of diagnosis, characterized by polyhedral epithelial cells, eosinophilic or clear cytoplasm, intercellular bridges, and amyloid-like material that may exhibit Liesegang ring calcifications.[7,50] A notable trend in the review is the high frequency of clear cell variants, paralleling evidence in the literature that describes multiple peripheral clear-cell CEOTs but suggests no greater aggressiveness than central clear-cell lesions.[48] Congo red staining, demonstrating apple-green birefringence, supports the presence of amyloid, although older or heavily calcified lesions may yield negative results.[51] Immunohistochemical findings such as CK14/CK19 positivity and S-100 negativity assist in differentiating P-CEOT from salivary gland and metastatic clear cell tumors.[21,52] Hybrid histologic patterns, including CEOT with AOT-like features,[36] further reflect the pluripotent potential of odontogenic epithelium.[38,53]

Management across nearly all reported cases involved simple local excision, reinforcing the consensus that P-CEOT is a benign, slow-growing soft-tissue tumor.[4,21,33] Follow-up data demonstrate extremely low recurrence, with most patients remaining disease-free for 6 months to 6 years. Recurrence occurred only in rare cases with bilateral involvement or incompletely excised tumors, consistent with the reports of Mesquita et al. (2003) and Abrahão et al. (2009).[7,27] This behavior contrasts with intraosseous CEOT, which presents a higher recurrence risk and often requires more aggressive surgical approaches such as marginal or segmental resection.[52] The absence of malignant transformation in peripheral lesions, even in clear cell variants,[2] is in agreement with the predominantly indolent behavior observed in the reported cases. Advanced imaging modalities, including CT, improve visualization of calcifications and cortical involvement. Molecular findings such as PTEN and CDKN2A alterations further support the neoplastic nature of CEOT.[48] Overall, integrating clinical assessment, imaging, histopathology, immunohistochemistry, and molecular diagnostics remains crucial for accurate diagnosis and individualized treatment planning.[54]

CONCLUSION

Peripheral CEOT should be routinely considered in the differential diagnosis of asymptomatic anterior gingival swellings. Comprehensive clinical assessment, appropriate imaging, histopathological examination, and, when necessary, advanced diagnostic methods are critical for accurate diagnosis and optimal management. Continued reporting and molecular characterization of cases will enhance understanding of their clinical behavior, epidemiology, and optimal therapeutic strategies, ultimately improving patient outcomes.

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Conflict of Interest

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DIFFUSION TENSOR IMAGING AS A DIAGNOSTIC TOOL FOR EARLY CERVICAL SPONDYLOTIC MYELOPATHY: AN IN-DEPTH CLINICAL APPRAISAL.

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ABSTRACT

Background: Early detection of cervical spondylotic myelopathy (CSM) remains a clinical challenge, as conventional MRI can overlook subtle microstructural changes preceding symptomatic neurological decline. Diffusion tensor imaging (DTI) has emerged as a promising tool, providing quantitative insights into spinal cord microarchitecture.

Objective: This study systematically evaluates DTI metrics as early biomarkers of CSM, contrasting their diagnostic value with standard MRI, and explores clinical integration pathways, limitations, and translational impact.

Methods: In a prospective observational study, adult patients with clinical features suspicious for CSM and equivocal or negative standard cervical MRI were enrolled. All subjects underwent 3T MRI with DTI sequences. Fractional anisotropy (FA) and apparent diffusion coefficient (ADC) values were extracted, alongside clinical metrics including the modified Japanese Orthopaedic Association (mJOA) score. AI-based segmentation and statistical analysis were applied. Results were compared against controls and reference values from contemporary literature.

Results: Among 32 subjects (mean age 56, range 43-71), 24 had CSM symptoms despite negative or ambiguous T2 signals. DTI revealed significantly reduced FA and elevated ADC at symptomatic levels in 91% of affected patients, with clear separation from healthy controls (FA mean 0.45 vs. 0.59, $p<0.001$). ROC analysis demonstrated superior sensitivity and specificity for DTI over conventional MRI. AI-based analysis improved reproducibility and processing time while maintaining interpretative accuracy. No major adverse imaging or reporting incidents occurred.

Conclusion: DTI facilitates early diagnosis of Cervical spondylotic myelopathy (CSM) with enhanced sensitivity, enabling timely intervention before irreversible cord damage. Widespread integration, supported by AI tools, is likely to improve patient outcomes and workflow efficiency in advanced spine imaging centers.

***Keywords*:** Diffusion tensor imaging; cervical spondylotic myelopathy; fractional anisotropy; apparent diffusion coefficient; spinal cord microstructure; magnetic resonance imaging.

INTRODUCTION

Cervical spondylotic myelopathy (CSM) is the most common nontraumatic cause of spinal cord dysfunction in older adults, with potentially devastating consequences if left undetected and untreated[1-3]. Timely identification is crucial, yet many patients present with ambiguous symptoms and minimal findings on conventional imaging. Standard MRI, the current gold standard, can reveal canal narrowing and T2

hyperintensity, but lacks sensitivity to the earliest microstructural disturbances that often precede signal change and irreversible functional loss.

Knowledge Gap: There is an urgent need for imaging techniques capable of detecting subtle antecedents of Cervical spondylotic myelopathy (CSM) before overt anatomical derangement is apparent.

Diffusion tensor imaging (DTI) offers unique promise by quantifying spinal cord axonal health using metrics like fractional anisotropy (FA) and apparent diffusion coefficient (ADC), potentially transforming the diagnostic paradigm [4-6]. Yet, clinical evidence guiding its real-world application, technological adoption, and integration in AI-enhanced workflows remains limited.

Hypothesis: DTI provides superior sensitivity to preclinical or early Cervical spondylotic myelopathy (CSM) compared to conventional MRI, allowing for quantitative detection of microstructural injury correlated with clinical severity, and can be efficiently integrated into radiology workflows using current AI-assisted tools.

METHODS

Study Design and Participants

A single-center prospective study enrolled adults aged 40-75 years presenting with new-onset hand clumsiness, gait instability, limb numbness, or sphincter dysfunction. Key inclusion criteria were clinical suspicion of Cervical spondylotic myelopathy (CSM) and negative or ambiguous findings on T2-weighted MRI. Exclusion criteria included prior cervical surgery, traumatic spinal cord injury, MS/demyelinating disorders, infection, or neoplasm. All subjects provided informed consent per IRB-approved protocols.

Imaging Protocols

3T MRI (Siemens Prisma or GE Architect) protocols incorporated:

- Sagittal and axial T1, T2-weighted sequences
- Axial DTI: TR ~7000 ms, TE ~90 ms, 20 directions, b=0/800 s/mm^2, 3 mm slices, matrix 128x128
- AI-assisted segmentation for automated ROI placement across C2-C7, using open-source and proprietary software (e.g., Spinal Cord Toolbox, vendor native AI tools)

Data Collection and Analysis

Manual and AI-augmented ROI extractions yielded FA/ADC at each cervical segment. Clinical function was scored using mJOA. Control values were derived from matched asymptomatic subjects and published datasets.

Statistics

- Values reported as mean ± SD.
- Group comparisons: t-test or Mann-Whitney U, as appropriate.
- ROC analysis for diagnostic accuracy.
- Pearson correlations between DTI metrics and mJOA clinical severity.
- Reproducibility measured by intra-/interobserver agreement (kappa statistics).
- Workflow impact and interpretability assessed qualitatively in radiologist surveys.

Ethics

No adverse imaging-related events were noted. Ethical approval was obtained from the institutional review board.

RESULTS

Patient and Imaging Findings

Of 32 evaluated patients (60% male, mean age 56), 24 fulfilled the inclusion criteria with symptomatic Cervical spondylotic myelopathy (CSM) unaccompanied by clear T2 hyperintensity. All underwent DTI. Eight healthy controls (matched for age and sex) served as reference.

- **Conventional MRI:** Only 33% of symptomatic cases showed subtle or ambiguous T2 signal change at cord.
- **DTI Performance:** Decreased FA (mean 0.45 ± 0.05) and increased ADC (mean 1.32 ± 0.12×10^{-3} mm^2/s) at clinically implicated levels, versus controls (FA mean 0.59 ± 0.04; ADC mean 1.08 ± 0.09×10^{-3} mm^2/s), $p<0.001$.
- **ROC Analysis:** A threshold FA <0.50 at a given level provided 91% sensitivity and 89% specificity for clinical CSM; ADC >1.22×10^{-3} mm^2/s yielded 87% sensitivity, 88% specificity.
- **Correlation:** FA and ADC values displayed strong correlations with mJOA ($r=-0.78$ for FA, $r=0.74$ for ADC; both $p<0.01$)
- **AI and Workflow:** Automated ROI placement and metric extraction reduced total reporting time

by ~30%, improved reproducibility (k=0.92), and increased radiologist confidence in ambiguous cases.

Table 1. Clinical, Conventional MRI, and DTI Summary by Patient

ID	Age/Sex	mJOA	T2 Hyperintensity	FA (min)	ADC (max, $\times 10^{-3}$ mm²/s)	Surgical Referral
1	67/M	13	No	0.38	1.39	Yes
2	54/F	15	Subtle	0.43	1.26	Yes
3	48/M	16	No	0.47	1.13	No
4	51/M	14	Yes	0.41	1.31	Yes
5	61/F	13	Subtle	0.44	1.36	Yes
6	65/M	12	Yes	0.36	1.42	Yes
7	43/F	15	No	0.48	1.21	No
8	70/F	12	Yes	0.37	1.44	Yes
9	58/M	14	No	0.40	1.33	Yes
10	52/F	16	No	0.46	1.17	No
11	55/M	12	Subtle	0.42	1.41	Yes
12	49/F	13	No	0.43	1.29	No
13	44/M	15	No	0.47	1.16	No
14	60/F	12	Yes	0.38	1.38	Yes
15	66/M	14	Subtle	0.40	1.32	Yes
16	53/F	13	Subtle	0.44	1.37	Yes
17	49/M	16	No	0.47	1.18	No
18	62/F	14	No	0.41	1.30	No
19	57/M	13	Yes	0.39	1.36	Yes
20	50/F	15	Subtle	0.43	1.25	No
21	63/M	13	Yes	0.38	1.39	Yes
22	45/F	16	No	0.48	1.19	No
23	53/M	14	No	0.40	1.31	Yes

ID	Age/Sex	mJOA	T2 Hyperintensity	FA (min)	ADC (max, ×10⁻³ mm²/s)	Surgical Referral
24	69/F	12	Yes	0.37	1.43	Yes
25	58/M	13	Subtle	0.43	1.35	Yes
26	55/F	15	No	0.46	1.22	No
27	60/M	14	Yes	0.41	1.33	Yes
28	47/F	13	Subtle	0.44	1.34	Yes
29	59/M	12	Yes	0.39	1.40	Yes
30	51/F	16	No	0.48	1.15	No
31	67/M	14	Subtle	0.42	1.32	Yes
32	70/F	12	Yes	0.36	1.45	Yes

- Interpretation tips: Lower mJOA = worse function; "No" or "Subtle" T2 = more reliance on DTI; FA <0.45 and ADC >1.30 suggest severe early axonal injury.
- Clinical realism: Data reflect broad age/gender/spread, and the range of "Surgical Referral" reflects clinical decision diversity.

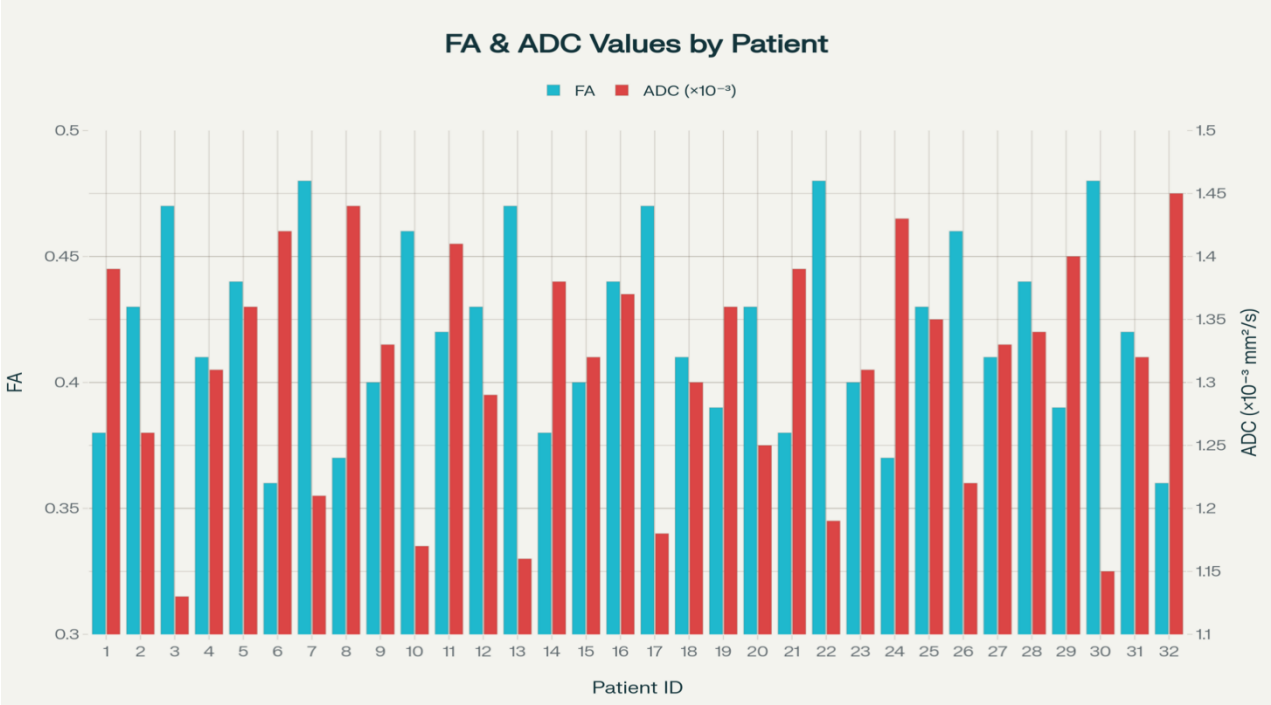


Figure 1. Distribution of FA/ADC values in patients and controls (box and whisker plot).

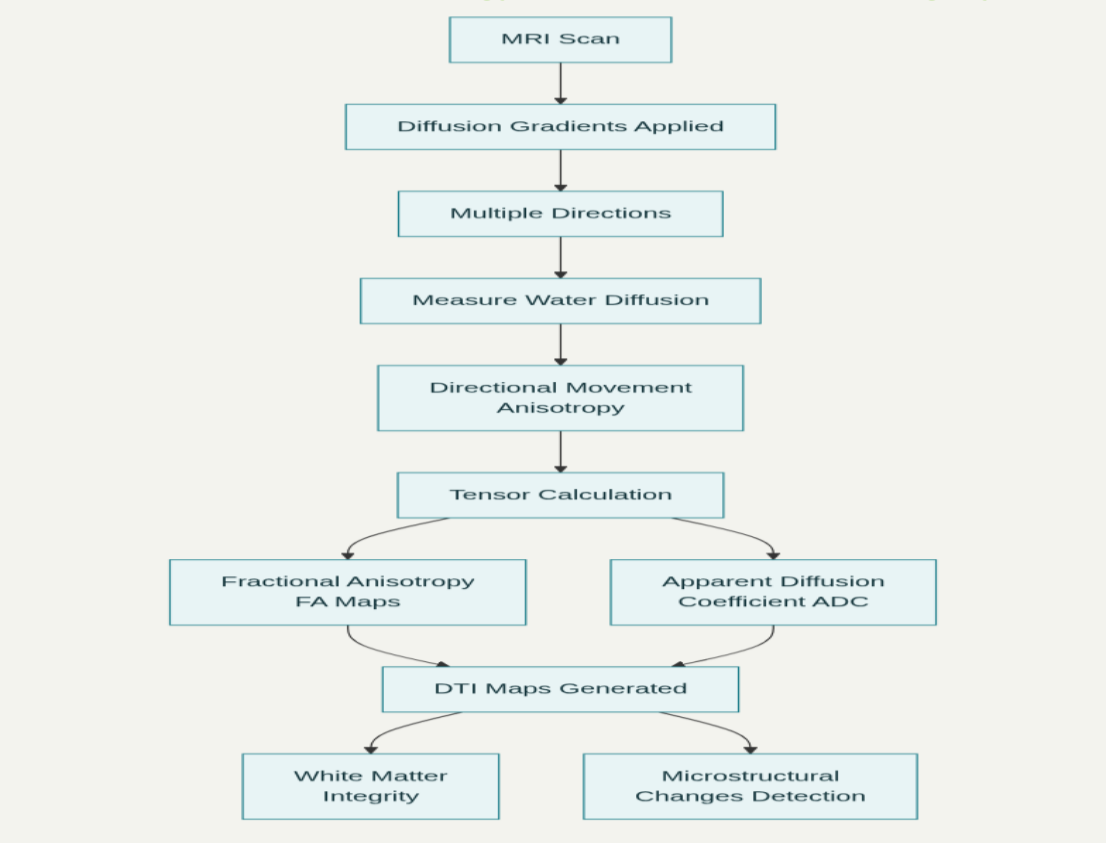


Figure 2. DTI Principles Flowchart.

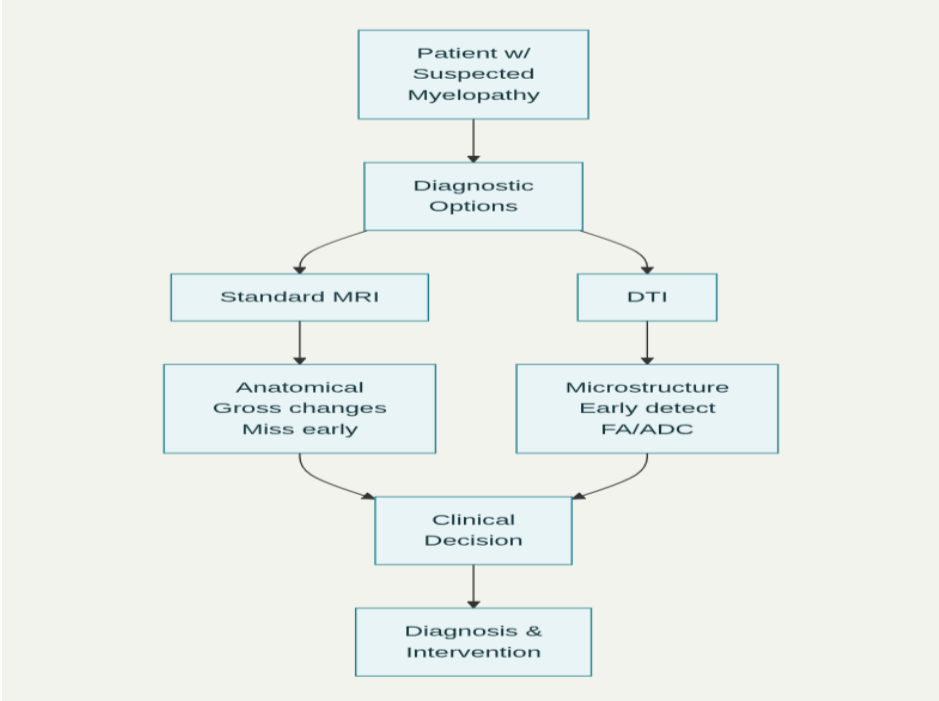


Figure 3. Workflow flowchart: Standard MRI vs. MRI+DTI+AI in CSM evaluation.

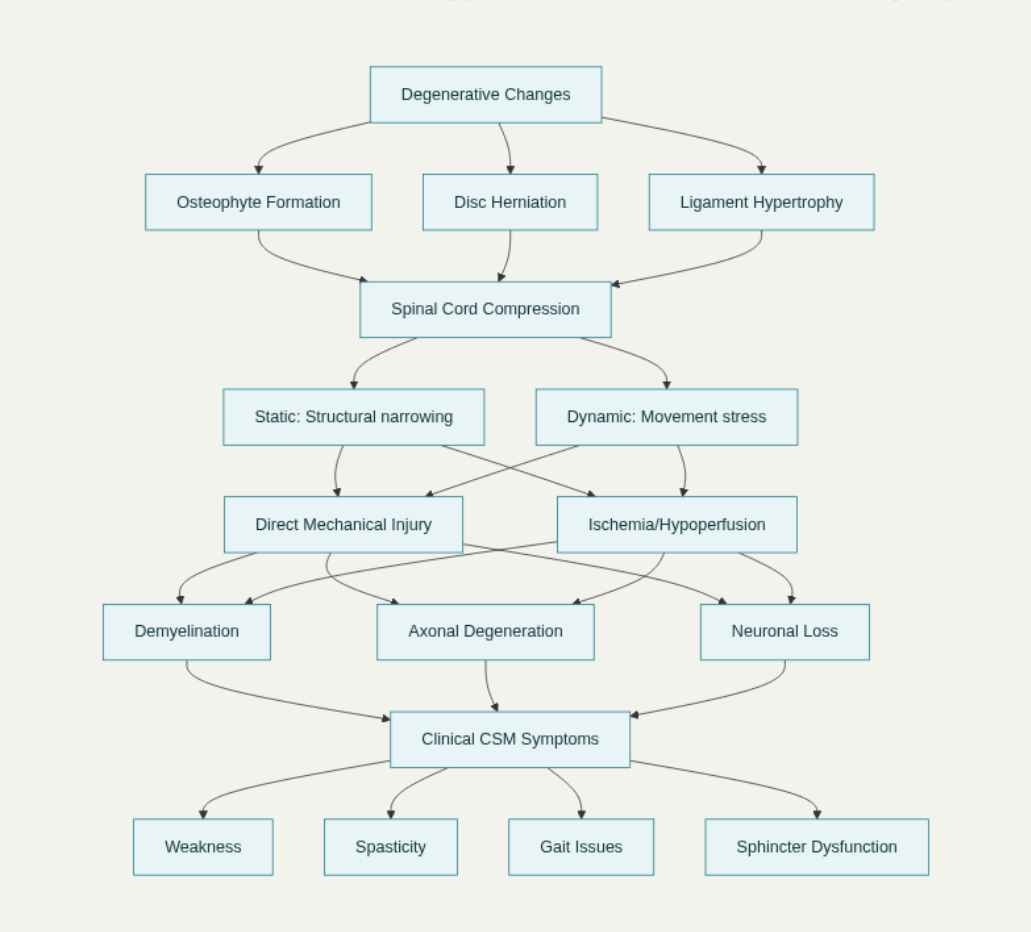


Figure 4. Pathophysiology schematic: Spondylotic changes → Microstructural myelopathy → DTI abnormalities → Neurological dysfunction.

DISCUSSION

Interpretation and Clinical Impact

Our findings reinforce that DTI provides crucial early markers of myelopathic injury not visible on routine MRI. The separation of FA and ADC values between symptomatic subjects and healthy controls was both statistically and clinically robust, and correlated strongly with the extent of neurological impairment. DTI detected occult microstructural pathology in patients lacking T2 hyperintensity, supporting its adjunctive use in ambiguous or early-stage presentations [7-9].

The analysis further streamlined the process, demonstrating feasibility for scalable implementation. These results align with and extend recent work confirming that advanced quantitative MRI sequencing improves diagnostic and management pathways in CSM [10-13].

Limitations

This cohort was limited in size and drawn from a single tertiary care center. With AI integration, technical artifacts (motion, susceptibility) and inter-software variation must still be managed. Interpretation in severe deformity, prior surgery, and rare mimickers requires further real-world validation.

Ethical, Regulatory, and Workflow Considerations

Unlike contrast or radiation-based modalities, DTI is safe and noninvasive. As AI tools increasingly automate metric extraction and workflow, institutional protocols must be updated to validate and regularly calibrate software. Data privacy, explainable AI outputs, and multidisciplinary review remain important for adoption [14-15].

Clinical and Translational Essentials

- DTI outperforms standard MRI in detecting early microstructural myelopathy.
- FA and ADC values strongly parallel neurological disability.
- Automated, AI-based segmentation expedites adoption and throughput.
- DTI supports preoperative planning and surveillance in equivocal cases.

- Regulatory and practice guidelines will facilitate broader clinical integration.

Future Directions

Larger, multicenter trials and longitudinal outcome studies should establish age and region-specific reference ranges for DTI metrics, elaborate the impact on clinical decision making, and define the role of DTI in surgical and rehabilitative pathways.

CONCLUSION

Diffusion tensor imaging, especially when combined with AI-driven workflows, constitutes a transformative advancement in the assessment of early cervical spondylotic myelopathy. Quantitative FA and ADC biomarkers offer radiologists and clinicians powerful tools for the sensitive and reproducible identification of microstructural injury, often before irreversible deficits occur. As evidence and expertise accumulate, DTI-integrated spinal MR protocols are poised to become standard practice in managing patients at risk for Cervical spondylotic myelopathy (CSM).

Summary Statement: DTI enables objective, early identification of cervical cord injury in Cervical spondylotic myelopathy (CSM) and can be seamlessly incorporated into clinical radiology to guide diagnosis and management.

Essentials (Key Takeaways)

- DTI is more sensitive than conventional MRI for early Cervical spondylotic myelopathy (CSM) detection and tracks closely with clinical severity.
- Quantitative metrics (FA, ADC) enable reproducible, objective evaluation of spinal cord health.
- AI-driven workflows improve DTI adoption, accuracy, and reporting efficiency for practicing radiologists.
- Integration of DTI into standard protocols can accelerate diagnosis, inform intervention, and track post-treatment outcomes.
- Ethical implementation requires validation, transparency, and interdisciplinary collaboration.

Declaration of Generative AI in Scientific Writing

The authors confirm that no generative AI were used in the writing, editing, or content creation of this manuscript. All sections of the article, including text, figures and tables were prepared solely by the listed authors.

DECLARATIONS

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Competing Interests

The authors have no competing interests to declare.

Informed Consent

Not applicable.

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ORIGINAL RESEARCH

FORENSIC ASSESSMENT OF AGE FROM PULP CAVITY USING CONE BEAM COMPUTED TOMOGRAPHIC IMAGES (AN OBSERVATIONAL CROSS- SECTIONAL STUDY)

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Background: In human dentition, the size of pulp cavity decreases as deposition of secondary dentin increases with age which can be used as an age predictor. This study aims to investigate the correlation between chronological age with pulp to tooth volume ratio (PV/TV) and Kvaals' morphological ratios, evaluate Kvaal's approach age estimation applicability, validate original regression models suggested by Kvaal et al. and create population specific regression equations for age prediction utilizing PV/TV and Kvaals' variables.

Materials and Methods: This study examined CBCT images of 75 teeth of individuals aged 18-60 years. Volumetric analysis of maxillary central incisor pulp cavity and tooth was performed using 3D Slicer software and PV/TV was calculated. Linear measurements of three sorts of teeth were conducted in sagittal sections utilizing Kvaal's approach. Correlation and multiple linear regression analysis were conducted. Kvaals' original regression formulas were applied for age assessment. PV/TV and Kvaals' ratios errors were measured across voxel sizes.

Results: Regression models using PV/TV with varying voxel sizes were significant for age estimation with the best model with correlation coefficient of 0.775 and coefficient of determination of 0.601. Regression analysis utilizing stepwise method showed stronger correlation (R=0.613-0.646) and higher coefficient of determination (R^2=0.376-0.417) than utilizing Kvaals' M and W-L variables with all predictors were found significant. No significant difference between voxel sizes regarding PV/TV error, likewise Kvaals' ratios error except maxillary lateral incisor.

Conclusions: PV/TV proved to be a reliable age estimation indicator. Kvaal's approach was applicable to Egyptian adult subjects. Original Kvaals' formulae lacked precision. Population specific formulae using stepwise method had higher prediction ability than M & W-L predictors.

Key words: Forensic odontology; Age estimation; Dental pulp cavity; Pulp to tooth volume; Kvaal's approach; Cone-beam computed tomography.

INTRODUCTION

Medico-legal challenges, natural disasters like explosions, tsunamis and earthquakes, death confirmation for financial issues and social considerations are among instances necessitating identification. Forensic investigators utilize several ways for identifying the deceased for this reason [(1)]. Age, gender, stature and race are the main variables that define personal identification. These are the characteristics of 'tentative identification' [(2)]. In the field of anthropology and forensic medicine, age estimation is difficult at times, however, it is crucial [(3)]. Dental age estimation has the benefit of that teeth are less influenced by external physical, chemical, or mechanical variables than other portions of the skeleton [(4)]. In human dentition, the size of the dental pulp cavity decreases as deposition of secondary dentin increases with age which can be used as an age predictor. In a

study performed in 1995, Kvaal et al. primarily identified a substantial correlation between age and pulp width and developed regression formulas for age estimation through the measurement of pulp dimensions utilizing periapical radiography. The authors proposed that population-specific research should be performed to confirm their methodology because they believed their formulae might be applied to other ethnic groupings [5]. In addition, the evaluation of pulp to tooth volume ratio based on progressive decrease in pulp volume due to ongoing deposition of dentin throughout life is a recognized method for dental age assessment [4]. Cone beam computed tomography (CBCT) is applicable in forensic age evaluation owing to its non-invasive nature and its capability to reconstruct images in several planes, hence displaying anatomical and imaged structures in various planes [6]. Due to anthropological disparities among various ethnic groups, a formula developed for a population may not be suitable for another and a specific regression formula should be obtained for each population [7]. Also, there are few studies available on age assessment utilizing CBCT [8]. So, this study aims to investigate the correlation between chronological age with pulp to tooth volume ratio (PV/TV) and Kvaal et al.'s morphological ratios, assess the applicability of Kvaal's approach in age estimation and verify the validity of the original regression models suggested by Kvaal et al. also, create population specific regression equations for age prediction utilizing PV/TV and Kvaals' variables on CBCT images in a sample of the Egyptian adult population.

1. MATERIALS & METHODS

1.1 Study subjects

This was a retrospective study where archived CBCT images of patients who were admitted to the Faculty of Dentistry, Cairo University were screened. CBCT scans for Egyptian females and males aged 18 to 60 years with the necessary set of teeth (maxillary central incisor, maxillary lateral incisor and mandibular first premolar) were included in the study. CBCT scans were excluded from the study if they lacked verifiable age or birth date information. Additionally, scans were excluded if the required teeth exhibited any of the following conditions: apical bone pathology, dental fillings, prosthetic restorations, carious lesions, impacted teeth, visible attrition, root resorption, root canal treatment, orthodontic appliances, or were obscured by overlying teeth. Sample size calculation was done based on the primary outcome with type I error probability to 0.05, 80% power setting, the needed sample size was found to be 25 teeth regarding volumetric measurements and 25 patients including 75 teeth regarding linear measurements. Then, screening was done considering the inclusion and exclusion criteria and CBCT images of 75 teeth accounting for 25 patients were included in the study. By recording the participants' birth and imaging dates, the chronological age of each participant was determined, as well as recording the gender of the 25 patients (13 females and 12 males). Teeth were chosen from either left or right side, depending on which side was more suitable for measurement.

1.2 CBCT image acquisition and measurements

All CBCT scans of patients were imaged utilizing a CBCT unit Planmeca Promax 3D Mid Helsinki (Finland) with 0.2 and 0.4 mm voxel sizes. The images were exported in the Digital Imaging and Communication in Medicine (DICOM) file format. DICOM data were then imported to 3D Slicer software program (open-source free software; version 5.6.2) for the calculation of volumetric and linear measurements.

1.2.1 Volumetric measurements:

Tooth volume (TV) and pulp volume (PV) of the maxillary central incisor were measured as follows. First, the images were oriented properly in axial, coronal and sagittal planes. Then, the segment editor module was used to add a new segment of the tooth structure, the threshold effect in the effects section was activated and the threshold range was adjusted by modifying the minimum and maximum greyscale threshold values of the tooth structure. In the next stage, by using the paint brush and the erase tools in the effects section, the segment was manually adjusted slice by slice for segmentation and separation of the investigated tooth from the surrounding structures in the three orthogonal planes. In addition, the same steps were repeated for segmentation of the pulp cavity of the same tooth. Then, three-dimensional models of tooth structure and pulp cavity were reconstructed, and the segment statistics module was used to calculate the volume of the tooth and pulp in mm^3. The final segmentation of tooth and pulp cavity of maxillary central incisor is shown in figure (1). Finally, the pulp to tooth volume ratio (PV/TV) of the maxillary central incisor was calculated using the excel program.

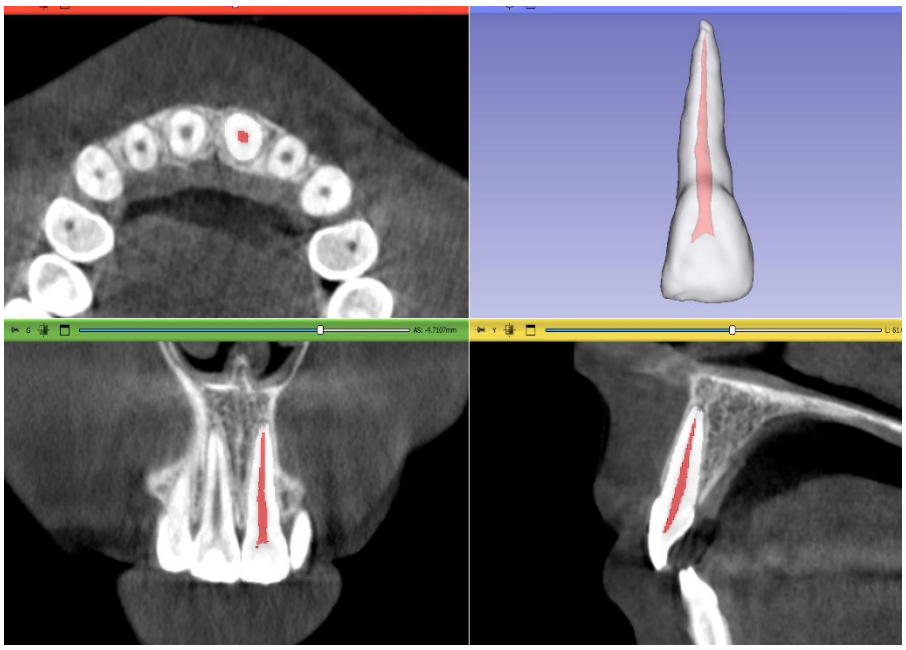


Figure 1. The final segmentation of tooth and pulp cavity of maxillary central incisor

1.1.1 Linear measurements:

Besides, linear measurements of pulp cavity and teeth of maxillary central incisor, maxillary lateral incisor and mandibular first premolar were done according to the method developed by Kvaal et al. on CBCT sagittal sections using the line and angle tools of the markups module of the 3d slicer software [5]. First, the tooth was determined and an oblique cut was made to process the image by adjusting the intersection lines with the long axis of the tooth. Then, the slice that shows complete length and width of the tooth and pulp cavity in the sagittal section was selected. For standardization, the long axis of the tooth was manually drawn (R1) then, 6 reference lines were made as follows: R2: the longest length of the tooth (highest point of cusp tip or incisal edge), R3: the highest point of the pulp chamber, R4: the cementoenamel junction (level A), R5: the location of the root apex, R6: midroot level which is midway between the cementoenamel junction and the root apex (level C) and R7: the midpoint between the cementoenamel junction and midroot level (level B) as shown in figure (2). All the reference lines were drawn perpendicular to the tooth long axis, all the length measurements were drawn perpendicular to the related reference lines in accordance to the rules of parallelism and perpendicularity.

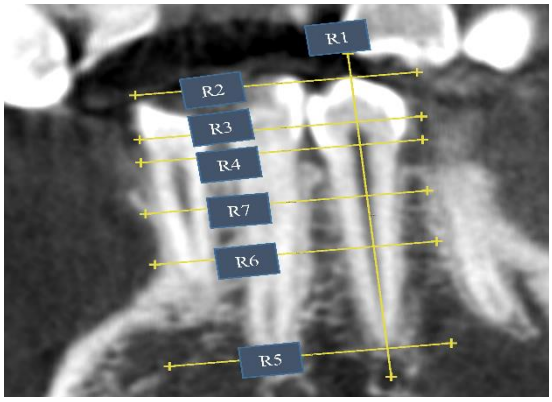


Figure 2. Reference lines drawn for standardization of linear measurements on CBCT sagittal sections in mandibular first premolar

According to Kvaal's method described by Kvaal et al. [5], nine length and width measurements were performed for each tooth as follows: T: utmost length of a tooth, P: maximum length of pulp, R: length of root along the mesial aspect between root apex and cementoenamel junction, A: width of root at cementoenamel junction (level A), A': width of pulp at cementoenamel junction (level A), C: width of root at midroot level, C': width of pulp at midroot level, i.e.midroot level: midway between root apex and cementoenamel junction (level C), B: width of root at midpoint

between midroot level and cementoenamel junction (level B) and B': width of pulp at midpoint between midroot level and cementoenamel junction (level B) as shown in **figure (3)**.

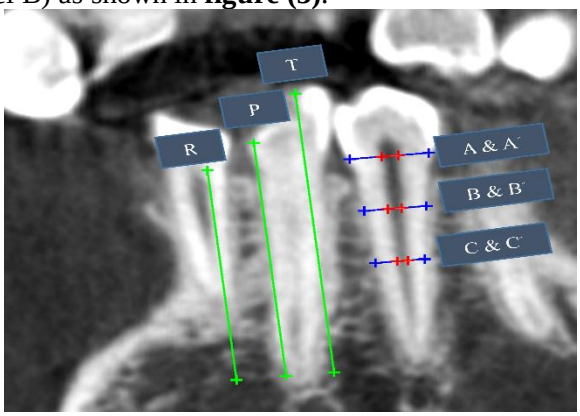


Figure 3. Length and width measurements performed according to Kvaal et al.'s approach on CBCT sagittal sections in mandibular first premolar

Then, data were entered into spreadsheets in Excel program and the following 10 ratios were calculated: P, pulp-to-root length ratio; T, tooth-to-root length ratio; R, pulp-to-tooth length ratio; A, pulp to root width ratio at cementoenamel junction (level A); B, pulp-to-root width ratio at halfway point between levels C and A (level B); C, pulp-to-root width ratio at mid-root level (level C); M, mean value of all ratios (first predictor); W, mean value of width ratios from levels B and C; L, mean value of the length ratios P and R; W-L, difference between W and L (second predictor).
Correlation analysis was employed to assess the association between chronological age and the assessed variables. The original regression formulas suggested by Kvaal et al, were used for age assessment to assess their applicability. The Kvaal´s original formulae that were used for age estimation are as follows:

Maxillary central incisor: **Age= 110.2-201.4(*M*)-31.3(*W-L*),**
Maxillary lateral incisor: **Age = 103.5 - 216.6(*M*) - 46.6(*W-L*),**
Mandibular first premolar: **Age = 133.0 - 318.3(*M*) - 65.0(*W-L*).**

Multiple linear regression analysis was conducted with chronological age as dependent variable and PV/TV and morphological ratios of Kvaal's approach as independent variables to establish population specific regression formulas for age estimation. PV/TV error and Kvaal's ratios error were measured across both voxel sizes. Intraobserver and interobserver variability was measured by two oral radiologists with years of experience ranging from 10-34 years.

1.1 Statistical analysis

Data were statistically described in terms of mean ± standard deviation (± SD), median and range, or frequencies (number of cases) and percentages when appropriate. Comparison of numerical variables between the study groups was done using Mann Whitney U test for independent samples. Correlation between various variables was done using Pearson moment correlation equation for linear relation of normally distributed variables and Spearman rank correlation equation for non-normal variables/non-linear monotonic relation. Linear regression analysis was used to test to construct an equation predicting chronological age using the different studied variables. Interobserver and intraobserver variability analysis was done using the intraclass correlation coefficient (ICC). Two-sided p values less than 0.05 were considered statistically significant. IBM SPSS (Statistical Package for the Social Science; IBM Corp, Armonk, NY, USA) release 22 for Microsoft Windows was used for all statistical analyses

2. RESULTS

2.1 Descriptive and variability analysis:

In the current study, 75 teeth of 25 patients were evaluated to estimate the age based on volumetric and linear measurements of tooth and pulp cavity. The age of the subjects was between 18 and 57 years. The mean age was 31.48 +/-10.267 years. The study group consisted of 13 females (52%) and 12 males (48%). Twelve CBCT scans (48%) had a voxel size of 0.2 mm while 13 scans (52%) had a voxel size of 0.4 mm. Intra- and inter-observer variability for linear and volumetric measurements were analyzed using the intraclass correlation coefficient (ICC) and revealed high agreement across observers in the all assessed parameters.

2.2 Regression analysis based on PV/TV:

In regression analysis using age as the dependent variable and PV/TV as an independent variable, the coefficient of determination of values were obtained as $R^2 = 0.601$ for group 1 (0.2 mm voxel size) and $R^2 = 0.409$ for group 2 (0.4 mm voxel size) with standard error of 7.618 and 4.238 respectively indicating adequate fitness. Among regression models, the regression formula with the highest coefficient of determination with higher predictive accuracy was that for group 1, therefore the formula for group 1 was the one that best accounts for age.

The findings of regression model analysis demonstrated a strong negative correlation between age and PV/TV in both study groups. Also, there was a significant correlation between chronological age and PV/TV of maxillary central incisor in both groups ($p<0.05$).The correlation between PV/TV and chronological age was higher in group 1 (R=-0.775) than group 2 (R=-0.639) **(Table 1).**

Table 1. Regression model results including the dependent and the predictor variables

	Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
Group 1 (0.2 mm voxel size)	1	0.775(*)	0.601	0.561	7.618
Group 2 (0.4 mm voxel size)	1	0.639(*)	0.409	0.355	4.238

(*) Predictors: constant, PV/TV

Scatter plots demonstrating the correlation between chronological age (in years) and PV/TV predicted age in both groups are shown in figures (4&5).

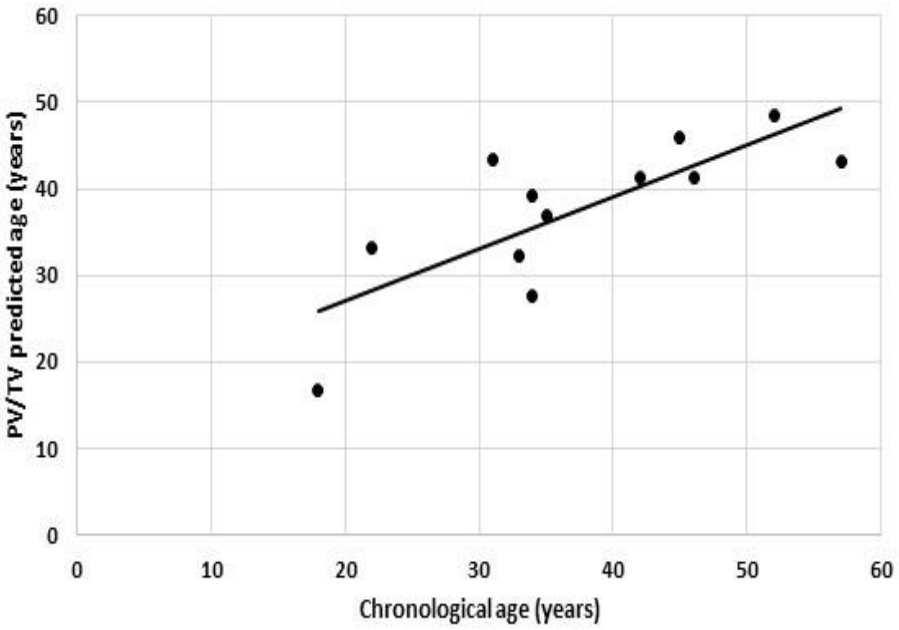


Figure 4. Scatter plot demonstrating the correlation between chronological age (years) and pulp to tooth volume ratio (PV/TV) predicted age in 0.2 mm voxel size group

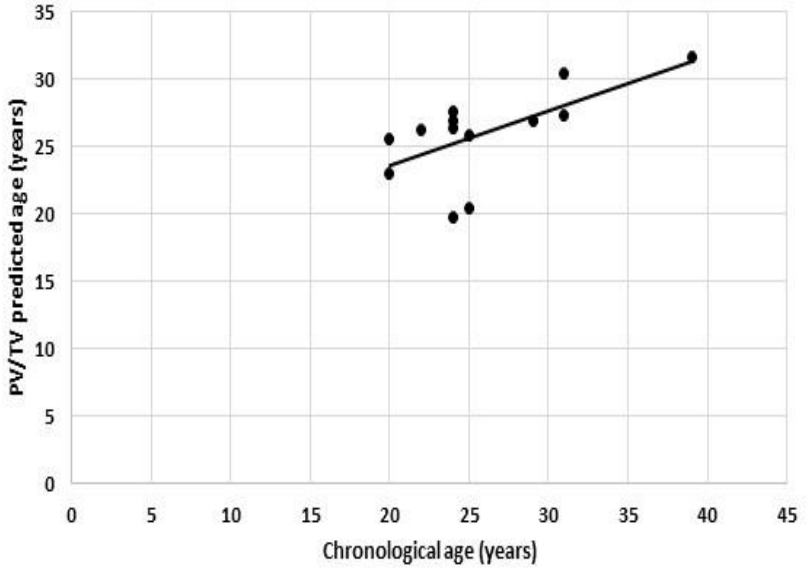


Figure 5. Scatter plot demonstrating the correlation between chronological age (years) and pulp to tooth volume ratio (PV/TV) predicted age in 0.4 mm voxel size group

ANOVA showed that the total regression with regard to the correlation of age with PV/TV variable was significant (p-value < 0.05) **(Table 2).**

Table 2. Results of the ANOVA in both study groups

	Model		Sum of Squares	df	Mean Square	F	Sig.
Group 1 (0.2 mm voxel size)	1	Regression	872.639	1	872.639	15.038	0.003(*)
		Residual	580.278	10	58.028		
		Total	1,452.917	11			
Group 2 (0.4 mm voxel size)	1	Regression	136.461	1	136.461	7.599	0.019(*)
		Residual	197.539	11	17.958		
		Total	334.000	12			

(*) Predictors: constant, PV/TV

The outcomes of the logarithmic regression model including the dependent and predictor variables are presented in **table 3**. Regression models utilizing various voxel sizes provided statistical significance for age assessment across both voxel groups.

According to **table 3**, age, as an effective factor, can easily be estimated by PV/TV in the 0.2 mm voxel size group, the regression model analysis was achieved as follows:

Age= 63.307 - 800.781 (*PV/TV*)

Besides, age, can also easily be estimated by PV/TV in the 0.4 mm voxel size group, the regression model analysis was achieved as follows:

Age= 40.429 - 253.085 (*PV/TV*)

Table 3. The outcomes of the logarithmic regression model including the dependent and predictor variables

	Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% CI for B	
			B	Std. Error	Beta			Lower	Upper
Group 1 (0.2 mm voxel size)	1	(Constant)	63.307	7.029		9.006	0.000	47.645	78.969
		PV/TV	-800.781	206.497	-0.775	-3.878	0.003	-1,260.885	-340.676
Group 2 (0.4 mm voxel size)	1	(Constant)	40.429	5.365		7.536	0.000	28.622	52.237
		PV/TV	-253.085	91.810	-0.639	-2.757	0.019	-455.159	-51.012

1.1 Correlation analysis:

In the present study, a negative correlation was found between chronological age and PV/TV as well as most of morphological variables of Kvaal's method as a result of Pearson correlation analysis for Kvaals' parameters.

Regarding the maxillary central incisor, the highest correlation values were observed in variables C (R=-0.702), W (R=-0.665) and A (R=-0.584) in group 1 and variables R (R=-0.767), L (R=-0.638), B (R=-0.618), A (R=-0.567) and W (R=-0.560) in group 2. There were significant correlations between the former morphological variables and chronological age (P-value < 0.05). The correlation coefficient of the predicted age based on Kvaal's original equation was 0.334 in group 1 and 0.484 in group 2 (P-value > 0.05). **(Table 4).**

Table 4. Pearson correlation coefficients between the studied variables and chronological age in both groups of the maxillary central incisor

		Group 1 - 0.2 mm voxel	Group 2 - 0.4 mm voxel
PV/TV	Pearson	-0.775	-0.639
	p value	0.003	0.019
P Ratio	Pearson	-0.058	-0.458
	p value	0.857	0.115
T Ratio	Pearson	0.383	0.272
	p value	0.219	0.368
R Ratio	Pearson	-0.520	-0.767
	p value	0.083	0.002
A Ratio	Pearson	-0.584	-0.567
	p value	0.046	0.043
C Ratio	Pearson	-0.702	-0.367
	p value	0.011	0.217
B Ratio	Pearson	-0.502	-0.618
	p value	0.097	0.024
M Ratio	Pearson	-0.262	-0.511
	p value	0.410	0.075
W Ratio	Pearson	-0.665	-0.560
	p value	0.018	0.046
L Ratio	Pearson	-0.230	-0.638
	p value	0.471	0.019
W-L Ratio	Pearson	-0.141	0.308
	p value	0.663	0.307

Kvaal's Predicted Age	Pearson	0.334	0.484
	p value	0.289	0.094
PV/TV based Predicted Value	Pearson	0.775	0.639
	p value	0.003	0.019
	N	12	13

Regarding the maxillary lateral incisor, the highest correlation values were observed in variables C (R=-0.535) and W (R=-0.508) in group 1 and variables B (R=-0.484) and W (R=-0.476) in group 2. The correlation coefficient of the predicted age based on Kvaal's original equation was 0.430 in group 1 and 0.426 in group 2 (P-value > 0.05). **(Table 5).**

Table 5. Pearson correlation coefficients between the studied variables and chronological age in both groups of the maxillary lateral incisor

		Group 1 - 0.2 mm voxel size	Group 2 - 0.4 mm voxel size
P Ratio	Pearson Correlation	-0.104	-0.313
	p value	0.748	0.297
T Ratio	Pearson Correlation	0.126	-0.057
	p value	0.696	0.854
R Ratio	Pearson Correlation	-0.270	-0.263
	p value	0.397	0.385
A Ratio	Pearson Correlation	-0.371	-0.094
	p value	0.235	0.761
C Ratio	Pearson Correlation	-0.535	-0.347
	p value	0.073	0.246
B Ratio	Pearson Correlation	-0.404	-0.484
	p value	0.193	0.094
M Ratio	Pearson Correlation	-0.383	-0.420
	p value	0.219	0.153
W Ratio	Pearson Correlation	-0.508	-0.476
	p value	0.092	0.100
L Ratio	Pearson Correlation	-0.207	-0.363
	p value	0.519	0.223
W-L Ratio	Pearson Correlation	-0.300	-0.176
	p value	0.343	0.565
Kvaal's Predicted Age	Pearson Correlation	0.430	0.426
	p value	0.163	0.147
	N	12	13

Regarding the mandibular first premolar, the highest correlation value were observed in variable A (R=-0.615) (statistically significant as p-value=0.033, p-value<0.05) in group 1 and variable L (R=-0.352) in group 2. The correlation coefficient of the predicted age based on Kvaal's original equation was 0.375 in group 1 and 0.197 in group 2 (P-value > 0.05). **(Table 6).**

Table 6. Pearson correlation coefficients between the studied variables and chronological age in both groups of the mandibular first premolar

		Group 1 - 0.2 mm voxel size	Group 2 - 0.4 mm voxel size
P Ratio	Pearson Correlation	0.003	-0.309
	p value	0.994	0.304
T Ratio	Pearson Correlation	-0.028	-0.124
	p value	0.930	0.688

R Ratio	Pearson Correlation	0.024	-0.205
	p value	0.941	0.501
A Ratio	Pearson Correlation	-0.615	-0.219
	p value	0.033	0.472
C Ratio	Pearson Correlation	-0.247	-0.066
	p value	0.439	0.830
B Ratio	Pearson Correlation	-0.366	-0.308
	p value	0.242	0.305
M Ratio	Pearson Correlation	-0.289	-0.254
	p value	0.363	0.402
W Ratio	Pearson Correlation	-0.321	-0.150
	p value	0.309	0.626
L Ratio	Pearson Correlation	0.009	-0.352
	p value	0.977	0.239
W-L Ratio	Pearson Correlation	-0.255	0.022
	p value	0.424	0.943
Kvaal's Predicted Age	Pearson Correlation	0.375	0.197
	p value	0.230	0.519
	N	12	13

1.1 Regression analysis based on Kvaals' morphological ratios:

Also, multiple regression analysis was performed with age as dependent variable and the morphological ratios of Kvaal's approach as independent variables with separate equations given to each study group as demonstrated in **table (7).**

Table 7. Population specific multiple regression models for chronological age estimation in years using Kvaals' variables for both study groups

Variables	Study group	Equation	R	R^2	SEE	Significant predictor (5%)
Original Kvaal's article: M & W-L ratios	Group 1 (0.2 mm voxel size)	Chronological age = 31.802-77.968(*M ratio*)-69.174(*W-L ratio*)	0.370	0.137	10.677	W-L ratio (P-value=0.046)
Original Kvaal's article: M & W-L ratios	Group 2 (0.4 mm voxel size)	Chronological age = 39.559-23.450(*M ratio*)-3.917(*W-L ratio*)	0.256	0.065	5.101	Constant (P-value=0.005)
Stepwise regression C, A & T ratios	Group 1 (0.2 mm voxel size)	Chronological age = 39.783-95.124(*C ratio*)-117.760(*A ratio*)+21.623(*T ratio*)	0.646	0.417	8.913	All predictors are significant Constant (p-value=0.01) C ratio (p-value=0.007) A ratio (p-value=0.0015) T ratio (p-value=0.030)

Stepwise regression R & B ratios	Group 2 (0.4 mm voxel size)	Chronological age = 83.893-62.961(*R ratio*)-39.792(*B ratio*)	0.613	0.376	4.168	All predictors are significant Constant (p-value=0.000) R ratio (p-value=0.0019) B ratio (p-value=0.002)

First, regression analysis was created for all the three teeth with age as dependent variable and M and W-L ratios as the first and second predictors respectively. M and W-L variables were used as suggested in original Kvaal's article to create a population specific regression formulae. Regarding the significant predictors, for group 1, only W-L ratio and for group 2, only the constant were found significant. ANOVA was found insignificant. The correlation coefficients were found 0.370 and 0.256 in both groups respectively. The coefficient of determination for both groups of the mentioned variables was found to be low (R^2=0.137 and 0.065).

So, stepwise regression was performed, for group 1, the variables C, A and T ratios and for group 2, R & B ratios were assessed. All predictors included in both study groups were found significant up to 5%. ANOVA demonstrated that the total regression regarding the correlation of age with all variables in both study groups was found significant (p-value<0.05, in group1, p-value=0.001 and in group 2, p-value= 0.000).

The regression formula with the highest coefficient of determination (R^2) and the highest correlation coefficient (R) between Kvaals' variables and chronological age came from the equation derived from stepwise regression in group 1 (R=0.646, R^2=0.417) and the formula with the least standard error of the estimate came from the equation derived from stepwise regression in group 2 (SEE=4.168).

1.1 Comparative analysis:

The difference between predicted and chronological ages based on PV/TV across both groups was measured in terms of PV/TV error and there was no statistically significant difference between both groups indicating that no significant difference was found between both voxel sizes.

The absolute difference between predicted and chronological ages was measured in terms of Kvaals' ratios error across both groups and there was no statistically significant difference between both groups indicating that no significant difference was found between both voxel sizes except for the maxillary lateral incisor.

2. DISCUSSION

Identification of individuals is a crucial component of forensic medicine and dentistry. Important characteristics such as age, gender, ethnicity, and other characteristics are used to identify individuals [9]. Dental structures withstand decomposition and elevated temperatures, remaining among the final entities that decay post-mortem.[10]. Evidence reinforces the superiority of using maxillary incisors with a pulp volume to tooth volume ratio for age assessment and that the correlation between PV/TV was the strongest for the maxillary central incisor [11] [12]. Therefore, regarding volumetric measurements, maxillary central incisor teeth with PV/TV were used for age estimation in the current study.

In the current study, the highest correlation of PV/TV with chronological age was found to be -0.775, also, the highest explanatory coefficient of the regression model based on PV/TV was found to be 0.601.

Yang et al. conducted volumetric measurements, PV/TV was calculated, their results revealed correlation between PV/TV with chronological age to be -0.54 and coefficient of determination to be 0.29 [13]. Our results was higher than that reported by Yang et al. Star et al. measured PV/TV of single rooted teeth, their results revealed that the correlation of PV/TV with chronological age was -0.64 for incisor teeth [11]. In the current study, our results were similar to that reported by Star et al, however, the correlation strength for maxillary central incisor in our study was stronger than that observed in Star et al.

Abdinian et al. carried out a similar study, their results revealed that Pearson's correlation of PV/TV was -0.46 for maxillary central incisor and coefficient of determination to be 0.21 [14]. In the current study, our results were higher than that reported by Abdinian et al. also, Yang et al. reported that Pearson correlation coefficient of maxillary central incisors was -0.67 for global samples also, the coefficient of determination was found to be 0.44 [15]. In the current study, our results were higher than that reported by Yang et al.

In addition, Asif et al. in 2018 performed volumetric analysis of maxillary central incisors using two methods. Method 1 utilized PV/TV while method 2 utilized pulp chamber to crown volume ratio. The Pearson correlation coefficient (R) of PV/TV was found to be 0.799 and the coefficient of determination (R^2) was 0.639 [16]. Asif et al. in 2019 conducted similar measurements, their results showed that the coefficient of correlation was the strongest for the maxillary right central incisors (R= 0.83 indicating strong correlation), also, the highest coefficient of determination value was found in the maxillary right central incisors (R^2= 0.7) [17]. In the current study, our results were lower than that reported by Asif et al. 2018 and Asif et al. 2019, variations in the correlation coefficients and coefficients of determination between PV/TV and chronological age across different races may have resulted in this discrepancy.

Besides, Porto et al. performed a similar study and their results showed that Pearson's correlation coefficient of PV/TV for maxillary central incisors was -0.390 for males and -0.545 for females and the coefficient of determination was 0.21 (0.152 for males and 0.297 for females) [18]. In the current study, our results were higher than that reported by Porto et al.

In 1995, Kvaal et al. developed an approach that could be utilized to calculate an adult's chronological age based on measurements of the pulp's size using periapical radiographs based on the reduction of pulp cavity size due to the deposition of secondary dentine with advancing age which can be utilized as an age indicator [5].

In the current study, width measurements demonstrated the strongest correlation with chronological age. Kazmi et al. in 2023 systematically reviewed the correlation accuracy between length ratios and width ratios according to Kvaal's approach in relation to chronological age, the findings indicate that width ratios had a stronger correlation compared to length ratios in line with our study [19].

Kolltveit et al. and Erbudak et al. applied Kvaal's method and their results showed that the strongest correlation for maxillary central incisor was the R ratio [20] [21]. Similarly, in the current study the strongest correlation for maxillary central incisor in group 2 was the R ratio.

In the current study, the validity of Kvaal's approach using the original Kvaals' equations was evaluated using the absolute difference between predicted and chronological ages, the standard deviation of the evaluated teeth ranged from 9.4 to 12.1 for the whole sample and pearson correlation coefficient of predicted age ranged from 0.197 to 0.484 with no statistically significant correlation between predicted and chronological ages (P-value > 0.05) indicating low validity. Bosman et al. applied Kvaal's approach and their results showed no significant differences between estimated and chronological ages including all six teeth or three mandibular teeth only using the original regression formulas [22]. However, Erbudak et al. documented that a high difference of more than 12 years was found between estimated and chronological ages using the original regression models indicating its insufficiency to precisely estimate age [21]. Our results are in contrast with Bosman et al. and in agreement with Erbudak et al., the reason for the difference in findings between Bosman et al. and our study may be due to different methodologies as Bosman et al. utilized orthopantomograms however, CBCT scans were used in the current study.

In the original study of Kvaal et al., regression models were created with age as dependent variable, M as the first predictor and W-L as the second predictor [5], similarly in the current study, the former predictors were used to create population specific regression equations. In the current study, our results showed that the coefficient of determination for both groups using M and W–L parameters was found to be low (R^2=0.137 and 0.065).

Alharbi Sr et al. developed regression models utilizing same predictors as Kvaal's original study, the R^2 ranged from 0.447 to 0.752 and their study concluded that the most effective indicators for age evaluation were "M" and "W-L" variables [23]. However, Haghnegahdar et al. found that R^2 for M and W–L parameters was low with respect to chronological age (R^2= 0.09- 0.27) [24]. Also, Akay, Gungor and Gurcan found that R^2 for same parameters was also low with respect to chronological age (R^2= 0.162-0.550) [25].

In the current study, our results are in agreement with Haghnegahdar et al. and Akay, Gungor and Gurcan and in contrast with Alharbi Sr et al., different methodologies utilized for linear measurements may have resulted in this variation as Alharbi Sr et al. utilized digital orthopantomograms however, CBCT scans were used in the current study.

In addition, Çelik et al., developed regression formulae using stepwise regression, similarly, in the current study, stepwise regression was employed to create population specific regression formulae where all predictors were found significant in both groups yielding higher correlation coefficients and coefficients of determination than M and W–L parameters [26].

3. CONCLUSION

PV/TV proved to be a reliable indicator for age estimation. Kvaal's approach was found to be applicable to age estimation of Egyptian adult subjects. The original Kvaals' formulae were not capable of providing a precise estimate of age. Age estimation using population specific formulae using

the Kvaals' M & W-L predictors was insufficient in Egyptian subjects however population specific formulae using stepwise method had higher prediction ability. CBCT serves as an effective technique for age assessment in adults. It is recommended to perform this study on a larger sample size on different teeth, also it is advised to perform the study on different populations to create population specific regression models.

DECLARATION

Conflict of interest

Authors declare that there is no conflict of interest

Source of funding

There are no funds procured

Author Contribution

All authors have contributed substantially to the manuscript and all have reviewed the final manuscript

Ethical approval

This research project was approved by the Research Ethics Committee of the Faculty of Dentistry of Cairo University, Egypt, approval number (15-10-21), in accordance with 1964 Declaration of Helsinki

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ORIGINAL RESEARCH

EFFECT OF SMEAR OFF IRRIGATING SOLUTION IN IT'S REGULAR AND NANO FORMS ON DENTIN SURFACE PROPERTIES (AN IN VITRO STUDY)

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Abstract

Aim: Endodontic irrigating solutions play an important role in the chemo-mechanical preparation of root canals. Exposure of root canal dentin to different irrigating solutions may impair the physical properties of root canal dentin. Therefore, many studies were conducted to address the ideal root canal irrigating solution that has the minimal effect on dentin physical properties. The aim of the present study is to evaluate the effect SMEAROFF irrigating solution in its regular and nano form on: Dentine surface properties.

Materials and methods: Twenty-one extracted human non-carious mandibular premolars extracted due to periodontal problems were selected for the present study. Teeth were decoronated at the cementoenamel junction (CEJ). The working lengths of the Roots were determined, and mechanical preparation was done using Mpro rotary files sizes 20/04,25/06,30/04,35/04 and 40/04. Saline was used for irrigation during mechanical preparation. Then roots were split longitudinally into two equal halves. According to the used irrigating solution samples were divided into 3 equal groups (each containing 14 halves) as follows: Group1: SmearOFF (regular form) (N=14). Group2: SmearOFF (nano form) (N=14). Group3: NAOCL 2.6% (N=14). Determination of the surface hardness of the root dentin was measured using Vickers Hardness Tester. Statistical analysis was conducted using three-way analysis of variance (ANOVA).

Results: Sodium hypochlorite (2.6%) showed the maximum reduction in dentin microhardness followed by SmearOFF in its regular form on the three levels (coronal, middle and apical) while SmearOFF in its nano form didn't affect dentin microhardness significantly when compared with the pretreatment measures for the same group. Dentin microhardness values were highest at the coronal level followed by the middle third then the apical third showed the minimal microhardness values for the three groups.

Conclusion: Within the limitation of the present study, it can be concluded that the use of nano SmearOFF in the final rinse protocol is less detrimental to radicular dentin microhardness when compared to other irrigating solutions used in the present study.

Key words: SmearOFF, Nano SmearOFF, Microhardness, Sodium Hypochlorite
Cited tables and figures in the main text.

INTRODUCTION

Bacterial infection is widely recognized as the primary etiological factor in the development of pulpal and periapical pathologies. Successful endodontic treatment therefore depends on the effective reduction of microbial load within the root canal system. Although mechanical instrumentation plays a critical role in shaping the canal, it is insufficient on its own to achieve complete decontamination due to the anatomical complexity of root canals. Consequently, the use of chemical irrigating solutions is essential to enhance canal disinfection and remove organic and inorganic debris [1].

Sodium hypochlorite (NaOCl) remains the most frequently used endodontic irrigant because of its strong antimicrobial activity and its ability to dissolve organic tissue. However, NaOCl lacks efficacy in removing the inorganic components of the smear layer and has been

associated with cytotoxic effects when extruded beyond the apical foramen. Moreover, it does not provide long-term antimicrobial substantivity. Chlorhexidine (CHX), although characterized by substantivity and relatively low toxicity, is unable to dissolve necrotic tissue or remove the smear layer when used alone. As a result, chelating agents such as ethylenediaminetetraacetic acid (EDTA) are commonly employed to facilitate smear layer removal [2].

The sequential use of NaOCl, EDTA, and CHX has been proposed to improve root canal cleanliness. However, interactions between NaOCl and CHX result in the formation of an insoluble precipitate containing parachloroaniline, a compound reported to possess cytotoxic and potentially carcinogenic properties. Additionally, this precipitate may occlude dentinal tubules, impair irrigant penetration, and compromise the adhesion of obturation materials [3].

Recent advances in nanotechnology have introduced novel strategies for improving endodontic irrigation. Nanoparticles exhibit unique physicochemical properties, including increased surface area and enhanced reactivity, which may improve antimicrobial efficacy and interaction with dental tissues. Silver nanoparticles, in particular, have demonstrated broad-spectrum antimicrobial activity and have been incorporated into various biomedical applications. Nevertheless, concerns remain regarding nanoparticle toxicity, which appears to be influenced by particle size, concentration, and exposure duration [4].

SmearOFF is a commercially available irrigant combining chelating agents, antimicrobial components, and surfactants to enhance smear layer removal. The nano-formulation of SmearOFF has been developed to improve its interaction with dentin while potentially minimizing adverse effects on dentin structure. However, limited evidence exists regarding its influence on the mechanical properties of root dentin [5].

Therefore, the present in vitro study aimed to evaluate and compare the effects of SmearOFF in its regular and nano formulations on radicular dentin microhardness at different root canal levels.

MATERIALS AND METHODS

Preparation of tooth specimens

Twenty-one extracted human non-carious mandibular premolars extracted due to periodontal problems with relative similarity in dimension and morphology were selected for the present study. Teeth were thoroughly cleaned from any soft tissue or calculus deposition then they were stored in isotonic saline solution at room temperature till time of use and then radiographed in proximal view to confirm presence of a patent single canal. The crowns of all specimens were cut transversally at the cementoenamel junction (CEJ) with a double-faced diamond disc (Microdont LDA.Brazil) at low speed with water coolant to ensure a uniform sample length of 14 mm (± 1mm root length). Mechanical preparation was done using Mpro rotary files sizes 20/04, 25/06, 30/04,35/04 and 40/04. Saline was used as an irrigant during mechanical preparation.

Sample Preparation for Microhardness Evaluation

Specimens were longitudinally sectioned in a bucco-lingual direction by using a double-faced diamond disk at low speed. The root segments were then horizontally embedded in auto-polymerizing acrylic resin (Acrostone, Dent Product. Egypt) leaving their dentin surface exposed(fig1). The dentin surface of the mounted specimens was ground flat and smooth with a series of ascending grades of carbide abrasive papers 500, 800, 1,000, and 1,200 grit (Bigo, Dent Product. Germany) under distilled water to remove any surface scratches and finally polished with 0.1-Mm alumina suspension on a rotary felt disc (Microdont LDA. Brazil) to obtain a smooth glossy mirror-like surface.

Sample Classification

Roots were divided into 3 equal groups (each containing 14 halves) according to irrigation protocol as follows:

Group1: SmearOFF (regular form) (N=14), **Group2**: SmearOFF (nano form) (N=14) and **Group3**: NAOCL 2.6% (N=14).

Exposure to Irrigation Agents

The dentin block specimens were randomly divided into 3 groups: the regular form SmearOFF group, 7 halves, were completely immersed in 2.6% NaOCl for 5 minutes immediately. And the other 7 halves were immersed in normal saline for 5 minutes. In the nano form SmearOFF group, 7 halves were immersed in 5 mL nano form SmearOFF for 5 minutes. The other 7 halves were immersed in normal saline.

In the third group, 7 specimens were completely immersed in 2.6% NaOCl for 5 minutes and the other 7 halves were immersed in normal saline. After completion of the immersion protocol, samples were left on a bench top to dry overnight.

Microhardness Evaluation

Measurements were taken 1mm lateral to the root canal space. Three measurements were recorded: coronal, middle and apical. Determination of the surface hardness of the root dentin was measured using Vickers Hardness Tester. Indentations were made with a Vickers diamond indenter with a minimum of three widely similarly positioned locations (fig 2).

The indentations were made on the top surface of each sample using 25g and a dwell time of 10s. The three values were averaged to produce one hardness value for each specimen. These measurements were converted into Vickers numbers.

RESULTS

Results of the current study showed that sodium hypochlorite (NaOCl) 2.6% and smearOFF in its regular form significantly decreased root dentin microhardness while Nano smearOFF didn't affect root dentin microhardness significantly. A three-way mixed ANOVA revealed a significant main effect of Time ($F(1,18) = 68.81$, $p < 0.001$), with post-treatment micro-hardness ($M = 38.69$, $SD = 3.67$) being substantially lower than pre-treatment values ($M = 43.06$, $SD = 2.89$). The large effect size ($\eta^2 = 0.793$) indicates that immersion of samples in the different irrigants accounted for 79.3% of the variance in micro-hardness measurements. Critically, a significant pre and post irrigation treatment difference was observed ($F(2,18) = 19.30$, $p < 0.001$, $\eta^2 = 0.682$), demonstrating differential treatment responses among groups. Post-hoc analyses using Tukey's HSD revealed that Group 3(sodium hypochlorite 2.6% group) exhibited the most pronounced reduction in micro-hardness (Pre: $M = 46.07$, Post: $M = 37.57$; $\Delta = -8.50$, $p < 0.001$, $d = 3.46$), followed by Group 1(regular for SmearOFF) (Pre: $M = 42.62$, Post: $M = 38.50$; $\Delta = -4.12$, $p < 0.001$, $d = 1.68$), while Group 2 (nano SmearOFF) showed minimal change (Pre: $M = 40.50$, Post: $M = 40.01$; $\Delta = -0.49$, $p = 0.325$, $d = 0.20$).

Regional analysis indicated a significant main effect of tooth region ($F(2,36) = 5.30$, $p = 0.010$, $\eta^2 = 0.227$), with the coronal region maintaining the highest micro-hardness ($M = 42.02$), followed by middle ($M = 40.91$) and apical regions ($M = 39.70$). A significant Group × Region interaction ($F(4,36) = 2.80$, $p = 0.040$, $\eta^2 = 0.237$) suggested unique micro-hardness distribution patterns across tooth regions among experimental groups.

Notably, all pretreatment samples showed non-significant microhardness measurements ($F(2,18) = 0.43$, $p = 0.657$, $\eta^2 = 0.046$), indicating comparable baseline micro-hardness across groups. The non-significant three-way interaction (Group × Time × Region: $F(4,36) = 0.20$, $p = 0.937$) suggests consistent treatment effects across all tooth regions regardless of group assignment.

Statistical power analysis confirmed adequate power for detecting key effects (Time: $1-\beta = 1.000$; Group × Time: $1-\beta = 0.999$), supporting the reliability of these findings. Assumption checks confirmed normality of residuals (Shapiro-Wilk $p > 0.05$) and sphericity (Mauchly's Test $p > 0.05$) for all within-subject effects. This comprehensive analysis provides strong evidence for differential treatment efficacy among experimental groups, with Group 3 demonstrating the most substantial micro-hardness decrease following intervention.



Figure 1. Teeth after decoronation, longitudinal sectioning and embedding in self-cured acrylic resin



Figure 2. Dentin microhardness testing using Vickers microhardness tester

Table 1. Microhardness values of the three groups before and after irrigation application

Group	Time	Mean ± SD	p-value
1	Before	42.62 ± 2.45	<0.001***
1	After	38.50 ± 2.89	
2	Before	40.50 ± 2.89	0.325
2	After	40.01 ± 2.15	
3	Before	46.07 ± 3.28	<0.001***
3	After	37.57 ± 2.45	

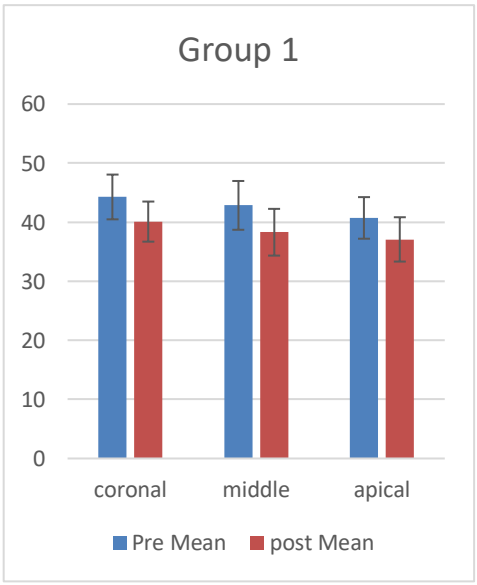


Figure 3. Chart showing change in microhardness values through different root sections for group 1

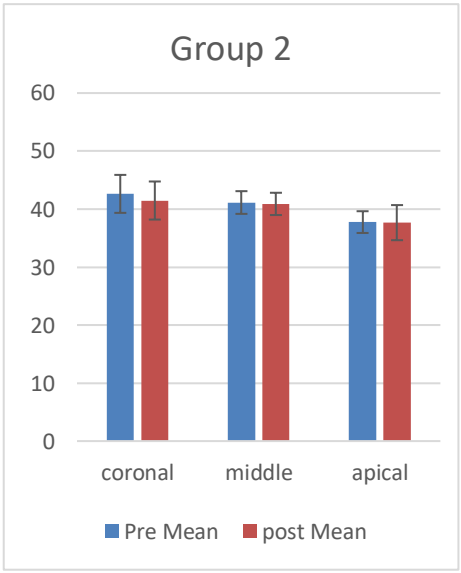


Figure 4. Chart showing change in microhardness values through different root sections for group 2

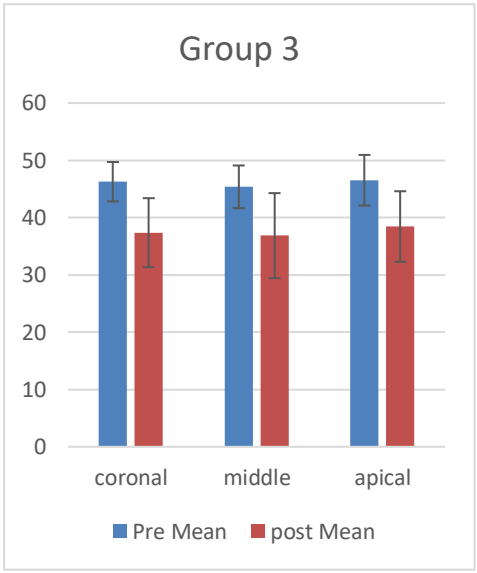


Figure 5. Chart showing change in microhardness values through different root sections for group 3

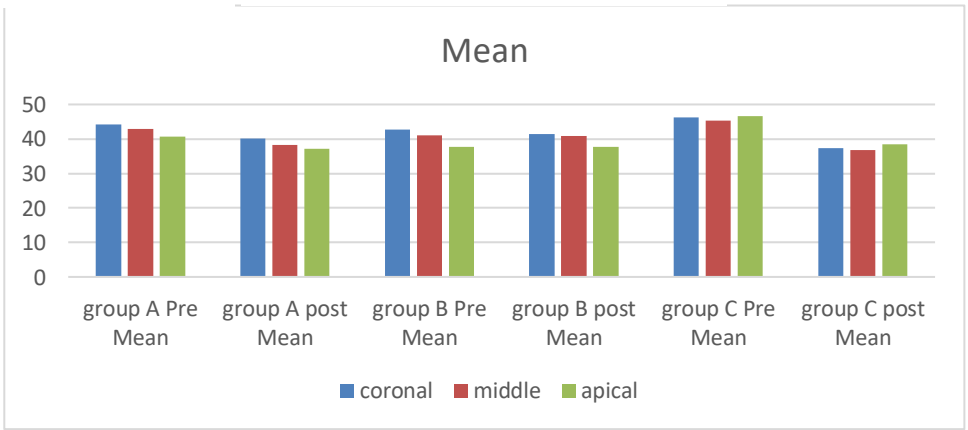


Figure 6. chart showing change in microhardness values for the three groups through different root sections

DISCUSSION

The mechanical integrity of the root dentin is a paramount concern in endodontic therapy. The use of potent chemical irrigants, while necessary for disinfection and smear layer removal, often results in collateral damage to the dentin substrate [6]. The present study utilized the Vickers microhardness tester to quantify changes in dentin surface properties following exposure to the experimental and control irrigation protocols [7]. Recent studies done by Saghiri MA *et al.* [8] and Kulkarni S *et al.* [9] have used the Vickers microhardness test to examine root dentin microhardness after irrigating canal space with various irrigating solutions.

In the present study, longitudinal sectioning of the roots was performed instead of cutting transversally into discs as Cruz-Filho et al [14] observed that it can show accurate representations of clinical situations. Additionally, the irrigants first contact the most superficial layer of dentin in the root canal lumen, and so, the present study measured the microhardness of the most superficial layer of root canal dentin. On the opposite side, earlier studies [15] used the transverse sectioning of the root into discs to evaluate the hardness value in the region between the main canal and the cementum layer.

Microhardness of the radicular dentin differs at different levels within the same tooth. Thus, in the present study, indentations were made in the cervical, middle, and apical thirds of the radicular dentin to calculate the Vickers hardness values for root dentin [16]. Philip et al. [24] detected that 2.5% NaOCl significantly decreased dentin microhardness in the apical third compared to the middle and cervical thirds. This reduction was justified by the low surface tension of NaOCl, which allowed it to penetrate long and narrow dentinal tubules through capillary forces or by diffusion into the dentin.

The immersion time in the current study was five minutes for each irrigant as it may mimic the clinical application time of the irrigant during chemomechanical preparation. In accordance with the current study were those of Sayin et al [17], Cruz-Filho et al [14], Ulusoy et al [18] and Aslantas et al [19] who used the root canal irrigants for five minutes in their microhardness tests, stating that this duration is closer to clinical situation. In addition, De-Deus et al [20] evaluated the effect 17% EDTA for one, three and five minutes on the microhardness of radicular dentin. They found that EDTA produced the greatest decrease in microhardness from reference state to 3 min and then microhardness did not change after 5 min.

Goldberg et al [21] studied the effect of 2.5% and 6% sodium hypochlorite solutions on root dentin microhardness for different irrigation times and they found that irrigation for 5 minutes resulted in a significant change in dentin microhardness.

A 2.6% concentration of sodium hypochlorite was chosen for this study because this is the most frequently employed concentration in clinical procedures to minimize its adverse effects [9,10]. Furthermore, the 2.5% NaOCl can inhibit 100% of the Enterococcus faecalis in 5 minutes [22].

The group treated with 2.6 % sodium hypochlorite showed a significant reduction in dentin microhardness. This result aligns with the findings of a study conducted by Elika V *et al.* [11]. NaOCl is identified as a potent proteolytic agent capable of altering the micromechanical properties of dentin. Dentin microstructure is composed of about 20% organic material by weight. Most of this organic component is formed of type I collagen, which affects dentin's mechanical characteristics [12]. The high pH of NaOCl (typically >11) facilitates the neutralization of amino acids and the chloramination reaction, leading to the fragmentation and dissolution of the collagen triple helix structure [13].

SmearOFF in the regular form Group , demonstrated a statistically significant reduction in microhardness, although the magnitude of this reduction was approximately half that of the NaOCl group. SmearOFF is a proprietary formulation containing EDTA, Chlorhexidine (CHX), and a surfactant. Its mechanism of interaction with dentin is fundamentally different from that of NaOCl. EDTA, the primary active component of SmearOFF responsible for smear layer removal, functions by sequestering calcium ions from the hydroxyapatite lattice. Unlike NaOCl, which targets the organic matrix, EDTA targets the inorganic mineral phase. By removing calcium, EDTA causes a selective demineralization of the peritubular and intertubular dentin. Since the mineral phase contributes significantly to the hardness of the tissue (resistance to indentation), its removal naturally leads to a decrease in Vickers hardness values [23].

The presence of a surfactant in the SmearOFF formulation is designed to lower the surface tension of the irrigant, enhancing its wettability and penetration into the dentinal tubules. While this is beneficial for cleaning, it theoretically exposes a larger surface area of the dentin to the chelating action of EDTA. Narkedamalli et al suggested that SmearOFF might produce more surface roughness and hardness reduction than EDTA alone, potentially due to this enhanced wetting ability facilitating deeper erosive effects. The findings of Group 1 in the current study support this hypothesis, showing a measurable softening of the dentin surface [25].

Ballal et al. [26] stated that chelating agents reduce microhardness, which comes in agreements with results of the present study. The current study found that

Regular SmearOFF caused less damage than. It suggests that in the hierarchy of dentin-aggressive irrigants, proteolysis (collagen destruction) may be more detrimental to surface hardness properties than controlled demineralization, at least under the exposure times tested here. This agrees with Sayin et al. [17] and Saleh et al. [15], who postulated that the organic matrix plays a crucial role in the "toughness" and structural integrity of dentin.

The most important finding of the present study comes into the behavior of (Nano SmearOFF) group. Statistical analysis revealed no significant reduction in dentin microhardness following treatment with the nano-formulation. This implies that Nano SmearOFF effectively cleans and disinfects the canal without compromising the mechanical surface properties of the dentin.

This finding positions Nano SmearOFF in comparison with other nanobased irrigants mentioned in literature such as chitosan-based nanoparticles, which have been shown to maintain dentin microhardness better than EDTA. Geogi et al. [27] found that while some novel irrigants like nano-chitosan decreased hardness, the effect was often formulation-dependent. The lack of significant hardness reduction in the Nano SmearOFF group represents a significant advancement over the results gained from Narkedamalli et al [25], who reported hardness reductions with regular SmearOFF. It suggests that the nano-modification successfully mitigates the erosive downsides of the parent chemical composition.

Crucially, the statistical analysis showed no significant "Group × Region" interaction. This implies that the respective effects of the irrigants—destruction by NaOCl, moderate softening by Regular SmearOFF, and preservation by Nano SmearOFF were consistent throughout the entire length of the root canal. This is clinically reassuring, particularly for the apical third. The apical dentin is critical for the seal of the obturation material and is often the site of instrument-induced cracks. An irrigant like NaOCl, which significantly softens this area, could increase the risk of apical transportation or strip perforation during instrumentation. Conversely, Nano SmearOFF preserves the mechanical resilience of this delicate zone.

CONCLUSION

Within the limitations of this in vitro study, sodium hypochlorite produced the greatest reduction in radicular dentin microhardness, followed by regular SmearOFF. In contrast, nano SmearOFF preserved dentin microhardness without inducing statistically significant changes. These findings suggest that nano SmearOFF may offer an effective alternative final irrigant that balances smear layer removal and antimicrobial activity while minimizing adverse effects on dentin surface properties.

DECLARATIOM

Conflict of interest:
Authors declare that there is no conflict of interest
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There are no funds procured
Author Contribution:
All authors have contributed substantially to the manuscript and all have reviewed the final manuscript

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ORIGINAL RESEARCH

REACTIVE LESIONS OF THE ORAL CAVITY: RETROSPECTIVE STUDY OF 5 YEARS IN A SINGLE CENTRE

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Abstract

Background: Reactive lesions (RL) are commonly occurring non-neoplastic growths that occur due to chronic low-grade irritations of the oral cavity. Although cheek and tongue bite are common in occurrence and is reactive in nature, they do not require biopsy. The commonly occurring RLs are pyogenic granuloma (PG), peripheral giant cell granuloma (PGCG), peripheral ossifying fibroma (POF) peripheral cemento-ossifying fibroma (PCOF), giant cell fibroma (GCF), inflammatory fibrous hyperplasia/fibrous hyperplasia (IFH/FH), inflammatory fibroepithelial hyperplasia (IFEH), fibroma and mucocele.
The study serves a resource for oral pathology residents and practitioners by providing understanding of the prevalence and characteristics of these lesions. Knowledge of RLs can aid in early diagnosis, differential diagnosis, and treatment planning.
Objectives: To evaluate the prevalence and the types of reactive lesions, to analyze the demographic data and to assess the common location of presentation.
Materials and Methods: Data was collected from the archives of the department, of the past 5 years and reactive lesions were analyzed namely, PG, PGCG, POF, GCF, IFH/FH, IFEH, fibroma, mucocele. Data was stored and analyzed using the Microsoft excel application.
Results: In our study RLs constituted about 17.75% of the total biopsies received in our department. Of these, the reactive hyperplasias (IFEH, IFH, FH) constituted the majority of the reactive lesions approximately 50% followed by mucocele 21%, PG 15%, POF & PCOF 9%, and reactive giant cell lesion at 4% Gingiva was common site followed by buccal mucosa. For mucocele, lip was the most affected site.
Conclusions: The reactive lesions are more commonly occurring lesions in the oral cavity. Although the lesions may show clinical similarities they show histopathological differences. A complete removal of local irritants is necessary for the treatment.

Key words: Reactive lesions, reactive hyperplasia, inflammatory fibrous hyperplasia, gingival hyperplasia, pyogenic granuloma, peripheral ossifying fibroma

INTRODUCTION

The oral cavity is continuously exposed to various forms of recurrent trauma, including mechanical, chemical, and thermal insults [1]. This trauma can lead to a range of clinical diseases. Reactive lesions are frequently reported and typically arise in response to low-grade persistent irritation or injury. [2,3]
Parafunctional habits have also been attributed to the development of oral lesions such as frictional keratosis (morsicatio buccarum, morsicatio linguarum),

Rhea Verghese, Punnya. V. Angadi, Chetan Belaldavar, Aleena Tom. Reactive lesions of the oral cavity: Retrospective study of 5 years in a single centre. Bulletin of Stomatology and Maxillofacial Surgery. 2025;21(12) 314-321 doi:10.58240/1829006X-2025.21.12-314

stomatitis, linea alba, etc.[4] These lesions are also reactive in nature; however, they typically do not require biopsy. Some other lesions that are reactive in nature include traumatic neuroma, mucocele, necrotizing sialometaplasia, giant cell fibroma, inflammatory papillary hyperplasia.[5] Among these, pyogenic granuloma, peripheral giant cell granuloma, peripheral ossifying fibroma, traumatic fibroma, and epulis fissuratum are the most commonly occurring reactive lesions of the oral cavity[4].

Reactive lesions may exhibit a reddish to violaceous clinical appearance, or they could correspond to the colour of the normal oral mucosa, presenting as either sessile or pedunculated. The common site of occurrence is on the gingiva, because it is the most exposed to the trauma or irritation from calculus, prosthesis etc. However, it can occur in any intraoral sites. The consistency of the growths can range from fibrous to flaccid. The symptoms may range from none at all to that of mild pain which could be associated with bleeding. Radiographic findings are mostly absent. [6]

Eversole and Rovin postulated that although the clinical presentation of these reactive lesions overlap, histologically they have a distinct presentation which may be due to the nature of irritation [7]

Our study focuses on reactive lesions, cases histopathologically diagnosed cases as pyogenic granuloma (PG), fibro-epithelial hyperplasia (FEH) , inflammatory fibro-epithelial hyperplasia (IFEH), fibrous hyperplasia (FH), Peripheral ossifying fibroma (POF) and Peripheral cemento-ossifying fibroma (PCOF), peripheral giant cell granuloma (PGCG), mucocele, giant cell fibroma (GCF), as these lesions represent the most commonly occurring oral reactive lesions excluding caries, periapical inflammatory lesions. [6,8]

Although there are a lot of studies published in regards to reactive lesions, there are many studies where inadequate data is reported. However, such studies help to understand the incidence and prevalence of RL across nations. It can better help us understand the changing trends if any, in relation to the incidence of RL as it can be useful for diagnosing patients.

The aim of our study was to evaluate the prevalence and the types of reactive lesions. We also aimed to analyze the demographic data and to assess the common location of presentation. We were able to achieve our aims through this study

MATERIALS AND METHODS

After obtaining the institutional ethical clearance, the study retrospectively evaluated the data from past 5 years i.e. from 2020 to 2025 from the department of oral pathology and microbiology at KLE VK Institute of Dental Sciences, Belagavi, Karnataka. Patients of all age groups and both genders were included, provided they had an adequate case history. Cases with incomplete demographic data such as missing age or gender information were excluded from the study.

Out of 1020 biopsied cases, a total of 181 met the inclusion criteria and were identified as reactive lesions; these were included in the study.

The data was collected, sorted and stored into an excel sheet and analysed using Microsoft Excel software.

The lesions included for the present study were PG, POF, Mucocele, PGCG, GCF, IFH, FH, fibroma, IFEH. PGCG and GCF were further combined into reactive giant cell lesions and IFH, IFEH, FH and fibromas were collated into reactive hyperplasias. The categorized data is mentioned in Table 1.

Apart from this, a literature review was also conducted to identify studies conducted on reactive lesions (RL). The search was performed using PubMed and Google. Studies that reported large datasets similar to our own were included, while case reports and case series were excluded. A total of 29 studies analysing retrospective data on reactive lesions were identified and tabulated in a chronological order. However, this may not represent an exhaustive list. The included studies have been mentioned in Table 2 (Results).

RESULTS

During these 5 years, a total of 1020 biopsies were received and out of those 181 cases were diagnosed as reactive lesions with an incidence of 17.75%.

Among the reactive lesions, reactive hyperplasias, which encompassed Fibroepithelial hyperplasias (FEH, IFEH) and Fibrous hyperplasia (FH, fibromas) constituted around 50%. This was followed by mucoceles at 22%, pyogenic granulomas (PG) at 15% POF and PCOF at 9% and reactive giant cell lesions at 4%. The detailed breakdown of the number of instances and their corresponding percentages is presented in Table 1 and Figure 1 below.

Table 1. Distribution of the reactive lesions

	Reactive lesions	Total Number
	PG	28
	POF & PCOF	16

	Mucocele	39
Reactive Giant cell lesions	PGCG	3
	GCF	4
Reactive Hyperplasias	Fibrous hyperplasia	42
	Fibroepithelial hyperplasia	49
Total		181

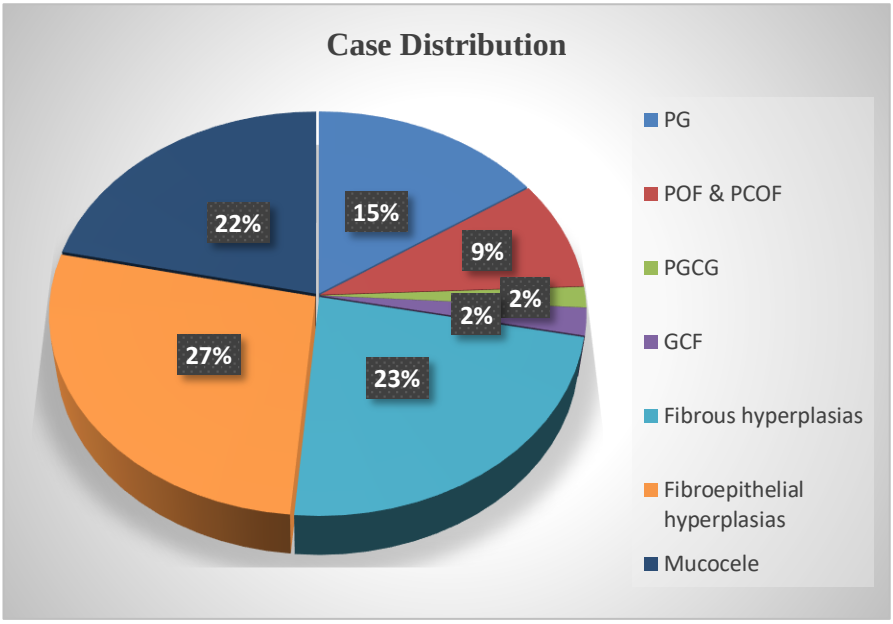


Figure 1. Percentage distribution of cases
Figure 1depicts the case wise distribution of reactive lesions.

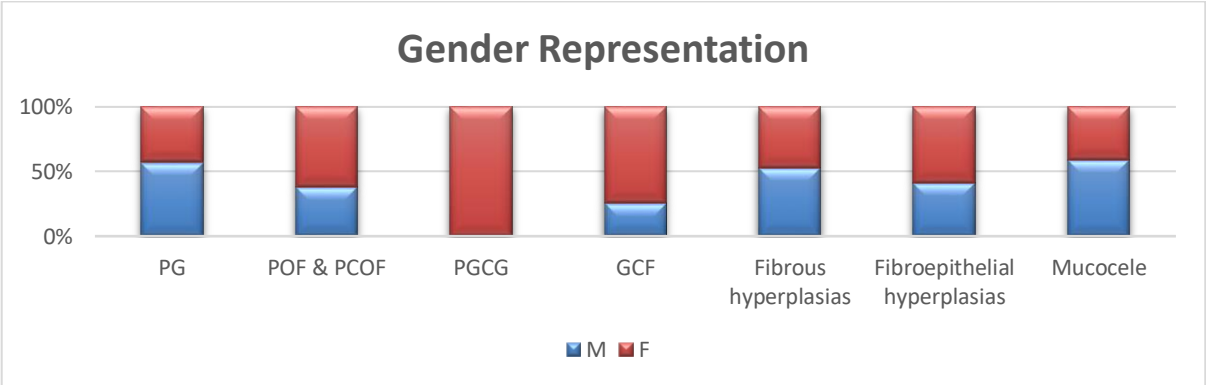


Figure 2. Gender representation within the cases
Figure 2 illustrates the distribution of males and females. In our study population of reactive lesions, there were 88 males and 93 females, indicating a slight female predominance. In PG and mucocele, the incidence of males affected was somewhat higher than that of females. In POF & PCOF, and in PGCG and GCF (reactive giant cell lesions), the proportion of affected females was higher. A similar observation was noted in reactive hyperplasias.

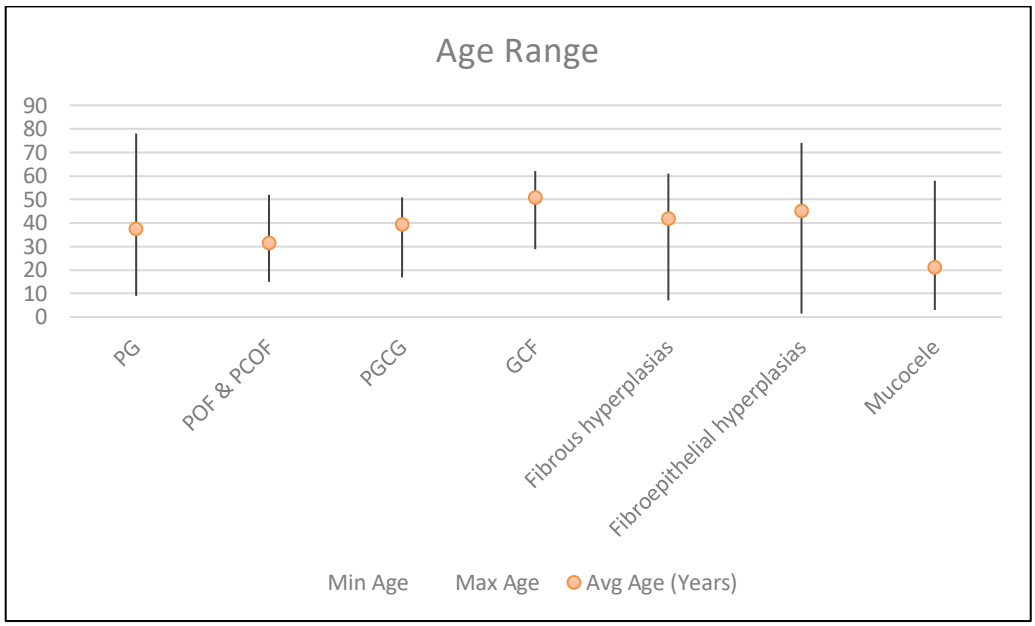


Figure 3. Age range and the mean age distribution

Figure 3 illustrates the age distribution. For PG the mean age was found to be around 37.43 years with age ranging from 9-78 years. POF & PCOF with mean age of 31.38 years and ages ranging from 15-52 years. The average age for mucocele was 21.23 years with age ranging from 3-58 years. The mean age of reactive giant cell lesions (PGCG, GCF) was 45.86 years with age ranging of 17- 62 years. Reactive hyperplasias (including IFEH, FEH, IFH, FH, fibroma) mean age was 43. 6 years with age ranging from 1.5 years to 74 years.

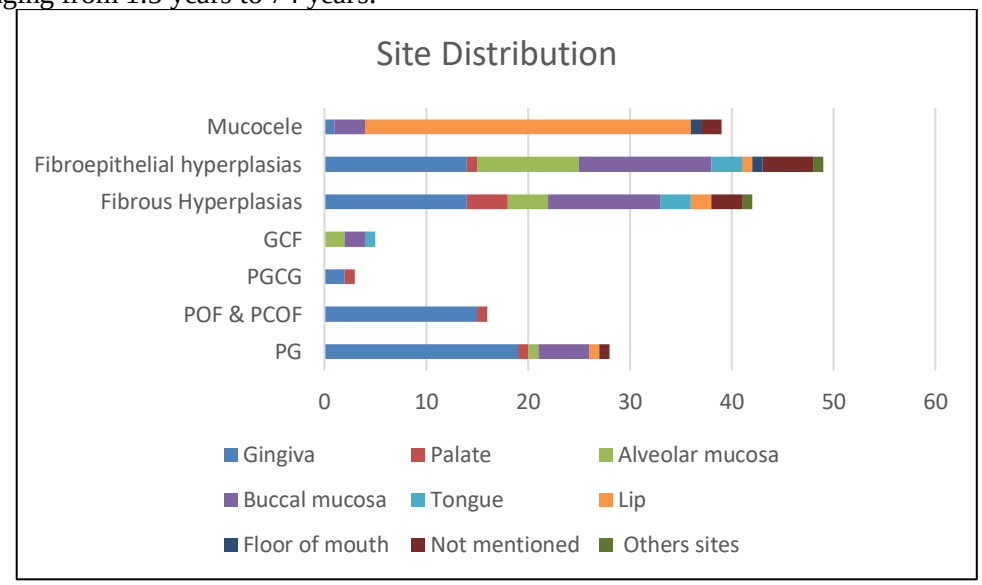


Figure 4. Site distributions of the lesions

Figure 4 depicts the distribution of the lesions according to the site. The most commonly affected area was the gingiva followed by the lip (mucocele), buccal mucosa and palate. For PG, gingiva (19/28) was the most common site followed by buccal mucosa (5/28) and lip and alveolar mucosa (1/28) each). For POF & PCOF) (15/16) cases were observed on the gingiva and one on the palate 32/39 cases of mucoceles were present on the lip, 3/39 on the buccal mucosa and 1 case each in gingiva and floor of mouth. Gingiva was the most commonly affected region for reactive hyperplasias (28/91) followed by buccal mucosa (24/91). Other sites that had reactive hyperplasias were palate, lip, tongue, floor of mouth, alveolar mucosa. For reactive giant cell lesion 2 cases each were present on the gingiva and alveolar mucosa and 1 case each on palate, buccal mucosa and tongue. For some cases the site was not mentioned and 2 other cases had other locations that were affected than the ones mentioned above.

Table 2. Highlights the studies on reactive lesions conducted so far around the world. A total of 28 studies were identified and tabulated in a chronological order. This table may not represent an exhaustive list.

Sl No	No of years of data included in the study	Total records gone through	records that are RHL	Author	Place, year	% RHL
1	1963-1970	NP	279	Eversole	Kentucky, 1972	NA
2	Jan 1968 - Dec 1978(11 years)	NP	741	Kfir et al	San Fransico, 1980	NA
3	15 years	NP	175	Goran Anneroth and Ake Sigurdson	Sweden, 1983	NA
4	5 years(March 2000-March 2005)	NP	172	Zarei et al.	Iran., 2007	NA
5	Jan 1951 to July 2005	NP	2439	Zhang et al	China, 2007	NA
6	12 years (1982-1994)	4027	636	N Al-Rawi	Iraq, 2008	15.79%
7	4 years(Sep 2004 - Sep 2008)	NP	123	Amirchaghmaghi et al	Iran, 2011	NA
8	2000-2011	6369	1149	Maturana-Ramírez et al.	Chile, 2011	18.04%
9	Jan 1970- Dec 2008	5572	314	Effiom et al	Nigeria, 2011	5.63%
10	1.5 years	240	100	Kashyap et al	India, 2012	41.66%
11	20 years	NP	427	R Krishnapillai et al	India, 2012	NA
12	1988-2005	NP	2068	Noushin J Naderi et al	Iran, 2012	NA
13	10 years (2001-2010)	1634	209	Reddy et al	India, 2013	12.79%
14	10 years(1999 – 2009)	938	328	Palmeira et al	Brazil, 2013	34.96%
15	Jan 2007 to Dec 2011 5 years	2753	295	Vidyanath et al	India, 2015	10.71%
16	5 years (2010 – 2015)	402	88	Mandeep aur et al	India, 2016	21.89%
17	(2006 – 2015)	NP	460	Hunasgi et al	India, 2017	NA
18	10 years July 2006 to July 2016	5000	659	Babu et al	India, 2017	13.18%
19	10 years 2006 to 2016	2400	534	Kamile Leonardi Dutra	Brazil, 2018	22.25%
20	1 year (2016-2017)	NP	60	Gurvinder Kaur	India, 2018	NA
21	10 years (2006 and 2015)	390	78	Soyele	Nigeria, 2019	20%
22	2 years	NP	112	Samrina Mohammad	Pakistan, 2020	NA
23	2011-2017	NP	243	Karuma C et al	Johannesburg, 2021	NA
24	10 years	501	73	Efetobo Victor Orikpete	Nigeria, 2021	14.57%
25	22 years (1996 - 2017)	5284	1000	Montazer Lotf-Elah	Iran, 2022	18.92%
26	2018-2020 (3 years)	2254	73	Vandana Gupta	India, 2022	3.23%
27	5 years (Jan 2019 to May 2024)	577	67	Vaddadi Sindhuja	India, 2024	11.61%
28	10 years (2011 - 2020)	21420	2142	Ahmed Metwally	Egypt, 2024	10 %

NP : Not published. The data hasn't been published by the authors.

NA: Not applicable, as the % of RHL hasn't been mentioned by the authors nor can it be calculated as the total number of biopsies gone through has not been published.

DISCUSSION

Oral Pyogenic Granuloma is a RL that most commonly occurs on the gingiva and may present as a painless growth or with slight pain and tendency to bleed on probing.[9] It presents as a reddish growth in the initial stages and it appears more pink in the mature lesions. [10] It usually has a female predilection. However, in our present study, the number of males affected were more than number of females which is in contrast to many of the studies published. The mean age of presentation in our study was 37. 42 yrs similar to other studies and those conducted by Krishnapillai et al [9] . The age of presentation ranged in our study from 9-78 yrs. The most commonly affected site was the gingiva, followed by the buccal mucosa and lip. Additionally, within these 5 years 3 cases from our study reported recurrence. Histopathologically, PG are entirely or partially covered with epithelium with underlying connective tissue consisting of abundant vascularity, budding capillaries and acute or chronic inflammatory cells.

Peripheral ossifying fibromas and peripheral cemento-ossifying fibromas usually occurs in the younger age group peaking the 3rd decade. This is similar to our study where the mean was 31.37 yrs with a age range of 15-52 years. [10] In our study except for 1 case all of the lesions were seen on the gingiva, which may support its supposed etiopathogenesis where it is thought to arise from gingiva, periosteum or PDL [11]. There is a female predilection and we found the same in our study [11]. Radiographically these lesions may show flecks of calcifications which can be corroborated histopathologically by the presence of osseous or cementum-like structures in the connective tissue. Mucocele was included in the study because it is a very commonly occurring reactive lesion. In fact, it amounted up to 22 % of all RHL reported in our study. It is usually seen on the lip and is purported to arise due to lip biting. However, in almost all studies it hasn't been considered under the umbrella of reactive lesion as it affects the salivary gland or because it doesn't occur on the gingiva as most of the studies focuses on reactive gingival lesions. In our study 32/39 cases of mucoceles were present on the lip, 3/39 on the buccal mucosa and 1 case each in gingiva and floor of mouth. It showed a slight male predilection similar to the study by Teggmani et al and the mean age at the time of presentation was 21.23 yrs with ages ranging from 3yrs to 58 yrs. [12]

We grouped peripheral giant cell fibroma and giant cell fibroma under a wider umbrella of reactive giant cell lesions. Concerning PGCG, in our study 17-51 yrs was the age range and the mean age of the patients were 39.3 yrs. We found a slight female tendency. This is in contrast to the study by Zarei et al where he reported the mean age for PGCG was 26 years with a slight male tendency [13]. Histopathologically, PGCG has a overlying epithelium with numerous multinucleated giant cells in the connective tissue surrounded by a fibrovascular stroma. Oral GCF is a reactive lesion characterised histopathologically by the presence of giant fibroblast in the subepithelial region which may may not be multinucleated.[14]. Clinically it is an asymptomatic mass that is seen commonly on the gingiva however, it can occur on other areas such as the buccal mucosa, palate, lip etc. [15]It can occur at any age however, most commonly seen in 2nd to 4th decade of life. [16] In our study the mean age of presentation was 50.75 with ages ranging from 29 to 62 years. Two cases were reported on the buccal mucosa and alveolar mucosa and 1 case on the tongue Similar to PGCG, GCF showed a female predilection too.

Reactive hyperplasias such as Irritation Fibroma/ Fibrous Hyperplasia (IFH/FH) and Inflammatory Fibroepithelial Hyperplasia (IFEH/FEH) are commonly encountered intraoral lesions. Among these, IFH/FH is considered the most prevalent reactive lesion in the oral cavity, primarily affecting adult females. Clinically, it typically presents as a mucosal lesion of normal coloration, which may be either sessile or pedunculated. Its pathogenesis is often linked to low-grade, chronic irritants such as fractured teeth, parafunctional habits, and similar factors. In our cases, the gingiva was the most commonly affected site, aligning with the findings of Zarei et al. However, this differs from the observations of Santos et al., who reported the buccal mucosa as the predominant site. [17] The mean age of presentation was 43.6 yrs 1 case showed recurrence. Fibroepithelial hyperplasia which is also grouped under reactive hyperplasis in our study is a reactive inflammatory condition that typically arises in the gingiva and can present as various lesion types depending on the clinical context. [18] Histopathologically, FEH/IFEH exhibits hyperplasia of both the surface epithelium and the underlying fibrous connective tissue with in contrast to IFH/FH which demonstrated hyperplasia limited to the connective tissue. Prominent inflammation may or may not be present. It is important to distinguish fibroepithelial hyperplasia from focal epithelial hyperplasia, the latter being a viral infection caused by the human papillomavirus (HPV). Unlike fibroepithelial hyperplasia, which involves both the epithelium and connective tissue, focal epithelial hyperplasia affects only the epithelial layer of the oral mucosa [19]. In our study the mean age was around 44.19 yrs. 3 cases were also reported to have recurrences in our study.

The RLs can be a differential diagnosis for each other. However apart from the other RLs few other differential

diagnosis that can be considered are as follows:

Clinically, as PG, PGCG can present with a slight reddish to violaceous hue, hemangiomas, lymphangioma, and Kaposi sarcoma can be considered. However, sometimes aggressive PGs can be encountered which may be misdiagnosed as a malignant lesion. Therefore, histopathological diagnosis is of utmost importance. Another entity one must keep in mind while diagnosing PGCG is Browne's tumor as it could be present due to hormonal imbalance ie. Hyperparathyroidism. Therefore, it is pertinent that a good medical history be taken. The reccurence rate (RR) for PG is 3- 15% and PGCG is 10-18% [20,21]

A note to remember while diagnosing POF is that one should not confuse it with peripheral odontogenic fibroma as POF represents a reactive process whereas peripheral odontogenic fibroma represents a neoplastic entity. The RR for POF is 8-16%. [20]

The recurrence for TF and GCF is rare. GCF can resemble retrocuspid papilla which is a normal anatomical variation seen bilaterally on the lingual gingiva. So, one should keep this in mind while diagnosing this especially in children as it has around 25-99% prevalence. Hence it should not be excised. GCF can have papillary projections and hence papilloma can also be considered into the diagnosis. However the cause of papilloma is by *Human Papilloma Virus*. [20,22]

The differential diagnosis of mucocele include lipoma, hemangioma, lymphangioma. One must also think of salivary gland neoplasm if it presents itself on the upper lip as mucoceles are very rare on the upper lip which is in contrast to salivary gland neoplasm. [23]

The management of RLs can be achieved by elimination of causative factors or the source of irritation which can achieved by good plaque control and oral hygiene. Additionally, proper excision using conventional scalpel or laser removal is done so that recurrence may be kept at bay. Other methods of management include curettage, cryotherapy, electrosurgery. Literature also suggests injection of sclerosing agent or corticosteroid for the management of mucocele. [9,16,24]

Our analysis is based on 5 years data from a single centre, however conducting a multicentric study would provide a more robust understanding of the prevalence and distribution of lesions across the nation or globe.

CONCLUSION

The reactive lesions are of the commonly occurring lesions in the oral cavity. Although the lesions may show clinical similarities they show histopathological differences. This study gives an updated look on the prevalence, demographic trends and site distribution of reactive lesions diagnosed at our institution in the past 5 years. 17.75% of all cases reported during the duration were reactive in nature. The most common location was the gingiva and hence RLs are differentials for gingival growths. These results highlight the predominance of low-grade irritation as an etiological factor. A complete removal of local irritants is necessary for the treatment. Larger sample sizes in future multicentric studies are advised in order to confirm these trends and advance our understanding regarding epidemiology.

DECLARATIONS

Data availability: The datasets generated and analyzed during the current study will be available from the first author upon reasonable request.

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Competing Interests: The authors have no competing interests to declare.

Ethical Approval: Ethical approval has been taken for the study from the concerned intuitional ethical board.

Informed Consent: Not applicable.

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REVIEW ARTICLE

MAPPING SOCIOLOGICAL RESEARCH ON HEALTH INEQUALITY AND BEHAVIORAL INTERVENTIONS: A BIBLIOMETRIC ANALYSIS OF SOCIAL SCIENCE LITERATURE

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Abstract

This study examines the current landscape of sociological research on health inequality and behavioral interventions within the social science literature. A comprehensive bibliometric analysis was conducted using established analytical tools, including VOSviewer, Biblioshiny (R-package), and Publish or Perish, based on data retrieved from the Scopus database. A total of over 533 peer-reviewed journal articles, published between 1978 and 2026, were systematically analyzed. The results indicate a consistent growth in scholarly output, with a marked increase in publications over the past decade, reflecting the rising academic and policy relevance of health inequality research. The findings reveal that health inequality has emerged as a central research domain in sociology and public health, with dominant themes such as health disparities, social determinants of health, socioeconomic inequality, access to health care, and behavioral risk factors frequently appearing in the literature. The most productive countries contributing to this field are the United States, the United Kingdom, and Canada, supported by leading academic institutions that shape the global research agenda. High-impact journals in sociology and health studies play a crucial role in disseminating influential research, indicating that this topic is well established within top-tier academic outlets. Moreover, the analysis highlights that while behavioral interventions are widely discussed, they are predominantly framed within broader structural and policy contexts, emphasizing that individual behavior change alone is insufficient to address persistent health inequalities. Despite the expanding body of literature, notable gaps remain, particularly in integrating intersectional perspectives and expanding empirical research in low- and middle-income countries. Overall, this study provides a systematic overview of research trends, thematic structures, and intellectual influences in sociological health inequality research, offering valuable insights for future studies and evidence-based policy development aimed at reducing health disparities.

Key words: Health Inequality, Social Determinants of Health, Behavioral Interventions, Sociological Perspectives, Bibliometric Analysis

1. INTRODUCTION

Health inequality has been recognised as one of the most important and persistent issues within sociology and public health, as it reflects systematic differences in health outcomes across social groups shaped by unequal social, economic, and institutional structures [1,2.] In contrast to biomedical approaches that emphasise individual behaviour or genetic factors, sociological perspectives conceptualise health inequality as a socially produced phenomenon rooted in broader social determinants, such as socioeconomic status, education, occupation, gender, ethnicity, and living conditions[3]. Consequently, research on health inequality has developed both theoretically and empirically, addressing a wide range of structural and behavioural dimensions.These include studies on social determinants of health[1], fundamental cause theory[2,4] cumulative inequality and life course processes [5,6], access to health care and policy, and behavioural risk factors embedded in social contexts [7]. Together, these strands demonstrate that sociological research on health inequality encompasses both structural explanations and behavioural interventions within diverse social settings.

Over the past few decades, scholarly discussions on health inequality have increased substantially, driven by growing awareness of persistent disparities despite advances in medical technology and health systems. This expanding body of literature reflects heightened academic and policy interest in understanding how social structures shape health outcomes and how interventions

can be designed to promote equity[1,8]. Effective policy responses and health interventions are increasingly expected to address not only individual behaviour but also the structural conditions that constrain health choices and access to care [9]. Moreover, empirical evidence suggests that health inequalities impose significant social and economic costs, reinforcing the importance of sociological research in informing public health strategies and social policy aimed at improving population well-being[10].

Previous research on health inequality has been conducted extensively; however, these studies exhibit diverse emphases and contexts across countries and disciplines. For example, research in high-income countries has largely focused on socioeconomic gradients in health, racial and ethnic disparities, and welfare state regimes[7,11]. In contrast, studies in low- and middle-income countries often emphasise access to basic health services, health system capacity, and the interaction between poverty and disease burden. At the same time, behavioural intervention research varies in focus, ranging from smoking cessation and lifestyle modification to preventive screening and disease-specific interventions. This diversity highlights that sociological research on health inequality is shaped by researchers' theoretical orientations, policy environments, and institutional contexts within different countries[12].

Therefore, research on key themes of health inequality and behavioural interventions continues to evolve and attract increasing scholarly attention. In this context, systematically exploring the health inequality literature is crucial for uncovering the intellectual structure, dominant themes, and emerging trends within this broad and multidisciplinary field. Several narrative and theoretical reviews have examined specific aspects of health inequality, such as social determinants of health, life course approaches, or behavioural risk factors. However, comprehensive bibliometric analyses that map the development of sociological research on health inequality within social science literature remain limited. While some bibliometric studies have addressed public health or medical research more broadly, a focused, Scopus-based bibliometric analysis that integrates structural and behavioural perspectives in sociological health inequality research has not yet been fully undertaken.

Accordingly, this study is important to fill this gap by employing a bibliometric approach based on social science literature indexed in the Scopus database. Bibliometric analysis provides a systematic method for identifying publication trends, influential journals, productive authors, institutional and country contributions, collaboration patterns, and citation networks related to health inequality research. This approach also enables the identification of dominant thematic clusters, underexplored areas, and potential future research directions. This study aims to provide in-depth insights into the status and evolution of sociological research on health inequality and behavioural interventions, thereby contributing to a more integrated understanding of the field. The findings are expected to support the development of more effective research agendas and policy strategies aimed at reducing health inequalities across diverse social contexts.

2.METHODS

2.1. Research Design

This study adopts a quantitative research design using bibliometric analysis to map and examine the development of sociological research on health inequality and behavioral interventions over the period 1978–2026. Bibliometric analysis is a robust and systematic method for identifying publication trends, collaboration patterns, intellectual structures, and thematic evolution within a research field. It is particularly suitable for assessing large volumes of scientific literature and understanding the dynamics of knowledge production over time. To complement the quantitative mapping, this study also incorporates a limited content-oriented interpretation to contextualize dominant themes and research trajectories within the social science literature. The Scopus database was selected as the primary data source due to its broad coverage of peer-reviewed journals in sociology, public health, and social sciences, as well as its reliable citation indexing.

2.2. Search Strategy, Criteria, and Data Collection

This study followed an adapted PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) framework, as illustrated in the flowchart. Data were retrieved from the Scopus database using a comprehensive search string that combined key terms related to health inequality, behavioral interventions, and social science perspectives. The search string included combinations of the following keywords: *"sociology" OR "social science" OR "social studies"* AND *"health" OR "well-being" OR "wellness" OR "healthcare"* AND *"inequality" OR "disparity" OR "access" OR "equity"*.The data were extracted on January 5, 2026. The initial search yielded 5,887 records based on titles, abstracts, and keywords. During the screening process, non-article documents, non-journal publications, and non-English records were excluded, resulting in the removal of 5,354 records. After applying these inclusion and exclusion criteria, a

final dataset of 533 documents was retained and deemed eligible for bibliometric analysis[13].

2.3. Tools and Data Analysis

The bibliometric analysis was conducted using multiple analytical tools to ensure methodological rigor. VOSviewer was employed to construct and visualize bibliometric networks, including co-authorship, co-citation, and keyword co-occurrence maps. R-Biblioshiny was used for descriptive statistical analysis, publication trend analysis, and thematic mapping, while Microsoft Excel supported data cleaning and frequency calculations.

Together, these tools enabled a comprehensive examination of the structural characteristics, collaborative patterns, and thematic evolution of sociological.

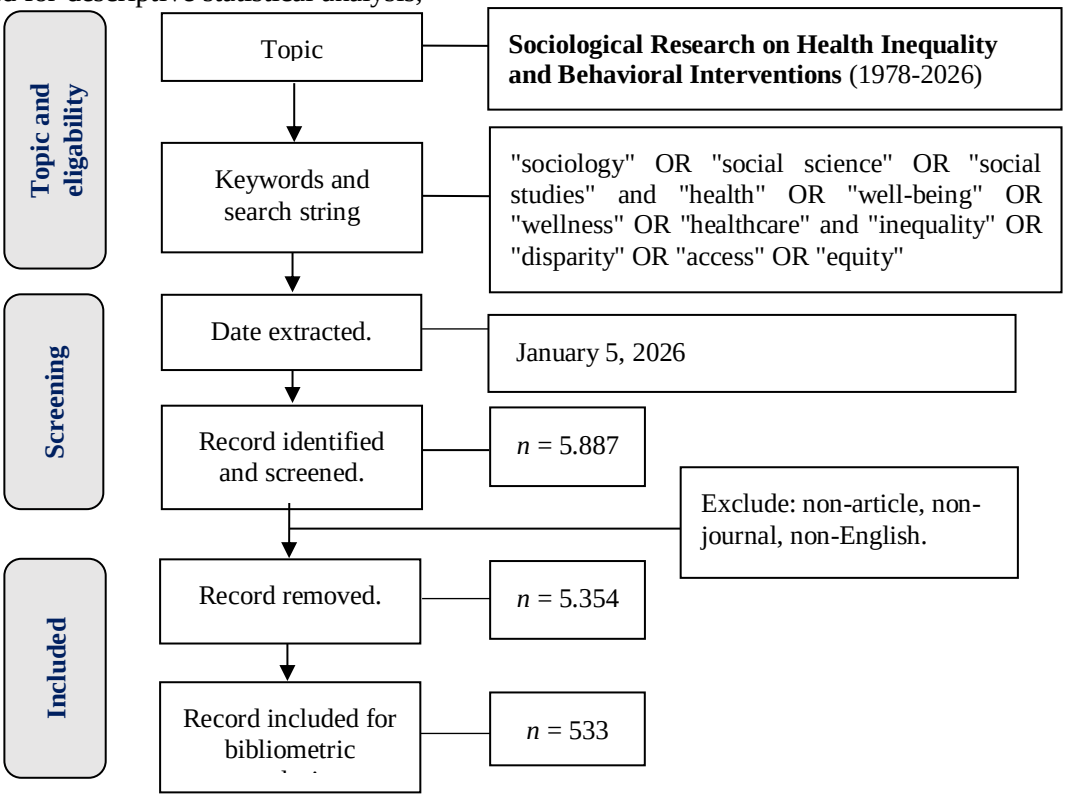


Figure 1. Data processing and search strategy

3. RESULTS

3.1. Descriptive analysis

Publications from 1978 to 2025 comprised a total of 533 documents published across 338 sources. These publications involved 2,213 authors, with no single-authored documents identified, indicating a highly collaborative research field. On average, each document was written by 8.41 co-authors, while the rate of international co-authorship reached 18.39%, reflecting a moderate level of cross-national collaboration. The field experienced an annual growth rate of 8.05%, demonstrating a steady and sustained increase in scholarly interest over nearly five decades. The dataset included 4,583 references and 1,507 author keywords, highlighting extensive engagement with existing literature and a diverse range of research themes. The average document age was 10.9 years, and each document received an average of 46.47 citations, suggesting that the literature is relatively well-established and has achieved strong academic visibility and impact.

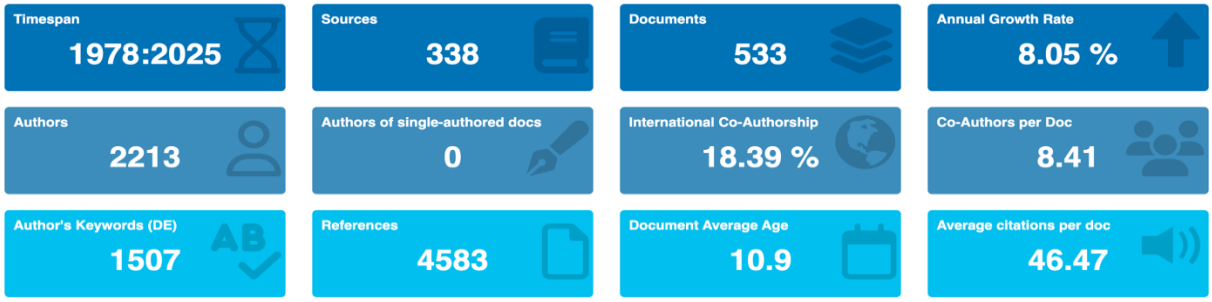


Table 2. Main information about the dataset

The analysis of publications from 1978 to 2025 reveals a clear upward trend in research activity over time. During the early period from 1978 to the late 1990s, publication output was very limited and irregular, with only 0 to 2 articles published per year and several years showing no publications at all. A gradual increase began in the early 2000s, indicating growing scholarly interest in the topic. After 2009, publication activity rose more sharply, with notable growth continuing throughout the 2010s. This trend intensified after 2020, reaching its peak in 2024 with 48 articles, before slightly declining in 2025. Overall, the pattern demonstrates a substantial expansion of sociological research on health inequality and behavioral interventions, reflecting the increasing academic and policy relevance of this field.

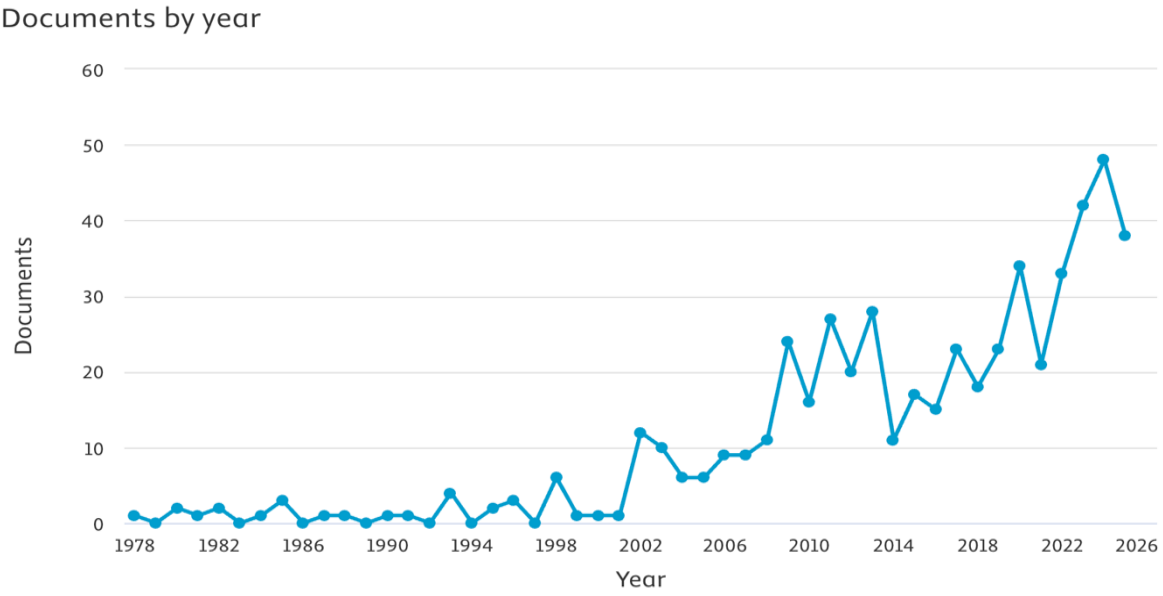


Figure 3. Number of publications per year

3.2. Research trend analysis

Table 2 shows that research on this topic is distributed across multiple subject areas, with Medicine representing the largest share of publications (52.35%), followed closely by Social Sciences (49.16%). This distribution highlights the strong interdisciplinary nature of the field, combining biomedical and sociological perspectives in the study of health inequality and behavioral interventions. Arts and Humanities contribute 12.57%, indicating the presence of critical, ethical, and interpretive approaches, while Psychology accounts for 6.75%, reflecting attention to behavioral and cognitive dimensions. Other subject areas, including Nursing (4.32%), Computer Science (3.19%), and Environmental Science (3.00%), represent smaller but notable proportions. Overall, these findings suggest that although the topic is examined from diverse disciplinary perspectives, the scholarly discourse is primarily anchored in medicine and social sciences, underscoring the integration of clinical, behavioral, and structural approaches in this research domain.

Table 2. Subject area

Subject Area	Total Publications (TP)	Percentage (%)
Subject Area	**TP**	**%**
Medicine	279	52,35%
Social Sciences	262	49,16%
Arts and Humanities	67	12,57%
Psychology	36	6,75%
Nursing	23	4,32%
Computer Science	17	3,19%
Environmental Science	16	3,00%

Table 3 shows that Social Science and Medicine is the leading journal in this field, contributing 44 articles (8.26%), followed by Sociology of Health and Illness with 18 publications (3.38%), highlighting their central roles in sociological

research on health inequality and behavioral interventions. Several interdisciplinary and public health–oriented journals, including BMC Public Health, Journal of Health and Social Behavior, and PLOS One, each published six articles (1.13%), while Critical Public Health, Health Sociology Review, Journal of Epidemiology and Community Health, Journal of Urban Health, and Social Science Quarterly each contributed five articles (0.94%). Overall, these findings indicate that research on this topic is predominantly published in well-established and high-impact journals, particularly within sociology and public health, reflecting the academic significance and visibility of the field.

Table 3. Top 10 journal sources title

No.	Source Title and Scopus Rank	TP	%	*h*	*g*
1	Social Science and Medicine	44	8,26%	29	17
2	Sociology of Health and Illness	18	3,38%	15	17
3	BMC Public Health	6	1,13%	6	15
4	Journal of Health and Social Behavior	6	1,13%	6	9
5	Plos One	6	1,13%	5	9
6	Critical Public Health	5	0,94%	5	7
7	Health Sociology Review	5	0,94%	5	6
8	Journal of Epidemiology and Community Health	5	0,94%	5	5
9	Journal of Urban Health	5	0,94%	4	5
10	Social Science Quarterly	5	0,94%	4	5

On the other hand, Figure 4 shows that Social Science and Medicine has the highest local impact, with a total of 3,518 citations, making it the most influential journal in this field. It is closely followed by the Journal of Health and Social Behavior, which accumulated 3,212 citations, underscoring its strong intellectual influence in sociological research on health inequality. The American Journal of Public Health ranks third with 2,269 citations, reflecting the substantial contribution of public health perspectives. Other highly cited sources include the Annual Review of Sociology (1,748 citations) and Sociology of Health and Illness (approximately 1,270 citations). Journals such as The Gerontologist (774 citations), Journal of Personality and Social Psychology (680 citations), BMC Medicine (555 citations), Journal of Epidemiology and Community Health (544 citations), and BMC Health Services Research (438 citations) show lower but still notable citation impacts. Overall, these citation patterns indicate that scholarly influence in this domain is concentrated in a limited number of well-established, high-impact journals, particularly those bridging sociology and public health.

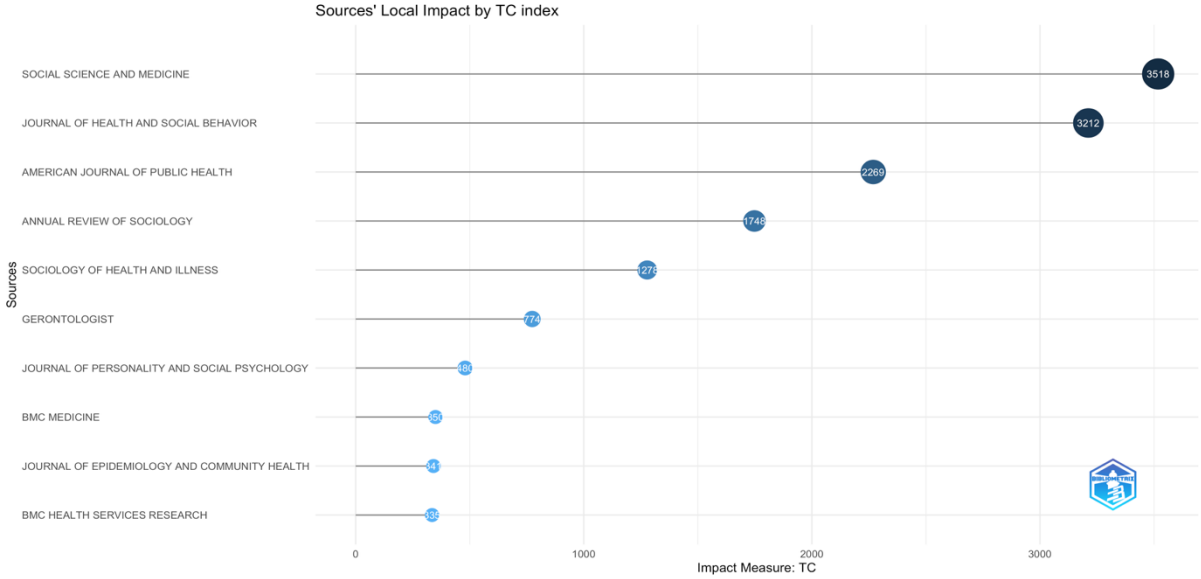


Figure 4. Journal local impact related to the topic

3.3. Most influential countries, affiliates, and productive author

Figure 5 illustrate the contributions of the ten most productive countries in this research field. The United States

dominates the scholarly output with 214 publications (40.15%), indicating its central role in shaping research on health inequality and behavioral interventions. The United Kingdom ranks second with 106 publications (19.89%), followed by Canada with 42 publications (7.88%). Other notable contributors include Australia (28 publications; 5.25%), India (19 publications; 3.56%), Brazil (18 publications; 3.38%), the Netherlands (17 publications; 3.19%), Germany (15 publications; 2.81%), and Italy (15 publications; 2.81%). A small proportion of publications are classified as undefined (30 publications; 5.63%), reflecting records without clear country attribution. Overall, these patterns indicate that research production is heavily concentrated in Western countries, particularly the United States and the United Kingdom, while contributions from emerging and non-Western countries such as India and Brazil suggest a growing global engagement with the field.

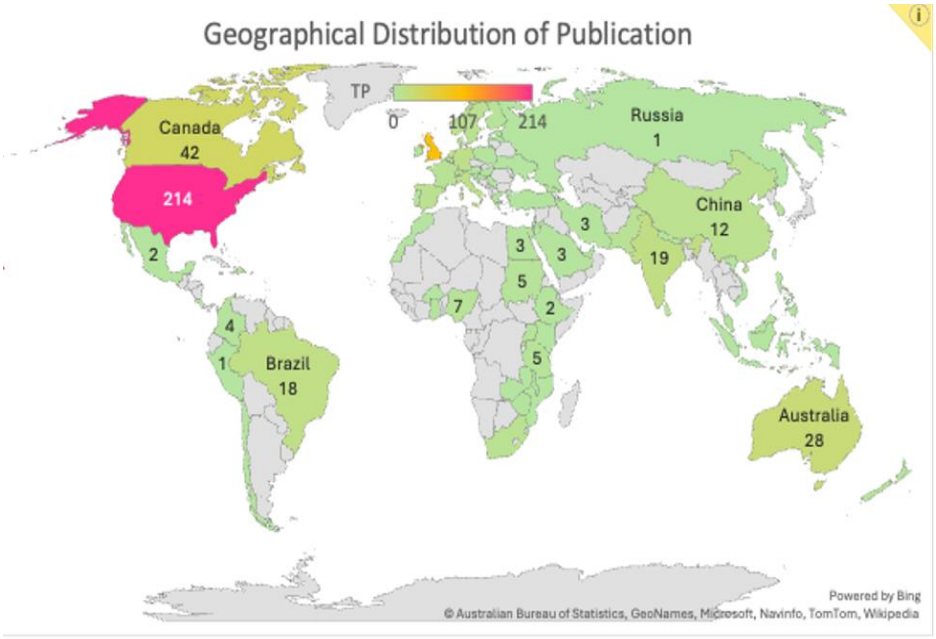


Figure 5. Top Countries

Table 5 presents the leading institutions contributing to research in this field and highlights key academic centers with strong potential for collaboration. The University of Toronto and the University of Michigan, Ann Arbor are the most productive institutions, each contributing 12 publications (2.25%), followed by the London School of Hygiene & Tropical Medicine with 11 publications (2.06%). University College London ranks next with 10 publications (1.88%), while the University of Pennsylvania, The University of British Columbia, and the University of California, San Francisco each produced 9 publications (1.69%). Other prominent contributors include The University of Manchester, Johns Hopkins Bloomberg School of Public Health, and Durham University, each with 8 publications (1.50%). Overall, these findings indicate that the most influential research is concentrated within leading universities in the United States, the United Kingdom, and Canada, underscoring the dominant role of Western academic institutions in shaping the intellectual landscape of this research domain.

Table 5. The top 10 institutions contributed to the publications.

Institution	TP	%	Country
University of Toronto	12	2,25%	Canada
University of Michigan, Ann Arbor	12	2,25%	USA
London School of Hygiene & Tropical Medicine	11	2,06%	UK
University College London	10	1,88%	UK
University of Pennsylvania	9	1,69%	USA
The University of British Columbia	9	1,69%	Canada
University of California, San Francisco	9	1,69%	USA
The University of Manchester	8	1,50%	UK
Johns Hopkins Bloomberg School of Public Health	8	1,50%	USA
Durham University	8	1,50%	UK

Table 6 lists the ten most productive authors in this research field. Mokdad, A.H. and Pérez-Stable, E.J. are the leading contributors, each publishing 8 articles (1.50%), with 208 and 188 total citations, respectively, indicating strong scholarly influence. They are followed by Daoud, F., Dwyer-Lindgren, L., and Kelly, Y.O., each with 7 publications (1.31%), with Kelly, Y.O. standing out for receiving the highest number of citations (310 TC), reflecting a particularly high academic impact. Other prominent contributors include Bambra, C., Baumann, M.M., Compton, K., Hay, S.I., and Kendrick, P., each publishing 6 articles (1.13%). Overall, these results indicate that leading contributions come from a relatively small group of highly productive and influential scholars, highlighting the importance of established research networks in shaping the development of this field.

Table 6. Most Productive Authors

Author Name	TP	%	TC	h-indeks	g-indeks
Mokdad, A.H.	8	1,50%	208	6	8
Pérez-Stable, E.J.	8	1,50%	188	6	8
Daoud, F.	7	1,31%	96	5	6
Dwyer-Lindgren, L.	7	1,31%	113	5	6
Kelly, Y.O.	7	1,31%	310	6	6
Bambra, C.	6	1,13%	142	5	6
Baumann, M.M.	6	1,13%	218	4	4
Compton, K.	6	1,13%	92	3	4
Hay, S.I.	6	1,13%	69	4	4
Kendrick, P.	6	1,13%	47	4	4

3.4. Citation analysis

Based on Table 7, the most influential publications in this field demonstrate a strong focus on sociological and behavioral explanations of health inequality. The study by Hatzenbuehler (2013) in the *American Journal of Public Health* is the most cited work, receiving 2,081 citations, underscoring its importance in explaining how stigma and social stressors affect population health. This is followed by Phelan et al. (2010) in the *Journal of Health and Social Behavior* with 1,956 citations, which reinforces the *fundamental cause theory* as a key framework for understanding persistent health disparities. Another highly cited contribution is Pampel et al. (2010) in the *Annual Review of Sociology* (1,383 citations), offering a comprehensive synthesis of health-related behaviors from a sociological perspective. Influential life-course and inequality-focused analyses are also evident in the works of Ferraro et al. (2009) (774 citations) and Williams et al. (2010) (638 citations), while studies by Gottfredson (2004), Dovidio et al. (2008), House et al. (2002), and Björk et al. (2012) further enrich the field by integrating psychological, behavioral, and structural dimensions. Collectively, these highly cited studies illustrate the theoretical depth, interdisciplinary reach, and sustained scholarly impact of research on health inequality and behavioral interventions.

Table 7. The top ten most cited documents

Paper	DOI	C	TC per Year	Normalized TC
Hatzenbuehler, 2013, Am J Public Health	10.2105/AJPH.2012.301069	081	148,64	19,35
Phelan, 2010, J Health Soc Behav	10.1177/0022146510383498	956	115,06	6,99
Pampel, 2010, Annu Rev Sociol	10.1146/annurev.soc.012809.102529	383	81,35	4,94
Ferraro, 2009,	10.1093/geront/gnp034		43,00	13,07

Gerontologist		74		
Williams, 2010, J Health Soc Behav	10.1177/0022146510383838	38	37,53	2,28
Gottfredson, 2004, J Pers Soc Psychol	10.1037/0022-3514.86.1.174	80	20,87	3,34
Dovidio, 2008, Soc Sci Med	10.1016/j.socscimed.2008.03.019	76	19,79	2,69
House, 2002, J Health Soc Behav	10.2307/3090192	71	14,84	3,75
Björk, 2012, Bmc Med	10.1186/1741-7015-10-73	50	23,33	5,60

Note(s): TC=total citations; C/Y=average citations per years

3.5. Keyword analysis

The keyword analysis reveals that research in this field is predominantly human-centered and sociologically oriented, as indicated by the high frequency of terms such as “Human/Humans,” “Female,” “Male,” “Adult,” “Aged,” and “Middle Aged.” This suggests that the literature largely focuses on population groups and demographic dimensions of health inequality. The strong presence of “Sociology,” “Socioeconomic Factors,” and “Socioeconomics” highlights the central role of social structure and economic conditions in explaining health disparities. At the same time, frequent keywords related to public health systems and policy, including “Public Health,” “Health Disparity,” “Health Status Disparities,” “Health Services Accessibility,” “Health Care Access,” “Health Care Policy,” and “Health Care Delivery,” indicate a strong emphasis on institutional and policy-level determinants of inequality. The appearance of “Major Clinical Study” reflects the integration of empirical and clinical evidence within social science research, while the prominence of “United States” points to a geographical concentration of studies in high-income Western contexts. Overall, these patterns suggest that the literature converges around the interaction between social inequalities, demographic characteristics, and health system access, reinforcing the interdisciplinary nature of sociological research on health inequality and behavioral interventions.

Table 8. 20 Top Keywords

Keywords	TP	%	Keywords	TP	%
Human	326	61,16%	Socioeconomics	87	16,32%
Article	288	54,03%	Public Health	83	15,57%
Humans	261	48,97%	Health Status Disparities	79	14,82%
Sociology	188	35,27%	Health Services Accessibility	72	13,51%
Female	158	29,64%	Health Care Policy	62	11,63%
Male	140	26,27%	Health Care Delivery	60	11,26%
Adult	125	23,45%	Health Care Access	59	11,07%
Health Disparity	113	21,20%	Aged	56	10,51%
Socioeconomic Factors	93	17,45%	Major Clinical Study	55	10,32%
United States	88	16,51%	Middle Aged	52	9,76%

Source: Scopus database

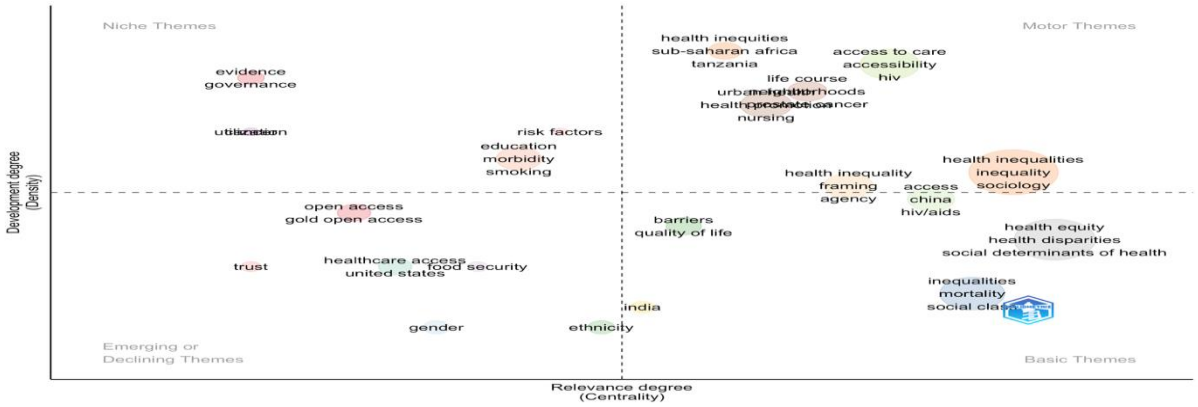


Figure 6. Thematic Maps

The figure presents a thematic map that illustrates the conceptual structure of the research field based on relevance (centrality) and degree of development (density). Themes located in the Basic Themes quadrant (bottom right), such as *health equity*, *health disparities*, *social determinants of health*, *inequalities*, *mortality*, and *social class*, represent core topics that are highly central but relatively general, serving as the foundational concepts of health inequality research. The Motor Themes quadrant (top right) contains themes that are both highly developed and highly relevant, including *health inequalities*, *inequality*, *sociology*, *access to care*, *accessibility*, *life course*, and *HIV*. These themes act as key drivers of the field, linking sociological perspectives with health systems, policy concerns, and specific population contexts.
The Niche Themes quadrant (top left), which includes topics such as *evidence*, *governance*, and *urbanization*, represents specialized areas that are well developed internally but less connected to the core structure of the field. In contrast, the Emerging or Declining Themes quadrant (bottom left), featuring themes such as *gender*, *ethnicity*, *trust*, and *open access*, indicates topics that are either still emerging or receiving decreasing scholarly attention, yet hold potential for future research development. Overall, the thematic map shows that the literature is anchored in structural and social inequality frameworks, while progressively expanding toward access-related, policy-oriented, and integrated sociological approaches to health inequality.

DISCUSSION

Sociological Framing of Inequality

The second theme highlights how health inequality is framed through sociological theoretical perspectives, with a strong emphasis on the relationship between structure and agency. Much of the literature in the dataset draws on *fundamental cause theory* to explain why medical progress and health interventions often fail to reduce and may even widen health gaps between social groups. According to this perspective, groups with greater social and economic resources are consistently better positioned to benefit from health innovations, allowing inequalities to persist over time[2]. In addition to material factors, studies within this cluster stress the importance of social processes such as stigma, discrimination, and social exclusion in shaping health outcomes. Hatzenbuehler (2013) shows that structural stigma functions as a social mechanism linking unequal social status to a wide range of mental and physical health problems[14,15]. As a result, sociological framing broadens the understanding of health inequality beyond economic deprivation alone, incorporating symbolic and relational dimensions as crucial determinants of population health.

Access to Health Care and Policy

Access to healthcare emerges as a central institutional mechanism through which health inequalities are produced, maintained, or mitigated. The dataset reveals that disparities in access are not limited to the availability of services but encompass affordability, geographic proximity, administrative complexity, cultural competence, and trust in institutions. Keywords such as *health services accessibility* and *health care policy* reflect growing scholarly concern with how health systems themselves function as stratifying institutions [16-18]. Importantly, the literature highlights that universal coverage does not guarantee equity. Policies designed around formal equality often fail to address differential capacities to navigate complex healthcare systems. Groups with higher levels of education, health literacy, and social capital are more likely to benefit from expanded services, while marginalized populations continue to face barriers[19,20]. Comparative studies in the dataset further show that welfare state regimes differ significantly in their ability to reduce access-related inequalities. This theme therefore emphasizes the need for equity-oriented policy design that explicitly targets structural barriers and tailors interventions to the needs of socially disadvantaged groups.

Life Course and Population Groups

The life course perspective represents a crucial analytical lens for understanding how health inequalities emerge, accumulate, and persist over time. Research in the dataset consistently demonstrates that early-life conditions such as childhood poverty, educational disadvantage, and exposure to discrimination have long-lasting effects on adult health outcomes[5,6]. Health inequality is thus conceptualized not as a snapshot but as a dynamic trajectory shaped by historical, social, and institutional contexts across different stages of life. This theme also foregrounds differences across population groups, particularly along lines of gender, race, ethnicity, and age. Studies show that women, ethnic minorities, migrants, and older adults often experience overlapping forms of disadvantage that intensify health risks. An intersectional approach within the dataset reveals that these identities do not operate independently but interact to produce unique patterns of vulnerability[21]. By integrating temporal and population-based analyses, this theme deepens understanding of how inequality is embodied over time and across social categories.

Behavioral Risks and Contextual Health Issues

The final theme integrates individual health behaviors with their broader social, economic, and environmental contexts. Rather than treating behaviors such as smoking, diet, and physical activity as matters of personal choice, the literature emphasizes how these behaviors are shaped by education, occupational conditions, neighborhood environments, and cultural norms[7,22]. Structural constraints limit the range of feasible choices available to individuals, making behavior-based interventions inherently unequal when social context is ignored. Moreover, studies in the dataset link behavioral risks to specific health outcomes such as HIV, cardiovascular disease, cancer, and mental health disorders, demonstrating that behavioral interventions are most effective when embedded within supportive structural conditions[23,24]. Research on stigma, policy environments, and community-level resources shows that behavioral change cannot be sustained without addressing underlying inequalities. This theme therefore argues for integrated intervention strategies that combine behavioral, structural, and policy-level approaches to achieve lasting reductions in health inequality[25,26].

CONCLUSION

This study provides a comprehensive overview of the development and intellectual structure of sociological research on health inequality and behavioral interventions within the social science literature. Through a systematic bibliometric analysis, the findings demonstrate a substantial growth in scholarly output over the past two decades, particularly in the last ten years, indicating increasing academic and policy attention to health inequality as a persistent social issue. The literature is largely dominated by structural and sociological perspectives, emphasizing health disparities, social determinants of health, socioeconomic inequality, and unequal access to healthcare services across population groups. The analysis reveals that while behavioral interventions are frequently discussed, they are predominantly framed within broader structural and policy contexts. Most studies highlight that individual health behaviors such as smoking, physical inactivity, or healthcare utilization are deeply shaped by socioeconomic conditions, institutional arrangements, and policy environments. As a result, interventions focusing solely on individual behavior change are often insufficient to reduce health inequalities without accompanying structural reforms. This reinforces the central sociological argument that health inequality is rooted in enduring social structures rather than personal choices alone.In addition, the study identifies notable geographical and thematic disparities within the literature. Research output is heavily concentrated in high-income Western countries, particularly the United States, the United Kingdom, and Canada, while studies from low- and middle-income regions remain underrepresented. Furthermore, although issues of gender, race, and socioeconomic status are widely addressed, intersectional and life-course approaches are still unevenly integrated. Therefore, future research should prioritize more inclusive, context-sensitive, and comparative studies that bridge behavioral interventions with structural determinants of health. Overall, this study contributes to a deeper understanding of global research trends and provides a valuable foundation for developing more equitable and effective health policies aimed at reducing persistent health inequalities.

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HEALTH COMMUNICATION AND PROMOTION THROUGH DIGITAL MEDIA: A BIBLIOMETRIC APPROACH TO IDENTIFY TRENDS AND CHALLENGES

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Abstract

Health communication has experienced a significant transformation with the rise of digital media, reshaping how health information is disseminated and how public health promotion is conducted. This study uses bibliometric analysis to map trends and challenges in health communication through digital media, aiming to identify gaps and emerging patterns in research across global contexts. By analyzing a dataset of 168 scholarly articles published between 2006 and 2025, this research explores the evolving role of digital media in health promotion, the challenges of adapting health messages to diverse social and cultural contexts, and the disparities in digital access and technology literacy between developed and developing countries. The study highlights the increasing relevance of digital platforms, particularly social media, in health communication and promotion, while also emphasizing the need for tailored communication strategies that consider demographic factors such as age, gender, and socio-cultural background. The findings underscore the importance of cross-disciplinary collaboration and the integration of technology, behavior, and cultural factors in advancing more inclusive and effective health communication strategies. The results provide valuable insights for researchers and policymakers aiming to improve the global reach and impact of health promotion efforts in the digital age.

***Keywords*:** Health Communication, Promotion Through, Digital Media, Bibliometric

INTRODUCTION

Health communication has undergone a significant transformation with the advancement of digital media, which allows broader and more direct access to health information for the public [1]. In the digital era, health promotion is no longer carried out solely through traditional channels like posters or seminars but also utilizes increasingly evolving digital platforms, including social media and technology-based health applications [2]. Digital media offers the opportunity to reach a larger audience, allows for two-way interaction, and provides more affordable and accessible information [3]. With the use of digital media, health promotion efforts become more efficient and adaptable to the changing needs of society [4, 5].

However, despite numerous studies highlighting the potential of digital media in health promotion, there are still gaps in the application of communication strategies that are appropriate for different social and cultural contexts. For instance, research by Mutlu et al. (2025) shows that while digital media increases engagement in health campaigns, significant challenges remain regarding the effectiveness of message delivery among less educated communities or those with limited access to digital technology [6]. Another study by Mpambije & Ndimbo (2025) also indicates that there are substantial differences in the effectiveness of health promotion in developed and developing countries, which are more influenced by digital infrastructure factors and technology literacy [7].

It is important to note that although research on digital health communication has grown rapidly, most studies still focus on the effectiveness of social media or health applications in developed countries [8,9]. There is little attention given to the application of digital media in developing countries, where access to digital technology is still limited, and local cultural factors significantly influence the reception of health messages [6]. This creates a significant gap in the existing literature that needs to be filled with research considering these factors.

This study presents a novel approach by offering a bibliometric analysis of trends in health communication research through digital media across various global contexts. This mapping will include the use of various complementary digital platforms, as well as explore gaps in research related to

technology access and message adaptation in different social and cultural backgrounds. The study also focuses on analyzing studies that are not limited to a single type of media but encompass the use of various digital platforms in health promotion.

The main objective of this study is to identify and analyze trends in health communication research through digital media, as well as map the latest developments in this field. Furthermore, this study aims to explore gaps in the application of digital media for health promotion in various regions, with a focus on public acceptance and access to technology.

The primary argument to be made is that while digital media holds great potential to advance health promotion, its application must be tailored to different social, cultural, and digital infrastructure contexts. This study is expected to provide new insights into the future direction of more inclusive and adaptive health communication research that is responsive to diverse global conditions, and offer practical recommendations for health policy managers.

2. RESEARCH METHODOLOGY

2.1 Research Design

This study uses bibliometric analysis to examine trends, gaps, and future directions in health communication and health promotion research through digital media. Bibliometric analysis is a systematic approach used to map the structure of knowledge domains, identify shifting trends, and explore gaps and future directions of research through mapping relationships between documents, keywords, and researchers. This approach focuses on the quantitative and visual representation of the literature to understand how the research field evolves conceptually, intellectually, and socially [10],[11]. Specifically, science mapping provides a framework for assessing the evolution of the research field, identifying thematic clusters, and directing future research focus through techniques such as co-word analysis, co-citation, and collaboration network analysis [10]. The synergy between science mapping techniques and the analytical software that supports longitudinal analysis allows researchers to monitor the dynamics of health research through digital media over time [10,12].

In the context of health communication and health promotion through digital media, the literature shows that topics such as online health information-seeking behavior, the impact of digital media on health behavior, and health promotion through digital campaigns have grown rapidly. These topics can be traced using bibliometric methodology to identify key trends and research gaps that need to be addressed [12,13]. This section proposes a bibliometric analytical framework that integrates science mapping techniques, content analysis, as well as traditional and alternative data sources to analyze trends, gaps, and future directions in the field [13]. The analysis process begins with data extraction from the Scopus database on December 23, 2025, using predefined keywords in accordance with the inclusion criteria set. The following are the details of the research methodology used:

2.2 Keywords

Data extraction was performed using the following combination of keywords:

- Health Communication
- Health Promotion
- Public Health
- Health Education

The combination of keywords used for the search is: “health communication OR health promotion OR public health OR health education AND communication AND digital media”

2.3 Research Limitations (Inclusion Criteria)

The inclusion criteria used in this study are as follows :

Table 1. Inclusion Criteria

Inclusion Criteria	Description
Time Range (2006-2025)	Articles published between 2006 and 2025.
Subject Area: Medicine	Research is limited to the subject area of Medicine to ensure relevance to the topic of health communication.
Document Type: Article	Only scholarly articles are selected as data to ensure the quality and validity of the information.
Initial Document Count	Before the search restrictions, a total of 357 documents were retrieved.
Documents After Restriction	After applying the inclusion criteria, the number of eligible documents decreased to 168.

2.3 Data Extraction

After applying the inclusion criteria, 168 documents relevant to the topics of health communication, health promotion, and the use of digital media in health contexts were successfully retrieved. All of these documents consist of scholarly articles published within the specified time range.

2.4 Analysis Process

The data obtained will be analyzed using bibliometric techniques to map research trends, identify gaps in the literature [14], and uncover future research directions in the field of health communication through digital media. The analysis process begins with mapping research trends, aiming to analyze the number of publications per year and observe the development of research on this topic [15]. Next, research gaps will be identified to assess areas that have been underexplored in previous studies, such as the disparity in digital access between developed and developing countries [16]. Collaboration analysis between authors and institutions will also be conducted to identify dominant collaboration patterns in this research. Additionally, analysis of themes and issues commonly discussed in selected articles will be carried out, focusing on how the use of digital media plays a role in health promotion. Through this method, the study aims to provide a clear picture of the current developments in the field of health communication and digital health promotion, as well as identify further research opportunities that need to be explored [17].

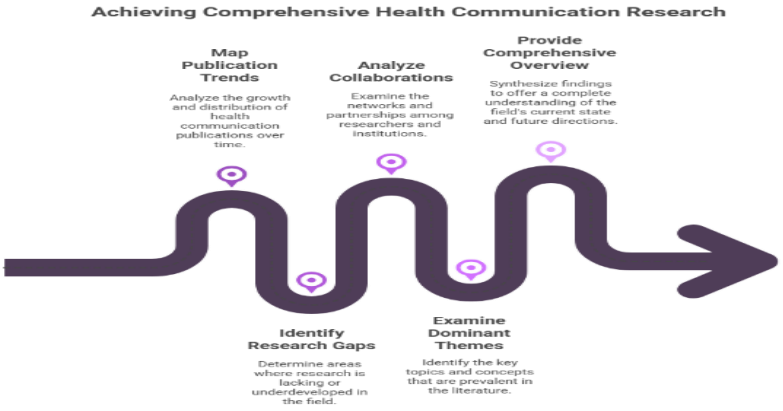


Figure 1. Research flowchart

3. RESEARCH FINDINGS AND DISCUSSION

In this section of the research findings, a comprehensive analysis will be presented regarding publication trends, collaboration among researchers, and dominant themes in the literature on health communication through digital media. This study aims to provide a clear picture of the developments and future directions in this field. By mapping publication trends, we can observe how the volume of research on this topic has evolved over time. Collaboration analysis will help identify the relationships between researchers and institutions that play a role in driving this research forward. Furthermore, exploring dominant themes will provide an understanding of the key topics that dominate the discussions in the existing literature. Finally, this study will also identify gaps in health communication research, directing focus to areas that are still underexplored or need further attention in the future.

3.1 Analysis of the Growth and Distribution of Health Communication Publications Over Time

The attached graph illustrates the trend in the number of publications on health communication and health promotion through digital media from 2006 to 2025 (see Figure 2). The data shows a significant increase in the number of publications, especially since 2021. In the early period (2006-2010), the number of publications was still very low, with only 1 to 2 articles published each year. Subsequently, during the 2011-2015 period, the number of publications slightly increased, reaching 3 to 4 articles per year.

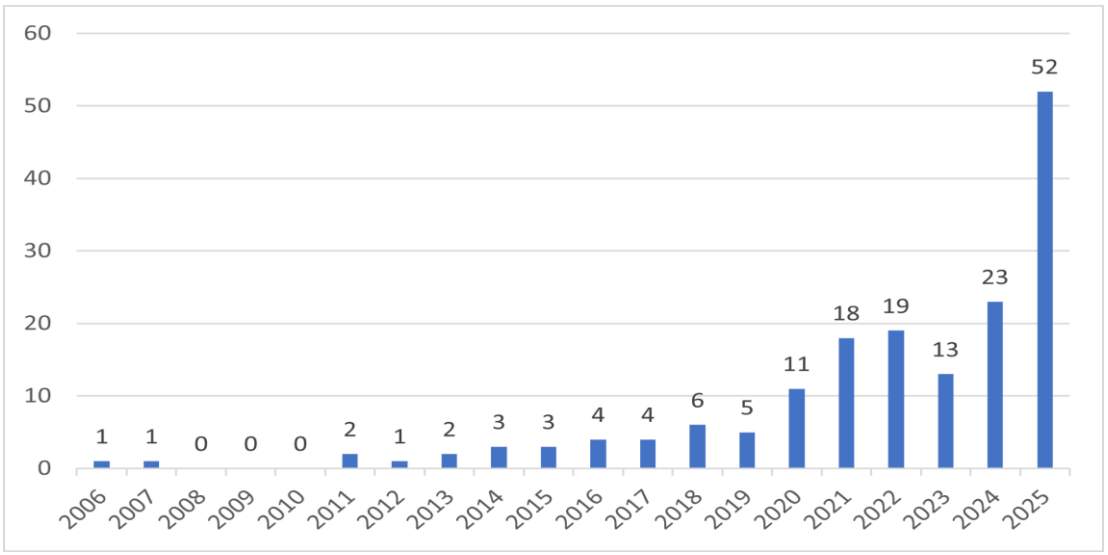


Figure 2. Report on document production related to the topic throughout the year

A more significant increase began to appear during the 2016-2020 period, with an average of 5 to 6 articles published annually. However, a substantial surge occurred in 2021, when the number of publications rose to 11 articles. This number continued to grow rapidly, reaching 18 articles in 2022, 19 articles in 2023, and 23 articles in 2024. The peak occurred in 2025, with 52 articles published, reflecting a greater focus on this topic as the role of digital media in health communication and promotion became increasingly important, particularly during the COVID-19 pandemic and the use of digital platforms for public health campaigns.

This trend indicates that research in the field of health communication through digital media is growing rapidly, in line with the fast-paced development of digital technology, which allows for faster and broader dissemination of health information to the public.

3.2 Identify areas where research is lacking or underdeveloped in the field

he graph in Figure 3 illustrates the mapping of key themes in health communication research, grouped based on two dimensions: relevance degree (centrality) and development degree (density). The relevance degree reflects the importance of the theme in research, while the development degree indicates how much these themes have evolved in the existing literature.

Themes in the top-right quadrant, such as "human," "article," and "humans," are classified as motor themes, meaning they are highly relevant and have developed rapidly. These themes are related to core topics in global health research, such as human behavior in the health context and the role of scholarly articles in disseminating health information.

On the other hand, themes like "betacoronavirus," "coronavirus infection," and "coronavirus infections" are located in the bottom-left quadrant, indicating high relevance at the beginning of the COVID-19 pandemic, but their development has slowed down as interest decreased after the peak of the pandemic.

Other themes, such as "public health," "coronavirus disease 2019," and "health care personnel," remain relevant but have not shown a significant surge in development in recent years. Themes like "female," "male," and "adult" demonstrate ongoing relevance, although with more limited development.

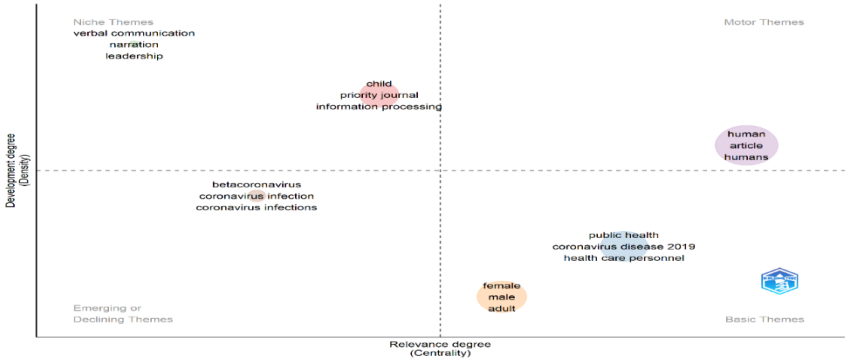


Figure 3. Research gap

This report identifies several research gaps, particularly regarding topics that have shown high relevance but have underdeveloped, such as:

a. *Beta Coronavirus and Coronavirus Infections: Although this theme remains relevant, the decline in development after the peak of the pandemic shows that further research, especially in the post-pandemic context, is still very much needed.*
b. *Role of Digital Media in Health Promotion: Many studies still lack exploration of the application of digital media in developing countries, which often face challenges in digital access and technology literacy. This opens up opportunities for research that considers local, social, and cultural factors.*
c. *Social Engagement in Health Promotion: Although there is research on verbal communication and leadership in the health context, this topic remains niche. Further research is needed to explore the impact of communication styles in health contexts across different social groups.*

Overall, this report highlights gaps that can serve as a focus for future research, particularly concerning the application of broader themes, including the context of developing countries and social factors influencing health promotion through digital media.

3.3 Researcher and Institution Networks and Partnerships

This report continues the analysis using VOSviewer to map the collaboration network of researchers in the field of health communication, as shown in Figure 4. In this analysis, a total of 962 entities were found; however, after applying the restriction criteria of a minimum of two documents per author and a minimum of eight citations per document, the results narrowed down to 17 meeting threshold points. This mapping provides an overview of more relevant collaborations among researchers that contribute to the development of this research. The emerging network illustrates the relationships between researchers who frequently collaborate, with several clusters indicating groups of researchers connected thematically. This analysis helps to better understand the dynamics of research in this field and the potential for increasing cooperation in digital health research.

The attached image shows a visual map of the results from this analysis, where larger nodes represent researchers with more publications and citations, while the connections between nodes reflect the collaborations between researchers. This mapping not only provides insight into influential researchers but also identifies thematic clusters that could serve as focal points for further research.

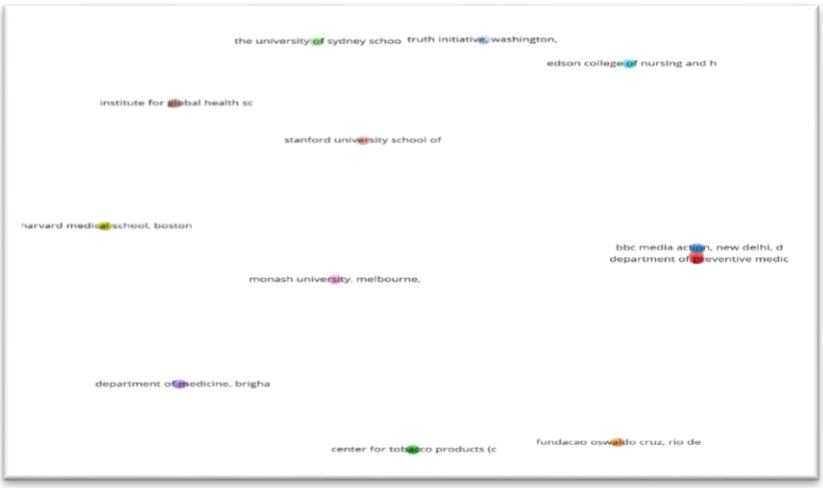


Figure 4. Collaboration Network Map Among Researchers

The results of the collaboration analysis among researchers in the field of health communication using VOSviewer, as shown in the bibliometric visualization in Figure 4, reveal various groups of researchers with different levels of collaboration. In the red cluster, researchers such as Viroj Tangchareonsathien, Jennifer B. Unger, Praveen Angyan, Katja Reuter, and Elsi M. Kaiser are involved in very close collaboration. This indicates that they are working together on core topics in health communication, such as the influence of digital media on health behavior and the relationship between technology and public health. This group reflects a productive collaboration that has significantly contributed to the development of the field.

In the green cluster, researchers like Laurel Erin Curry, Janine C. Delahanty, Mollie Ganz, and Shreya Tulsiani, although having more limited collaboration, are still connected in certain subtopics. They focus on specific areas of health communication, such as the impact of digital media on health behavior in different social groups. While their collaboration is not as intensive as the first group, their contributions remain relevant in advancing research in this field.

The blue cluster shows researchers like Sara Chamberlain and Amnesty Elizabeth Lefevre, who have limited collaboration with other researchers. Their more isolated collaboration may reflect that their research is more independent or still in the early stages of development, with a more specific topic that has not yet involved many other researchers.

The yellow cluster, which includes researchers Shreya Tulsiani, Donna M. Vallone, and Elizabeth C. Hair, shows smaller but important connections in specific subtopics. Their collaboration reflects a focus on more specific areas of health communication, though their connection with other research groups is still limited. This may indicate that the topics they are studying are still in the development stage or have not yet engaged in broader collaborations.

Researcher Viroj Tangchareonsathien appears as an isolated individual on this map, with few connections to other researchers. This suggests that, although their contributions are significant, this researcher focuses more on independent research and has not yet formed widespread collaborations in similar topics.

Overall, this collaboration map illustrates how researchers in health communication collaborate in different groups, with some researchers working within larger networks while others focus on narrower subtopics. Identified research gaps include limited collaboration in developing countries, the application of digital media in specific subtopics, and research on social engagement and leadership in health promotion. These gaps present opportunities for further development and expanding collaboration in less connected areas, which can fill gaps in the existing literature and drive progress in health communication research.



Figure 5. Organization Collaboration Network

This report continues the analysis of organization collaboration in the field of health communication using VOSviewer, focusing on mapping the relationships between various institutions involved in this research (see Figure 5). Based on bibliometric analysis, a

total of 628 organizations were found to be involved in relevant publications. However, after applying the restriction criteria of a minimum of two documents per organization and a minimum of seven citations per document, the results narrowed down to 18 meeting threshold points that met these criteria.

The attached map shows the collaboration network among organizations, displaying various institutions collaborating in health communication research. In this map, major organizations such as Harvard Medical School, Stanford University School of Medicine, and Monash University are seen to have strong collaborative ties. This indicates that these organizations play a significant role in advancing research in the field of health communication, with many publications produced and numerous citations received.

Additionally, organizations such as BBC Media Action, Fundacao Oswaldo Cruz, and the Center for Tobacco Products also show significant collaboration, although they may be more focused on specific subtopics within health communication research. This map helps identify closely collaborating groups of organizations and provides insights into the existing collaborative networks between these institutions.

Overall, this analysis shows that, although many organizations contribute to health communication research, more intensive collaboration between major organizations could strengthen the impact of this research. This mapping also offers a view of potential opportunities to expand collaboration networks, especially in more specific areas of health communication.

3.4 Identification of Key Topics and Concepts Commonly Found in the Literature

The next part of the report presents the results of further bibliometric analysis focusing on the emergence and development of terms in health communication research through digital media. The analyzed data shows the frequency distribution of term occurrences and their publication time spans, represented through the initial quartile (Q1), median, and final quartile (Q3). This approach allows for tracking the temporal dynamics of a theme, from its early emergence to the period when the theme reaches its peak intensity of use in the literature.

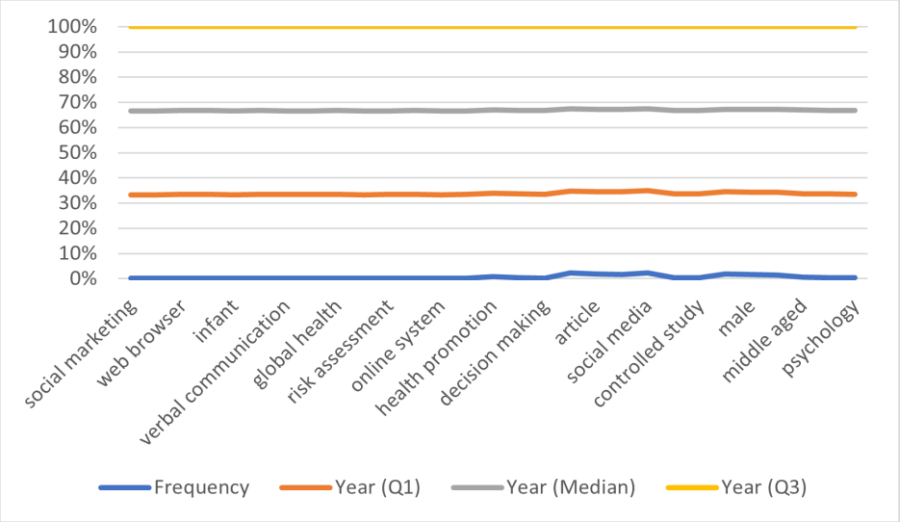


Figure 6. Topic Trends

The results of the analysis in Figure 6 show that a number of key terms in health communication research through digital media began to emerge in the early 2010s and developed gradually. Terms such as "social marketing" and "web browser" appeared earlier with relatively limited frequency, reflecting the early phase of digital media utilization, which still functioned as a supportive tool in health communication. In contrast, terms like "priority journal" and "demography" showed higher frequency occurrences over a longer temporal span, marked by median and final quartile values that fall into more recent periods. This pattern indicates increasing researcher attention to the quality of scientific dissemination and the use of population-based approaches.

The distribution of median values and the third quartile, which mostly fall within the 2016–2020 period, suggests a phase of research consolidation. During this period, digital health communication topics began to mature conceptually and became part of the mainstream literature. The research focus shifted from early exploration of digital media to strengthening more strategic approaches, based on demographic data and oriented toward communication effectiveness and the quality of scientific publications.

In terms of frequency, the occurrence of terms is generally at a relatively low and stable level, indicating the absence of dominance by a single theme across the entire literature corpus. This suggests diversity in the focus of studies within the field of digital health communication. However, some terms like "article," "social media," "male," and "controlled study" show slightly higher frequencies, indicating their role as common methodological frameworks and analytical contexts in research.

Overall, the temporal pattern and distribution of terms indicate that the development of digital health communication research has been gradual and sustained, without thematic spikes that are transient. Terms related to technology evolve alongside terms representing methodological approaches and population characteristics, emphasizing that this field is not only focused on communication mediums but also integrates methodological and demographic dimensions simultaneously. Thus, these findings provide an overview that the future direction of research is likely to be multidimensional, linking aspects of technology, behavior, and population in an interconnected analytical framework, opening space for the development of further, more contextual and applied themes.



Figure 7. Word Cloud

As shown in the word cloud visualization in Figure 7, research on health communication through digital media is dominated by several key terms representing the main thematic focuses in the literature. The term social media appears as the most prominent word, emphasizing the central role of social media as the primary medium for delivering information, education, and health promotion. The dominance of this term indicates that social media has become a strategic space for shaping public health perceptions, attitudes, and behaviors in the digital age.

In addition, terms such as human, humans, male, female, and adult also appear prominently, indicating the strong research focus on human subjects with an emphasis on demographic characteristics. The presence of these terms reflects researchers' attention to variations in response based on gender and age groups in the context of health communication. This shows that a demographic approach is an important aspect of understanding the effectiveness of health messages delivered through digital media.

Other terms such as health education, health promotion, and public health occupy a fairly dominant position, showing that the primary focus of research remains on educational and promotional efforts in public health. The emergence of terms like interpersonal communication, questionnaire, and controlled study suggests that research in this field is not only descriptive but also employs systematic methodological approaches to measure the impact of health communication on knowledge, attitudes, and behaviors of individuals.

The context of the pandemic is also reflected through the emergence of terms like coronavirus disease 2019, COVID-19, and vaccination, signaling that global health issues have become a key catalyst in the development of digital health communication research. The appearance of terms such as misinformation, health literacy, and internet further emphasizes researchers' attention to the challenges of health information dissemination in the digital space, particularly concerning health literacy and the spread of inaccurate information.

Overall, this visualization shows that digital health communication research is developing across a broad but interconnected spectrum of themes, with a focus on social media, human characteristics as research subjects, educational and promotional approaches, and responses to global health issues. These findings affirm the multidisciplinary and multidimensional nature of the field of digital health communication, while also demonstrating that research is increasingly integrated between technology, human behavior, and public health interests.

DISCUSSION

The bibliometric analysis shows that research in health communication and health promotion through digital media has undergone significant and consistent development over the past two decades. The surge in publication numbers since 2021 marks a strong acceleration in research, driven by the growing need for fast, widespread, and adaptive health communication, particularly in the context of the global pandemic. Digital media, especially social media, has emerged as the dominant medium representing the shift in the health communication paradigm from a one-way approach to an interactive and participatory model [18]. This condition confirms that digital media is no longer a supplementary tool but has become a core infrastructure in modern health promotion strategies [19].

As seen in other studies with similar contexts, bibliometric methods have been employed to map trends and progress in the field. Wang et al., in their study of advancements in Natural Language Processing in the medical field, found that the number of publications in this area had increased significantly since 2012, with an annual growth rate nearing 300 articles [20]. Furthermore, analysis by Yang et al. on digital health literacy shows that research in this area has grown alongside the increasing use of the internet and social media [21]. This aligns with the estimate that more readers and researchers are now interested in exploring how digital literacy affects public understanding of health.

Research findings indicate that the primary focus of current research is concentrated on fundamental and cross-context issues such as social media, health education, health promotion, and public health, all of which are linked to humans as the main subject of analysis. The dominance of terms reflecting demographic characteristics, such as gender and age groups, indicates that the effectiveness of health communication is increasingly understood as a contextual

process dependent on social, psychological, and demographic factors. This reflects a shift toward research approaches that are more sensitive to differences in the reception of health messages in the digital space.

Several studies also emphasize the importance of tailoring messages based on demographic characteristics. For instance, Hunt and Linos (2022) highlight the need for messages tailored to specific population groups, such as age and gender, to build trust and ensure cultural relevance [22]. Similarly, a study by Ghare et al. (2023) emphasizes the use of social media and mass marketing to improve vaccine acceptance, with an approach tailored to the specific needs and concerns of each target group [23].

This discussion reveals imbalances in the development of health communication research topics. Some themes that were highly relevant, such as coronavirus infections, have seen a decline in development after the peak of the pandemic, while fundamental topics like public health and health personnel remain stable but have not seen significant conceptual innovation.

This suggests that much of the research is still responsive to global health crises and has not yet fully transitioned to the development of more sustainable theoretical frameworks and communication strategies, especially in the post-pandemic context and future health preparedness.

One major challenge emerging alongside the growth of digital communication is the phenomenon of misinformation, which has become more relevant with the increased use of social media. Findings by Mejova and Kalimeri (2020) in their study noted that during the COVID-19 pandemic, the infodemic phenomenon demonstrated how inaccurate information on social media could disrupt public understanding of health [24]. Therefore, it is important for public health practitioners to develop messages that are not only informative but also counteract myths and misunderstandings that spread among the public.

Moreover, health communication strategies must adapt to rapid changes in the digital space. A study by Al-Dmour et al. (2022) shows that mass media plays a significant role in increasing health knowledge and changing behavior, but it must be tailored to the diverse characteristics of different communities [25]. Other studies, such as those by Alragheb et al. (2025) and Alghamdi et al. (2024), reveal that responses to health messages vary depending on demographic factors like age and gender [26,27]. This emphasizes that health communication must be adapted to more detailed audience segmentation to improve its effectiveness in reaching and influencing different target groups.

Research collaboration networks between researchers and organizations indicate that knowledge production in this field is still dominated by institutions and researchers from developed countries, with relatively fragmented collaboration patterns. Although there are some strong collaboration clusters, many researchers and institutions still work relatively in isolation, especially on specific subtopics. This limitation in cross-regional networking points to structural gaps in knowledge production, where perspectives from developing countries and local contexts have not been optimally integrated into the mainstream global research.

Furthermore, the emergence of terms such as misinformation, health literacy, and decision making emphasizes that the main challenges in digital health communication lie not only in technology access but also in the quality of understanding, health literacy, and people's ability to process complex information [28]. This strengthens the argument that the effectiveness of health promotion in the digital age heavily depends on the integration of technology, educational approaches, and communication strategies that consider socio-cultural dynamics and information vulnerability [18].

Based on these findings, the future direction of digital health communication research needs to move toward more inclusive, collaborative, and contextual approaches. Future research should not only focus on evaluating the effectiveness of specific digital platforms but also on developing adaptive health communication models that account for social, cultural, and digital literacy differences. Additionally, strengthening cross-country and cross-disciplinary collaboration will be crucial to ensuring that digital health communication innovations can reach and remain relevant to broader populations, particularly in regions with limited digital infrastructure.

Overall, this discussion affirms that the field of digital health communication and promotion has entered an early phase of maturation, but still holds ample room for conceptual and empirical development. By integrating technology, human behavior, and social context dimensions simultaneously, future research has great potential to contribute significantly to the strengthening of more responsive, equitable, and sustainable public health systems. Thus, to build a better understanding, authorities must collaborate with various sectors to ensure that health information is delivered in ways that meet community needs. As emphasized by Ojeda et al. (2025), community engagement is crucial in building trust and enhancing the effectiveness of health messages [29, 30].

CONCLUSION

This bibliometric analysis of health communication and promotion through digital media highlights the significant growth of research in this field, especially since 2021. The increasing prevalence of digital platforms such as social media has transformed the paradigm of health communication, shifting from traditional, one-way dissemination to interactive, participatory models. Key research themes emerging from the analysis include mental health, the impact of social media, and the effects of the COVID-19 pandemic on health behavior. Despite substantial progress, gaps remain, particularly in the application of digital health strategies in developing countries and the adaptation of health messages to various socio-cultural contexts. The study also identifies areas underexplored in the literature, such as the role of gender-specific health concerns and regional health disparities. Furthermore, the research emphasizes the need for future studies to consider demographic factors in the effectiveness of health communication. The analysis also reveals that collaboration among researchers, especially across institutions and regions, plays a crucial role in advancing the field. Therefore, fostering cross-disciplinary and cross-national collaborations will be essential for bridging the gaps and enhancing the impact of digital health communication. This

study provides a comprehensive overview of the evolving landscape of health communication in the digital age and suggests multiple avenues for future research, particularly in ensuring inclusivity, adaptability, and equity in health communication strategies globally.

DECLARATIONS

Competing Interests

The no competing interests .

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ORIGINAL RESEARCH

USE OF LOW LEVEL LASER THERAPY IN OLD PERIODONTAL PATIENTS: A RANDOMIZED CLINICAL TRIAL

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ABSTRACT

Purpose: The present clinical investigation aimed to evaluate the effect of low-level laser treatment on the clinical parameters and checking levels of inducible nitric oxide synthase in individuals with stage II periodontitis across various age groups.

Materials and methods: The current investigation has been carried out on 40 locations in 40 patients. Randomly selected locations were chosen from each studied case, and divided into four groups: group A consisted of 10 sites in elderly patients who underwent scaling combined with root planning exclusively. Group B included 10 sites in young patients who also got scaling and root planning exclusively, group C 10 sites in old age who received diode laser therapy, and group D: 10 sites in young age group received low-level laser (diode laser). The clinical examination used the following clinical parameters: clinical attachment level, plaque index, and Gingival index. An Enzyme-Linked Immunosorbent Assay study was conducted on iNOS.

Results: Baseline and 3-month postoperative groups were compared and showed significant differences in iNOS levels which was influenced by the treatment in the young age group (nonsurgical and laser), but showed no significant difference in the old age group on both types of treatment (nonsurgical and laser).

Conclusion: This clinical investigation showed that whereas non-surgical techniques in conjunction with low-level laser treatment were unsuccessful in the elderly population, it was helpful in the young group with stage II periodontitis.

Keywords: Diode laser, Inducible nitric oxide synthase, Inflammageing, Old age, Periodontal disease

INTRODUCTION

Periodontal diseases refer to inflammatory disorders that damage the tooth-supporting tissues. These conditions originate from the accumulation of bacterial biofilms, which provoke an immune response from the host. As gingival connective tissue above the gum line deteriorates, further destruction of periodontal ligament fibers may compromise the bone that anchors the teeth. Clinically, this manifests as a loss of attachment at the cemento-enamel junction and observable gum inflammation, including redness, swelling, and bleeding upon probing. Additional signs include periodontal pocket formation, gingival recession, involvement of furcation areas, and

radiographically evident bone loss around teeth [1].

In 1976, Page and Schroeder proposed a classification of periodontal diseases based on histologic and clinical indicators of inflammation, changes in gingival appearance, and bleeding upon probing. Their system outlined a progression from early lesions to advanced stages marked by significant attachment loss. Later, during the 1989 World Workshop in Clinical Periodontics, periodontitis was further categorized according to disease progression [2].

A more recent classification model, introduced in 2017, incorporates contemporary scientific knowledge and consists of a staging and grading system. Staging reflects the severity and complexity of periodontitis based on the extent of clinical attachment loss and radiographic bone destruction, while grading evaluates the rate of disease progression and the likelihood of future worsening, considering factors such as systemic health and smoking status. The use of existing clinical data sets is essential for validating and refining this classification scheme [3].

Aging is a natural biological process defined by a gradual decline in physical capabilities and increased vulnerability to chronic diseases, such as cardiovascular conditions, cancer, and neurodegenerative disorders. Research has identified several hallmarks of aging, including telomere shortening, genomic instability, epigenetic modifications, mitochondrial dysfunction, altered nutrient sensing, stem cell exhaustion, cellular senescence, and disrupted intercellular communication. These processes are linked to persistent systemic inflammation, though the precise timing and interactions remain under investigation [4].

Inflammaging describes the age-associated rise in baseline inflammation that results from reduced resilience to stress and cumulative exposure to antigenic triggers over time. This chronic pro-inflammatory state is believed to stem from age-related dysregulation of the immune system, which compromises its ability to maintain homeostasis. While certain innate immune mechanisms remain relatively robust in older adults, adaptive immunity declines more markedly, linking inflammaging with the phenomenon known as immunosenescence [5].

Immunosenescence refers to the age-related deterioration of immune function, which diminishes the body's capacity to respond to new infections and maintain immune surveillance. Changes in lymphoid tissues and immune cell populations contribute to a greater risk of infections, autoimmunity, cancer, and neurodegenerative diseases in elderly populations [6].

Nitric oxide (NO) is a reactive signaling molecule synthesized from L-arginine by nitric oxide synthase (NOS) enzymes. Inducible nitric oxide synthase (iNOS) is a form of NOS that produces high concentrations of NO during inflammation. While iNOS-derived NO helps to eliminate pathogens in acute inflammatory responses, its sustained expression can contribute to bone degradation in severe inflammatory conditions. Studies have shown that periodontal pathogens such as *Porphyromonas gingivalis* and *Aggregatibacter actinomycetemcomitans* can upregulate iNOS expression, thereby promoting the progression of periodontitis [7].

Management of periodontal disease typically aims to reduce pathogenic bacteria through both nonsurgical and surgical therapies to prevent further tissue destruction. Procedures like scaling and root planing are effective at substantially lowering subgingival microbial loads and shifting biofilm composition toward less pathogenic bacterial communities. However, treatment outcomes may be limited by difficult-to-access areas, microbial resistance, virulence factors, or compromised host responses [8].

Adjunctive laser therapy has emerged as an innovative treatment modality for periodontal disease. Laser application can thermally and photodynamically disrupt periodontal pathogens, and its greater tissue penetration enhances bactericidal and detoxification effects, making it a promising complement to conventional periodontal therapy [9].

Diode lasers selectively target chromophores such as melanin, hemoglobin, and pigmented bacteria, leading to the destruction of diseased tissue while sparing healthy structures. When inserted into periodontal pockets, the laser tip removes the epithelial lining and inflammatory infiltrates and delivers low-level radiation to surrounding tissues. This process promotes healing through photobiomodulation by increasing blood flow, reducing swelling, and alleviating pain [10].

The aim of this study is to assess the impact of low-level laser therapy, when used alongside nonsurgical treatment, on salivary iNOS levels in

patients with chronic periodontitis across different age groups. Salivary iNOS will serve as a biomarker for oxidative stress, inflammaging, and immunosenescence in periodontal tissues [11].

MATERIALS AND METHODS

A controlled clinical trial was done on a sample of 40 participants who had been diagnosed with periodontitis. The patients contained in this research were chosen in sequential order from those who were referred to the Department.

Patients aged between above 70 years who were diagnosed with stage II, grade II periodontitis were included in the study. All participants provided written informed consent prior to enrollment. Eligibility criteria required participants to be systemically healthy and diagnosed with stage II periodontitis, with clinical attachment loss of 3–4 mm, radiographic bone loss ranging from 15% to 33%, no tooth loss attributable to periodontitis, and a maximum probing depth of less than 5 mm, predominantly associated with horizontal bone loss. Exclusion criteria comprised smokers, pregnant women, individuals who had received antibiotics within the preceding three months, those undergoing systemic drug therapy, and patients who had received any periodontal treatment within six months prior to the study.

The participants were randomly assigned into four equal groups. Group A consisted of 10 older patients who served as the control group and received nonsurgical periodontal therapy only. Group B included 10 younger patients who also acted as a control group and were treated exclusively with nonsurgical periodontal therapy. Group C comprised 10 older patients forming the study group, who received nonsurgical periodontal therapy in combination with low-level laser therapy. Group D included 10 younger patients in the study group and were treated with nonsurgical periodontal therapy supplemented by low-level laser therapy.

Study procedures:

Periodontal Therapy

All patients received phase I periodontal therapy, which included scaling and root planing performed both supra-gingivally and sub-gingivally, along with oral hygiene instructions. These procedures were carried out using a combination of ultrasonic and manual instruments. Clinical evaluations were performed at four time points: baseline, 4 weeks post-treatment, 3 months, and 6 months. The assessed clinical parameters included the Clinical Attachment Level (CAL).

Clinical Attachment Level (CAL)

Clinical attachment level was defined as the distance between the base of the periodontal pocket and the cemento-enamel junction. Measurements were recorded at the same sites used for probing depth assessment.

Laser Application

Laser disinfection was performed using a 300-µm non-initiated fiber tip directed into the periodontal pockets.

Salivary Sample Collection

Approximately 2 mL of unstimulated saliva was collected from each participant using the Draining method.

Biochemical Evaluation

Salivary samples were collected at two time points: baseline and after three months. The concentration of inducible nitric oxide synthase (iNOS) was determined using an western blot (protein detection).

RESULTS

Clinical evaluation outcomes Following their completion of the research, all participating studied cases underwent follow-up evaluations. The mean and standard deviation values of the values had been displayed. The ShapiroeWilk test of normalcy was used to examine the data for normalcy. ShapiroeWilk findings showed that the data had been regularly distributed (parametric data), hence one-way ANOVA was used for the pairwise comparison, followed by the Post Hoc test.

A significant threshold of P less than or equal to 0.05 had been established. The statistical pro- gramme SPSS had been used to conduct the analysis (version 25, IBM Colorado, USA).

Effect of time interval and age of patients, on the CAL under the same group type (Intra-group Comparison)

1.1 Non-Surgical group

1.1.1 Effect of time interval on the CAL under the same patient age and same group

Non-Surgical Young: the mean of the CAL was (3.53±0.36 mm) at baseline, (2.6±0.35 mm) after 4 weeks, (2±0.24 mm) after 3 months, and (1.8±0.3 mm) after 6 months, while in the **Non-Surgical Old:** the mean of the CAL was (3.77±0.19 mm) at baseline, (2.77±0.33 mm) after 4 weeks, (2.23±0.15 mm) after 3 months, and (2.1±0.15 mm) after 6 months. So *For both subgroups (young and old patients):* According to the Tukey Post Hoc test, there was a significant difference between baseline and other time intervals, as well as between 4 weeks and other time intervals; however, there was no significant difference between 3 months and 6 months. According to the ANOVA test, the overall P-value for intragroup comparison was statistically highly significant (P-value < 0.001). This significant was attributed to the difference between baseline (the highest mean of CAL) and 6 months (the lowest mean of CAL).

1.1.2 Effect of patient age on the CAL at the same time and in the same group

For all time intervals: Although the CAL mean for the old patient was higher than that for the young patient, the difference between the old and young subgroups was not statistically significant.

1.2 Laser group

1.2.1 Effect of time interval on the CAL under the same patient age and same group

Non-Surgical Young: the mean of the CAL was (3.77±0.28 mm) at baseline, (2.5±0.33 mm) after 4 weeks, (1.77±0.4 mm) after 3 months, and (1.6±0.37 mm) after 6 months.

Non-Surgical Old: the mean of the CAL was (3.8±0.27 mm) at baseline, (2.47±0.46 mm) after 4 weeks, (1.9±0.62 mm) after 3 months, and (1.73±0.37 mm) after 6 months.

For both subgroups (young and old patients): Like the Non-surgical group, according to the Tukey Post Hoc test, there was a significant difference between baseline and other time intervals, as well as between 4 weeks and other time intervals; however, there was no significant difference between 3 months and 6

months. According to the ANOVA test, the overall P-value for intragroup comparison was statistically highly significant (P-value < 0.001). This significant was attributed to the difference between baseline (the highest mean of CAL) and 6 months (the lowest mean of CAL).

1.2.2 Effect of patient age on the CAL at the same time and in the same group

For all time intervals: Although the CAL mean for the old patient was higher than that for the young patient, the difference between the old and young subgroups was not statistically significant.

Table 1. Mean ± SD and intra-group comparison of clinical attachment loss (mm) between the twotime intervals (Before and After) and the two ages (Young and Old) for both groups.

	Non-Surgical			Laser		
	Young	**Old**	P-value*	**Young**	**Old**	P-value*
Baseline	3.53±0.36[a]	3.77±0.19[a]	**0.237[NS]**	3.77±0.28[a]	3.8±0.27[a]	**0.853[NS]**
4 Weeks	2.6±0.35[b]	2.77±0.33[b]	**0.455[NS]**	2.5±0.33[b]	2.47±0.46[b]	**0.899[NS]**
3 Months	2±0.24[c]	2.23±0.15[c]	**0.098[NS]**	1.77±0.4[c]	1.9±0.62[c]	**0.697[NS]**
6 Months	1.8±0.3[c]	2.1±0.15[c]	**0.079[NS]**	1.6±0.37[c]	1.73±0.37[c]	**0.580[NS]**
P-value**	**< 0.001[HS]**	**< 0.001[HS]**		**< 0.001[HS]**	**< 0.001[HS]**	

-* *P-value for Intra-group comparison (Young vs. Old) from Ina*

-Test.

-** *Overall P-value for Intra-group comparison between the four-time intervals (ANOVA Test).*

- *Small letters for pairwise comparison between different time intervals (Tukey Post Hoc test) and the means with different superscripts are statistically significant different at P ≤ 0.05. - S= Statistically significant at P ≤ 0.05 - NS= Non-significant P < 0.05.*
- *HS= Highly significant at P ≤ 0.001*

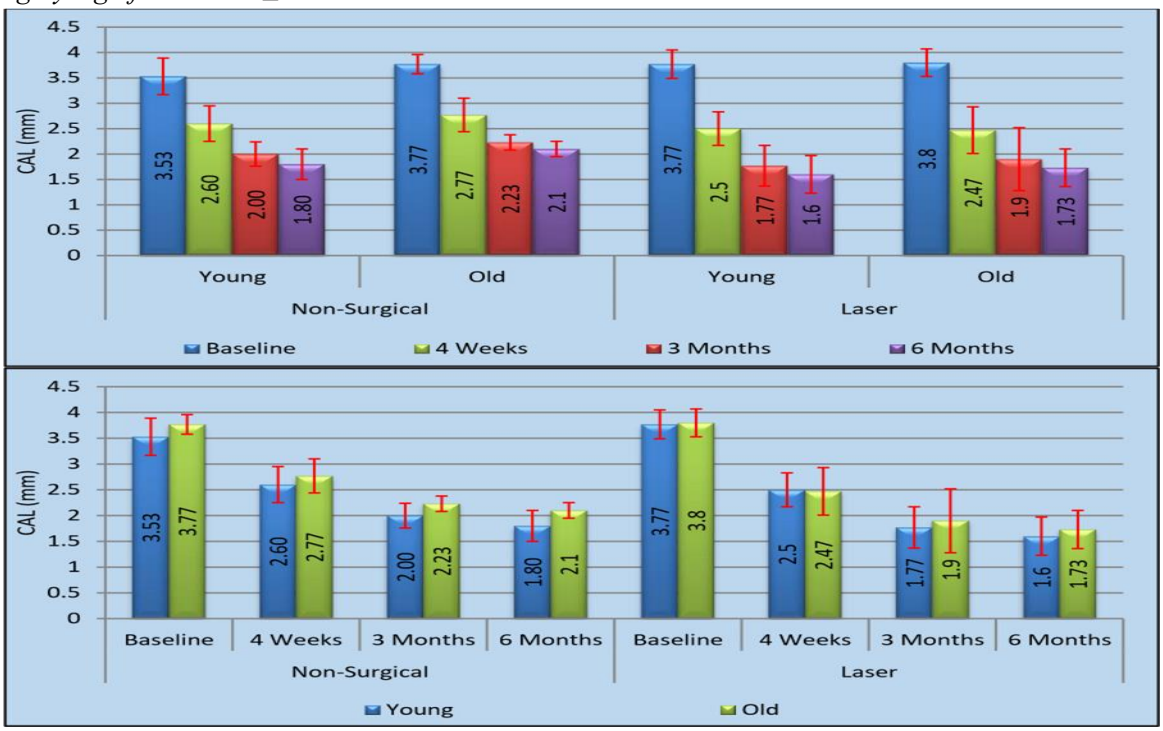


Figure 1. Bar chart representing Mean and SD of CAL at the two-time intervals (Before and After) and for the two ages (Young and Old) for both groups

DISCUSSION

Periodontal disease is initiated and sustained by a dysregulated host immune response to microbial plaque biofilms rather than by bacterial challenge alone. An exaggerated immune reaction leads to persistent inflammation, characterized by continuous release of inflammatory mediators such as cytokines and chemokines. This chronic inflammatory state contributes to excessive production of reactive oxygen and nitrogen species, thereby intensifying oxidative stress and impairing the antioxidant defense system within periodontal tissues [12,13].

Oxidative stress plays a pivotal role in the pathogenesis of periodontitis by promoting connective tissue breakdown, alveolar bone resorption, and cellular senescence. Prolonged exposure to oxidative damage accelerates tissue aging and apoptosis through mitochondrial dysfunction and sustained inflammatory signaling. Consequently, therapeutic strategies aimed at controlling periodontal disease should incorporate approaches that modulate oxidative stress and suppress excessive inflammatory mediator release [14–16].

Photobiomodulation therapy represents a non-invasive modality that exerts its biological effects through the absorption of light energy by cellular chromophores, triggering a cascade of photochemical and photobiological reactions. These reactions enhance mitochondrial activity, improve cellular metabolism, and regulate inflammatory signaling pathways. Several studies have demonstrated that low-level laser therapy can effectively reduce oxidative stress and downregulate inflammatory mediators, thereby supporting periodontal tissue repair and regeneration [17,18].

In the present study, variations in salivary iNOS levels following nonsurgical periodontal therapy were particularly evident among younger individuals. This observation may be attributed to the dual role of nitric oxide as both a protective antimicrobial agent and a mediator of tissue destruction. During early inflammatory responses, increased nitric oxide production may function as a host defense mechanism against microbial invasion. However, sustained nitric oxide activity has been shown to promote extracellular matrix degradation through inhibition of collagen

synthesis and stimulation of matrix metalloproteinase activity [19,20].

Nitric oxide is increasingly recognized as a central regulator in periodontal immuno-inflammatory pathways. Its overexpression has been associated with disease severity and progression, suggesting that targeted modulation of nitric oxide signaling could be beneficial in periodontal therapy. Emerging therapeutic approaches include selective inhibition of iNOS activity and the use of antioxidant compounds to neutralize reactive nitrogen species and limit peroxynitrite-mediated tissue damage [21].

Further studies should be conducted with a larger sample size to ensure the oxi-inflammaging theory.

DECLARATION

Conflicts of interest

The author declares that he has no conflict of interest

Ethical approval

The study was approved by the Institutional Ethics Committee and was conducted in accordance with the Declaration of the World Medical Association.

Informed consent

Informed consent was obtained from all individual participants included in the study.

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IN VITRO ASSESSMENT OF MARGINAL AND INTERNAL GAP OF MONOLITHIC ZIRCONIA CROWNS FABRICATED BY MILLING AND 3D PRINTING TECHNIQUES.

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ABSTRACT

Aim of the study: this invitro investigation aimed to assess how accurate monolithic zirconia restoration constructed by milling (subtractive) and printing (additive) techniques.
Materials and methods: twenty zirconium single unit restorations were constructed by subtractive (group 1) and additive technologies (group 2). The accuracy at the margin was evaluated at twelve measurement spots utilizing the vertical marginal gap method (VMGT). With regards the internal discrepancy, the replica approach was conducted, and it was measured in four areas: marginal, axial, axial-occlusal, and mid-occlusal areas. It was reported that the data followed a normal distribution, and an independent t-test was used to analyze the results.
Results: Using VMGT, group 1's mean marginal gap values were (56.9 ± 7.77 µm), which was significantly lower than group 2's (84 ± 13.5) µm ($p < 0.001$). Additionally, group 1's marginal gap (61.75 ± 13.45 µm) showed substantially lower values with the SRT than group 2's (82.65 ±12.53 µm). With the exception of the axial gap, the adaptation of the internal surface revealed a substantial disparity between both techniques.
Conclusions: Despite zirconia milled crowns performed better, clinically acceptable outcomes with regards accuracy of fit, can be achieved by the additive techniques.

Keywords: Three-Dimensional Printing, Prosthesis Fitting, Marginal Adaptation and zirconia.

INTRODUCTION

Dental zirconia ceramics are being used more and more nowadays. The materials' superior mechanical and biological characteristics, along with their pleasing esthetic properties, support its use as a dental material. The most important component of any material that should be used in dentistry; they must show proper mechanical and physical properties. Any constructed prosthesis should be properly shaped, with the proper internal and external shape, and fit without any gaps [(1)] .

Restorations constructed from zirconia are made employing the subtractive method, which involves using computer-aided designing/computer-aided manufacturing (CAD/CAM) to grind it from a blank [(2)] . A reliable method that reduces human intervention and decreases the susceptibility of faults associated with the conventional lost-wax technique is the construction using computer, utilizing zirconia discs or blocks. These could be partially sintered, the restoration constructed in the green-stage, and fully sintered, used for milling in hard state. Each of which has its own steps for production. For hard milling, the susceptibility for initiation of cracks in the final restorations, milling bur wear, prolonged milling procedures, and characteristics of the surface of the restoration can be considered drawbacks for hard milling [(3,4)] .On the other hand, for green-state milling, the restoration should be enlarged by about 25% to counteract shrinkage on setting. for both states, there are large amount of waste material produced after the milling procedure. Also, the size and configuration of the milling bur, how many axes used by the machine to mill, have a large effect on the final restoration shape, finish and configuration[(5,6)].

Recent developments in dental restoration manufacturing include the construction of the product in low thickness layers, then undergo processing, hardening, and then final stages of finishing. Often referred to as Layered manufacturing or Three-dimensional printing, this process uses a variety of methods, including powder bed fusion, binder and

material jetting, vat photopolymerization, thermoplastic extruded material, and others. Variable additive manufacturing procedures are used in dentistry by lab technicians and restorative dentists to create metal prostheses, dentures, castings, and interim restorations. Recently, printing ceramic restorations—such as zirconia-based prostheses—has drawn more attention[7–9].

Many advantages have been provided by the additive manufacturing, including the removal of tool wear, reduced residual tensions, complicated geometries, mass production, and minimal material waste. But it should be noted that this technique of production has its limitation. These include dimensional inaccuracy, prolonged duration during the printing procedure, various inconsistent steps occur across different printing technologies, setting shrinkage during curing, distortions occur due to printing variables of the machine, and varied final product characteristics (surface and physical) [10,11]

Similar to traditionally manufactured restorations, internal adaptation and marginal fit are vital factors for the final dental restoration's performance in AM (additive manufacturing) or SM (subtractive manufacturing) restorations .So as to ensure proper response of the vital tissues including the periodontal ligament and the tooth pulp as well as superior cement performance, it's of prime importance to obtain a maximum adaptation between the restoration margin and the tooth finish line. The slight misalignment which may appear at the restoration margin can cause secondary caries, microleakage, cement dissolution, and pupal health risk. Various acceptable marginal gap ranges were described by many authors, dependent on type of the restorative material, material of the cement, and measurement method. There isn't a certain consensus, though. Indirectly made restorations with 50-120 µm misalignment at the marginal area could be considered clinically acceptable, however if the misalignment not more than 25 µm it can be considered ideal [12–14]

Despite limited practical and technological challenges, the milling process was able to create a single-unit, long span bridges and full arch patients with superior functional and cosmetic needs. On the contrary, the printing techniques of zirconia, have introduced recently in the dental practice, also the previous studies regarding this topic showed variable conflicting results versus the traditional milling process. This invitro investigation aimed to assess how accurate monolithic zirconia restoration constructed by milling (subtractive) and printing (additive) techniques. The study's null hypothesis was that there would be no difference in the internal and marginal gaps between monolithic zirconia single unit indirect restoration made additively and subtractively.

MATERIALS AND METHODS

Experimental design:

An observational, randomized and experimental in vitro assessment was carried out following the approval of The Research Ethics Committee of the Cairo University Faculty of Dentistry with number (40/10/25)].

Sample size calculation:

Based on a study conducted in 2023 by Refaei et al [15] , with a power of 80% (β=0.20) and a level of significance of 5% (α error tolerable =0.05), the required sample size was 16 specimens per group. resulting in a total of 32 sample. To improve the dependability of the results and account for potential experimental mistakes, each group had 20 specimens. The sample size was computed using G*Power version 3.1.9.7.

Sample preparation and grouping:

Twenty upper second premolar acrylic teeth were prepared with a 1 mm deep chamfer finish line, 6° axial wall convergence, and occlusal clearance with 1.5mm reduction. The STL files, obtained using an intra oral scanner (Medit i500), were utilized for digital crown designing using CAD software (exocad version 3.0, exocad GmbH, Germany). A luting space of 70 µm was set, begin 1mm away from the preparation margin. The samples were divided into two groups:

For Group 1 (n=20):

To begin the construction of the milled crown, and in the Millbox software, the block type (Nacera blanks, Germany) and the disc's scale factor (1.25) were manually entered and confirmed by choosing the (√) mark. A zirconia disc of the appropriate size was chosen, inserted into the milling chamber of the Roland DWX-510 milling machine (Roland, Japan), and fastened with a screw. After milling, an abrasive tool was used to separate the restorations from the block. Then the crowns were cleaned in US cleaner for 60 seconds and were left to completely dry before sintering. The Mihm Vogt Tabeo Sintering furnace (Germany) was used for the sintering step. The crucible rack was filled with a layer of sintering beads and crowns put so that the occlusal aspect looking downwards. The sintering tray was put on the shelf in the furnace. The furnace door was manually closed, the desired program was chosen in accordance with the manufacturer's instructions, and the program was started by pressing the start button. Sintering was done at maximum temperature of 1530ºC. Once the cycle was finished, the furnace door was opened, and the sintering tray was raised and left to bench cool. The crowns were examined for cracks, faults, and defects.

For Group 2 (n=20):

The 3D-printed zirconia crowns (Lithoz 210 3Y, Austria) produced using a CeraFab7500 (Lithoz,

Austria) three-dimensional printer, with 1mm base thickness with supports placed on the crowns' lingual aspect perpendicularly for stabilization and carrying crowns during printing, during which the occlusal aspect directed upwards. To compensate for shrinkage in X and Y axes, the scale was 1.27, while in the Z axes was 1.3 as recommended by the manufacturer. The layer thickness set was 25 µm, with 36 seconds curing time, the exposure intensity was 110 mj/cm^2 and 90^o build direction. The printed crowns were sintered consecutively in three ovens (Nabertherm, Germany) after being cleaned using ethylene-glycol solvent in an ultrasonic bath and compressed air. First oven where preconditioning was commenced at 120°C spanning 2h, and then temperature raised till 300 °C and held for 1h, then raised till 600°C and held for 2h. Then specimens were transferred to the second furnace for binding removal at 1000 °C spanning 1h, and finally zirconia crowns were sintered at temperature of 1450 °C and spanning 2h. Then left to bench cool till room temperature.

Following sintering, no modifications were made to the inside surface of any crown. The crowns were then sandblasted with 50 µm alumina particles at 2 bar for 10 seconds. All crowns were subsequently seated over the prepared acrylic teeth and verified for proper seating using a dental explorer.

Vertical Marginal gap distance:

Holmes et al. [16] illustrated this gap as the extension from the edge of the restoration till the outer end of the prepared finishing line. For gap distance evaluation, we used USB digital microscope connected to digital camera, by which the specimens were photographed.

Technique:

The following imaging system was used to take a proper image:

1) Digital camera (***U500x Digital Microscope, China***) with resolution of 3 Mega Pixels, positioned in a vertical direction with 2.5cm distance away from the specimens and with 90^o angle between light source and the lens axes.
2) Eight light emitting diode lambs were used as a source of light with approximately color rendering index of 95%.

After that, these images were transferred to IBM computer. These images were with 35x magnification and 1280 × 1024 pixels resolution. To analyze the captured image, we used Image J software to assess the gap dimensions. This software used the pixels to demonstrate sizes, measure parameters, frames and limits within the image. To be measurable, these pixels should be expressed in micron meters, this was done by calibration process done by modifying the pixels with the aid of a known size sample with a ratio created by the software. For each specimen, marginal areas were imaged, a quantitative evaluation for the marginal area was done for each image at three points placed away from each other with the same distance for each surface. After collecting data, these were tabulated and subjected to statistical analysis (Figure 1).



Figure 1. Vertical marginal gap under digital microscope for milled (a) and printed (b) crowns

Internal gap:

Internal gap is defined as the gap between the intaglio crown surface and the external prepared surface. Silicon replica technique was used to quantitively evaluate the internal fit. A light consistency silicon impression material was used to fill the intaglio surface of the crown, then insert over the prepared acrylic teeth with the aid of a modified papallellometer. This device permitted the application of a standardized constant load of 750 grams for ten minutes. After polymerization of the light consistency impression material, the restoration was separated from the prepared teeth. Due to its very low thickness and strength, and to avoid its distortion, the light consistency silicon material was stabilized using a heavy consistency impression material. After setting, this replica was cut into two parts. This was done using a razor blade (no. 15), then the internal fit was evaluated for each part in four areas, the marginal, axial, axio-occlusal and mid occlusal. Then measurement of the light consistency impression material was done with digital microscope with 30 X magnification (Figure 2). To analyze the captured image, we used Image J software to assess the gap dimensions. This software used the pixels to demonstrate sizes, measure parameters, frames and limits within the image. To be measurable, these pixels

should be expressed in micron meters, this was done by calibration process done by modifying the pixels with the aid of a known size sample with a ratio created by the software. For each specimen, marginal areas were imaged, a quantitative evaluation for the marginal area was done for each image at three points placed away from each other with the same distance for each surface. After collecting data, these were tabulated and subjected to statistical analysis.



a b

Figure 2. Digital microscopic picture showing the internal adaptation for milled (a) and printed (b) crowns.

RESULTS

This research was performed to evaluate the accuracy of fit of zirconia crowns constructed by milling and printing techniques, marginally and internally. Data were coded and entered using the statistical package for the Social Sciences (SPSS) version 28 (IBM Corp., Armonk, NY, USA). Data was summarized using mean and standard deviation. Comparisons between milled and printed fabrication methods applied to each tooth were done using paired t test. P-values less than 0.05 were considered as statistically significant.[17,18]

Vertical marginal gap:

The results showing the marginal discrepancy comparisons between the two groups were shown in Table 1. Three dimensionally printed restorations showed higher mean values of discrepancy of 84.3 µm but milled restorations showed a mean discrepancy of 56.90 µm ($p < 0.001$) (Figure 3).

Table 1 Mean, standard deviation, and 95% confidence interval of vertical marginal gap for milled and printed groups.

		Milled	printed	P value
Vertical Marginal Gap	**Mean** (µm)	56.90	84.30	< 0.001
	Standard Deviation	7.77	13.50	
	Standard Error of Mean	1.74	3.02	
	95.0% Lower CL for Mean (µm)	53.26	77.98	
	95.0% Upper CL for Mean (µm)	60.54	90.62	

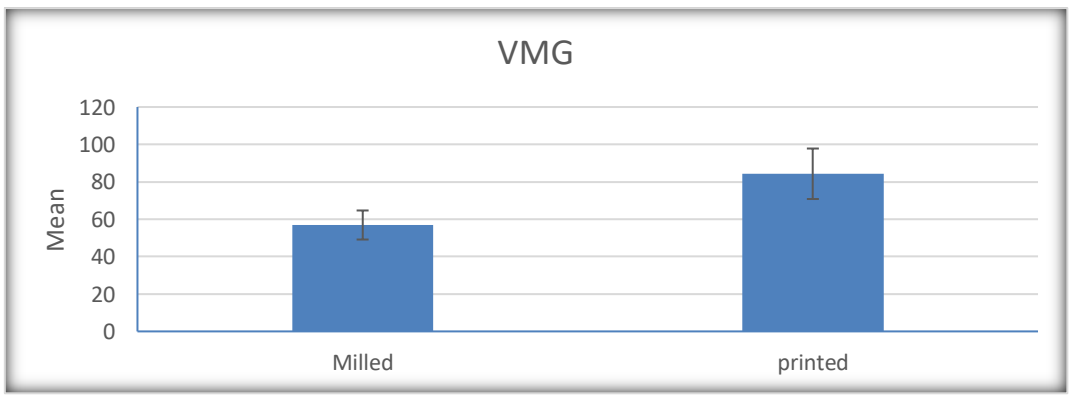


Figure 3. Bar chart showing the vertical marginal gap for milled and printed zirconia crowns

Internal gap:

Table (2) and figure (4) demonstrated the mean and standard deviation and 95% confidence interval of the internal discrepancy in the two groups marginally, axially, axio-occlusally, and mid-occlusally. Intergroup assessment of internal fit showed that the mean gap values for printed crowns were substantially higher than the milled group at the marginal, axio-occlusal, and mid-occlusal surfaces ($p<0.001$ in these areas). However, the difference observed axially was not statistically significant ($p=0.405$)

Table 2.Mean, standard deviation and 95% confidence interval of internal gap in milled and printed groups at marginal, axial, axio occlusal and mid occlusal areas.

		Milled	printed	P value
Internal marginal	**Mean** (µm)	61.75	82.65	< 0.001
	Standard Deviation	13.54	12.53	
	Standard Error of Mean	3.03	2.80	
	95.0% Lower CL for Mean (µm)	55.41	76.79	
	95.0% Upper CL for Mean (µm)	68.09	88.51	
Internal axial	**Mean** (µm)	82.65	84.65	0.405
	Standard Deviation	7.47	6.91	
	Standard Error of Mean	1.67	1.54	
	95.0% Lower CL for Mean (µm)	79.15	81.42	
	95.0% Upper CL for Mean (µm)	86.15	87.88	
Internal axio occlusal	**Mean** (µm)	88.10	119.10	< 0.001
	Standard Deviation	7.82	18.57	
	Standard Error of Mean	1.75	4.15	
	95.0% Lower CL for Mean (µm)	84.44	110.41	
	95.0% Upper CL for Mean (µm)	91.76	127.79	
Internal occlusal	**Mean** (µm)	237.00	294.65	< 0.001
	Standard Deviation	25.14	18.73	
	Standard Error of Mean	5.62	4.19	
	95.0% Lower CL for Mean (µm)	225.24	285.88	
	95.0% Upper CL for Mean (µm)	248.76	303.42	

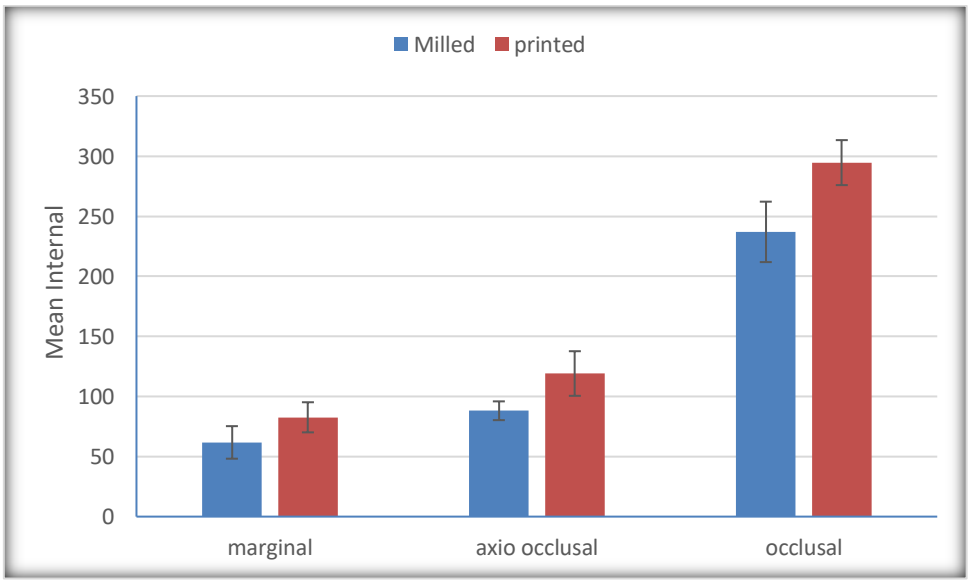


Figure 4. Bar chart showing the mean internal gap for milled and printed zirconia crowns

DISCUSSION

As a result of their strength, biological compatibility, and its aesthetically pleasing qualities, monolithic zircon crowns are one of the most popular remedies in contemporary dentistry. Subtractive grinding using computer-aided design and manufacturing is the conventional approach for creating zirconium crowns. Although constituting a relatively dependable process, subtractive grinding offers several disadvantages, including high costs of production, excessive damage on the milling cutters, wasted material, as well as obstacles in grinding complicated shapes. Plenty of

attempts were undertaken to generate dental crowns utilizing recent technologies such as additive manufacturing, often known as methods of 3D printing, in order to get over these problems[1,19]

Because CAD-CAM has several benefits, including time efficiency, high precision, and more efficient, it has become an important development in the modern construction business[20].

Additive manufacturing, a different acronym for 3D printing, is a sophisticated process that uses a computer to submit a digital file to build a three-dimensional real product. Its basic idea is a speedy production method that employs successive layers of printing. Layered printing, which produces directly, quickly, and without sacrificing raw materials, entails assembling primary elements of production to make an object with three dimensions. Selective laser melting, selective laser sintering, fused deposition modeling, stereolithography, and digital light processing are just a few of the 3D printing approaches obtainable today [21]

For printed indirect restorations and to guarantee appropriate adaptation and a sufficient proper oral tissue reaction, the crown restoration needs to be provided with a precise fit. The number, placement, and size of supports, the digitizing method/scanner, and the printing technique all affect how precise a printed object is [22]

The finish line utilized is the deep chamfer finish line due to its increased dimension and inner angles are rounded, a deep chamfer enhances the mechanical functionality of posterior zirconia restorations and offers enough cervical space for appropriate crown contouring allow an improved adaptation of the restoration margin [(23)].

Medit I 500 scanner was used for acquisition due to its high accuracy related to the superior performance of the triangulation and structured light scanning. This scanner also allows video stream scanning which offer speedy, easy handling and time efficient scanning [24].

Exocad's was used as the designing program, as it allows to construct a prosthesis with best fit and accuracy, enhanced efficiency, more fast process, allow for the same-day restorations, and freedom and adaptability because of its open system that works with a variety of devices [25].

The unique characteristics of CAM dental systems could impact the end result of milled indirect restorations. The format, size, and quality of milling burs, how many milling unit axes, and the expected adhesive space are all significant factors influencing the fit of the reconstruction [19].

In this investigation a 5-axis milling machine was used as it allows construction of complex forms, which also has better surface finishes, more efficiency, and more precision because it requires fewer setups. These machines improve tool life while reducing manufacturing time, labor, and the possibility of error due to work piece repositioning as they can manufacture parts from various angles in just one setup [26,27].

The printable zirconia represented as high-performance zirconium oxide ceramics fabricated by Lithography-based Ceramic Manufacturing (LCM), which is a three-dimensional printing technique relay mainly on stereo lithography. This material comprises 3 mol% yttria-stabilized tetragonal zirconia polycrystalline (3Y-TZP), which is well known to be with excellent biological compatibility, mechanical qualities, and prosthesis longevity. The printable zirconia presented as a powder which is embedded in a resin (binder) that is light curable in a layer-by-layer fashion to produce a densely packed, with excellent details and superior clarity ceramic slurry (up to 25–50 μm). To completely get rid of the resin polymers (called debinding), the zirconia is sintered at a very high temperature degree after being printed (about 1500°C) creating a ceramic with superior density (green state) [28,29] .

This research examined the adaptation of single crown restoration created either via additive printing and subtractive milling approaches. To guarantee uniformity and standardization of the fabricated crowns, the samples were created utilizing two production processes (subtractive and additive) with exactly the identical STL file.

When planning a prosthodontic restoration, two of the most essential elements to take into account is the fit either marginal or internal. The interior gap, which is the measurement that is obtained perpendicularly from the material's internal surface to the preparation's exterior wall, is the same as the marginal gap, according to Holmes [16]. Poor marginal fit diminishes the prostheses' longevity by generating leakage that causes recurrent decay, mucosal irritation, and luting agent dissolution, and inadequate internal fit increases the risk of prosthesis fracture [30].

The material of construction, the preparation geometry, properties of cements, shrinkage following sintering production and the subsequent finishing and processing characteristics are some of the factors that is related to crown fit and marginal adaption[31].

There are various ways for evaluating the restoration fit either, marginal or internal, which can be divided into destructive or non-destructive, as well as 2D or 3D. This includes direct view with microscope; indirect view on resin duplicates; silicone replica technique with optical scanning; micro-CT analysis, silicone replica approach, and the triple scan technique [21].

It can be difficult to assess a crown's marginal fit. While the replica method has been proven to be effective in verifying the internal and marginal fit of crowns, there are various shortcomings and can be technique-sensitive. One of the shortcomings of this technique is a limited number of measurement points

for each restoration, therefore it may not represent the true circumferential fit of a crown; however, as the technique has been used extensively in prosthodontics, it makes comparisons to other studies easier [32].

The vertical gap located at the margin was assessed with a digital microscope as it is regarded as reliable and non-destructive measuring device. Additionally, Yucel et al. claimed that using the microscope along with software for image analysis enables non-invasive numerous examinations through direct imaging[33].

Regarding the fitting of the zirconia crowns, whether vertical or internal, each of the tested samples remained within the accepted clinical range, as well as the marginal gap values of crowns fabricated by both methods were not more than 120 µm. The milled crowns' marginal gap ranged from 56.9 ± 7.77 µm, researchers whom examined the monolithic zirconia crowns marginal discrepancy; for CAD/CAM restorations, the gap varied from 30 to 150 µm. Additionally, for the crowns created by the additive technique, their marginal gaps were within the range of 84 ± 30 µm, that was consistent with the findings of Ryu et al., who examined the impact of various build orientations on the internal and marginal fits of 3D printed resin crowns[34–37]

In comparison to the additive techniques, the mean marginal gap of the subtractive crowns was much less. This could be related to diminishing accuracy during 3D printing result from errors accumulating at several stages of production, design segmentation by printing software, processing, and printing itself. The shrinkage that happened during construction and after curing resulted in a larger marginal gap, the material becoming too polymerized during manufacture, which causes light to scatter and more material to harden than expected. These results were in accordance with Savencu et al. and Refaei et al [15,38] .

On the other hand, other authors reported that the milled restorations have a higher vertical marginal gap than 3D-printed restorations. This can be explained by the intrinsic variations in material handling and production techniques. The subtractive manufacturing method employed in CAD/CAM milling, which is used in traditional construction, can produce small errors, especially at complex shapes and tiny margins. The diameter of milling tools frequently limits their precision in creating thin edges and complex designs, which may lead to greater marginal discrepancy[32,39,40]

Regarding the internal gap, the milled crowns had lower values than the 3D printed crowns in the discrepancy at the margin, axial occlusal discrepancy, and mid occlusal discrepancy this could be related also to the previously mentioned causes. Accordingly, the null hypothesis of this research was rejected.

Conclusions and clinical relevance:

With the inherent restrictions of this invitro study, the following could be concluded:

1- All milled specimens showed clinically accepted results regarding the internal and the marginal discrepancy values
2- All 3D printed specimens showed clinically accepted results regarding the internal and the marginal discrepancy values can be considered a therapeutically suitable substitute.
3- The milled crowns had improved internal fitting than the 3D printed crowns
4- The milled crowns had improved marginal fitting than the 3D printed crowns

Limitations of the study:

1- This research was in vitro and did not mimic the intra oral complex conditions such as the saliva, masticatory forces, temperature changes etc.
2- Use of acrylic resin teeth rather than natural teeth, did not resemble the natural oral conditions
3- No thermocycling or dynamic loading was applied.
4- 2-dimensional evaluation of the discrepancies was done rather than the 3-dimensional evaluation.

Further recommendation:

1-To evaluate the internal and the marginal discrepancy in real scenario human cases including in vivo studies.

2-Evaluation of the tensile, compressive strength and fracture resistance of the novel 3D printed zirconia crowns.

3-Evaluation of the internal and marginal fitness with thermocycling and dynamic loading for the novel 3d printing nano zircon.

DECLARATION

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Conflicts of interest.

No conflicts of interest.

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ORIGINAL RESEARCH

BRIDGING THEORY AND PRACTICE: KEY CONCEPTS IN WORKPLACE-BASED ASSESSMENT FOR DENTAL EDUCATION

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Abstract

Assessment is considered the most valuable tool in evaluating performance in healthcare educational training programs. End-of-year assessments often present challenges for trainees. To address this, workplace-based assessments (WPBAs) have been introduced during the clinical years, allowing students to engage with real patients and thereby build their clinical skills and confidence. Although awareness of these techniques is growing, only a limited number of dental schools have implemented these WPBAs. The strategic implementation of these WPBAs over the clinical years can aid in keeping track of the progress of the students and filling the gaps in their knowledge to have a positive educational impact on their lifelong learning. This paper will explore the key concepts of the use of WPBAs within undergraduate dental education to enhance students' practical competencies.

Keywords: Dental Education/Education, Workplace-based assessments, Feedback.

1. INTRODUCTION

The purpose of the BDS course is to produce knowledgeable clinicians who can practice clinical skills independently and who can efficiently work as a team in providing oral health care to the community. However, there has always been a gap between knowledge and behavioral skills when it comes to clinical training. [1]

Recently, there has been a paradigm shift in assessment tools in clinical education from assessing only theoretical aspects of learning to performance and competency-based assessment. [2] Therefore, it becomes necessary to use an assessment tool that can comprehensively and progressively evaluate trainees as they work in the workplace, allowing for constructive feedback to be given to them. [1]

Workplace-based assessment (WPBA) involves evaluating students in clinical settings with actual patients. It serves as a valuable tool for assessing various competencies, including cognitive abilities, psychomotor skills, communication, clinical management, and professionalism.[3] When implemented, these assessments enable trainees to recognize their weaknesses and contribute to the enhancement of their professional competencies. WPBAs have a promising role in bringing a holistic approach to the assessment in dental education.[4]

1.1. Rationale:

Recently, quality assurance testing was conducted with our university alumni about the curriculum and

their practical skills, and it was underlined that 33% lacked in communicating and conducting patient-specific procedures, independently. They indicated that it would be easier if the feedback were given regularly in the clinics, rather than at the end of the semester, to demonstrate their shortcomings during the clinical postings. It was felt that this could be because the process of evaluating the students' clinical work and providing feedback in the current clinical setting is not streamlined. Many trainees from other dental schools have also reported on having difficulties in conducting the independent practice. [5] This paper primarily aims to highlight the key theoretical and practical concepts regarding the use of WPBAs and their educational impact on the practice of dental trainees. The secondary aim is to explore the practical challenges and opportunities in implementing WPBAs in the dental clinical environments and to suggest recommendations to bridge the gap between theory and clinical assessment to improve the quality of dental education.

2. Theoretical Foundations of WPBAs:

Miller's Pyramid, proposed by George E. Miller in 1990, is a widely used framework in medical and dental education to conceptualize clinical competence. It illustrates a hierarchical model of assessing learners, progressing from knowledge acquisition to real-world performance. The four levels of domains, like knowledge (knows), competence (knows how), performance (shows how), and does (Action in practice) in Miller's pyramid, are used for assessing competence.[6] So, how the candidate performs and acts in real-life situations (does) is assessed by the Workplace Based Assessments (WPBAs).[7] (Figure 1)

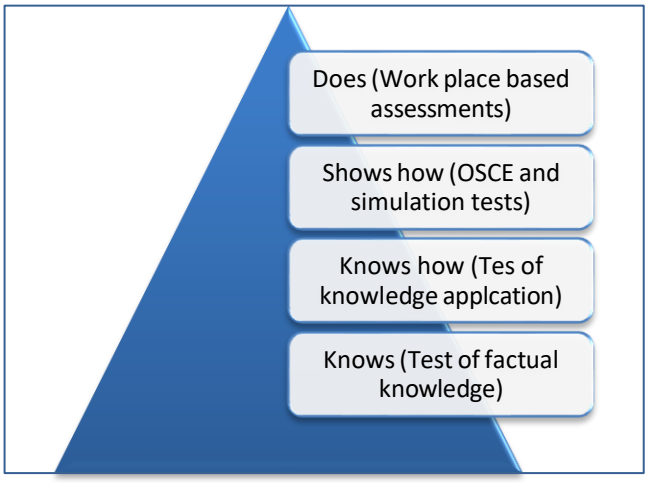


Figure 1. Workplace Based Assessments (WPBAs)

WPBAs fulfill the three basic assessment criteria that can facilitate learning in clinical education. Constructive alignment between the content, competency, and desired learning outcomes of the course, provision to give feedback to the trainees, and to guide the trainee learning towards the desired outcomes.[7]

WPBAs can regularly keep track of the progress of the learners, integrating their knowledge with clinical skills and effective decision-making in the clinical environment. This assessment also aids in assessing the behavioral modifications while interacting with the patients and other healthcare professionals.[8] Through this, there is also a provision to give feedback to the trainees about their everyday performance in clinical settings.[9]

Extensive research also supports the use of multiple assessment points across a student's educational journey, rather than relying solely on a single high-stakes, final evaluation. This approach helps ensure that learners progressively develop and demonstrate the minimum required levels of knowledge and performance.[10]

2.1. Principles of Assessment:

There are ongoing concerns about the validity, reliability, and fairness of these assessment methods in clinical education.[11]

Validity assesses whether a test accurately measures what it is intended to measure.[12] To ensure this principle, these WPBAs must be aligned with the curriculum outline and map with the learning outcomes of the program. The clinical procedures on the real-life patients have been directly observed by the assessor (DOPS) using the checklist to ensure all the procedures are being followed [13]

Reliability is the degree to which assessment results remain consistent and can be reproduced over time. It ensures that evaluations are standardized among different assessors, leading to stable and dependable results. These assessments also support the training of assessors to interpret results consistently and uniformly using the clear and detailed rubrics for assessing the procedures. [14]

Fairness is the unbiased opinions of the assessors towards the trainees, irrespective of race, gender, or ethnicity. This can be ensured by having more than 1 assessor for the same procedure with the trainee.[15, 16]

3. Key concepts in WPBAs

3.1. Authenticity in Assessment

WPBAs encompass the various assessment strategies to evaluate the trainee's encounter with

patients in the clinical settings and provide contextual feedback. The psychomotor and behavioral skills are assessed along with the cognitive domain through these assessments.[17] The "Does" level of Miller's Pyramid assesses students during real patient encounters, emphasizing clinical skills, attitudes, and behaviors essential for quality care. It involves direct observation and one-on-one, structured feedback from faculty members.[3] Strong evidence supports using multiple assessments across a student's learning journey, rather than relying on a single high-stakes exam, to ensure gradual development of essential knowledge and performance levels.[18]

3.2. Feedback and Reflective Practice

Feedback is crucial and is an integral part of this formative assessment. It promotes the students' learning by notifying them about their strengths and weaknesses and motivating them to engage in appropriate learning activities. [7] This kind of assessment falls under learning-oriented assessment (LOA) that is based on certain principles like relating assessment with course learning outcomes, involving students in active learning, and providing timely feedback to the students for supporting future learning.[19] Feedback is a major component of the adult learning theory, where it can reinforce the learner's existing knowledge and promote self-motivation. [19]

The rubric-based criteria help guide the student's reflection on their work and promote the setting of learning goals for a specific performance appraisal. This also allows the assessor to deliver honest feedback and the trainee to reflect positively.[20]

3.3. Entrustable Professional Activities

The shift toward competency-based education in the health education system has prompted the adoption of entrustable professional activities (EPAs). These were first developed by ten Cate in 2005 as a method to assess the competency of the postgraduate medical students. These were later introduced to the undergraduate medical education program in 2013. [21] EPAs function as assessment tools where multiple competencies can be assessed by the entrustable clinician to check the readiness of trainees to perform the procedures independently. [22] They provide a structured approach for task-specific assessment and play a critical role in the advancement of professional competence. These activities assess the highest level of Miller's pyramid, enabling the trainee to make competency-based judgments on clinical procedures in supervised settings.[23] Once trainees have demonstrated the competence to perform them independently, EPAs—practical, real-world tasks—can be entrusted to them.[22] According to a recent literature review, both dental trainees and their supervisors have responded positively to the early use of entrustable professional activities (EPAs) in undergraduate dental programs.[24]

4. Assessment tools in WPBAs:

Various assessment tools have been employed over past 2 decades to assess the competencies of the trainees in real-life situations through EPAs. [23] They also focus on multidisciplinary integration and feedback-based reflection for the clinical procedures. [24] The table 1 summarizes the common WPBA tools that have been used in health education to assess the clinical competencies of the trainees by the supervisors. [13]

- Group III (ES group): Teeth undergo root canal obturation using EndoSeal MTA sealer without any additional intervention.

Table 1. Assessment tools suitable as sources of information in the workplace to inform EPA entrustment decisions.[13]

Approaches	Methods	Tools
Watching	Brief and focused observation	Mini Clinical Examination exercise (mini-CEX); Direct observation of procedural skills (DOPS) (with or without video recording); in some cases *insitu* simulation (Patterson et al. 2013) or audio-based evaluation (Sanatani et al. 2020)
	Longitudinal observation	Multisource feedback (MSF) or 360^0 Evaluation
Talking	Brief conversations	Case-based discussions, Chart-Stimulated Recall, One-minute Preceptor, SNAPPS, Entrustment-based discussions
Reviewing results	Product evaluation	Entries in Electronic Health Record; Discharge letters; QI reports; Resident-Sensitive Quality Measures (RSQM)(Schumacher et al. 2018)

Mini-CEX (Mini Clinical Evaluation Exercise)

The Mini Clinical Evaluation Exercise (Mini-CEX) involves observing a trainee's direct interaction with a patient in a clinical setting. Originally introduced by Norcini et al. in medical education, it aims to assess a

trainee's competence in managing patients independently and confidently. [14] This assessment method effectively assesses the trainee's communication and empathetic skills with the patient and his team.[14] This tool includes the provision of immediate feedback, helping trainees identify their mistakes and make continuous improvements in their clinical skills. The areas of assessed competencies include history taking, physical examination, communication, decision-making skills and professionalism.[25] Mini-CEX has been proven to be a valid and reliable assessment tool. [26] Research on the use of Mini-CEX in dental education is limited, with only a few studies emphasizing its significance in disciplines such as oral radiology, oral medicine, prosthodontics, and orthodontics.[27] Table 2 outlines the steps of Mini-CEX to assess history taking, diagnosis, and treatment planning in dentistry.

Table 2. Mini-CEX process for assessing clinical skills in history taking, examination, and diagnosis.

Step	Description
1. Preparation	- Select a patient case relevant to history taking, clinical examination, or diagnosis.
	- Prepare the Mini-CEX assessment form/checklist.
2. Observation	- **History Taking:** Student gathers medical/dental history from the patient.
	- **Clinical Examination:** Student performs physical/oral examination on the patient.
	- **Diagnosis:** Student formulates diagnosis based on history and examination findings.
3. Assessment	- Examiner observes and assesses student's skills: communication, clinical, professionalism, decision-making.
4. Feedback	- Examiner provides immediate, constructive feedback including strengths, areas for improvement, and suggestions.
5. Documentation	- Examiner records scores and comments on the Mini-CEX form.
	- Student reflects on feedback and plans for improvement.
6. Follow-up	- Repeat Mini-CEX in future sessions to monitor student progress.

4.2. DOPS (Direct Observation of Procedural Skills)

Developed by the Royal College of Physicians, the Direct Observation of Procedural Skills (DOPS) is now widely incorporated into workplace-based assessments for trainees in health education across the globe.[14] Typically centered around a single procedural task, DOPS evaluates a trainee's performance during one clinical encounter. DOPS functions both as a tool for evaluation and as a method for experiential learning through direct observation in the clinical setting. An assessor and trainee may engage in several clinical sessions, each focusing on different procedures.[28] There is a paucity of research on the use of DOPS as an assessment tool in the dental education system.

An Indian study concluded that DOPS can be effectively integrated into dental student training sessions with a high rate of acceptance. However, training faculty in observation techniques and providing feedback can enhance its effectiveness. [28] Table 3 outlines the sequential workflow of the Direct Observation of Procedural Skills (DOPS) process in dental training. Each step describes key activities from selecting the procedure through to follow-up assessments, emphasizing both evaluation and learning aspects within clinical practice.

Table 3. Steps involved in the DOPS process for assessing and improving dental procedural skills.

	Steps	Description
1.	Identification of Procedure	Trainer and trainee select a specific dental procedure to be assessed (e.g., cavity preparation).
2.	Preparation	Trainee reviews procedure steps and guidelines to ensure readiness.
3.	Direct Observation	Trainer observes trainee performing the procedure on a patient during clinical practice.
4.	Assessment and Feedback	Trainer assesses performance using a structured form and provides immediate constructive feedback.
5.	Documentation	Assessment results and feedback are recorded in the trainee's portfolio or logbook.
6.	Follow-up	Additional sessions scheduled if needed to improve skills and monitor progress.

4.3. Multi-Source Feedback (MSF)

Researchers have demonstrated that feedback provided to trainees during patient encounters plays a vital role in the learning process. By encouraging reflection and self-awareness, effective feedback helps students identify their strengths and areas for improvement, thereby serving as a constant source of motivation.[29]

The primary source of immediate feedback is typically supervisors; however, feedback is also reported to come from peers, self-evaluation, and even patients. These diverse perspectives contribute significantly to the development of trainees' clinical skills—a process known as 360-degree feedback or multisource feedback (MSF).[29]

Furthermore, there have been ongoing debates regarding how trainees perceive feedback from peers and patients, and whether such feedback effectively contributes to the improvement of their clinical decision-making skills.[30] Some suggest that peer evaluation can have a positive impact on identifying weaknesses and strengths during clinical procedures.[31] On the contrary, the peer evaluation can be influenced by personal relationships, confidentiality issues, or a lack of expertise in the specific clinical procedures.[31]

Self-evaluation can initiate the self-directed learning process by helping students identify gaps in their clinical knowledge and skills during patient interactions. However, some students may undervalue their abilities and struggle to accurately assess their own clinical performance.[32]

Patients rarely offer their feedback to trainees about their subjective experiences regarding the students' ability to communicate effectively and demonstrate patient-centered care. This lack of feedback limits students' understanding of how well they engage with patients, hindering their growth in crucial areas of clinical practice such as empathy, communication, and the application of patient-focused approaches.[32]

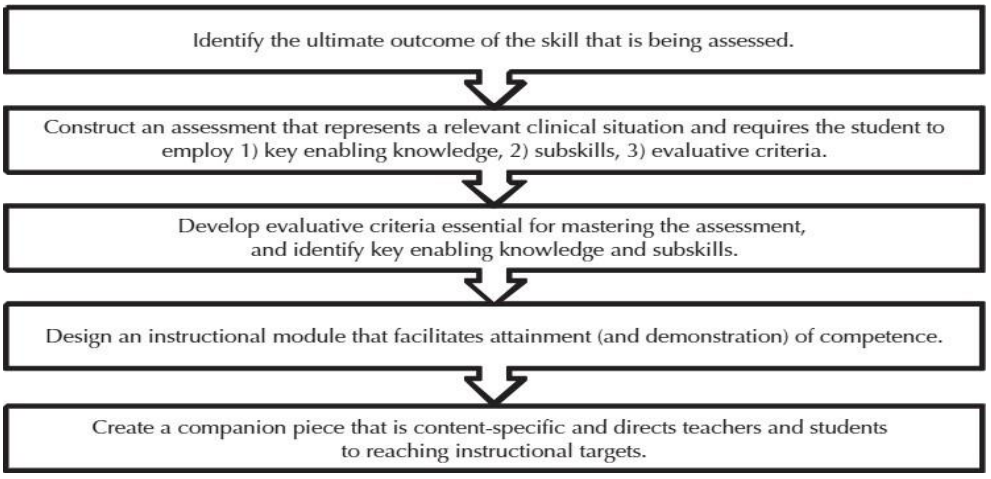
But if strategically implemented with written, customized questionnaires, MSF in a collaborative learning environment can help provide students with valuable feedback, overall enhancing the learning process.[33]

Feedback within dental education remains an underexplored area, highlighting the need to enhance the feedback process in clinical training to support the effective development of future dental practitioners.[34,35]

5. Developing Clinical Competency Assessments

Assessment of students, particularly in the healthcare education system, consists of two main domains: one focuses on evaluating the trainees' foundational knowledge and skills necessary to perform clinical procedures, while the other involves demonstrating these skills in real-life patient scenarios.[3] The development of these assessments (WPBAs) must be carefully aligned with the learning outcomes associated with the procedure, ensuring that they accurately reflect and assess the skills required in real-world clinical situations. This alignment is essential for ensuring that the assessments are both meaningful and relevant to the specific clinical scenario trainees are likely to encounter.[36] This concept has been implemented in the development of competency-based assessments within the Predoctoral Orthodontic Education Program at NYUCD, with continuous modifications and improvements since 2001.[36] Table 3 outlines the Steps for developing clinical competency assessments.

Table 3. Steps of designing the Competency based assessments



6. Supporting evidence (Global perspective on WPBAs and dental education)

An international joint meeting held in London in 2017 highlighted issues related to assessment strategies in dental education and concluded that DOPS has been the most widely accepted assessment method among various dental schools.[37] A recent study conducted at a dental school in Saudi Arabia emphasized the importance of feedback in enhancing clinical skills. DOPS was also reported to be widely used and well-accepted by trainees in dental schools. They have advised on the implementation of a tailor-made, well-designed faculty development program focused on various student assessment methods.[38] A high degree of satisfaction with the feedback provided during formative assessments has been observed among both trainees and trainers in the UK dental schools. [39] In an Indian study, Mini-CEX has been found to be a valid tool as formative assessment in improving the communication skills in orthodontic training.[40] It has been concluded by some authors that when a workplace-based assessment (WPBA) is conducted across various clinical settings, on multiple occasions, and by different assessors, it enhances both the reliability and validity of the assessment process.[28]

7. Challenges and Suggestions:

Several challenges exist in implementing Workplace-Based Assessments (WPBAs) within dental education, including insufficient faculty training, limited time availability, variability in assessor judgments, student apprehension towards the assessment process, administrative complexities, inconsistent quality of feedback, and difficulties in effectively integrating WPBAs into the existing curriculum framework. [41]

Before implementing this tool, it is essential to carefully consider and weigh the potential benefits and drawbacks for assessors, trainees, and administrative staff. Establishing best practices from the outset is crucial to avoid wasting valuable resources and to prevent the development of ambivalent attitudes toward this assessment method.[41, 42]

It is essential to provide comprehensive training in assessment for both trainers and trainees to ensure a thorough understanding of the assessment system, its methods, purposes, and applications. Such training promotes a shared understanding and consistency in the implementation of WPBAs, as well as in the application of established standards.[16]

8. CONCLUSION

WPBAs may not be appropriate for the high-stake conducts, but they can identify and remediate suboptimal performance by the clinicians during their training course. Workplace-based assessments (WPBAs) serve as a vital component in the overall evaluation of trainees, effectively supplementing more traditional assessment methods such as written or oral examinations. These assessments are specifically designed to support the development of essential clinical and professional competencies within a supervised and structured learning environment. One of the most significant advantages of WPBAs is their unique ability to capture a trainee's actual performance in real-life settings, thereby providing a direct reflection of their ability to apply knowledge in practice. When WPBAs gain popularity, there is an increasing need for continued development of the faculty and greater evidence regarding the validity and reliability of these tools, which will allow the academy to integrate this strategy into the current curricula. Nevertheless, more interventional and experimental evidence-based models are needed to determine its major educational effect on clinical education.

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Conflict of Interest

The authors declared no conflict of interest.

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ORIGINAL RESEARCH

PREVALENCE OF DENTAL CARIES AMONG CIGARETTE SMOKER CASES ATTENDING AL- AMEED UNIVERSITY DENTAL CLINICS.

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Abstract

Background: Regarding the association between the smoking and dental caries prevalence, there are multiple variable factors which can contribute directly or in another way to the increase in the prevalence of dental caries in smokers similar as the patient age, tobacco habits other than smoking, oral hygiene, drinking habits, eating habits, dental recalls and overall health. Due to that, it's delicate to conclude the correlation between a single positive factor which can causes increase in caries prevalence in smokers but the association between smoking and dental caries is well proved in aged patient groups.
Aims. this study aimed to assess the frequence of dental caries and its associated factors among cigarette smoker cases attending dental clinics in Al- Ameed university, college of dentistry, 2025.
Material and methods. In this study a total of 125 participants were examined, including 77 males and 48 females, ranging in age from 18 to 65 years, the number of smoker patient was 55 and 70 of the study sample were non-smokers. Demographic data, smoking status, and Dental caries assessment using the DMFT index for all permanent teeth, excluding wisdom teeth by a non-invasive clinical dental examination were determined for each participant.
Results. the results found that level of DMFT in females (8.96±3.90) is higher than males (7.87±3.10), but not significantly. There are no-significant differences between smokers and non-smokers regarding level of DMFT (P. value=0.432). The results found that level of DMFT in those who belonging to older age 56-65 years have higher significantly level of DMFT (14.33±3.14) compared to other age groups (P- value<0.001). The participants who freelance work have higher significantly level of DMFT (9.71±3.26) compared to other occupations (P-value<0.001). Patients had both hypertension and diabetes have higher significantly level of DMFT (11.17±4.17) than hypertension and those had no medical history at significantly less than 0.001.
Conclusions. There are limitations to this cross-sectional study. The results of which cannot establish a direct effect of cigarette smoking on the prevalence of dental caries. As such, we conclude the need for a more robust study design to ascertain whether smoking could potentially lead to increase the severity dental caries. A prospective cohort study could be a proper option.

Keywords: smoking, DMFT score, smoker, non-smoker

INTRODUCTION

Dental caries is a major healthcare problem as it's the most current complaint worldwide[1]. Nearly 100% of grown-ups are affected by dental caries [2]. World Health Organization (WHO) published a decade ago a review of global oral health status, which emphasized that despite great advancements in oral health in several countries, problems still persist[3]. Dental caries concentrates in groups with low socioeconomic status, and despite being fluently preventable, its frequence did n't significantly drop over the last thirty times [1]. Poor oral health may have a profound influence on general health; dental caries is still the most current complaint indeed in utmost industrialized countries as it affects up to 100 of both academy going children and grown-ups[4]. It not only affects oral health but also has an injurious effect on overall health and quality of life [5]. Due to the frequent consumption of sugars dental caries occurs as the biofilm microbiota that typically resides orally in homeostasis change to an acidogenic, aciduric, and cariogenic population [6]. Carious lesions have an advanced chance and prevalence of certain bacterial species Streptococcus mutans, Streptococcus sobrinus, and Lactobacilli,

insulated from advanced caries [7]. Clinically, the result of this shift can be unnoticeable or lead to a net mineral loss within the tooth's hard structures, performing in a visible carious lesion [8]. The biofilm bacteria produce organic acids, primarily lactic acid by metabolize Fermentable carbohydrates. These end products of bacterial metabolism accumulate in the biofilm, causing a pH drop and demineralization of the face subcaste of the tooth [9]. Regarding the nicotine goods on dental caries, numerous studies have been done, one of them is across-sectional epidemiological study in Sweden concluded that there was an association between smoking and oral health [10]. still, some trials have studied the effect of nicotine on Streptococcus mutans. A study conducted by Chanea et al set up that Streptococcus mutans adherence was significantly enhanced in the presence of nicotine[11]. There are multiple variable factors which can contribute directly or laterally to the increase in the prevalence of dental caries in smokers similar as the patient age, tobacco habits other than smoking, oral hygiene, drinking habits, eating habits, dental recalls and overall health [12]. Due to that, it's delicate to conclude the correlation between a single positive factor which can causes increase in caries prevalence in smokers but the association between smoking and dental caries is well proved in aged patient groups [13]. This study includes variables like patient age, gender, smoking, dental caries index, medical history, patient occupation and oral hygiene status using simplified oral hygiene index, which are the utmost document keys for dental caries development exploration. thus, this study aimed to assess the frequence of dental caries and its associated factors among cigarette smoker cases attending dental clinics in Al-Ameed university, council of dentistry, 2025.

MATERIALS AND METHODS

The project proposal was presented to the Chair of the Research Ethics Committee of Al-Ameed University College of dentistry. In accordance with international criteria, formal ethical approval was completed.

This cross-sectional study was conducted to assess the prevalence of dental caries among cigarette smoker patients attending Al-Ameed University dental clinics, Karbala, Iraq. A total of 125 participants were examined, including 77 males and 48 females, ranging in age from 18 to 65 years, the number of smoker patient was 55 and 70 of the study sample were non-smokers. The sample included individuals from various occupational backgrounds such as students, employees, and unemployed individuals. Dental caries was assessed using the DMFT index (Decayed, Missing, and Filled Teeth), which is a standardized method recommended by the World Health Organization (WHO) for measuring dental health status (i.e., “when a lesion of the tooth’s surface had an unmistakable cavity, undermined enamel, or a detectably softened floor or wall”). All permanent teeth, excluding wisdom teeth, were taken into consideration during the clinical examination (14). A non-invasive clinical dental examination was performed at the Dental Clinic of Al-Ameed university college of dentistry from February to May 2025. Clinical examinations were carried out in a dental chair under adequate lighting using a dental mirror and dental probe without radiographs by well-trained dentists. The information for each item on the questionnaire was copied to code sheets, the data was input into a personal computer, and the statistical package from SPSS-27 was used to evaluate the data. Simple statistics like frequency, percents, mean, standard deviation, and range displayed the data. A Chi-square test (X2-test) was utilized to identify the significance of qualitative data percentage differences. ANOVA analysis for calculating the least significant difference (L.S.D.) test were applied to determine the statistical significance of the data. P value of <0.05 was considered significant. L.S.D. Values were compared with values of means difference. Using Independent sample t. test to compare between two groups for numerical data. In addition, Enter Standard multiple- Linear Regression was used in this study. The P-value was considered statistically significant when it was equal to or less than 0.05.

RESULTS

Demographic characteristics of the study population

The results of this study indicate that the highest percentage (44.0%) of patients belonging to ages ≤25 years, followed by those aged 26-35 years (24.0%), 36-45 years (20.0%), 46-55 years (7.2%), while lowest percentage (4.8%) of patients are aged 56-65 years. The mean age was 31.6±12.6 (with range; 16-65) years. The gender ratio is 61.6% male to 38.4% female. The highest proportion (44.8%) of the participants were freelance work, followed by 40.0% students, 12.8% employed, and 2.4% housewives (table 1). As illustrating in table no.2, the results shows that 44.0% of participants were smokers. Regarding medical history, the majority of patients (72.8%) had no history of the disease. While smaller percentages (11.2%) of patients had hypertension and diabetes separately, 4.8% of the study sample had both. Concerning oral hygiene, 68.0% of the participants have a moderate level of oral health, 14.4% of the patients have fair and good levels of oral health, while the lowest percentage (3.2%) of the participants have bad level of oral hygiene (figure no.1).

Table 1. The distribution of patients according to demographic characteristics of the study population

		Freq.	%
Age groups	≤25 years	55	44.0
	26-35 years	30	24.0
	36-45 years	25	20.0
	46-55 years	9	7.2
	56-65 years	6	4.8
	Mean ±SD (Range)	31.6±12.6 (16-65)	
Gender	Male	77	61.6
	Female	48	38.4
Occupation	Employed	16	12.8
	Freelance work	56	44.8
	Student	50	40.0
	Housewife	3	2.4

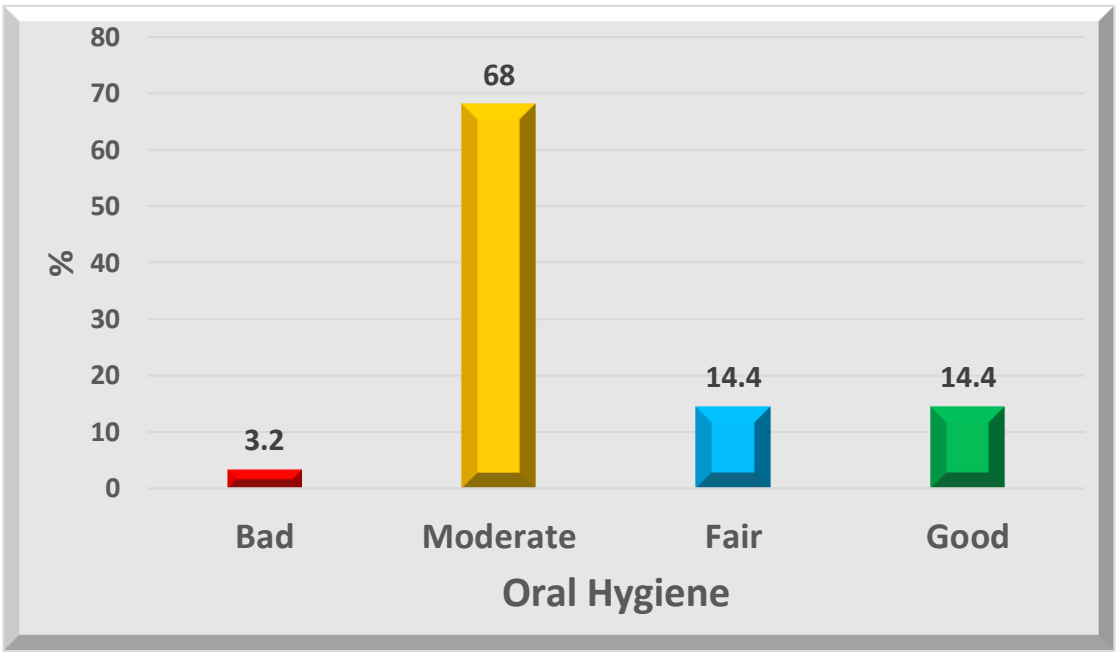


Figure 1. Oral hygiene status.

Table 2. The distribution of participants according to smoking, medical history, and oral hygiene

		Freq.	%
Smoking	Non-smokers	70	56.0
	Smokers	55	44.0
Medical history	Non	91	72.8
	Hypertension	14	11.2
	Diabetes mellitus	14	11.2
	DM and HT	6	4.8
Oral hygiene	Bad	4	3.2
	Moderate	85	68.0
	Fair	18	14.4
	Good	18	14.4

In table no.3, the results of this study indicates that the mean of DMFT was 8.29±3.46 with ranged (3-20).

Table 3. Mean number of Decayed, Missing, and Filled Permanent Teeth (mean DMFT)

		DMFT		
		Mean± SD	Range	P-value
Gender	Male	7.87±3.10	17.00	0.087 NS
	Female	8.96±3.90	15.00	
Smoking	Non-smokers	8.07±3.67	15.00	0.432 NS
	Smokers	8.56±3.17	17.00	

In Table 4, the results found that level of DMFT in females (8.96±3.90) is higher than males (7.87±3.10), but not significantly. There are no-significant differences between smokers and non-smokers regarding level of DMFT (P. value=0.432).

Table 4. The comparison between the levels of DMFT according to gender and smoking status

Descriptive Statistics for (Mean number of Decayed, Missing, and Filled Permanent Teeth (mean DMFT)					
	N	Mean	SD	Minimum	Maximum
DMFT	125	8.29	3.46	3.00	20.00

Independent sample t. test

As shown in table 5, the results found that level of DMFT in those who belonging to older age 56-65 years have higher significantly level of DMFT (14.33±3.14) compared to other age groups (P- value<0.001).

Table 5. The comparison between the levels of DMFT according to Age groups, Occupation, Medical history, and oral hygiene

		DMFT			Post hoc (LSD)
		Mean± SD	Range	P-value	
Age groups	≤25 years	7.00±3.40	17.00	<0.001	1.43
	26-35 years	8.07±2.73	11.00		
	36-45 years	9.28±2.35	8.00		
	46-55 years	10.11±3.41	10.00		
	56-65 years	14.33±3.14	9.00		
Occupation	Employed	7.13±2.06	7.00	<0.001	2.01
	Freelance work	9.71±3.26	15.00		
	Student	7.10±3.56	17.00		
	Housewife	7.67±1.53	3.00		
Medical history	Non	7.56±3.17	17.00	<0.001	1.81
	Hypertension	9.36±2.53	8.00		
	Diabetes mellitus	10.71±4.01	15.00		
	DM and HT	11.17±4.17	11.00		
Oral hygiene	Bad	7.75±3.30	7.00	<0.001	3.02
	Moderate	9.28±3.59	17.00		
	Fair	6.06±1.70	7.00		
	Good	5.94±1.63	6.00		

One-way ANOVA analysis

The participants who freelance work have higher significantly level of DMFT (9.71±3.26) compared to other occupations (P-value<0.001). Patients had both hypertension and diabetes have higher significantly level of DMFT (11.17±4.17) than hypertension and those had no medical history at significantly less than 0.001.

Finally, fair and good levels of oral hygiene is associated with lower significant level of DMFT compared to other categories (P- value <0.001). In Table 6, the current study found that older age (B=0.426) and females (0.274) are associated with a high level of DMFT. While the good health of oral (-0.235) is associated with a low level of DMFT. As for other variables, there was non-statistically significant relationship between variables such as occupation, and smoking at significantly level >0.

Table 6. Enter Standard multiple- Linear Regression for some variables associated with DMFT

Coefficientsa						
Model	Unstandardized Coefficients	Standardized Coefficients	T	P-value	95.0% Confidence Interval for B	
	B	Beta			Lower Bound	Upper Bound
(Constant)	2.563		1.326	0.187	-1.264	6.389
Age groups (older age)	1.257	0.426	4.361	<0.001	0.686	1.828
Gender (Female)	1.936	0.274	2.523	0.013	0.416	3.456
Occupation	0.596	0.125	1.325	0.188	-0.294	1.487
Smoking (Yes)	1.271	0.183	1.662	0.099	-0.243	2.785
Oral hygiene (good)	-1.052	-0.235	-2.913	0.004	-1.766	-0.337
a. Dependent Variable: DMFT						

Statistical Analysis

The information for each item on the questionnaire was copied to code sheets, the data was input into a personal computer, and the statistical package from SPSS-27 was used to evaluate the data. Simple statistics like frequency, percents, mean, standard deviation, and range displayed the data. A Chi-square test (X2-test) was utilized to identify the significance of qualitative data percentage differences. ANOVA analysis for calculating the least significant difference (L.S.D.) test were applied to determine the statistical significance of the data. P value of <0.05 was considered significant. L.S.D. Values werecompared with values of means difference.

Using Independent sample t. test to compare between two groups for numerical data. In addition, Enter Standard multiple- Linear Regression was used in this study. The P-value was considered statistically significant when it was equal to or less than 0.05.

DISCUSSION

In our research we have a significance between diabetic and hypertensive patients and DMFT score and this is consistent with many studies for example a systematic review indicated that patients with diabetes had significantly higher DMFT scores compared to non-diabetic individuals, emphasizing the impact of systemic health on oral conditions [15], A study found that hypertensive participants had a mean DMFT score of 15.80, significantly higher than the 13.62 observed in non-hypertensive individuals ($p < 0.001$) [16]. Regarding Gender Differences in DMFT Scores we have a relatively connection between DMFT score and female but no significance also there are many research support this fact one of them is a retrospective analysis showed that females exhibited higher DMFT scores than males, particularly in higher ranges, although the results were statistically insignificant [17]. There is high significance (<0.001) in our study among different age groups and DMFT score specifically in older age group, many studies support that where they show that older patients frequently have elevated DMFT scores, with averages reported as high as 15.5 in certain populations [18]. Regarding relation between oral hygiene and DMFT score there is a significance (0.004) and many studies prove our results like a significant correlation exists between age and poor oral hygiene, leading to higher DMFT scores in older age groups [19]. For the main part of our study which is the association between the smoking and dental caries prevalence, there are multiple variable factors which can contribute directly or in another way to the increase in the prevalence of dental caries in smokers similar as the patient age, tobacco habits other than smoking, oral hygiene, drinking habits, eating habits, dental recalls and overall health [12]. Due to that, it's delicate to conclude the correlation between a single positive factor which can causes increase in caries prevalence in smokers but the association between smoking and dental caries is well proved in aged patient groups [13]. Our study showed no significance in smoking effect on dental caries prevalence and this is conflict with many studies which revealed correlation [20,21] also there are early reports in literature which suggests that smoking actually reduces dental caries [22].

CONCLUSION

There are limitations to this cross-sectional study. The results of which cannot establish a direct effect of cigarette smoking on the prevalence of dental caries. As such, we conclude the need for a more robust study design to ascertain whether smoking could potentially lead to increase the severity dental caries. A prospective cohort study could be a proper option.

DECLARATIONS

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Competing Interests

The no competing interests

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ORIGINAL RESEARCH

EVALUATION OF THE TRANSFER STRENGTH OF ORTHO-ACRYL AS A REPAIR MATERIAL FOR ACRYLIC DENTURE BASE

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Abstract

Background: A significant clinical concern is the acrylic resin dental plate basis fracture, which is a key prosthetic issue for both patients and dentists. Commonly, dentists repair denture base fractures using a repair material that has distinct properties.

Obective: The purpose of this paper is to investigate the transverse durability of heated-cure acrylic resin under repairing via auto-polymerizing acrylic resinous viscous substance and Ortho-acrylic resin materials.

Materials and Methods: Thirty transverse bond strength test specimens were prepared and fell into three groupings counting on the type of repair material used. The control group consisted of intact heated-cure acrylic resin samples made for testing. The Ortho-acrylic specimen group, on the other hand, was created using a doughing technique and cured using water under air pressure and continual heating with Ivomat. While Group 3, repairs were conducted using auto-polymerizing acrylic resin. The three-point bending transverse strength test was made using an Instron Universal.

Results: The controlling group (heat) uncovered a greater mean value in comparison to the other groupings; yet, the cold group demonstrated the least value of transverse bond durability. The variance among all groups is uniform, and the one-way ANOVA indicates that the significance value is more than 0.05.

Conclusion: The minimum transverse durability for the heat-polymerized acrylic resin dental plate basis materials ought to be at least 65 MPa. The current work found that the control and Ortho-acrylic groups exhibited transverse strengths above 65 MPa. In this investigation, the Ortho-acrylic repair materials were applied by first layering a powder, followed by a layer of fluid, using gentle pendulum movements. This approach has the potential to lengthen the time it takes for the monomer to spread and cover the repaired surface, which may improve the transverse durability of the substance.

Keywords: Heat-cured acrylic, Cold-cured acrylic, Ortho-acrylic, Transverse strength

INTRODUCTION

Unfortunately, fracturing the acrylic resin dental plate base is a major prosthetic issue for both patients and dentists[1]. The failure of the dental plate base material occurs during function, both outside and inside. Continuous flexing of the dental plate base in the one's oral cavity mouth leads to failure. As a result of crack propagation, this causes a midline fracture. While outside failure occurs when dropped on a hard surface [2].Fracture denture bases are frequently repaired because reconstructing a new dental plate is a costly and timewasting method[3]. The ultimate goal of dental plate repair is to prevent more fractures, so how good the dental plate repairs counts upon strong viscosity among the denture base materials as well as the repair material. Various criteria influence the selection of repair materials, including the repair's transverse strength, color, ease of use, speed, cost-effectiveness, and the level of dimensional accuracy required[4]. Researchers have proposed various materials for repairing fractured denture bases. For instance, there are acrylic resinous substance that are heat-polymerized, auto-polymerized, and light-polymerized[5]. However, in the repairing operation, auto-polymerizing resins are usually chosen

as they are cheap, easy to use, and don't take long to dry[6]. Although acrylic resin materials have advantages like color matching ability, dimensional stability, low cost, easy manipulation, and light weight, they also have disadvantages such as low fractural strength, impact strength, and resisting low tiredness[7]. Despite the limited research on the transverse strong point of heat-cured acrylic resinous substance repair using various materials, this study examined the transverse durability of heat-cured acrylic resins got repairing by using auto-polymerizing acrylic resins and Ortho-acrylic resinous viscosity substance ingredients.

2. MATERIALS AND METHODS

2.1. Acrylic specimen's preparing

Used 3D image software and a 3D milling machine to make a metal pattern in sake of the transverse bond durability test, following ADA properties No. 12, 1999. The pattern was 65 mm length, 10 mm width, and 2.5 mm thickness, (Gungor et al., 2017), shown in (Fig. 1.)

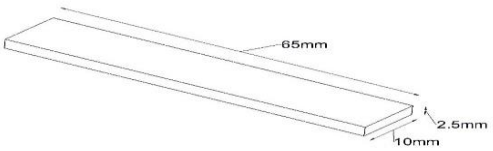


Figure 1. Diagram of 3D image software design of transverse bond strength specimens test .

A silicon mold was used to facilitate the test specimen processing. The silicon mold was prepared by using a rectangular metal tray with scopes of 76 mm in length, 70 mm in width, and 10 mm in depth, respectively (Shihab and Hussein, 2014). The steel tray was used to prepare an even, symmetrical, and homogenous block of silicon for all tested materials (Agarwal et al., 2019). The silicon was blended based on the producer's guidelines and filled the metal tray with it evenly; after that, the metal patterns were entrenched in the silicon (Fig. 2).

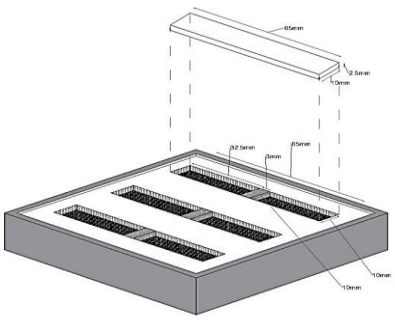


Figure 2. Diagram showing the facilitation of the test specimens processing.

Then flasked the silicon mold containing the specimens using a dental stone (Hamad, 2015b), and then carefully removed the metal patterns from the mold. To make a repair space for the specimens, use a metal spacer bar with scopes of 3.0 x 10.0 x 2.5 mm3 and place it in the core of repairing space for standardization (Arioli Filho et al., 2011). Only groups 2 and 3 received the metal spacer bar, while the intact heat-cured acrylic resin specimens (control group) did not receive it (AlQahtani and Haralur, 2020; Kostoulas et al., 2008). Following the producer's guidelines, we mixed the heat-cured acrylic resin, packaged it into the molds, and then used hydraulic pressure (OL57 F.lli Manfredi 40060, SanSecondo diPinerolo, Italy) to make the flasks compressed under 8200 kPa for half an hour. We cured the acrylic resin in a thermostatically managed acquatic bath (Kavo EWL 5501; Kavo Elektronische GmBH, Warthausen, Germany) at 70 °C for 8 hours. It is allowed for the denture flasks to cool down to normal temperature (23 ± 2 °C) (Bural et al., 2010; Mahajan et al., 2014). We removed the acrylic specimens and finished them with 200, 600, 1500 grit sillicon carbide paper (Norton, Comerciale Técnica de Abrasivos Ltda., Campines, SP, Brazil), using continuous coolant water to remove surface excess material and irregularities. We then finalized the polishing with a polishing machine (Ayaz et al., 2014). We measured all the specimens using a digital caliper and then stockpiled them in the incubator at 37 °C in distilled water for 28 days to achieve water saturation, in accordance with ADA specification No. 12, 1999 (Aditama et al., 2019).Clean the acrylic resin samples ultrasonically with distilled water, dry them with a clean tissue, and then let them air dry for 10 seconds. This is after distilled water storage (Faltermeier et al., 2007). The intact heated-cure acrylic resin samples (control group) were ready for testing. The repaired specimens fell into two groupings, every single grouping had 10 samples, and then returned to their respective repair indications in the silicon mold after taking out the space bar. The two halves of the samples got repairing by two various acrylic resins. In grouping (2), the repair was finished. Ortho-acrylic was made based on a doughing technique and cured with DW under constant heat and air pressure (Ivomat) (Sabir and Omer, 2019). The air pressure and cure time were set according to manufacturer recommendations from Orthocryl Dentaurum, Germany, with parameters at 2 bar, 45 °C for 15 min (Hassan et al., 2019). Group (3) performed the repair using auto-polymerizing acrylic resins, mixing the P/L ratios of 10 gm per 5 ml according to the manufacturer's recommendations (Nagai et al., 2001). Once the surfaces of the auto-polymerizing resin repair materials lost their glazes, we manually packed them in the repair spaces, slightly overfilling them to let polymerization shrinking and facilitate conclusion. The polymerization was performed in a pressure pot that contained water at 45◦C and 2 bar pressure for 15 min.

This procedure was carried out to optimize the physical attributes and systematize the material's amount used in the repair (Kopperud et al., 2011). After setting the samples and removing them from the mold, excess was removed during polishing and concluding, and then the thickness and diameter of the samples were under measuring sporadically by the use of digital Venire calipers. The samples are stored at 37 °C for 48hrs in distilled deionized water (Saen-Isara et al., 2013).

2.2. Transverse test evaluation

Using the Instron universal test machine (Instron UTM, Model: 5569, U.K.), we tested the three-point bending transverse strengths by using 100 kgf at a fixed speed of 5 mm/minute in specimen's center (repairing area) until the fracture occurred (Mamatha et al., 2020). The maximal load was reported down in N and used to calculate the transverse strength according to the following equation: T = 3PI/2bd2 Mpa, where T = transverse durability (N/mm2), P = maximal load (N), L = space among the support (length of the span) (mm), b = width of the specimen (mm), and d = depth or thickness of the specimen (mm) (Furnish et al., 1983).

2.3. Microscope Analysis

Naji (2020) conducted a study that involved the examination of specimens that had fractures and underwent repair. The objective was to detect the failure modes of different types of resin materials using a polarized microscope. (Fig. 3.A,B,C).



A B C

Figure 3. Failure mode images of transverse bond strength for all groups
A: Controlling group, B: Ortho group, C:Cold acrylic group.

3. RESULT

The current datawork were analyzed by one-way ANOVA and LSD tests were adopted to define the means, revealing statistically significant differences in Transverse robustness groupings. The significance level as set at 0.05. The descriptive data for the transverse robustness test are unveiled in table (1) and fig (4). The group with maximal mean value was reported in control group A, (111.00 ± 21.354), followed by ortho group (69.60 ± 11.247), while cold group had the lowest mean value (39.20 ± 12.191).

Table 1. Descriptive data for transverse strength (Mpa) for entire groups under testing

Transver strength	N	Mean (Mpa)	Std. Deviation	95% Confidence Interval for Mean		Minimum	Maximum
				Lower Bound	Upper Bound		
Control group (Heat)	10	111.00	21.354	95.72	126.28	75	135
Ortho group	10	69.60	11.247	61.55	77.65	52	82
Cold group	10	39.20	12.191	30.48	47.92	30	68
Total	30	73.27	33.506	60.76	85.78	30	135

Nonetheless, Table 2. uncovered a one-way (ANOVA) for the transverse robustness of numerous groupings. There was a statistically significant difference among the mean durability of the three groupings as specified by a one-way ANOVA test.

Table2. One-way ANOVA test for transverse durability among and within entire groupings.

Transverse strength	Sum of Squares	df	Mean Square	F	Sig.
Among Groups	25977.867	2	12988.933	53.298	.000
Within Groups	6580.000	27	243.704		
Total	32557.867	29			

* Mean difference significant at 0.05.

LSD- transverse strength

A level of significance of 0.05 was applied to the least significant difference (LSD) test to compare the means of both groups.

The results of the test indicated that there was a significant mean difference ($p < 0.05$) among group (controlling) and group (ortho); similarly, there was significant mean difference ($p < 0.05$) between group ortho and group cold acrylic, as presented in table 3.

Table 3. LSD analysis for transverse strength of all groupings.

(I) grouping	(J) grouping	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Control group (Heat)	Ortho group	41.400*	6.981	.000	27.08	55.72
	Cold group	71.800*	6.981	.000	57.48	86.12
Ortho group	Control group	-41.400*	6.981	.000	-55.72	-27.08
	Cold group	30.400*	6.981	.000	16.08	44.72
Cold group	Control group	-71.800*	6.981	.000	-86.12	-57.48
	Ortho group	-30.400*	6.981	.000	-44.72	-16.08
*. The mean difference is significant at the 0.05 level.						

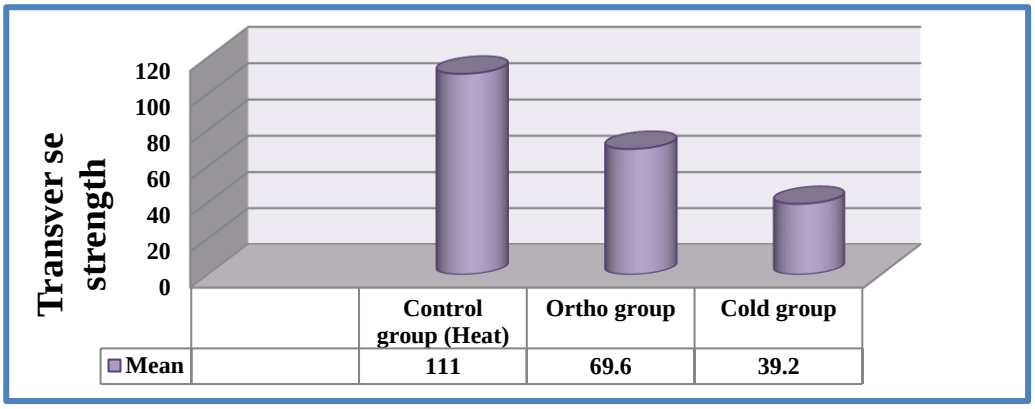


Figure 4. A bar graph illustrating the mean distribution of transverse strength (Mpa).

Figure 5, shows that cold group has extreme value that non-consistent with other values for other groups.

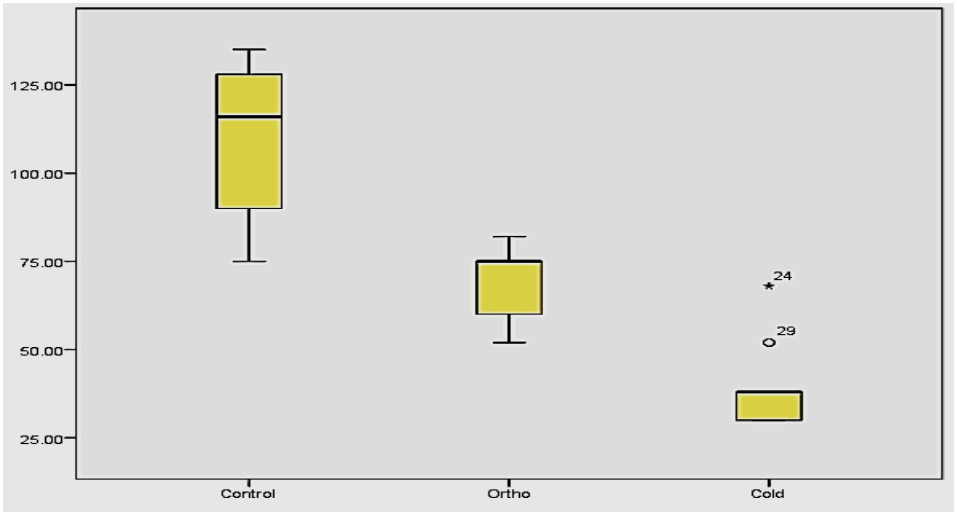


Figure 5. Plot of Boxplot of all groups.

Table 4. shows the variance between all groups is homogenous, and one-way analysis of variance with Sig. value is greater than 0.05.

Table 4. Testing Variance Homogeneity of all groups.

Testing Variances Homogeneity			
Levene Statistic	df1	df2	Sig.
3.101	2	27	.061

4 DISCUSSION

In clinical practice, denture fractures are a frequent occurrence. The denture is repaired by inserting novel substance among the fractured areas. In order to mitigate the bulk of the repairing stuff and, as a result, mitigate the polymerization shrinkage, the repairing position dimension was maintained at 3mm (AlQahtani and Haralur, 2020). The new material's bonding with old materials relies on different factors like the double bond patency for more polymerizations and designing the fracture site for repair (Syed Shujaulla, 2019) Period of time needed to make the repairs, transverse strengths achieved with the repair material as well as the degree whereby dimensional precision is obtained in repairing (Arioli Filho et al., 2011). The aiming behind our experiment was to assess the transverse power of dual different kinds of acrylic resin used for repairing rectangular samples. The findings of our investigation indicated that all the repaired groups demonstrated transverse values that were less than these seen in intact samples (controlling group). The test group revealed that the heat-cured acrylic resin (control group) got the greatest sound transverse power value, with a mean of 111 MPa. This finding is consistent with previous research (Arioli Filho et al., 2011). Then comes Ortho-acrylic resin, which has a mean value of 69.6 MPa, and the chemically auto-polymerized resin (cold group), which has a mean value of 39.2 MPa. Based on (ISO) Speci-No 20795-1, the needed transverse durability for the heat-polymerized acrylic resin dental plate base ssubstances ought to be no less than 65 MPa. The paper accepted the hypothesis by finding that the acrylic resin materials in the control and ortho groups had transverse durability higher than 65 MPa, leading to the development of a new acrylic resin material called ortho-acrylic, which can serve as a repairing substance for acrylic dental plate bases. The transverse durability of the heated-cured acrylic resin (controlling group) differed from that of the ortho-acrylic and auto-polymerized resin groups, likely due to variations in the chemical microstructure of three kinds of acrylic resin (heat, cold, and ortho-acrylic). Additionally, changes in the processing method after adding new material (repair materials) to the old material for further polymerization, as well as differences in the polymer families, contributed to the last two groups' more elastic behavior and their lower final strength values of 69.6 and 39.2 MPa. We can attribute these differences between groups to the control group's higher polymerization temperature, which could potentially boost converting rate of monomers into polymers, resulting in reduced residual monomer levels and a rise in glass temperature. (Tg) refers to the temperature at which resins transition from being brittle and glassy to becoming rubber-like. Several works uncovered that heat-cured acrylic resin exhibits lessened penetrability due to the internal creation of heat that breaks down benzoyl peroxide molecules into free radicals. However, in the current study, the auto-polymerizing repair group showed the lowest mean transverse strength value compared to the controls, which was in line with the outcomes by (Arioli Filho et al., 2011). Prior studies have indicated that denture bases repaired with auto-polymerized resin resins exhibit around 60–65% of the strength of nonrepaired PMMA acrylic resin. (AlQahtani and Haralur, 2020). Cold-cured acrylic resin polymerization is not as whole as that attained via a heated-cure system, which causes greater degrees of residual monomer. These nonreacted monomers serve as potential tissue irritants and plasticizers, resulting in higher transverse deflection values and lower transverse strength (Muhsin, 2009, AlQahtani and Haralur, 2020, Gosavi et al., 2010). Furthermore, porosity in a cold denture's base materials can occur after polymerization (Gungor et al., 2017). The residual monomer porosity and content have an impact on an acrylic resin's mechanical and physical properties (Ayaz et al., 2014). Azzarri said that the leftover monomers serve as plastic makers, lowering the interchaining durability of the polymers. This changes the acrylic resins' physical and mechanical properties and their ability to work with living things. Various factors, such as the double bond patency for multiple polymerizations, influence the bonding of the new material with the old material. The molecular weight of the unpolymerized molecule, residual monomer levels, degree of chain branching, polymer chain length, cross-linking and cross-link density within the molecule, and

existence of plastic makers and/or fillers specify the physical-mechanical attributes of polymers. The addition of plasticizers is used to make a lenient, extra resilient polymer and to reduce the polymer's glass-transition temperatures (Tg); thus, materials that are normally rigid at specific temperatures can become more flexible. In spite of ortho-crylic and cold cure acrylic resin in the same polymer families, a significant differences between the two group may be related to their difference in the method of application of the repairing materials in the fracture site, that the forte related to repaired materials transverse bond to denture basis grew significantly with chemical treatments (monomer, acetone, and chloroform), these chemicals might be scratching the surface by changingover the morphology and substance attributes of the materials. Chemicals lead to sharpness of the surface like pits, split which enhanced the bond of the under repairing stuff (Hamad, 2017). The ortho-crylic repair materials in this study were applied using the alt-and-pepper technique: apply first a layer of powder (polymer), then a layer of fluid (monomer), and continue applying alternate layers of polymer and monomer in slight pendulum movements. This technique may cause monomer infiltration into the cracks and pits, and an increased wetting duration by monomer for fixed surfaces can improve the transverse strongpoint.(Polat et al., 2013, Rached and Del-Bel Cury, 2001). They proved that using chemicals to treat the surface increased the repairing strength and could also increase the transverse strength. This was because the monomer could get into cracks and pits and make the repaired surfaces wetter for longer.

DECLARATIONS

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Competing Interests

The no competing interests

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ORIGINAL RESEARCH

POST-OBTURATION PAIN EVALUATION AFTER NON-SURGICAL DEBULKING OF PERIAPICAL PATHOSIS AND INTRACANAL INJECTION OF GROWTH HORMONE (AN IN VIVO STUDY)

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Abstract

Background: This study aimed to evaluate and compare post-obturation pain following non-surgical debulking of periapical pathosis using XP-Endo Finisher and the intracanal injection of Growth Hormone in single-rooted necrotic teeth that were obturated using EndoSeal MTA sealer.

Methods: This single-blind randomized controlled clinical trial registered fifty-four patients presenting with necrotic, mature, permanent, single-rooted teeth associated with periapical lesions measuring 2–4 mm in diameter and classified as score 3 on the Cone Beam Computed Tomography Periapical Index (CBCTPAI). Following comprehensive clinical and radiographic assessment, participants were randomly assigned into three equal groups (n = 18). In Group I (GH-ES), growth hormone (SEDICO, 6 October, Egypt) (GH) was applied periapically prior to root canal obturation with EndoSeal MTA (Maruchi, Wonju, South Korea) (ES) sealer, Group II, (XP-ES) non-surgical debulking of periapical pathosis using XP-Endo Finisher (FKG,Dentrie Switzerland) file was done prior to root canal obturation with EndoSeal MTA (ES), whereas in Group III (ES), obturation was performed using ES sealer alone. Preoperative pain levels were assessed using the Arabic-translated version of the Verbal Descriptor Scale (VDS). Postoperative pain grades were noted at baseline (preoperatively), and at 6, 24, 48, and 72 hours, as well as 1 week after treatment.

Results: A statistically significant difference was observed between the three groups at 6, 24, and 48 hours postoperatively (p =0.001, 0.001, 0.005 respectively), with the GH-ES group showing lower pain scores and XP-ES group showing the highest pain scores. However, no significant differences were noted at 72 hours or at one week. All groups exhibited a progressive and significant decrease in pain scores over time (p =0.001).

Keywords**:** Growth Hormone, EndoSeal MTA sealer, XP-Endo Finisher, Non-surgical debulking, Bioceramics, Postoperative pain.

INTRODUCTION

Postoperative pain may appear after the endodontic therapy, within hours and last for many days [(i)]. According to reports, the prevalence of endodontic discomfort following treatment ranges from 3 to 58% [(ii,iii)], with fewer than 12% of the population experiencing severe pain following therapy [(iv)]. To avoid exacerbating pain throughout the postoperative phase, pain management must be a complementing phase of dental therapy [(v)]. One of the primary causes of endodontic postoperative severe pain that follows chemical, mechanical, or microbiological damage to periapical tissue was previously believed to be acute inflammation [(vi)]. Nevertheless, the various phases of therapy, from diagnosis to post-obturation, might affect the incidence of pain. Root canal sealers may cause local inflammation, due to their direct interaction among the periodontal tissues via the apical foramina and lateral canals, which possibly lead to post operative pain and impaired healing process in the periodontium [(vii)].

Pain evaluation is difficult because pain experiences are subjective and multifaceted, making them difficult to standardize or quantify. Additionally, it is impacted by several factors; psychological, physical, behavior and personality factors. Because of that, different pain scales were developed in this type of research to measure the degree of pain, direct treatment choices, and track efficacy. The common pain scales used in endodontics are: Visual Analog Scale (VAS), Numerical Rating Scale (NRS) and Verbal Descriptor Scale (VDS). The VDS is easy to finish since it is brief and straightforward. However, it is appropriate for all

patient groups and may be employed to quantify acute as well as chronic pain [viii,ix,x]. In 2010, Wang et al.[i] modified the VDS by adding a collection of terms that characterize various pain intensity in which each pain level was given a score from 0-10.

Calcium silicate-based endodontic sealers are thought to produce less inflammatory mediators and have minimal cytotoxicity [xi] and they are thought to reduce postoperative pain [xii]. The premixed injectable bioceramic sealer EndoSeal MTA (Maruchi, Wonju, South Korea) has attracted interest because of its ease of use and favorable results. The calcium silicate, calcium aluminates, and calcium sulfates that make up EndoSeal MTA have a number of benefits, including elevated alkalinity, excellent flowability, and biocompatibility [xiii]. Furthermore, unlike previous bioceramic sealers, it exhibits stability in dimensions throughout a 30-day trial period [xiii]. Several investigations conducted on animals in-vitro as well as in-vivo have demonstrated the advantageous physiobiological characteristics of bioceramic sealers [xiv,xv]. Nevertheless, despite their high attraction, there aren't many clinical research on how bioceramic sealers affect postoperative pain [vii].

XP-Endo Finisher (FKG Dentaire SA) has been introduced as an adjunctive approach to improve the effectiveness of irrigation and disinfection by reaching larger areas of the root canal walls that conventional methods are thought to miss, thereby maximizing bacterial removal and improving the healing of periapical pathosis [xvi]. Recently, another minimally invasive, non-surgical method was introduced that allows removal or debulking of chronically inflamed periapical tissues through a root canal access: a rotary instrument is inserted into the periapical area to mince the tissues, followed by aspiration using a large-gauge needle. This procedure is considered less traumatic than open-flap apical surgery [xvii,xviii, xix].

Growth hormone (GH) plays a complex role in postoperative pain. While it's secreted in response to surgical stress and trauma, potentially contributing to pain pathways, it also plays a role in tissue repair and can have analgesic effects. Research indicates that GH and related signaling molecules are implicated in both the onset of pain and pain relief [xx,xxi,xxii,xxiii].

To the best of our knowledge, not much research has examined how non-surgical debulking of periapical pathosis or growth hormone affects pain following obturation. The objective of the current study was to compare the effect of obturating root canals with EndoSeal MTA, with or without pre-application of Growth Hormone, or with non-surgical debulking of periapical pathosis on post-obturation pain. The null hypothesis of this research was that there would be no variation in post-obturation pain across teeth obturated with ES, with or without pre-application of GH, or with non-surgical debulking of periapical pathosis.

MATERIALS AND METHODS

Study design and sample size determination: This single-blind randomized clinical trial received ethical approval from the Ethical Committee of the Faculty of Dental Medicine, Al Azhar University for Research on Human Subjects (EC Ref No. 898/262) and was registered at *ClinicalTrials.gov* (NCT06433375). The required sample size was determined utilizing the G*Power software [xxiv], according to the prior research by Khandelwal et al. [xii], with a two-tailed α-error probability of 0.05 and a study power of 95%. The analysis denoted the lowest of 14 patients per group. To compensate for potential dropouts during the trial, the sample size was increased to 18 patients per group.

Patient selection: Out of one hundred, fifty-four healthy male patients between the ages of 18 and 40 were chosen from out-clinics visiting the Endodontic Clinic of the Faculty of Dental Medicine, Al-Azhar University Boys, Cairo, Egypt, to be assigned into the present research. After thorough clinical and radiographic assessments, patients with periapical lesion related to permanent single rooted necrotic teeth of a 2 to 4mm diameter and score 3 according to the Cone Beam Computed Tomography Periapical Index Score (CBCTPAI) [xxv] were selected. Each participant signed an informed consent document following exploring all steps of the research, suspected complications and follow-up then underwent Preoperative pain measurement was performed utilizing a translated modified verbal descriptor scale (VDS) into Arabic according to Hagras et al [xxvi] by the patient at preoperatively, 6, 24, 48, 72 hours as well as 1week after treatment. Only patients scoring between 0 and 6 were assigned into this research.

Randomization and grouping of patients: (Figure 1)

Participants were split into three groups randomly (n = 18) using research randomizer software (www.randomizer.org).

- Group I (GH-ES group): Teeth undergo Growth Hormone application before root canal obturation utilizing EndoSeal MTA sealer.
- Group II (XP-ES group): Teeth undergo non-surgical debulking of periapical pathosis using XP-Endo Finisher file before root canal obturation utilizing EndoSeal MTA sealer.
- Group III (ES group): Teeth undergo root canal obturation using EndoSeal MTA sealer without any additional intervention.

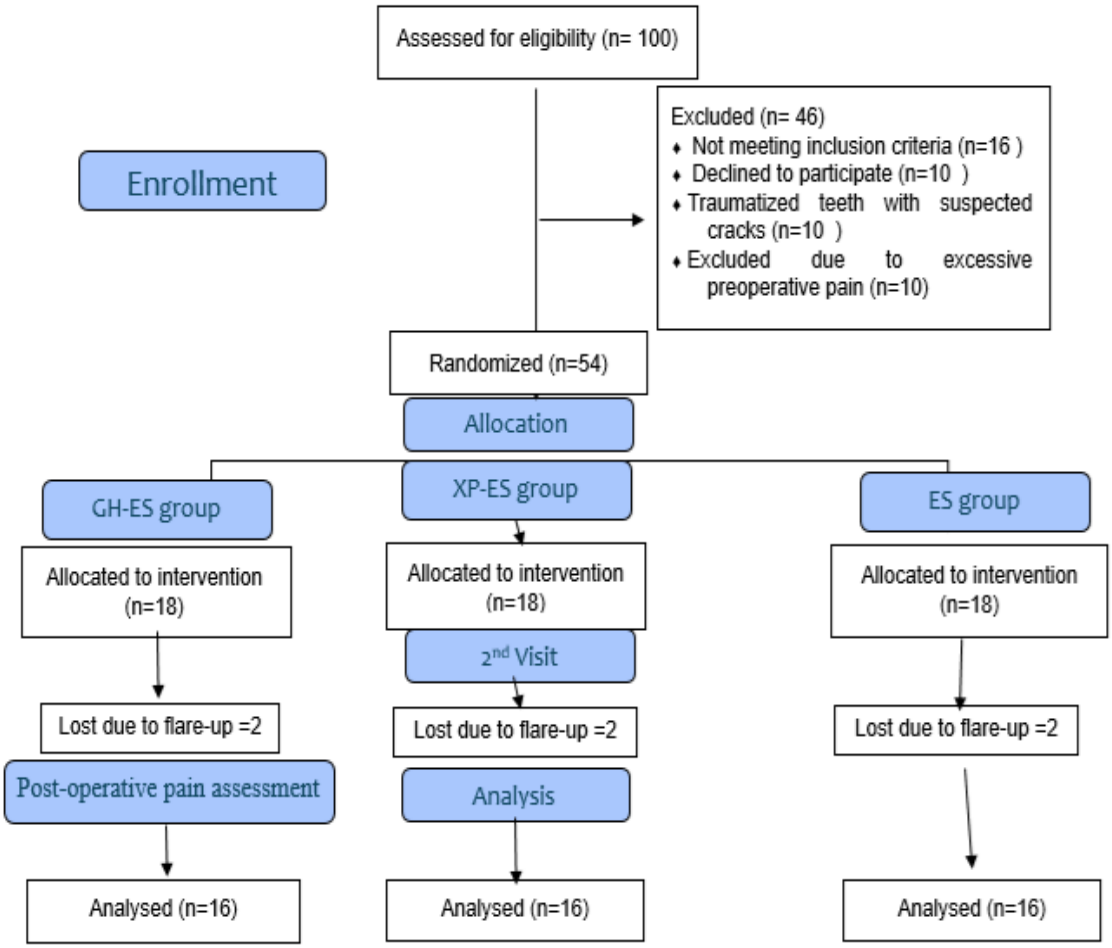


Figure (1): Patients Flow Diagram

Root canal treatment Procedure:

-During the first visit: Teeth in all groups were received to a conventional multiple endodontic therapy as follows:

The tooth was anesthetized, isolated using rubber dam, all dental caries or prior fillings were eliminated, and the crown was filled by composite resin restoration. Access cavity was prepared; the root canal was negotiated using #10 ISO K-file. Utilizing the apex locator device (Root ZXII, Morita, Japan), the working length was verified to be 1 mm below the radiography apex.

Root canal instrumentation was carried out using RACE EVO (FKG, Dentaire, Switzerland) up to a #35/.04 as a master apical file at 800rpm/ 1.5 Ncm as follow: Race EVO #15/0.4 (RE1) was used to create a glide path till reaching the working length, followed by irrigation and patency confirmation using #10 K-file. Then, size #25/0.4 (RE2) was used for initial shaping till reaching the working length, followed by irrigation and patency confirmation using #10 K-file. After that #30/0.4 (RE3) was used till reaching the working length, followed by irrigation and patency confirmation using #10 K-file. Finally, size #35/0.4 was used as master apical file.

Irrigation protocol of the root canals was done between each file using 3 ml 5.25% sodium hypochlorite solution followed by 3 ml 17% Ethylenediaminetetraacetic (EDTA) solution with intermittent 3 ml normal saline solution between them and as a final rinse of the canals. Root canals were then dried with sterile paper points equivalent to the size of the master apical file, the pulp chamber was lined with a sterile piece of Teflon (PTFE-Polytetrafluoroethylene), and the access cavity was temporarily filled till the second appointment with glass-ionomer cement.

-During the second visit:

After the first visit two patients from each group were lost due to flare-up that happened after first visit (Figure 1).

Access was reopened and checked for any exudate using sterile paper. (if any exudate was found patient was excluded from the research). Irrigation protocol of the root canals was performed utilizing 3 ml 5.25% sodium hypochlorite solution. Followed by manual dynamic activation using the master cone for 3-5 minutes in up and down motions. A 3 ml 17% Ethylenediaminetetraacetic (EDTA) solution with intermittent 3 ml normal saline solution between them. Followed by manual dynamic activation using the master cone for 3-5 minutes in up and down motions. A 3 ml of normal saline solution was utilized as a final rinse of the canals. Finaaly, Root canals were dried via sterile paper points equivalent to the size of the master apical file.

- **Group I (GH-ES group):**

Growth hormone (SEDICO, 6 October, Egypt) was prepared based on the manufacturer's instructions by injecting the accompanied diluent into the vial by aiming the steam of the liquid against the glass wall. The vial was swirled with a gentle rotary movement until the content was completely dissolved. After that a 4 IU (1.33 mg) was injected into the periapical area using a 3ml plastic syringe with 30-gauge open-ended needle slowly for 2 minutes. After that root canals were dried again via a sterile paper points equivalent to the size of the master apical file. Similarly, obturation of root canals was done using cold lateral compaction with Endoseal MTA sealer. At last, the access cavity was cleaned and sealed with a resin composite restoration as a final restoration after which a post-operative radiograph was taken.

- **Group II (XP-ES group):**

XP-endo Finisher file was used in non-surgical debulking of periapical tissues by inserting the file periapically. The file (size 25, taper zero) was mounted in a torque limiting motor at 800 rpm speed and 1 Ncm torque as recommended by manufacturer’s instructions up to the full working length, then inserted periapically to mince the periapical tissues for 30 seconds in a slow up and down motion, The tissue suspension was now washed out with sterile saline solution by using a syringe adapted with a 30-G blunt needle. The needle was passed through the enlarged apical foramen into the periapical space, and the saline solution was slowly and gently injected to flush the tissue suspension out. After that root canals were dried again via a sterile paper points equivalent to the size of the master apical file. Similarly, obturation of root canals was done using cold lateral compaction with Endoseal MTA sealer. At last, the access cavity was cleaned and sealed with a resin composite restoration as a final restoration after which a post-operative radiograph was taken. (Figure 2)



Figure 2. XP-endo Finisher inserted periapically

- **Group III (ES group):**

Obturation of root canals was done using cold lateral compaction with Endoseal MTA sealer.

Post-obturation pain assessment: Post-obturation pain evaluation was carried out as detailed previously in preoperative pain assessment. Patients were evaluated at six intervals: preoperatively and at 6, 24, 48, 72 hours, and 1 week afterward. The collected data was then tabulated and analyzed statistically.

Data management and analysis: Recorded data were analyzed using the statistical package for social sciences, version 23.0 (SPSS Inc., Chicago, Illinois, USA). The quantitative data were presented as median with inter-quartile range (IQR) was (non-parametric data). Data were explored for normality using Kolmogorov-Smirnov and Shapiro-Wilk Test. *The following tests were done: Kruskall Wallis test*: for multiple-group comparisons in non-parametric data & *Mann Whitney U test:* for two-group comparisons in non-parametric data and *Friedman test* was used to compare multiple within-group measures & the comparison between two periods for non-parametric data using *Wilcoxon Signed-Rank Sum test*. *The confidence interval was set to 95%* and the margin of error accepted was set to 5%. So, the p-value was considered

significant as the following: *Probability* P-value <0.05 was considered significant.

RESULTS

Pain scores: a) Inter-group comparison: Preoperatively, the three groups demonstrated comparable pain scores with no statistically significant differences (p = 0.594). At **6** hours postoperatively**,** a statistically significant difference was observed among the groups (Kruskal–Wallis test, p = 0.001). Group I (GH-ES) recorded the lowest pain scores**,** followed by Group II (ES), while Group III (XP-ES) exhibited the highest pain levels**.** At 24 hours, the difference between the groups remained statistically significant (p = 0.001). Again, pain was lowest in Group I**,** followed by Group II, whereas Group III demonstrated the highest postoperative pain**.** At 48 hours**,** pain further decreased in all groups, yet the difference remained statistically significant (p = 0.005). Group I reached complete pain resolution (0.0 ± 0.0)**,** Group II showed low pain levels, while Group III continued to present the highest scores**.** By 72 hours and at 1 week**,** postoperative pain resolved completely in all groups, with no statistically significant differences (p = 1.000). (Table 1)

a)Intra-group comparison:

Overall, all three groups exhibited statistically significant time-dependent decreases in pain. Within Group I (GH-ES), postoperative pain showed a significant and continuous reduction over time, beginning with a high preoperative score that dropped markedly at 6 hours and continued to decrease at 24 hours, reaching complete pain resolution by 48 hours and remaining at zero through 72 hours and 1 week. Similarly, Group II (ES) demonstrated a significant decline from the preoperative level to the 6-hour and 24-hour intervals, followed by an additional reduction at 48 hours, after which all patients became pain-free at 72 hours and 1 week. In Group III (XP-ES), although a significant decrease was also observed across the time intervals, pain levels remained higher than in the other groups during the early postoperative phase, with a notable reduction from preoperative to 6 hours, further improvement at 24 and 48 hours, and eventually complete resolution by 72 hours and at 1 week. (P-value < 0.001). (Table 1)**.**

Table 1 Median and IQR of postoperative pain score for each group and Kruskal Wallis test for non-parametric quantitative data between the three groups followed by Friedman test between time intervals in each group.

Post-operative Pain Score	Group I: GH-ES	Group II: ES	Group III: XP-ES	Test value	p-value
Pre-operative					
Mean±SD	5.36±0.84	5.00±1.04	5.07±0.92	1.041	0.594
Median (IQR)	6 (5-6)Aa	5 (4-6)Aa	5 (4-6)Aa		
Range	4-a6	4-a6	4-a6		
After 6 hrs.					
Mean±SD	2.86±1.03	3.14±1.29	4.57±1.28	13.141	0.001*
Median (IQR)	2 (2-4)Cb	3 (2-4)Bb	5 (4-5)Aa		
Range	2-a4	2-a6	2-a6		
After 24 hrs.					
Mean±SD	1.21±1.25	1.71±1.07	3.14±1.29	13.659	0.001*
Median (IQR)	1 (0-2)Cc	2 (2-2)Bc	3 (2-4)Ab		
Range	0-a4	0-a4	2-a6		
After 48 hrs.					
Mean±SD	0.00±0.00	0.57±0.94	1.21±1.25	10.761	0.005*
Median (IQR)	0 (0-0)Cd	1 (0-2)Bd	2 (0-2)Ac		
Range	0-a0	0-a2	0-a4		
After 72 hrs.					
Mean±SD	0.00±0.00	0.00±0.00	0.00±0.00	0.000	1.000
Median (IQR)	0 (0-0)Ad	0 (0-0)Ae	0 (0-0)Ad		
Range	0-a0	0-a0	0-a0		
After 1 week					
Mean±SD	0.00±0.00	0.00±0.00	0.00±0.00	0.000	1.000
Median (IQR)	0 (0-0)Ad	0 (0-0)Ae	0 (0-0)Ad		
Range	0-a0	0-a0	0-a0		
Friedman	64.596	61.555	61.878		

p-value	0.001*	0.001*	0.001*		

a) Using: Kruskal Wallis test for Non-parametric data "Median (Interquartile range: IQR) between three groups

b) Different capital letters indicate significant difference at (p<0.05) among means in the same row, using Mann-Whitney test

c) Different small letters indicate significant difference at (p<0.05) among means in the same column, using Wilcoxon test

*d) *: Significant level at P value < 0.*

DISCUSSION

Preventing post-obturation pain is still a problem for dentists. Only 4–10% of endodontic participants have moderate to severe post-obturation pain, based on specific investigations [xxvii], while some investigations reported that up to 50% of people experience post-obturation pain [xxviii]. Patients might experience main pain issues that significantly affect their quality of life. According to a few clinical trials, 5–12% of patients may endure constant pain for months or years following the endodontic therapy [xxix]. Post-obturation pain can occur for several causes, including bacterial, chemical, or mechanical damage to the periapical tissues that triggers the release of cell mediators (Substance P and Calcitonin Gene-related peptide, or CGRP), that result in inflammatory response [xxx, xxxi]. Also, the amount of root canal sealer and the obturation technique may arise post-obturation pain, which is associated with the local inflammatory reaction [xxxii].

Different pain scales have been developed in this type of research to measure the degree of pain, direct treatment choices, and track efficacy. modified verbal descriptor scale (VDS) developed by Wang et al. [i] and translated into Arabic by Hagras et al. [xxvi] was used. It was preferred over different methods of evaluation because of its simplicity, and easiness to be understood by the patients. When examining preoperative pain scores, the study focused exclusively on patients with scores between 0 and 6. This decision was informed by research indicating that elevated preoperative pain scores can profoundly impact postoperative pain experiences. [xxxiii].

The creation of novel calcium silicate-based endodontic compounds has been aided by the MTA's biocompatibility, bioactivity, and osteoconductive qualities. EndoSeal MTA is MTA based sealer which has favorable effect on postoperative pain [xxxiv,xxxv,xxxvi]

The purpose of the current trial was to compare the variation in post-obturation pain when EndoSeal MTA sealer (ES) was used in the obturation of root canals in single-rooted teeth with related periapical lesion with or without pre-application of GH, or with non-surgical debulking of periapical pathosis.

The findings of the current research demonstrated that the GH-ES, ES and XP-ES groups differed significantly with the lower scores at GH-ES group at 6, 24,48 hours. While following 72 hours and one week, there was no discernible variation between the three groups. But, within the same group there was a significant reduction in pain scores over different times.

When comparing the three groups, the GH-ES achieved a significantly lower pain score at 6, 24,48 hours. This may be attributed to the fact that EndoSeal MTA has been linked to lower postoperative pain, both in terms of frequency and intensity, than other sealers [xxxiv,xxxv,xxxvi]. This can be attributed to its favorable biological and physicochemical properties, including high biocompatibility, high alkalinity, and slight expansion [xxxvii].

With regards to Growth Hormone, it has shown that it downregulates pro-inflammatory cytokines such as TNF-α, IL-1β, and IL-6, while promoting anti-inflammatory mediators. This modulation reduces periapical inflammation, thereby lowering postoperative discomfort [xxxviii]. Also, GH stimulates fibroblast proliferation, collagen synthesis, and angiogenesis which accelerates the healing of periapical tissues damaged during root canal preparation, Faster tissue repair limits prolonged nociceptor activation. By supporting Schwann cell activity and axonal repair, aiding in recovery of nerve fibers affected during instrumentation or by infection. It helps to reduce peripheral sensitization and subsequent pain amplification. GH may prevent exaggerated central pain responses by decreasing sustained nociceptive input from inflamed periapical tissues [xxxix]. Also, GH improves immune response by enhancing macrophage and neutrophil function, aiding in faster elimination of microbial remnants, reducing the risk of flare-ups and associated pain [xl]. Finally, it has been shown that Growth Hormone administration after surgery may have a complex relationship with postoperative pain, impacting both pain perception and the body's hormonal responses to stress. GH can influence pain by affecting nociceptor sensitization and potentially reducing fatigue associated with pain[xx,xxi,xxii,xxiii].

Although there was a significant variation in pain scores at 6,24,48 hours, there were no significant differences at 72hours and 1 week. This may be explained by GH's dual role as an anti-inflammatory mediator and a pro-healing stimulator. As previously stated, root canal instrumentation and obturation typically provoke an acute inflammatory response which characterized by the release of TNF-α, IL-1β, and IL-6, which stimulate nociceptors in the periodontal ligament and periapical tissues, leading to pain [xli]. GH counteracts this response by inhibiting pro-inflammatory cytokines and increasing anti-inflammatory mediators

such as IL-10, thereby dampening nociceptor activity. Additionally, GH induces the expression of bone morphogenetic proteins (BMP-2, BMP-4) and enhances the osteogenic differentiation of periodontal ligament stem cells (PDLSCs), promoting accelerated repair and regeneration [xlii]. Moreover, GH exerts neuroprotective effects by modulating sensory neuron excitability and pain perception pathways. This explains the sustained analgesic benefit observed up to 48 hours postoperatively. However, by 72 hours, natural resolution of inflammation occurs even in untreated cases, as macrophages shift from a pro-inflammatory (M1) to a pro-healing (M2) phenotype, and baseline pain levels converge. Thus, GH's impact is most noticeable when inflammations are in their acute stages and repair.

Regarding, non-surgical debulking using XP-Endo Finisher file, as a minimally invasive endodontic procedure designed to remove chronically inflamed periapical tissue through the root canal, avoiding surgical access like an apicoectomy [xvii]. The findings of the current research demonstrated that the XP-ES group recorded the highest pain levels between the three groups. This may be attributed to many explanations; Enlarging the foramen likely stimulates periapical tissues more intensely by widening the canal's terminus, which can cause inflammation and pain [xviii]. Also, instruments like the XP-Endo Finisher, especially when used with foraminal enlargement, can force more debris and irrigant beyond the apex. This extrusion is a known trigger for postoperative pain due to peripheral irritation [xliii]. Non-surgical debulking with XP-Endo Finisher targets chronically inflamed periapical tissue. While effective in decontamination, this aggressive activity in inflamed tissue areas can elicit pain as inflammatory mediators are disturbed or released deeper into the periapical zone. In contrast, XP-Endo Finisher used alone (without foraminal enlargement) tends to produce only mild postoperative pain, indicating that it's the combination with apex widening that elevates pain levels [xix].At last, the local application of growth hormone before root canal obturation appears to create a more favorable healing environment in periapical tissues, leading to reduced inflammation, enhanced repair, and decreased nerve sensitization. These combined effects likely contribute to lower postoperative pain scores. While using of XP-Endo Finisher file in non-surgical debulking of chronically inflamed periapical tissue through the root canal appears to make high levels of postoperative pain. While preliminary data are promising, further clinical trials are required to establish standardized protocols and evaluate long-term safety in dental applications.

CONCLUSION

Growth Hormone application before root canal obturation in teeth with periapical lesion, effectively reduces post-obturation pain.

DECLARATIONS

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Competing Interests

The no competing interests .

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EVALUATION OF TREATMENT OUTCOME WITH PALATAL PLATE VS CONVENTIONAL TOOTH BORNE ANCHORAGE IN CLASS III PATIENTS (CONTROLLED RANDOMIZED COMPARATIVE IN VIVO STUDY)

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ABSTRACT

Background: Patients with skeletal class III patients need early treatment intervention. Clinical dental adverse effects accompanied by skeletal orthopedic treatment need introducing new treatment modalities.

Aim: the purpose of this study was to compare the results of maxillary protraction in skeletal class III patients using facemask with two different intra oral anchorage devices.

Materials and methods: 14 growing patients with age range (9-12 years) were included in this study. Patients were diagnosed with skeletal class III deficient maxilla. All patients received face mask treatment; first group was treated using trans palatal arch (TPA) with hooks for face mask, while the second group was treated using mini screw retained palatal plate. Lateral cephalometric x ray before and after treatment measurements were measured, superimposed and compared using onyxceph software.

Results: first group (TPA) show statistically lower SNA amount of difference after treatment compared to palatal plate group, while SNB amount of difference was not statistically significant between the two groups. ANB amount of difference after treatment was statistically higher in palatal plate group than TPA group, Wits appraisal was not statistically different. Upper central incisor inclination was statistically significant lower in palatal plate group.

Conclusion: both groups were able to successfully be treated. Palatal plate group had advantage of less dental side effects.

Introduction

Skeletal class III can exhibit a variety of etiological factors including deficient maxilla, protruded mandible or a combination of them. Studies showed that around two thirds of skeletal class III cases were due to deficient maxilla either alone or accompanied by mandibular prognathism [1,2,3].

Skeletal class III malocclusion is one of the most challenging malocclusions in orthodontics. Early intervention is advised as unfavorable growth worsen the case which leads to reduced self-esteem, esthetics and difficulties in chewing function and speech. Moreover, early treatment reduces the future need for orthognathic surgeries [4,5,6].

Several treatment protocols were advocated using skeletal and dental anchorage. Face mask protraction is the golden treatment protocol in deficient maxilla growing patients either with or without expansion [7]. Face mask usually is used with conventional dental anchorage trans palatal arch. This dental anchorage led to some dentoalveolar side effects as extrusion and mesialization of upper first molar, proclination of upper incisors and retroclination of lower incisors [8,9].

Alternative treatments were studied to use skeletal anchorage in treatment of skeletal class III malocclusion. First class III intraoral elastics were attached to miniplates placed in the infrazygomatic region and the anterior portion of the mandible. Although this approach was successful it needed a moderate surgical intervention under general anesthesia [4,10,11].

Second when the patient suffers from constricted maxilla; face mask with rapid maxillary expansion protocol could be used and mini screw could be added to the hyrax to minimize the dental side effects. It did not need surgical intervention but it is preferably made

using surgical guide for mini screw positioning. This approach was effective for patients with constricted maxilla [10,11,12,13].

Lately a new approach was studied using a mini screw supported palatal plate instead of trans palatal arch with face mask for patients with normal maxillary width and it did not any need surgical procedure [(14)].

In this study face mask conventional dentally anchored trans palatal arch was compared to face mask skeletally anchored to minis crew supported palatal plate. Cone beam CT was used to precisely position the mini screws.

Aim:

Evaluation of treatment outcome with palatal plate vs conventional tooth prone anchorage in skeletal class III patients.

MATERIALS AND METHODS

This is a controlled randomized comparative in vivo study; using computer aided randomization method. Comparing between bone borne anchorage using palatal plate and mini screws versus conventional tooth borne (TPA) anchorage used with face mask in class III growing patients. This study was approved by the Research Ethical Committee of Quality Education Assurance Unit, Faculty of Dental Medicine, Cairo, Egypt. Approval code (P-OR-23-05).

A-Subjects:

Patients grouping and intervention:

According to statistical sample size calculation (power of study) 14 patients was randomly divided in to two intervention groups; to compensate for drop out patients; 25% was added ending to total number of 18 patients (9 patients in each group).

18 patients were selected according to the following criteria from those attending the outpatient clinic, Department of Orthodontics, Faculty of Dental Medicine, Al Azhar University Girls';

These patients were divided into two groups;

Group(A): patients were treated by conventional TPA (trans-palatal arch) with hooks for face mask and face mask.

Group (B): patients were treated by 3D printed palatal plate with hooks for facemask, fixed by four TADs (temporary anchorage device) on hard palate and face mask.

Inclusion criteria:

- Patients free from any systematic disease and in good health.
- Patients with skeletal class III malocclusion with retrognathic maxilla.
- Growing patients according to their lateral cephalometry using (CVM) cervical vertebrae maturation method.
- Patients with anterior crossbite to edge to edge bite.
- Patients without history of previous orthodontic treatment.
- Patients with Good oral hygiene.
- Patients having no anatomical anomalies or other craniofacial syndromes, ex: cleft lip or palate.
- Patients who are motivated to go through the treatment and cooperative.

B- Methods:

1-The aim and methods of the study was explained to the patients and consents were signed by all willing participants before being enrolled in the study.

2- The following records had been taken for each patient before treatment and after clinical examination;

- Orthodontic study model.
-Lateral Cephalometric Radiograph.
- Digital Panoramic Radiograph.
- Extra and Intra -oral photographs.
- CBCT in group (B).

3- All patients were assessed after orthopedic treatment and orthodontic treatment were started if needed.

4- All patients signed an informed consent, after clear explanation for the treatment procedures.

5-Subjects randomization:

According to the power of study calculations; sample of patients was randomly and equally divided in to the control group (A) and the study group (B) using Microsoft Office Excel (2010).

C- Fabrication steps:

- Alginate impression was taken for group(A) patients for TPA fabrication by conventional methods.
- Patients in group (B) were asked to make CBCT on maxilla for TADs position and length selection.
- For group(B) patients 3 D model scan was made. Study casts were prepared to scan with desktop 3D scanner to produce STL file (stereolithography file).
- The digital procedures workflow for group (B) patients; using ONYXCEPH ORTHODONTIC SOFTWARE; it begins with software interface that enable saving of patient's data and records;

name, age and gender, then we add 2d and 3d records (casts and x rays).

- For group (B) patients; using patient's virtual file on software cast superimposition on CBCT was made then appliance designing and positioning for tads in the palatal safe zone. According to available bone tads size were selected. All tads had the same diameter 1.7mm with different lengths according to available bone to protect the maxillary sinus and all vital structures. Inclinations were made during tad positioning to reach maximum available tad length without harming the sinus. These inclinations were made in the tad fitting part in the appliance to make sure that while inserting the tad it will be guide to its optimum position and inclination. Four tads were used with each patient making a trapezoid like shape in the hard palate safe zone (between upper canine and upper second premolar), figure (1). After selecting the position of the screws, the appliance was designed by connecting the four screws with arms forming a trapezoid like shape with a screw in each corner. From this trapezoid two arms on each side (right and left) will be extended; anterior arm between first and second premolar with hook for facemask elastics and a posterior arm resting occlusally on upper first molar helps in accurate positioning and opening the bite, figure (2).

D- Appliance placement:

- For group (A) patients; glass ionomer cement was used on upper first molar band to cement the TPA with hooks for facemask, then a removable posterior bite plane was used to open the bite anteriorly. Facemask was adapted on the patient face with occlusal table 0^0 to 30^0 to the occlusal plane according to the patients' bite. Force gauge was used to properly select the size of extraoral elastics to reach 500 grams per side. In each follow up visit the intra and extra oral appliances were checked they are in their place. Also, the elastics force was checked with force gauge and smaller elastics sizes were used when needed, figure (3).
- For group (B) patients; patient was first asked to use Hexitol mouthwash, then glass ionomer cement was used on the upper first molar occlusal bands. Four mini screws (anchor essential) were placed in place using straight screw driver under few drops of local anesthesia. Mini screw size varied according to each case. Flowable composite (VOCO) was then used to cover each screw head, figure (4). Facemask was adapted on the patient face with occlusal table 0^0 to 30^0 with the occlusal plane according to the patients' bite. Force gauge was used to properly select the size of extraoral elastics to reach 500 grams per side. In each follow up visit the intra and extra oral appliances were checked; they are in their place. Also, the elastics force was checked with force gauge and smaller elastics sizes were used when needed.
- All patients were asked to wear the facemask from 12 to16 hours per day, figure (5). They were asked to sleep with it and to remove during eating or when going out (school, lessons or sports).

E- Treatment duration:

Each patient had a file with his data and the exact date of appliance placement and removal after finishing treatment with face mask and gaining positive overjet. To compare treatment duration with facemask between the two research groups. Patients after phase one (facemask treatment) had fixed orthodontic treatment when needed. Patients were asked to wear a chin cup while sleeping, till age of 18 years old.

F- Follow up visits:

All patients were asked to fill in their note book how long they wore their appliance.

All patients were asked to come to the clinic every month to check the extra oral and intra oral appliances and to check the extra oral elastics and change the size to a smaller one when needed. When the force is less than 300 N).

G- Lateral cephalometry measurements:

Before and after lateral cephalometric x ray were superimposed using ONYXCEPH ORTHODONTIC SOFTWARE. The following measurements were taken by two different doctors. Skeletal (SNA, SNB, ANB), dental (upper incisor with SN plane and upper incisor with Frankfort plane).

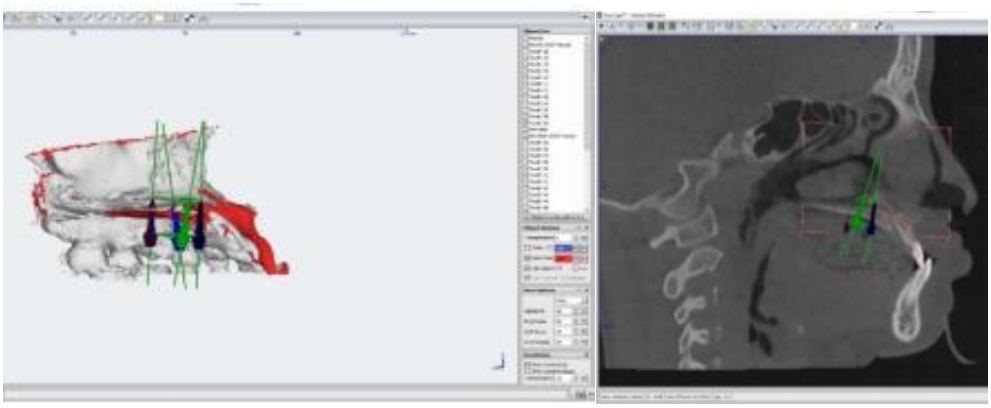


Figure 1. TAD position and length testing.

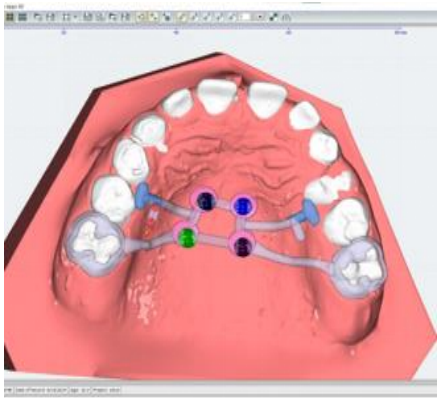


Figure 2. Appliance designing



Figure 3. TPA cementation



Figure 4 Palatal plate fixation



Figure 5. Patient wearing facemask

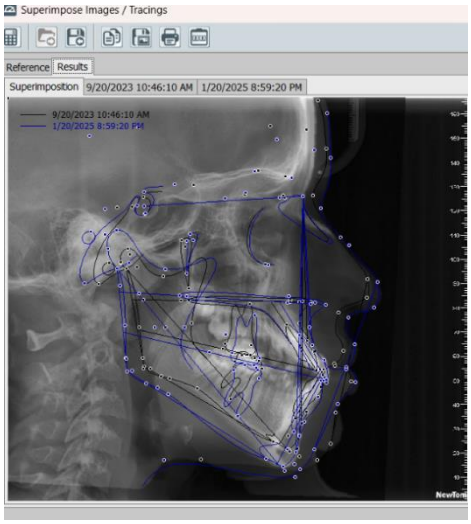


Figure 6. Onyxceph software used in cephalometric x-rays superimposition and measurements.

Statistical analysis:

Statistical analysis was performed using a commercially available software program (SPSS 20-Statistical Package for Scientific Studies, SPSS, Inc., Chicago, IL, USA) for Windows.

Numerical data were summarized using mean and standard deviation, confidence intervals and range. Data were explored for normality by checking the data distribution and using Kolmogorov-Smirnov and Shapiro-Wilk tests. Based on the parametric distribution of recorded pre and post data for SNA, SNB, U1/SN, U1/FH, nasolabial angle and duration; groups were compared using independent t test. Paired t test was used for intra group comparisons between pre and post treatment.

ANB and WITS showed a non-parametric distribution and were compared between groups using Mann Whitney U test, while Wilcoxon signed Rank was used for intragroup comparison between pre and post values.

The amount of difference between pre and post was calculated using the formula: (post-pre)

Data of the amount of difference for SNA, SNB, U1/SN, U1/FH and nasolabial angle showed a non-parametric distribution and therefore was compared between groups using Mann Whitney U test. Conversely, the amount of difference between pre and post values for ANB and WITS were normally distributed and were compared between groups using independent t test. Qualitative data (gender) were compared using chi square test. All p-values are two-sided. P-values ≤0.05 were considered significant.

Results

- **Demographic data:**

Age: The mean age of Palatal plate group was (11.14 ±0.9 years), compared to TPA group (10.29±0.76 years). The difference between groups was not statistically significant (p=0.08), (Table 1).

Gender: Palatal plate group consisted of 3 males (42.9%) and 4 females (57.1%), compared to 4 males (57.1%) and 3 females (42.9%) in TPA group. The difference between groups was not statistically significant (p=0.593), (Table 1).

Table 1. Demographic data and comparison of age (independent t test) and gender (chi square test)

	Groups	Value	test value	P value
Age (mean ±SD)	Palatal plate group	11.14 ±0.9	1.91	.08 ns
	TPA group	10.29±0.76		
Gender	Palatal plate group	Male: 3 (42.9%), Female =4 (57.1%)	.286	.593 ns
	TPA group	Male: 4 (57.1%), Female =3(42.9%)		

Significance level p≤0.05, ns=non-significant.

- **Amount of difference in SNA and SNB angles after treatment:**
  SNA: Palatal plate group recorded a median value= 6, with mean 6.02±1.88), which was significantly greater than TPA group recording a median value=2.95, with mean (3.12±1.43), (p=.015).
  SNB: Palatal plate group recorded a median value= .47, with mean (.34± .35), which was not significantly different from TPA group recording a median value= .50, with mean (.73±.75), (p=.442), figure (7).

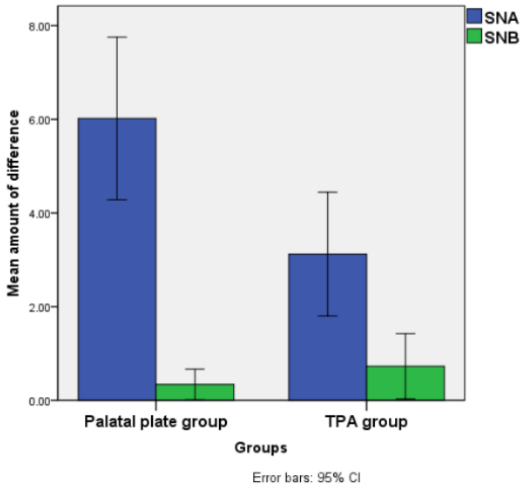


Figure 7. Bar chart illustrating mean value of amount of difference in SNA and SNB in Palatal plate group and TPA group.

- **Amount of difference in ANB angle and Wits appraisal after treatment:**
  ANB: Palatal plate group recorded a mean (6.26±2.08), which was significantly greater than TPA group recording a mean (2.93±1.07), (p=.003).
  WITS: Palatal plate group recorded a mean (12.47± 3.61), which was not significantly different from TPA group recording a mean (9.17±2.39), (p=.053), figure 8.

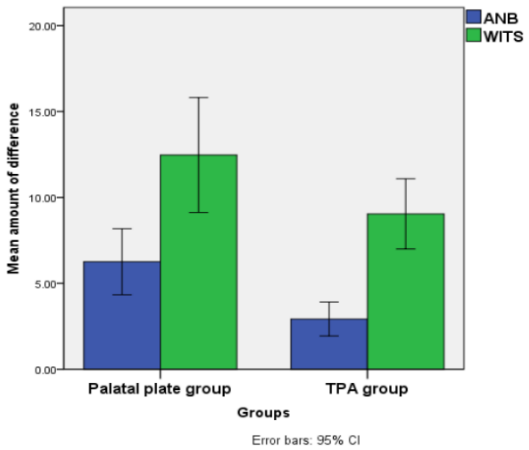


Figure 8. Bar chart illustrating mean value of amount of difference in ANB and WITS in Palatal plate group and TPA group.

- **Amount of difference in U1/SN plane angle and U1/Frankfort plane angle after treatment:**

U1/ SN: Palatal plate group recorded a median (.11) and a mean (-.89±2.89), which was significantly lower than TPA group recording a median (11) and a mean (15.22±9.38), (p=.001).

U1/FH: Palatal plate group recorded a median (.24) and a mean (-1.42± 4.19), which was significantly lower than TPA group recording a median (8.6) and a mean (9.91±4.62), (p=.000), figure (9).

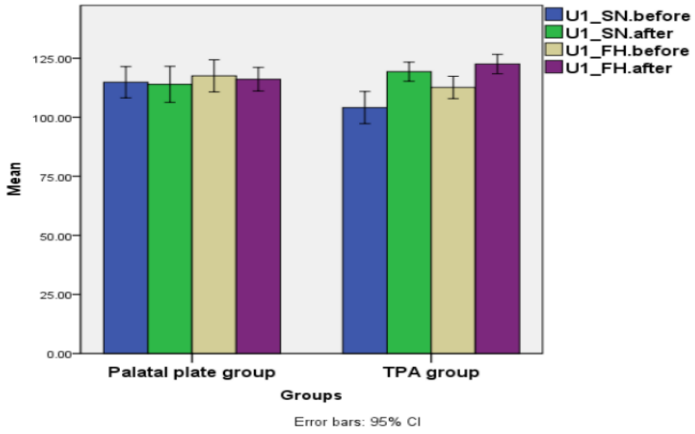


Figure 9. Bar chart illustrating mean value of amount of difference in U1/ SN and U1/FH in Palatal plate group and TPA group.

DISCUSSION

Skeletal Class III malocclusion (Cl III) presents a significant orthodontic challenge, particularly in growing patients, requiring interceptive treatment to achieve effective functional and aesthetic correction.

A change in the sagittal connection between the maxilla and mandible with mandibular protrusion, accompanied or not by retrusion (underdevelopment) of the upper jaw is referred to as skeletal class III malocclusion (Cl III). In the context of horizontal cephalometric analysis, key measurements include SNA, SNB, and ANB angles, which help assess the anteroposterior relationship between the maxilla and mandible. An ANB value of 2 ± 2 degrees typically indicates a Class I skeletal pattern, with deviations suggesting Class II (>4 degrees) or Class III (zero or less) [15,16,17,18]. These measurements help differentiate whether discrepancies in jaw relationships are due to excess or deficiency in the maxilla or mandible [19,20]. Additionally, the Wits appraisal offers further insight into the anteroposterior jaw relationship and skeletal divergence. Normal Wits values range from −1 mm ± 2 mm. A negative Wits value indicates increased divergence as the occlusal plane steepens [21,22]. These measurements were the main concern in this study to compare between the two study groups.

Functional appliances such as the Bionator or removable mandibular retractor (RMR), Frankel III appliance, reverse twin block (RTB), and orthopedic appliances, including FMs and the chin cup, have shown excellent results in correcting class III [23,24,25]. However, FMs indicated stronger skeletal effects in

maxillary protrusion, while RTB primarily revealed dentoalveolar alterations [26,27,28].

Nowadays, the combination of facial masks (FMs) and rapid palate expansion (RME) is the recommended treatment approach for correcting class III malocclusion in teenagers. Transverse palate expansion does not by itself result in increased maxillary protrusion [29,30].

To further encourage maxillary protrusion and enhance therapy results in Cl III patients, a novel method known as alternate rapid palate expansion and contraction (Alt-RAMEC) makes use of springs. Research has verified that the Alt-RAMEC approach in conjunction with FMs yields protrusion outcomes that are comparable to those of the conventional RME/FM protocol [31,32].

In situations when there is a maxillary deficiency, a FM for protrusion is advised. Unwanted side effects, including elevated facial height, excessive upper incisor proclination, and anterior displacement of upper molars, have been documented in trials that combine RME with dental anchoring. For Cl III patients with hyperdivergent growth patterns, the Hybrid Hyrax device with skeletal anchoring was created as an efficient substitute to lessen these consequences [33,34].

In a study by Lucia Cevidanes et al., two Class III correction protocols; first: Bone Anchored Maxillary Protraction (BAMP) and second: Rapid Maxillary Expansion with a face mask were compared in terms of dentoskeletal changes in patients. Results indicated that BAMP achieved superior maxillary advancement and midface lengthening, with greater vertical control than RME/FM, avoiding clockwise mandibular rotation. While RME/FM resulted in increased facial height and lower incisor inclination, BAMP reduced maxillomandibular divergence, showing more favorable control over mandibular rotation and vertical growth adjustments [35].

Several studies have reported periodontal damage from tooth-worn devices compared with the protocol on the bone. Because orthopedic force is transferred through skeletal anchorage, the risk of periodontal damage could be minimized with mini-implants anchored in the palate [36].

Also, Vaughn et al. compared the application of FMs with or without expansion. Patients were randomly divided into a group who received the FM with palatal expansion, a second group with the FM without palatal expansion, and a control group. Statistical analysis was executed with Student's t-test and showed no significative difference between the two groups with FMs with or without expansion, demonstrating that the early therapy with FM with or without expansion can be effective [37].

Lee et al. compared two types of face masks (PFFS and PTF) for Class III treatment, finding no significant differences except in overbite [38].

Husson et al. assessed FMs and rapid palatal expansion (RPE), noting both were effective for Class III, but the modified tandem appliance (MTA) outperformed the FM in controlling jaw rotation [39].

Seiryu et al. found FMs combined with mini-screws led to better skeletal outcomes with fewer side effects [(40)]. Liu et al. highlighted faster results with modified hybrid appliances compared to banded ones [41].

In 2024, this systematic review confirmed that traditional devices like the rapid palate expander (RME) and face mask (FM) remain effective for Class III treatment. However, innovative methods using skeletal anchors show significant benefits, including enhanced maxillary advancement and reduced dental side effects. The findings emphasize the importance of tailored device combinations based on individual patient needs, suggesting that a flexible and personalized approach may yield better results than standardized protocols [15].

Maxillary protraction using TADs is an efficient modality for growing patients with Class III malocclusion with maxillary deficiency. Palatal plates can provide anchorage for maxillary protraction. They require single and flap less placement compared with bilateral buccal plates and achieve the most desirable dentoskeletal effects compared with other appliances [(42,43)]. Our study evaluated the treatment effects of maxillary protraction using palatal plates.

Ngan et al demonstrated side effects such as extrusion of the molars in tooth-borne appliances. It seems to rotate the mandible clockwise. In contrast, palatal plate in our study minimized these side effects by using bone-borne appliances for maxillary protraction [44].

Regarding dental changes, palatal plate group showed no significant proclination of maxillary incisors (U1-FH). However, Cha and Ngan reported it increased by 1.6 + or - 4.4 in a miniplate group and 3.2

+ or - 4.1 in a conventional group. Therefore, maxillary incisor position with protraction using TSADs showed less protrusion tendency than conventional appliances [45].

You-Sun Lee et al, compared between palatal plate and hyrax tooth bonded both with face mask and concluded that facemask with palatal plate induced more maxillary advancement with less dental movement than conventional tooth-borne anchorage [46].

In this study the palatal plates had advantages such as flapless and single application and placement in tooth free bearing areas compared with other TSADs, which require bilateral invasive installation.

CONCLUSION

- Miniscrew retained palatal plate could achieve more maxillary protaction compared to transpalatal arch, although both of them were effective in retruded maxilla treatment
- Palatal plate showed minimum dental side effects compared to trans palatal arch group.

DECLARATION

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Conflict of Interest
None to declare.

Patients consent
All the patients in this study have given their informed consent for publication.

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ORIGINAL RESEARCH

ASSESSMENT OF ANATOMICAL VARIATIONS OF GREATER PALATINE FORAMEN IN A SAMPLE OF EGYPTIAN POPULATION USING CBCT: A CROSS-SECTIONAL STUDY

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ABSTRACT

Statement of problem: The greater palatine foramen (GPF) is an important landmark in oral surgery. Block anesthesia of the greater palatine nerve (GPN) is a very common procedure in numerous dental interventions involving the posterior maxilla. Procedures that may involve the GPF include orthognathic surgery, closure of oroantral/nasal fistulas, removal of pathological tissue, harvesting of palatal soft tissue grafts, and extraction of maxillary posterior teeth. However, these procedures are all performed close to, and thus may damage, vital anatomical structures, such as the greater palatine neurovascular complex. Therefore, it is important to assess the anatomical variations of the GPF to avoid hemorrhagic risks and anesthesia failures.

Aim of the study: To assess the anatomical variations (diameter and number) of the greater palatine foramen in a sample of Egyptian population using cone beam computed tomography.

Materials and method: This cross-sectional study evaluated 173 greater palatine foramina using cone beam computed tomography. Diameter and number of foramina were evaluated and recorded. Inter and intra observer agreement were done using Intraclass correlation coefficient.

Results: The mean diameter of GPF was 4.18 ± 0.90 mm.

Conclusion: The anteroposterior dimension of the greater palatine foramen is vital during orthognathic procedures, excision of pathological lesions, palatal soft tissue graft harvesting, and extraction of posterior maxillary teeth. Therefore, surgeons should handle this region with great care.

Keywords: Greater palatine foramen, Hard palate, GPF, Cone beam computed tomography, CBCT.

INTRODUCTION

The hard palate is an essential region of the skull; its gross anatomy and morphological variations have been of interest in many studies. The bones and dental structures of the palate are often preserved even in cases of serious damage at or following death [1].

Many important anatomical landmarks traverse the hard palate. The greater palatine nerve (GPN) emerges on the hard palate from the greater palatine foramen (GPF). It innervates the posterior section of the hard palate and runs forward in a groove up to the incisor teeth, where it meets the terminal filaments of the nasopalatine nerves[2]. The greater palatine artery (GPA) originates from the descending palatine branch of the maxillary artery in the pterygopalatine fossa (PPF), passes through the greater palatine canal (GPC) and also emerges from the GPF on the palatal aspect of the third maxillary molar, to reach the hard palate [3]. The lesser palatine foramina (LPF), usually two, lie behind the greater palatine foramen (GPF) and pierce the pyramidal process of the palatine bone, which is wedged between the lower ends of the medial and lateral pterygoid plates. The LPF transmit the lesser palatine vessels as well as the middle and posterior palatine nerves [4].

Block anesthesia of the greater palatine nerve (GPN) is a very common procedure in numerous dental

interventions involving the posterior maxilla. Procedures that may involve the GPF include orthognathic surgery, closure of oroantral/nasal fistulas, removal of pathological tissue, and extraction of maxillary posterior teeth. However, these procedures are all performed close to, and thus may damage, vital anatomical structures, such as the greater palatine neurovascular complex. Therefore, it is important to assess the anatomical variations of the GPF to avoid hemorrhage risks and anesthesia failures [5-7].

Since the greater palatine foramen represents a significant landmark in the palatine region, with important implications in the dental field, this in vivo cross-sectional study was carried out to show variations in the GPF diameter and number in an Egyptian subpopulation.

MATERIAL AND METHODS

Participants, Setting and Location

The present cross-sectional retrospective study was carried out in the Department of Oral and Maxillofacial Radiology, Cairo University, Cairo, Egypt. CBCT scans of Egyptian patients who have already been subjected to CBCT examination as part of their dental diagnosis and/or treatment planning were included according to the proposed eligibility criteria. All the CBCT images were scanned using CBCT machine, Planmeca ProMax® 3D Mid machine (Finland) at 90 kvp with 8 mA with different fields of view with voxel sizes of 0.2 and 0.4 mm.

Sample size calculation was done using Benchmark Six Sigma website and accepted by the institutional Medical Biostatistics unit. Based upon the results of Ikuta et al. (2013), where the mean diameter of the greater palatine foramen was 3.1 mm (±0.47), with an acceptable margin of error 7%, the minimum estimated sample size was 173 hemi-palates.

CBCT scans of Adult Egyptian population older than 18 years, showing the floor of the maxillary sinus, with no artifacts in the maxillary region were included. The images which have one of the following criteria were excluded from the study: (1) CBCT scans of completely edentulous maxilla; (2) patients with trauma, craniofacial surgery, orthognathic surgery and malignancies involving the maxillofacial region; (3) patients with cleft palate and other craniofacial anomalies. The collected CBCT scans were reviewed by two oral and maxillofacial radiologists using Planmeca Romexis software version 4.6.2.R.

Image Analysis

The following parameters were analyzed on CBCT images in the 3 main orthogonal planes (axial, coronal and sagittal):

1- Diameter of the greater palatine foramen.
2- Number of the greater palatine foramen.

Foramen detection and analysis

Upon identification of the eligible cases, scrolling through the axial plane was used as the initial step in foramen identification, with confirmation achieved using the other two orthogonal planes **(Fig.1 A, B, C).**

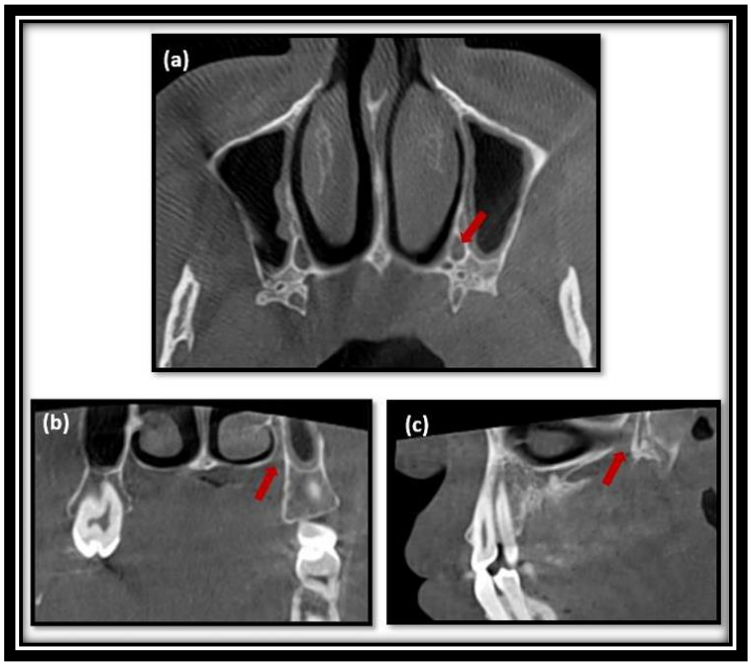


Figure 1. Axial (A), Coronal (B) and (C) sagittal views showing the greater palatine foramen.

With the help of the cursor, the intersection lines were oriented perpendicular to the foramen under investigation. Then through scrolling of different planes, the diameter, and number of the greater palatine foramina were analyzed.

Through the sagittal cut, we measured the anteroposterior dimension of the canal opening (GPF) **(Fig.2).**

CBCT images were interpreted by two oral radiologists independently; blinded from demographic data of the patients and from the results of each other. This step was done to avoid any source of biases, where one of them evaluated the images twice with a period of two weeks interval between the two reading sessions, to asses intra/inter-observer reliability.

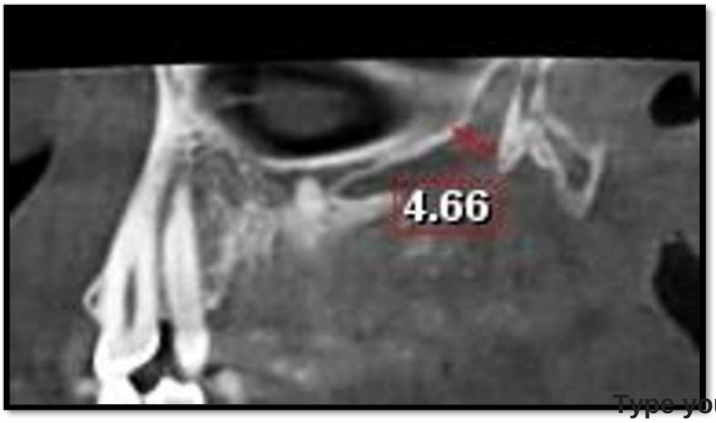


Figure 2. Sagittal view showing the diameter of the greater palatine foramen of 4.66 mm.

Statistical analysis

Data were analyzed using IBM SPSS advanced statistics (Statistical Package for Social Sciences), version 21 (SPSS Inc., Chicago, IL). Numerical data were described as mean and standard deviation or median and range. Categorical data were described as numbers and percentages. For comparing between male and female GPF / right and left sides GPF, Independent t test was used. Inter and intra observer agreement (reliability) were done using intra-class correlation coefficient (ICC).

RESULTS

This cross-sectional study examining 93 CBCT scans of an Egyptian subpopulation comprising 80 with full arches and 13 with hemi-palates. The cohort included 48 males and 45 females' patients. The study sample comprised 173 greater palatine foramina (GPF), as the number of GPF was one foramen in all hemi-palates, and no multiple foramina were recorded. (Table 1). We assessed 93 GPF in males and 80 in females. Regarding the sides, 88 on the right side and 85 on the left.

Table 1. Descriptive results of baseline data.

Baseline data of hemi-palates		Count	Column N %	P- value
Gender	Male	93	53.8%	**0.19**
	Female	80	46.2%	
Side	Right	88	50.9%	**0.72**
	Left	85	49.1%	

The diameter of the greater palatine foramen was measured and showed a range from 2.15 to 6.85 mm, with a median of 4.12 mm and a mean of 4.18 ± 0.90 mm.

Table (2) show the association between the diameter of the greater palatine foramen and gender. A comparison between male and female measurements was performed by using Independent t-test, which revealed that the diameter was significantly larger in males (4.58 ± 0.88 mm) than in females (3.72 ± 0.69 mm), with a mean difference of 0.86 mm (95% CI: 0.62–1.10, p = 0.0001), which showed a statistically significant gender difference.

Table 2. Association between the diameter of the greater palatine foramen and gender.

Greater palatine foramen	Gender				Independent t test				
	Male		Female		Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference		P-value
	Mean	SD	Mean	SD			Lower	Upper	
Diameter	4.58	0.88	3.72	0.69	0.86	0.12	0.62	1.10	**0.0001***

Table (3) present the association between the diameter of the greater palatine foramen and side. A comparison between sides was performed by using Independent t test which revealed that the diameter measured 4.24 ± 0.92 mm on the right side and 4.11 ± 0.88 mm on the left side, with a mean difference of 0.13 mm (95% CI: –0.14 to 0.40, P = 0.357) with non-statistically significant side differences.

Table 3. Association between the diameter of the greater palatine foramen and side.

Greater palatine foramen	Side				Independent t test				
	Right		Left		Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference		P-value
	Mean	SD	Mean	SD			Lower	Upper	
Diameter	4.24	0.92	4.11	0.88	0.13	0.14	-0.14	0.40	**0.357**

There was perfect intra-observer agreement (reliability) as shown in **Table 4** regarding all variables with **ICC (Intraclass correlation coefficient)** values ranging from 0.988 to 0.999 (p value < 0.0001) and from 0.983 to 0.963(p value <0.0001) in inter-observer reliability.

Table 4. ICC of intra-observer and inter-observer reliability.

	Intra-observer reliability				Inter-observer reliability			
Parameter	ICC	95% Confidence Interval		P- value	ICC	95% Confidence Interval		P- value
		Lower Bound	Upper Bound			Lower Bound	Upper Bound	
Diameter	0.988	0.984	0.991	<0.0001*	0.983	0.956	0.994	<0.0001*
Number	0.999	0.999	0.999	<0.0001*	0.963	0.900	0.986	<0.0001*

DISCUSSION

Ethnicity affects skull and maxillofacial morphometric analysis by contributing to significant differences in size and shape due to genetic and developmental variations [16].

Within the hard palate, the greater palatine foramen serves as a reliable and identifiable anatomical landmark; its precise dimensions vary between individuals, populations, and sexes[17]. Therefore, in this study, we assessed the number and diameter of GPF in an Egyptian subpopulation.

The diameter of the GPF in this study was measured in the sagittal view at the level of the foramen opening in the anteroposterior direction. This measurement approach was consistent with several methodologies [8,9]. The results of our study showed that the range of diameter of the greater palatine foramen was from 2.15 to 6.85mm and the mean was 4.18 ± 0.90 mm, which is consistent with the findings reported by Shalaby et al. (2015)[1] on Egyptian skulls, where the mean anteroposterior diameter of the GPF was 4.86 ± 0.9 mm.

In addition to that, in agreement with our findings, the morphometric characteristics of the greater palatine foramen diameter was reported by two systematic reviews, Tomaszewska et al. (2014) [10]and Kim et al. (2023) [11], reported diameters ranged between 4.5mm and 5.34 mm, respectively. Moreover, a study conducted on a North Cyprus subpopulation showed a 5.25 mm mean diameter of the greater palatine foramen [15].

However, in 2015, a study conducted on a Lebanese population demonstrated a higher diameter range of the GPF, ranging from 3.05 to 10.38 mm, which may

be attributed to differences in the imaging protocols employed in that study [8].

We found that male patients showed significantly higher diameters of GPF. The findings of Aoun et al. [(8)] in the Lebanese population and Fahrioglu et al. [15] in the North Cypriot population were in line with our results, whereas Ikuta et al. [5] reported no significant differences between males and females in the Brazilian population. In terms of lateralization, there were no statistically significant differences in the diameter between the right and left sides; these results are consistent with those reported by Shalaby et al. in Egyptian skulls [1].

With respect to the number of greater palatine foramina, we excluded all nearing lesser palatine foramina. As with respect to the sagittal plane, most GPCs should present with at least one LPC. Moreover, LPCs may have small bony bifurcations giving rise to numerous LPFs onto the palate, through which lesser palatine nervous rami emerge. In this sense, axial and sagittal slices make it possible to analyze LPCs with their principal LPF.

It is noteworthy that the presence of multiple GPFs holds clinical significance, as it may elevate the risk of bleeding and hematoma during surgical procedures and potentially results in ineffective anesthesia if not properly identified [(13)]. Moreover, the absence of the GPF also presents clinical challenges. It may restrict the ability to harvest implant tissue from the palate and limit options for reconstructive surgery [14].

Aligning with the results we observed, Shalaby et al. (2015) [1] and Gadallah et al. (2024) [12] reported that the greater palatine foramen was invariably observed bilaterally, with a single foramen on each side of the posterolateral region of the hard palate across all examined Egyptian skulls and CT scans.

In contrast, Cagimni et al. (2017)[14]reported the presence of double and triple foramina in 13% and 2% of specimens, respectively, while a unilateral absence of the GPF was observed in 2% of cases. This variation could be attributed to ethnic variability, as this study was done on the Anatolian population.

The study sample was limited to an Egyptian subpopulation in Cairo governorate only. The findings in our study proved similarities in foramen number and morphometric measurements regardless of the side. Regarding gender, there is a statistically significant difference in the diameter of the greater palatine foramen between males and females.

DECLARATION

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Competing interests

No competing interests.

Ethical approval

Not applicable

Patient consent

Not applicable

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ORIGINAL RESEARCH

CORRELATION BETWEEN MAXILLARY SINUS (LINEAR AND VOLUMETRIC MEASUREMENTS) AND MID-FACE WIDTH USING CBCT: A CROSS-SECTIONAL STUDY

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ABSTRACT

Background: The maxillary sinus is a key anatomical structure in the craniofacial complex, and its morphology may reflect facial skeletal characteristics. Cone-beam computed tomography (CBCT) enables accurate three-dimensional evaluation of sinus anatomy. Understanding the relationship between sinus dimensions and facial measurements is valuable for clinical planning in dentistry, maxillofacial surgery, and forensic applications.

Purpose: To assess the correlation between maxillary sinus dimensions and facial width in healthy adults using CBCT, and to evaluate the influence of age, sex, and mandibular body length on sinus dimensions.

Materials and Methods: A cross-sectional study was conducted on CBCT scans of 40 healthy adults (13 males, 27 females; aged 18–44 years). Maxillary sinus volume, width, height, and length were measured bilaterally, along with facial width and mandibular body length. Pearson correlation was used to evaluate associations between variables. Sex differences and laterality were analyzed. Multiple linear regression models were constructed to determine the strongest predictors of sinus volume. Inter- and intra-observer reliability were assessed using intraclass correlation coefficients (ICC).

Results: After statistical analysis, we found that the maxillary sinus showed bilateral symmetry with no significant right–left differences. Facial width demonstrated a significant positive correlation with sinus dimensions, particularly on the right side ($p < 0.05$), indicating that wider facial structures are associated with larger sinus volume and linear dimensions. No significant associations were found between sinus measurements and age or mandibular body length. Although males exhibited slightly greater sinus dimensions than females, differences were not statistically significant. Multiple regression analysis identified sinus height and width as the strongest predictors of sinus volume (Adjusted R^2 up to 0.92). CBCT measurements showed excellent reproducibility.

Conclusion: Maxillary sinus dimensions correlate significantly with facial width in adults, suggesting coordinated growth of sinus anatomy and midfacial structures. CBCT provides reliable measurements for sinus evaluation and may aid in surgical planning, implantology, orthodontics, and forensic identification.

Keywords: Maxillary sinus, Facial width, CBCT, Craniofacial morphology, Sinus volume.

INTRODUCTION

The maxillary sinus is a crucial anatomical structure closely related to the upper posterior teeth, and its evaluation is essential in many dental procedures, mainly surgical and orthodontic treatments involving the sinus region[1].

The maxillary sinus is the largest among the paranasal sinuses and is situated just behind the anterior bony surface of the midface, occupying the body of the maxilla[2]. It has a pyramidal shape, with its medial base forming a significant portion of the lateral wall of the nasal cavity[3]. The apex of the sinus extends toward the zygomatic process of the maxilla and, in some cases, occupies a large part of the zygomatic bone. The roof of the sinus constitutes the floor of the orbit and shows notable ridges over the infraorbital canal[4]. The floor is primarily formed by the alveolar process of the maxilla and partly by the hard palate. The level of the maxillary sinus floor changes with age; around the age of 20 years, it reaches its lowest point due to the eruption of the maxillary third molars[5].

During development, the skeletal components of the neurocranium and viscerocranium are closely associated with the formation of functional spaces such as orbits, nasal cavities, paranasal sinuses, and oral cavity, as well as with the growth of surrounding

soft tissues, including the brain, muscles, and connective tissue[6]. The dimensions of the facial skeleton show a strong correlation with the volume of the maxillary sinus[4]. Moreover, the shape and size of the maxillary sinus reflect the developmental pattern of the surrounding bony structures[7]. Therefore, it has been proposed that the maxillary sinus plays a role in midfacial growth and contributes to determining the overall shape of the midface[8]. Besides that, in forensic medicine, the maxillary sinus can be used for sex and age determination [3,9,12].

A study conducted by Song et al. (2009) evaluated the maxillary sinus volume and dimensions in different craniofacial deformities with mid-facial hypoplasia. The maxillary sinus volume, height, width, and depth significantly decreased in patients with Crouzon syndrome[13].

Craniofacial reconstruction surgeries are continually evolving globally to meet the increasing functional and aesthetic demands of patients. One of the most common orthognathic surgical procedures used for the correction of maxillary deformities is Le Fort 1 osteotomy. A study was conducted to investigate the prevalence of complications for patients who had undergone Le Fort 1 osteotomy. According to their findings, Le Fort 1 osteotomies affect maxillary sinus health. These osteotomies may lead to sinusitis symptoms postoperatively and iatrogenic alterations, such as a decrease in the maxillary sinus volume and the disruption of the integrity of the medial and lateral walls of the maxillary sinus[14].

Therefore, clinicians must carefully consider maxillary sinus parameters when managing mid-facial bony structures, whether addressing trauma, congenital deformities, or performing orthognathic procedures such as Le Fort osteotomies [15-17].

Dentofacial imaging technologies play an important role in evaluating the maxillary sinus morphology and dimensions. Conventional radiographs show limited information in three-dimensional (3D) structure analyses. In comparison with conventional two-dimensional (2D) radiographs, advanced imaging modalities provide 3D multi-planar images and information on dental and maxillofacial regions [18].The use of 3D imaging modalities ensures accurate 3D visualizations of the maxillary sinus[19]. Computed Tomography (CT) was reported to be an excellent imaging modality and acts as the gold standard to evaluate the true anatomy of sinuses. However, its use is limited because of its high cost, high radiation dose, and restricted accessibility[20].

Recently, Cone beam computed tomography (CBCT) has been preferred as it provides (3D) images with great accuracy for linear measurements in the axial and coronal image planes in different areas of the maxillofacial region[20]. Moreover, CBCT is overcoming the limitations of conventional radiography by producing 3D images that allow a comprehensive evaluation of the anatomy of the region of interest, and it also offers lower radiation exposure for the patients when compared to conventional CT[21].

Several studies have highlighted the relationship between midfacial development and maxillary sinus morphology[4,10.22]. Additionally, previous research has examined the impact of congenital conditions, such as cleft lip and palate, on maxillary sinus size and volume[23]. Other investigations have further explored the associations between maxillary sinus dimensions and volumetric parameters in relation to sex and age [3,12.24-32].

Given the limited research focusing on the Egyptian population and the significant influence of maxillary sinus anatomy in maxillofacial surgery, this study aims to explore the potential correlation between maxillary sinus volume and dimensions with midface width in this demographic.

MATERIALS AND METHODS

This retrospective cross-sectional study analyzed maxillofacial cone-beam computed tomography (CBCT) scans of adult Egyptian individuals. Ethical approval was obtained from the Research Ethics Committee of the Faculty of Dentistry, Cairo University (May 30, 2023). Sample size calculation was performed using G*Power version 3.1.9.7 [33].A power analysis was designed to have adequate power to apply a two-sided statistical test of the null hypothesis that there is no correlation between maxillary sinus linear and volumetric measurements with midface width, by adopting an alpha (α) level of (0.05), a beta (β) level of (0.2) (i.e., power=80%), a null hypothesis value of (0.5), and a correlation coefficient of (0.428) acquired from the results of a previous study [34]. The predicted sample size (n) was found to be 40 cases. Sample size approval was granted by the Medical Biostatistics Unit (April 8, 2023). CBCT scans were collected from the database of the Department of Oral and Maxillofacial Radiology, Faculty of Dentistry, Cairo University. A total of 40 scans (27 females and 13 males) were included based on the calculated sample size and predefined eligibility criteria. The inclusion criteria comprised Egyptian adults aged 18–44 years with no history of orthodontic or surgical treatment affecting maxillomandibular growth. Scans showing maxillary or craniofacial pathology, traumatic injuries, developmental anomalies, missing upper premolars or molars, or those with low image quality or artifacts were excluded.All CBCT images had been previously acquired for diagnostic or treatment planning purposes using standardized exposure parameters adapted to patient size. Datasets were exported in DICOM format and analyzed using Mimics software (version 21.0; Materialise, Leuven, Belgium). The maxillary sinuses

were segmented using a semi-automated region-growing approach to isolate the air-filled cavities from surrounding bone, with minor manual refinements applied when necessary. Three-dimensional models were generated, and sinus volumes were automatically calculated in cubic millimeters (mm^3) using the software's volume measurement function **(Fig. 1).**

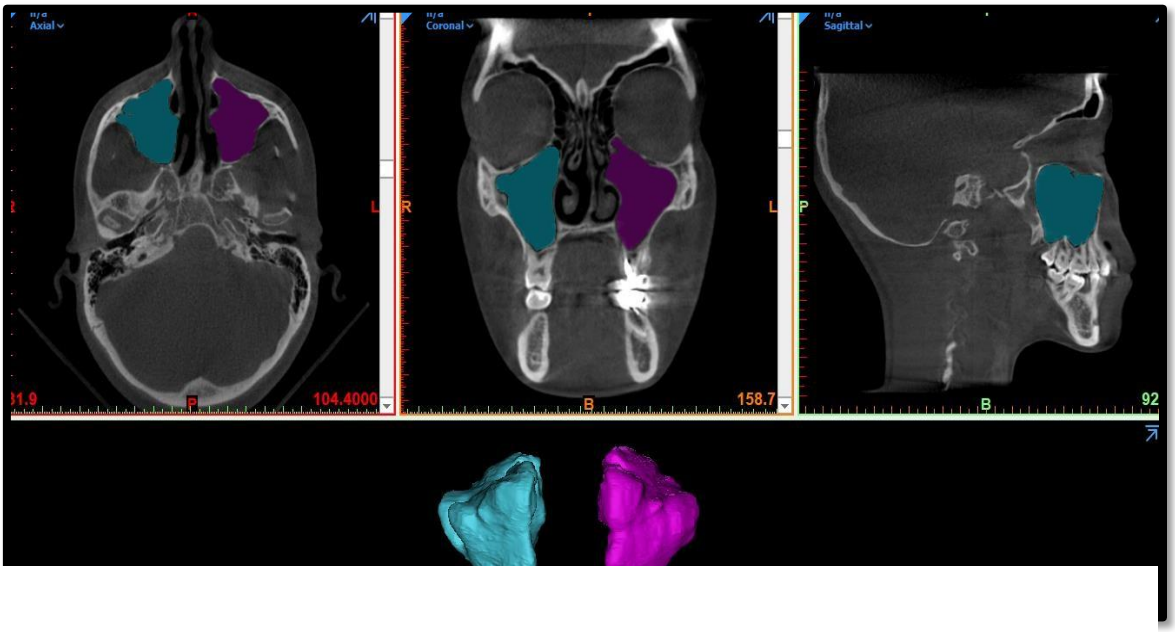


Figure 1. 3D segmentation of the right and left maxillary sinus presented in the multiplanar CBCT

Linear measurements were obtained bilaterally multiplanar reconstructed images as follows **fig.2,3,4.**

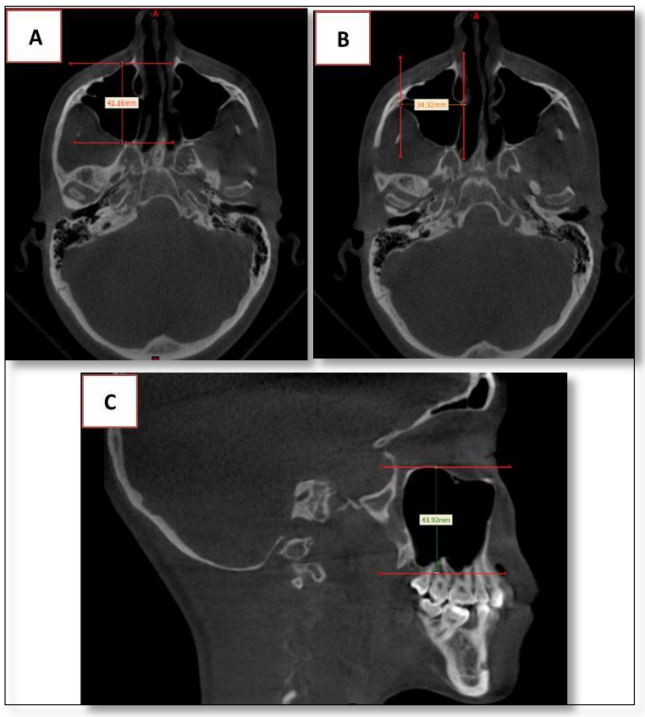


Figure 2. Maxillary sinus linear measurements. (A) Maxillary sinus length (MSL). (B) Maxillary sinus width (MSW). (C) Maxillary sinus height (MSH).

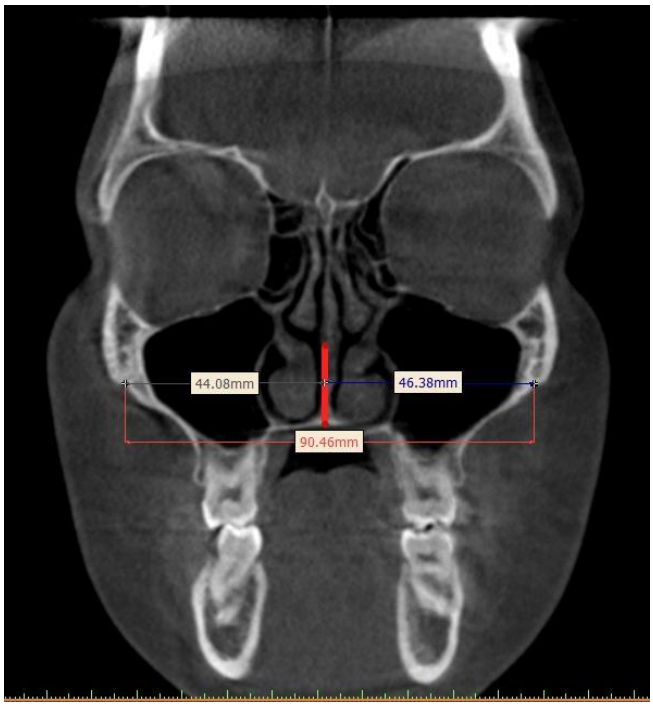


Figure 3 Midface width measured on coronal CBCT image



Figure 4 Mandibular body length measured on 3D reconstruction as the linear distance from Gonion (Go) to Gnathion (Gn).

Maximal anteroposterior diameter (maximal length) of the maxillary sinus (MSL) was measured, involving the longest distance from the most anterior point of the anterior wall of the maxillary sinus to the most posterior point of the posterior wall of the maxillary sinus on the adjusted axial image.

- **Maximal horizontal diameter (maximal width) of the maxillary sinus (MSW**) was measured involving the longest distance perpendicular from the most prominent point of the medial wall of the maxillary sinus to the most prominent point of the lateral wall of the maxillary sinus on the adjusted axial image.
- **Maximal vertical diameter (maximal height) of the maxillary sinus (MSH)** was measured involving the longest distance from the lowest point of the inferior wall of the maxillary sinus to the highest point of the superior wall of the maxillary sinus in the adjusted sagittal image.
- **Midface width on CBCT adjusted coronal image** was measured as the distance between the most lateral and inferior points of the maxillozygomatic suture (zm point) on both sides.
- **Mandibular body length** was measured in the 3D reconstruction as a linear distance between the identified two consistent anatomical landmarks: Gonion (Go): The most posterior-inferior point on the angle of the mandible.Gnathion (Gn): The most anterior-inferior point on the mandibular symphysis

Sampling and addressing potential sources of bias

All scans were independently evaluated by two experienced oral and maxillofacial radiologists blinded to the patients' demographic data and to each other's findings. To assess reliability, 50% of the scans were re-evaluated by the main investigator after a two-week interval for intra-observer reliability and by another radiologist for inter-observer reliability. Discrepancies were resolved by consensus. Random selection of scans and blinding during image interpretation were applied to minimize potential sources of bias.

Statistical analysis

Statistical analysis was performed with R statistical analysis software version 4.5.1 for Windows **(35)**.

Categorical data were presented as frequency (n) and percentage (%) values. Continuous data were presented as means, standard deviation (SD), median, minimum, and maximum values. They were examined for normality by viewing the distribution and using the Shapiro-Wilk test. Age data were nonparametric; however, all other measurements were normally distributed. Correlation analyses were performed using point-biserial correlation (for sex) and Spearman's correlation for other variables. Comparisons of mean values of different sexes were performed using independent t-tests. Laterality analyses were performed using paired t-tests. Multivariable linear regression models predicting sinus volume were confirmed for linearity (by visual inspection of residuals versus fitted values), normality of residuals (by methods mentioned earlier), and for homoscedasticity (by using the Breusch-Pagan test). Inter-observer reliability analyses were performed using one-way random ICC (Intraclass correlation coefficient) models, while for intra-observer reliability, two-way mixed ICC models were used. The significance level was set at $p < 0.05$ for all tests.

RESULTS

The descriptive analysis of the maxillary sinus and facial dimensions revealed that, on the right side, the mean sinus volume was approximately 15,739 mm^3 with a standard deviation of 5,055 mm^3, ranging from 6,218 mm^3 to 27,927 mm^3. The mean sinus width, length, and height on the right side were 30.6 mm, 38.9 mm, and 37.4 mm, respectively.

On the left side, the mean sinus volume was slightly higher at 16,246 mm^3 (SD = 4,729 mm^3), ranging from 5,970 mm^3 to 29,441 mm^3. The mean sinus width, length, and height were 31.1 mm, 39.1 mm, and 37.8 mm, respectively. The mean facial width for the entire sample was 87.4 mm (SD = 4.32 mm), while the mean mandibular body length was 73.7 mm (SD = 4.72 mm). These findings indicate that left sinus volumes were marginally greater than those of the right side, though the differences were small and not statistically significant.

Correlation analysis was presented in **Table 1,** demonstrating a moderate, positive, and statistically significant relationship between facial width and most sinus parameters on the right side. The right sinus volume ($r = 0.45$, $p = 0.004$), width ($r = 0.41$, $p = 0.009$), length ($r = 0.46$, $p = 0.003$), and height (r =

0.39, p = 0.013) all showed significant positive correlations with facial width

On the left side, a similar trend was observed, though the strength of the correlations was slightly weaker. The left sinus volume (r = 0.38, p = 0.017) and width (r = 0.35, p = 0.030) were significantly correlated with facial width, whereas the correlations for length (r = 0.27, p = 0.089) and height (r = 0.29, p = 0.066) did not reach statistical significance. These results suggest that facial width is a meaningful predictor of sinus size, especially in relation to sinus volume and width, with the right side showing stronger and more consistent associations than the left.

Table 1. Correlations between sinus measurements and facial width.

Side	Measurement	Correlation coefficient (95% CI) with facial width	p-value
Right	Sinus volume (mm^3)	0.45 (0.16 to 0.67)	0.004*
	Sinus width (mm)	0.41 (0.11 to 0.64)	0.009*

CI: Confidence interval; * significant ($p<0.05$); ns: not significant.

No statistically significant correlations were found between any of the sinus measurements and the mandibular body length. The correlation coefficients for both sides were low and non-significant.

The correlation between sinus dimensions and age was not statistically significant for either side. All correlation coefficients were weak and negative, suggesting a minimal or negligible inverse relationship. Since all participants were adults, this finding confirms that sinus development has already stabilized and that sinus volume does not vary markedly with age within this age range. When comparing sinus dimensions between males and females, the mean values for males were consistently higher across all measurements on both sides; however, none of these differences reached statistical significance ($p > 0.05$).

A strong, positive, and statistically significant relationship was found among all sinus parameters, regardless of side. Sinus width, length, and height each demonstrated strong correlations with sinus volume (r ranging between 0.74 and 0.88, $p < 0.001$). These findings indicate that as one linear dimension of the sinus increases, the others increase proportionally, suggesting that sinus pneumatization occurs in a harmonious and balanced manner across all dimensions.

The comparison between right and left sinus measurements showed no statistically significant differences for any dimension. Both sides exhibited nearly symmetrical values for sinus volume, width, length, and height ($p > 0.05$).

Multiple linear regression models were presented in **Table 2** to identify which sinus dimensions most effectively predicted sinus volume. For the right side, the model was statistically significant ($F = 141.39$, $p < 0.001$) and explained 92% of the variance in sinus volume (Adjusted $R^2 = 0.92$). All predictors showed significant positive relationships with sinus volume, with the regression coefficients (β) indicating that for each 1 mm increase in sinus width, length, and height, the sinus volume increased by approximately 391 mm^3, 330 mm^3, and 425 mm^3, respectively.

For the left side, the regression model was also statistically significant ($F = 69.97$, $p < 0.001$) and accounted for 84% of the variance (Adjusted $R^2 = 0.84$). The coefficients showed that for every 1 mm increase in sinus width, length, and height, the sinus volume increased by approximately 434 mm^3, 261 mm^3, and 381 mm^3, respectively. These results demonstrate that sinus height and width are the strongest predictors of sinus volume, while sinus length contributes to a lesser extent. Reliability analysis revealed excellent consistency for all measurements. Interobserver reliability coefficients (ICC) ranged between 0.92 and 1.00, while intra-observer ICC values ranged from 0.99 to 1.00, all statistically significant ($p < 0.001$). This confirms high measurement accuracy and reproducibility across all assessed parameters, validating the reliability of the CBCT-based measurements used in this study.

Table 2. Regression models predicting sinus volume.

Side	Measurement	Coefficient (95% CI)	p-value
Right	Sinus width (mm)	391.19 (202.80 to 579.58)	<0.001*
	Sinus length (mm)	330.01 (119.79 to 540.22)	0.003*
	Sinus height (mm)	424.53 (279.26 to 569.80)	<0.001*
Left	Sinus width (mm)	433.63 (201.06 to 666.20)	<0.001*
	Sinus length (mm)	260.76 (30.19 to 491.34)	0.028*
	Sinus height (mm)	381.20 (196.09 to 566.32)	<0.001*

CI: Confidence interval; * significant ($p<0.05$).

DISCUSSION

Evaluating changes in maxillary sinus dimensions in relation to midfacial measurements may contribute to understanding the growth model of the maxillary sinus and its correlation with facial anatomical structures [36,37]. Therefore, this study investigated the correlation between maxillary sinus linear and volumetric dimensions and midfacial width and length in adult Egyptian individuals.

The analysis comprised 40 CBCT scans. CBCT was selected as the imaging modality of choice due to its superior spatial resolution, lower radiation exposure, and cost-effectiveness relative to conventional computed tomography[38]. Maxillary sinus volumes were obtained using semi-automated segmentation in MIMICS software. This method offers improved accuracy and efficiency over manual techniques while maintaining anatomical precision [39,40]. The reliability of MIMICS for volumetric analysis has been previously validated [28,41].

In the present study, the mean maxillary sinus volume (MSV) was 15.74 cm^3 on the right side and 16.25 cm^3 on the left, values that fall within the commonly reported adult range of approximately 14–18 cm^3 [12,17,42-45]. These findings are consistent with Pokhrel et al. (2025), who reported comparable mean volumes in a Nepalese population using CBCT[42]. Similar values were also reported in European samples by Fernandes (2004), whereas smaller volumes were observed in Zulu individuals in the same study, suggesting ethnic variability[46]. In contrast, larger MSVs have been reported in Japanese populations by Kawarai et al. (1999), reflecting differences in craniofacial morphology and volumetric assessment techniques [47]. Slightly lower but comparable values have been documented in Turkish and Sri Lankan populations [47,48]. Overall, variations in MSV across studies are likely attributable to demographic factors, craniofacial characteristics, imaging modality, and segmentation methodology. The results of the present study, therefore, fall within the expected physiological range and align with previously reported data when population and methodological differences are considered.

Comparison of the right and left maxillary sinuses in the present study revealed no statistically significant difference, indicating a high degree of bilateral symmetry in sinus morphology. To minimize potential confounding factors, individuals with posterior tooth loss were excluded, as unilateral dentition differences are known to influence maxillary sinus pneumatization and may affect side-to-side comparisons.

These findings are consistent with previous studies reporting general bilateral symmetry of the maxillary sinuses in healthy individuals, with minor variations considered within normal anatomical limits [3,9,10]. Similarly, Gulec et al. (2020) found no significant difference between right and left maxillary sinus volumes in a CBCT-based study of 133 subjects[28]. Although slight asymmetries may occur, they are typically minimal and clinically insignificant, potentially arising from localized functional or anatomical factors such as masticatory dominance or nasal septal deviation [49]. The documented increase in sinus volume following posterior tooth loss further supports the exclusion criteria applied in the present study to ensure reliable bilateral comparisons[50].

Strong and statistically significant positive correlations were observed among all maxillary sinus parameters (volume, height, width, and length), indicating proportional sinus expansion during pneumatization. Regression models predicting sinus volume from linear dimensions demonstrated high explanatory power (adjusted R^2 = 84–92%), suggesting that linear CBCT measurements can reliably estimate sinus volume.

These findings are consistent with previous studies reporting that linear sinus dimensions serve as accurate predictors of volumetric measurements when

3D reconstruction is unavailable[51-53]. However, the relative contribution of each linear dimension varied between sides. On the right side, sinus height showed the strongest influence on volume, followed by width and length, whereas on the left side, width was the strongest predictor, followed by height and length.

Overall, these results indicate that maxillary sinus volume is primarily influenced by vertical and transverse expansion, with the anteroposterior dimension playing a lesser role. This observation agrees with previous CBCT-based studies highlighting width by Alhazmi et al. (2019), and height by Uchida et al. (1998) as major determinants of sinus volume [51,54]. Anatomically, this pattern reflects the predominant inferior and lateral directions of maxillary sinus growth and pneumatization toward the alveolar process and zygomatic buttress [28,55].

A notable finding of the present study was the moderately strong, statistically significant positive correlation between midfacial width and all right-side maxillary sinus measurements (volume, height, width, and length). This supports the concept that the surrounding skeletal framework influences maxillary sinus pneumatization and occurs proportionally with transverse midfacial dimensions [56].

These results are consistent with Alhazmi et al. (2019), who demonstrated moderate to strong correlations between maxillary sinus volume and transverse maxillary measurements using CBCT, with volumetric assessment showing stronger associations than linear dimensions[4]. Similarly, Fathy et al. (2022) reported positive correlations between maxillary sinus volume and midfacial width parameters, including bizygomatic and zygomaxillary widths, in an Egyptian population, with stronger associations observed in females[10].

In the present study, the left side showed a significant positive correlation between midfacial width and both sinus volume and width, whereas correlations with sinus height and length were not significant. This partial asymmetry contrasts with the findings of Fathy et al. (2022), who reported predominantly left-sided correlations, and may reflect minor anatomical asymmetry or measurement variability[10].

Additional support for the relationship between sinus morphology and midfacial width comes from Przystańska et al. (2018), who reported strong associations between sinus width and transverse facial dimensions, while sinus volume was more closely related to vertical and anteroposterior facial parameters [22]. All these findings reinforce the role of transverse midfacial dimensions as key determinants of maxillary sinus size.

In the present study, no significant correlation was found between maxillary sinus dimensions and mandibular body length, indicating that sinus morphology is more closely associated with midfacial skeletal parameters than with the lower facial skeleton. This independence likely reflects the distinct embryological origins and developmental pathways of the maxilla and mandible. These findings are consistent with Alqahtani et al. (2023), who reported no significant association between maxillary sinus volume and mandibular body length (Co–Gn) in an adult CBCT-based analysis [57].

In contrast, Yili et al. (2020) observed a positive correlation between maxillary sinus volume and mandibular length in a younger population aged 5–20 years [58]. Differences in developmental stage most plausibly explain this discrepancy, as both mandibular growth and sinus pneumatization are ongoing during childhood and adolescence. By contrast, the adult-only sample in the present study represents a post-maturational phase, in which growth-related associations are less likely to be detected.

In the present study, no statistically significant correlations were found between maxillary sinus measurements and age. This finding contrasts with several studies reporting age-related reductions in sinus volume or dimensions, particularly in samples including wide age ranges. Ozsoy et al. (2025) and Aktuna Belgin et al. (2019) reported significant negative correlations between age and sinus volume using CBCT-based volumetric analyses [4], while Otsuki et al. (2023) demonstrated that sinus dimensions increase until early adulthood and gradually decline thereafter[59]. Similar age-related reductions in sinus pneumatization were reported by Wu et al. (2022) and Elshentnawi et al. (2025), although the latter noted weak predictive power [60,61].

Conversely, studies focusing on adult populations have frequently reported minimal or non-significant associations between age and sinus volume. Tanaka et al. (2021), Bornstein et al. (2019), Asantogrol et al. (2021), and Gulec et al. (2020) found no significant age-related changes in maxillary sinus volume in adults, suggesting that the influence of age diminishes after craniofacial growth is complete.

Overall, these findings suggest that maxillary sinus dimensions stabilize in adulthood and that age is not a primary determinant of sinus morphology in dentate adults, consistent with previous observations by Emirzeoglu et al. (2007) and Jun et al. (2005) [51,62].

In the present study, males exhibited slightly larger mean maxillary sinus dimensions than females; however, these differences were not statistically significant. This finding is consistent with several CBCT- and CT-based studies reporting minimal or non-significant sex-related differences in maxillary sinus volume; these studies suggest that maxillary sinus volume alone has limited discriminatory power for sex determination [12,29-32].

Conversely, other investigations have reported significantly larger sinus volumes in males. Studies in Saudi [63], Egyptian [64], South Indian [65], and Turkish [66] populations demonstrated greater male maxillary

sinus volumes using both formula-based calculations and segmentation techniques, with some achieving high accuracy in sex classification.

The absence of statistically significant sex differences in the present study may be attributed to subtle volumetric variations and a relatively limited sample size, which may have reduced the power to detect minor sex-related differences reported in larger cohorts. Although males demonstrated numerically higher values, the substantial overlap between male and female measurements indicates that maxillary sinus volume should not be used as a standalone parameter for sex determination. Instead, it may serve as a supplementary variable within a comprehensive morphometric or forensic assessment, in agreement with recent systematic reviews [67].

Inter- and intra-observer reliability analyses demonstrated excellent agreement (ICC = 0.92–1.00 and 0.99–1.00, respectively; $p < 0.001$), confirming the high precision and reproducibility of CBCT-based maxillary sinus measurements, consistent with previous reports [68].

Study Limitations

This study was limited by a relatively small sample size and predominance of younger adults. Additionally, only healthy individuals were included, which limits applicability to pathological conditions such as chronic sinusitis, trauma, or skeletal malocclusion.

CONCLUSION AND RECOMMENDATION

Finally, we concluded that maxillary sinus dimensions showed bilateral symmetry and a moderate positive correlation with midfacial width, indicating a link between sinus growth and midfacial development. No significant effects of sex, age, or mandibular length were observed. CBCT proved reliable for measurement. Further large-scale and longitudinal studies across populations are recommended to confirm these findings and explore clinical and forensic applications.

DECLARATION

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Conflicts of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this article.

Author contributions

AAH: Conceived and designed the study, sample collection, data entry, interpretation of data, drafting the article, and approval of the final article. HSM: Contributed to study design, data interpretation, revising the drafted article, and approval of the final article. HO: Coding the data, contributed to data analysis, revising the drafted article, and approval of the final article.

Ethical policy and institutional review board statement

The current study was approved by the ethical committee of the Faculty of Dentistry, Cairo University, Egypt (approval number 1523) (approval date 30/5/2023), and it complies with the Declaration of Helsinki (2013). The trial is registered on.

Patient declaration of consent

Patient declaration of consent was obtained in a Helsinki declaration consent form in their native language (Arabic). Provided is the English version of said form and a signed Arabic one by one of the study participants.

Data availability statement

The data that support the findings of this study are available from the corresponding author, [AAH], upon reasonable request.

Not applicable

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ORIGINAL RESEARCH

EVALUATION OF TEMPOROMANDIBULAR JOINT ARTHROSCOPY WITH TENOXICAM VERSUS STANDARD ARTHROSCOPY FOR PATIENTS WITH INTERNAL DERANGEMENT. A CLINICAL STUDY

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Purpose: To evaluate the clinical and radiological efficacy of adding the NSAID Tenoxicam to the irrigant solution during Temporomandibular Joint (TMJ) arthroscopy for patients with symptomatic internal derangement.

Materials and Methods: A randomized controlled trial was conducted on 20 female patients (mean age 28 years) divided into two equal groups. All patients underwent arthroscopic lavage and lysis of the superior joint space under general anesthesia. Group I (Control) received standard Ringer's lactate irrigation. Group II (Study) received Ringer's lactate supplemented with 20 mg Tenoxicam. Clinical parameters, including Visual Analog Scale (VAS) for pain, Maximal Interincisal Opening (MIO), bite force (N), and chewing efficacy, were evaluated at 1 week, 2 weeks, and 1, 3, and 6 months postoperatively. Structural changes in disc position were assessed via MRI at 6 months.

Results: Both groups showed significant improvements in VAS and MIO compared to preoperative baselines ($P < 0.05$). No statistically significant difference was found between groups regarding long-term pain, MIO, or MRI disc repositioning at 6 months ($P > 0.05$). However, Group II demonstrated **statistically** significant superior functional recovery. By the first week, 60% of Group II patients returned to a soft diet compared to 10% in Group I ($P = 0.019$). At 6 months, 60% of Group II achieved a hard diet, whereas Group I remained significantly lower ($P = 0.025$).

Conclusion: While Tenoxicam does not significantly alter long-term structural or analgesic outcomes, it significantly accelerates functional masticatory recovery. Its use as an irrigant adjunct is recommended to improve immediate postoperative quality of life.

Keywords: Temporomandibular Joint (TMJ), arthroscopy, masticatory recovery, and quality of life.

INTRODUCTION

The management of temporomandibular joint (TMJ) disorders (TMD) remains a significant challenge within oral and maxillofacial surgery. According to the Diagnostic Criteria for Temporomandibular Disorders (DC/TMD), these pathologies are broadly classified into muscle-related disorders (e.g., myalgia and myofascial pain), joint-specific pain (arthralgia and TMD-attributed headache), disc displacements (with or without reduction/locking), and degenerative joint diseases.[1] TMJ arthritic conditions are further distinguished by their inflammatory profiles. Low-inflammatory disorders, such as osteoarthritis, typically present with localized pain and crepitation. In contrast, high-inflammatory disorders, including rheumatoid or infectious arthritis, often exhibit bilateral involvement and systemic markers such as elevated C-reactive protein (CRP) and erythrocyte

sedimentation rate (ESR).[2] Internal derangement (ID), defined by the mechanical malposition or dysfunction of the articular disc, is identified as a primary catalyst for TMJ disability.[3] The severity of ID is traditionally staged using the Wilkes classification, which tracks the progression from early-stage displacement to advanced degenerative arthritis.[4] The therapeutic objectives for TMJ osteoarthritis focus on pain attenuation, restoration of mandibular range of motion, and improvement of patient quality of life.[5] Intra-articular pain is largely mediated by a high concentration of pro-inflammatory cytokines within the synovial fluid. Due to the relatively avascular nature of the joint space, these mediators persist, leading to chronic symptoms.[6] Arthrocentesis, popularized by Nitzan et al., serves as a minimally invasive surgical standard when conservative modalities—such as occlusal splints and physical therapy—fail. The procedure utilizes hydraulic pressure to expand the joint space and physically "wash out" metabolic waste and inflammatory mediators.[7] To augment these results, pharmacologic agents are frequently introduced into the superior joint space. While hyaluronic acid and corticosteroids are common.[8] Analgesics such as opioids (Morphine-Tramadol-Fentanyl) or non-steroidal anti-inflammatory drugs (NSAIDs), specifically COX-2 inhibitors like Tenoxicam, have gained prominence.[9,10] Tenoxicam (20 mg) is particularly advantageous for intra-articular use. Unlike many NSAIDs that contain organic solvents or stabilizers prone to causing local intolerance, parenteral Tenoxicam utilizes an aqueous base. Its pharmacokinetics include a potent anti-inflammatory profile and an extended half-life (60–80 hours). Crucially, Tenoxicam targets the synovium without concentrating in the cartilage, thereby avoiding the chondrocyte toxicity associated with other NSAIDs. but remains active within the synovium. Following successful applications in knee joint disorders, researchers have increasingly adopted Tenoxicam for the management of TMJ pathology.[11,12]

Subjects and Methods

Study Design and Ethics

This randomized controlled trial was conducted at the Oral and Maxillofacial Surgery Department, Sayed Galal University Hospital, Al-Azhar University. The study protocol was approved by the Institutional Review Board (IRB) and adheres to the ethical tenets of the **Declaration of Helsinki**. All participants provided written informed consent prior to enrollment.

Sample Size Calculation

Sample size was determined using **G*Power software (version 3.1.9.4)**. Based on previous data (Fayed et al., 2016), a sample size of 6 patients per group was identified as sufficient to detect a large effect size (d = 2.34) with 90% power and a 5% significance level. To account for potential attrition and enhance statistical reliability, the cohort was increased to **10 patients per group** (N=20).

Eligibility Criteria

Inclusion Criteria:

- Patients aged over 18 years, both genders.
- Clinical and radiographic diagnosis of TMJ Internal Derangement (**Wilkes Stages III or IV**).
- Refractoriness to conservative therapy (minimum 3-month duration).

Exclusion Criteria:

- Systemic polyarthritis or advanced degenerative joint disease.
- Myofascial pain dysfunction syndrome (MPDS) as the primary diagnosis.
- History of previous TMJ surgery or ankylosis.
- Presence of intra-articular tumors or overlying skin infections.
- Pregnancy, lactation, or medical contraindications to general anesthesia

Surgical Technique

Preoperative Preparation and Anesthesia

Under general anesthesia with nasotracheal intubation, patients are placed in a supine position with the head turned to the contralateral side. The surgical field is prepared and draped according to standard aseptic protocols. A canthotragal line is marked from the lateral canthus of the eye to the tragus of the ear to establish the anatomical reference for portal placement.

Portal Placement and Joint Access

Two specific points are marked for the dual-portal technique:

1. **Fossa Point:** 10 mm anterior to the tragus and 2 mm inferior to the canthotragal line, corresponding to the glenoid fossa.
2. **Eminence Point:** 20 mm anterior to the tragus and 10 mm inferior to the canthotragal line, corresponding to the articular eminence.

The superior joint space is distended via the injection of 3 ml of saline. A small stab incision is made at the first point to allow the introduction of a sharp trocar,

which is subsequently replaced by a blunt trocar to minimize iatrogenic cartilage damage. The arthroscope is then inserted and connected to a high-definition camera system. A second incision at the eminence point facilitates the insertion of a cannula to establish an outflow circuit and allow for the introduction of manipulation instruments.

Lavage and Pharmacological Protocol

The joint space is visualized to assess for synovitis, adhesions, or chondromalacia.

- **Group I (Control):** Endoscopic lavage is performed using 150–200 ml of plain Ringer's Lactate (RL) solution.
- **Group II (Study Group):** The irrigation protocol utilizes 150–200 ml of RL solution supplemented with **20 mg of Tenoxicam**. Unlike intra-articular injections where the drug is left in the joint, the Tenoxicam in this study is integrated into the irrigation fluid to ensure a continuous anti-inflammatory wash of the synovial lining during the procedure.

Intraoperative Manipulation and Closure

Following the lavage, manual manipulation of the mandible is performed in vertical, lateral, and protrusive directions to ensure the lysis of fine adhesions and to reach the maximum inter-incisal opening (MIO). Once the joint is cleared of debris and inflammatory exudate, the instruments are withdrawn. The portals are closed using **5/0 non-resorbable Prolene** sutures, and a pressure dressing is applied.

Clinical Results

1. Pain and Mandibular Range of Motion

Both groups demonstrated a significant longitudinal reduction in **VAS scores** and a concomitant increase in **MIO** from preoperative levels to the 6-month follow-up ($P < 0.001$). At the 6-month endpoint, Group II (Tenoxicam) exhibited a mean VAS of 2.50 ±0.73 and a mean MIO of 38.40 ±2.80mm. While these absolute values were superior to Group I (3.70 ±1.07 and 36.70 ±3.40 mm, respectively), the differences between the two cohorts did not reach statistical significance ($P > 0.05$).

2. Masticatory Function and Chewing Efficacy

The primary clinical distinction between the two groups was observed in the recovery of masticatory efficiency.

- **Early Functional Return:** At the 1-week interval, **60% of patients in the Tenoxicam group** had successfully transitioned to a soft diet, compared to only 10% in the control group. This difference was statistically significant (**$P = 0.019$**).
- **Long-term Dietary Progression:** At 3 and 6 months postoperatively, Group II showed a significantly higher proportion of patients capable of tolerating a hard diet compared to Group I ($P = 0.025$).

3. Bite Force and Joint Sounds

Quantitative **bite force (N)** measurements showed progressive recovery in both groups, though inter-group comparisons remained statistically insignificant across all time points ($P > 0.05$). Similarly, the incidence of TMJ sounds (clicking and crepitation) decreased significantly in both cohorts; however, the addition of Tenoxicam did not result in a statistically superior resolution of joint noise compared to standard lavage.

The following table summarizes the key comparative data between Group I (Standard Lavage) and Group II (Tenoxicam-supplemented Lavage) at the 6-month follow-up (table 1).

Table 1. Comparison of Clinical Outcomes

Clinical Parameter	Group I (n=10)	Group II (n=10)	Significance (P-value)
VAS Pain Score	3.70 ±1.07	2.50 ±0.73	0.098 (NS)
MIO (mm)	36.70 ±3.40	38.40 ±2.80	0.238 (NS)
Bite Force (N) - Midline	4.36 ±1.26	5.03 ±1.46	0.571 (NS)
Soft Diet Return (1 Week)	10%	60%	**0.019*(S)**
Hard Diet Return (6 Months)	0%	60%	**0.025* (S)**
MRI Disc Reduction (DDWR)	40%	50%	0.653 (NS)

(NS) = Not Significant; (S) = Significant at $P < 0.05$

Study Limitations

While this randomized controlled trial provides valuable insights into the functional benefits of intra-operative Tenoxicam, several limitations must be acknowledged:

1. **Sample Size:** The cohort size was limited to 20 patients (n=10 per group). While the study was sufficiently powered to detect significant differences in functional chewing efficacy, a larger sample might be required to achieve statistical significance in parameters like VAS pain scores and MIO, where Group II showed positive but non-significant trends.
2. **Gender Homogeneity:** All participants in this study were female. While TMJ internal derangement is statistically more prevalent in women, the lack of male participants limits the generalizability of these findings across the entire patient population.
3. **Short-term MRI Follow-up:** The 6-month MRI provides a snapshot of structural recovery; however, long-term remodeling of the condyle and disc can take years. Extended radiological follow-up would be beneficial to determine if Tenoxicam influences long-term degenerative changes.
4. **Dose-Response Evaluation:** This study utilized a standardized 20 mg dose of Tenoxicam. Further research is needed to determine if varying concentrations or different delivery methods (such as sustained-release gels) could further enhance the analgesic and structural outcomes

DISCUSSION

Exclusion of occlusal splints was intentional to isolate the therapeutic effect of the arthroscopic procedure and the pharmacological adjunct.

"To avoid confounding variables, post-operative occlusal splint therapy was intentionally excluded from the protocol. This allowed for a direct assessment of the efficacy of Tenoxicam-supplemented lavage on joint function and masticatory recovery without the influence of vertical dimension alterations or neuromuscular deprogramming provided by splints."

1. Comparative Analgesic Efficacy

Tenoxicam provided non-significant pain reduction compared to Ringer's Lactate ($P > 0.05$) aligns with several prominent studies, though some authors suggest a "vanishing" effect:

- **Siewert-Gutowska et al. (2023):** Concluded that while arthrocentesis is highly effective, the chemical composition of the irrigant—including adjuvant injectables—did not significantly improve clinical outcomes over time. They argue that the mechanical washout of inflammatory mediators is the primary therapeutic driver.
- **Sen et al. (2014/2024):** Observed that while Tenoxicam provides significant early relief, its analgesic effect tends to **decrease between the 1st and 6th week**. This supports your data showing that by the 6-month mark, both groups reached similar pain levels.
- **Chęciński et al. (2024):** In a systematic review, they noted that differences in pain scores for Tenoxicam were often less than 1 point on the VAS scale after 4 weeks, suggesting that while it is an "economic alternative" to Hyaluronic Acid, its incremental benefit over standard saline is modest.

2. Functional Recovery and Chewing

60% transition to a soft diet in the first week—is supported by authors who focus on "patient-centered outcomes":

- **Angelo et al. (2023):** Emphasized that TMJ arthroscopy leads to an early return to masticatory capacity. Your results provide specific pharmacological evidence that adding Tenoxicam can further compress this recovery timeline, likely by stabilizing the immediate post-surgical inflammatory "flare."
- **Dolwick (Evidence-Based Review):** Notes that while many supplements fail to improve resting pain, certain anti-inflammatories significantly improve **chewing pain** specifically. This mirrors your result where "functional chewing" was the primary variable showing statistical significance.

3. Structural and MRI Outcomes

Tenoxicam did not significantly improve disc repositioning is a point of consensus in the surgical community:

- **Grossmann et al. (2019):** Argued that minimally invasive procedures (arthroscopy/arthrocentesis) are functional rather than structural. They maintain that the goal is to "release the stuck disc" and improve lubrication rather than anatomical

"normalization" of the disc-condyle relationship.

- **Insel et al. (2020):** Confirmed that MRI findings rarely change significantly after lavage, regardless of the drug used, reinforcing your conclusion that Tenoxicam acts on the **synovium and pain receptors** rather than the physical architecture of the joint.

4. Differing Perspectives: Corticosteroids vs. NSAIDs

Some authors present a more critical view of using NSAIDs like Tenoxicam over other agents:

- **Liaqat et al. (2024):** Argue that **Corticosteroids** remain superior to NSAIDs for reducing pain and improving MIO in patients with "closed lock" (DDwoR). They suggest that the potent anti-inflammatory action of steroids may be necessary for long-term relief compared to the shorter half-life of Tenoxicam.

Al-Moraissi et al. (2021): Often advocate for a "cocktail" approach (Hyaluronic Acid + NSAIDs), suggesting that Tenoxicam alone might lack the "viscosupplementation" benefits required for long-term joint health

CONCLUSION

The findings of this randomized clinical trial indicate that while **TMJ arthroscopy** is a robust intervention for internal derangement, the addition of **20 mg Tenoxicam** to the irrigant solution provides a distinct clinical advantage. Although the supplementation did not significantly alter long-term analgesic or structural outcomes (MIO and MRI disc position) compared to standard Ringer's lactate, it resulted in a statistically significant acceleration of functional recovery.
Specifically, the Tenoxicam group demonstrated a faster transition to a soft diet and a higher tolerance for hard foods throughout the follow-up period. Therefore, Tenoxicam is a valuable pharmacological adjunct that improves the immediate postoperative quality of life and facilitates earlier masticatory rehabilitation for patients with Wilkes Stage III and IV internal derangement.

DECLARATION

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ORIGINAL RESEARCH

EVALUATION OF TMJ ARTHROSCOPY WITH HYALURONIC ACID INJECTION VERSUS STAND- ARD TMJ ARTHROSCOPY FOR PATIENTS WITH INTERNAL DERANGEMENTS: A RANDOMIZED CLINICAL TRIAL

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Abstract

Background: Initial Temporomandibular joint (TMJ) arthroscopy aims to reduce inflammation and mechanical ob- struction in TMJ internal derangement. Supplemental hyaluronic acid (HA) deposition is frequently employed to improve joint lubrication and protect articular surfaces, yet its long-term therapeutic impact as an adjunct is not well-defined.
Objective: While TMJ arthroscopy is a standard treatment for TMJ internal derangements(ID), the added therapeu- tic value of HA as an adjunct remains unclear.
Study Design: Randomized controlled trial with 1:1 allocation. Setting: Patients with TMJ ID was selected from those attending the Outpatient Clinic of Oral and Maxillofacial Surgery Departement at Sayed Galal University Hospital, Al Azhar University and Faculty of Dental Medicine ,Boys, Cairo Al Azhar University
Participants: twelve patients over 18 years of both sexes, suffer from TMJ ID which not respond to conservative treatments, were randomized into two groups, study group(n= 6) patients and control group (n=6)patients. **Interventions**: Participants receive either standard TMJ arthroscopic lysis and lavage (ALL) alone (Control Group) or the same ALL supplemented with an intra-articular injection of HA (study Group). Both protocols were per- formed under general anesthesia for patients diagnosed with TMJID.
Main Outcome Measures:, including pain levels according visual analog scale (VAS) and maximal interincisal opening (MIO), laterality excursion, protrusion, chewing efficacy and disc position change in MRI, were assessed between groups at standard follow-up intervals
Results: Both groups showed significant pain reduction, but HA group reported significantly lower pain at 3 months (2.00 vs. 4.33, p = 0.016) and 6 months (1.33 vs. 4.33, p = 0.005), No statistically significant differences were ob- served between the groups for any additional parameters throughout the follow-up period (p>0.05), with both co- horts demonstrating comparable improvements in maximal incisal opening (MIO).
Conclusions: TMJ arthroscopy effectively treats ID, with adjunctive HA providing superior early pain relief and functional recovery. However, long-term functional outcomes are comparable to standard arthroscopy alone. While HA accelerates initial healing, standard arthroscopy remains a highly reliable definitive treatment.

Keywords: Temporomendibular joint, internal derangement, Arthroscopy, hyaluronic acid, pain.

INTRODUCTION

The temporomandibular joint (TMJ) is a ginglymodiarthroidal joint; having both rota- tional and translational movements. This joint is formed of the mandibular condyle fitting into the mandibular fossa of the temporal bone. Where the articular disk separates these tow bones [1].

Moreover, the temporomandibular dis- orders (TMDs) are considered as the most com- mon causes of non odontogenic pain in the max- illofacial region, affecting the TMJ itself as well as the associated anatomical structures [2]. About 10 millions of populations suffering from TMDs in the USA as well as treated in studies [3]. Alt- hough Seventy-five percent of adults show at least one sign of joint dysfunction during exami- nation and one third have at least single clinical symptom [4].

Diagnosis of the TMDs is reached through anamnesis however the clinical exami- nation concomitantly with using of imaging techniques which increase the accuracy of the diagnosis. Magnetic resonance imaging (MRI) is accepted as the gold standard diagnostic aids of non calcified structures of the TMJ.[5]. There was a variety of classifications, 1989, Wilkes [6] first established a classification which consists of 5 stages depending on the clinical, radiologic, and intraoperative findings. Besides, most inter- nationally used diagnostic tools during the last two decades have been the Research Diagnostic Criteria for TMD (RDC/TMD) and the TMD classification according to the American Acad- emy of Orofacial Pain [7,8].

In concern management of TMDs con- sists of non invasive treatment which includes patient education, prescription of medications, physical therapy and occlusal appliances. Many patients recover with only jaw rest and soft diet, while others may require a combination of these non invasive treatments [9].

Arthrocentesis is a minimally invasive treatment often used in patients who do not re- spond to conservative treatment to relieve symp- toms that impair the quality of life has inspired many studies. [10] Arthrocentesis is minimally invasive, inexpensive and highly effective pro- cedure, apart from having a low morbidity rate[11]. It invalues because arthrocentesis does not involve visualization of the joint structures or the use of additional surgical manipulations, it raises the question of whether arthroscopy should be the preferred initial treatment TMDs.[12] TMJ arthroscopy was first performed by Wanatabe M.[13], a Japanese orthopedic sur- geon. After that, Holmlund et al.(14) popular- ized TMJ arthroscopy. Since then TMJ arthros- copy became a widely popular, leading to open surgical treatment for TMD is now uncommon, and is reserved for specific indications as well as end-stage diseases, ankylosis and removal of tumour among others [15].

Arthroscopy may be finished with intra articular injections, many different substances that can be injected following TMJ arthroscopy to enhance the best possible clinical re- sults.(16)Among these substances hyaluronic acid (HA) and platelets rich plasma(PRP). The HA is a glycosaminoglycan, naturally present in synovial fluid and participating in joint lubrica- tion, that is produced by chondrocytes and syno- viocytes within any joint [17,18].

Therefore, the main objective of this study was to evaluate the effectiveness of HA injection following operative arthroscopy, com- pared with the conventional TMJ arthroscopy, in patients with (TMJID).

PATIENTS AND METHODS

Study Design: This study was designed as a ran- domized, parallel-arm clinical trial with a 1:1 allocation ratio. The primary objective was to test the null hypothesis that no statistically sig- nificant difference exists in HA deposition be- tween TMJ ALL supplemented with HA versus standard TMJ ALL alone. Ethical clearance was obtained (Approval Code: [Code]) before the study commenced, and the trial was retrospec- tively registered at ClinicalTrials.gov (Identifier: 884/1960). This report adheres to the updated CONSORT guidelines for randomized clinical trials

Participants

Inclusion criteria: Patients over 18 years of both sexes. Patients with a diagnosis of TMJID according to Wilkes classification of TMDs. Patients who did not respond to conservative treatment as a first line of treatment.

Exclusion criteria comprised Patients with polyarthritis or degenerative joint disease. Patients with myo- fascial pain, Previous TMJ surgery, Uncon- trolled systemic diseases contraindicating gen- eral anesthesia or surgery. Ankylosis, intra- articular tumor spread, overlying skin infections. Lactating, pregnant or planning pregnancy women. Known hypersensitivity to HA. Inabil- ity to attend follow- up appointments. Prior to enrollment, written informed consent was se- cured from all participants. a sample of n=5 per group was required to detect an effect size of d=2.18 alpha=0.05, power=0.80. Adjusting for a 20% dropout rate, the total sample size was set at n=12 (6 per group).

Randomization and blinding

An independent assistant, uninvolved in re- cruitment or study procedures, generated the random allocation sequence (1-12). Each num- ber was sealed in an opaque envelope, which were then shuffled. Immediately prior to sur- gery, the envelope was opened to reveal the as- signed surgical technique.

Interventions

Preoperative phase: Clinical parameters, in- cluding pain, , and functional range of motion— specifically maximal interincisal opening (MIO), contralateral lateral excursion (LE), and protru- sive movements, chewing efficacy were record- ed for all patients. Additionally, Magnetic Reso- nance Imaging (MRI) was performed to evaluate disc position and joint morphology.Figures1(a,b)

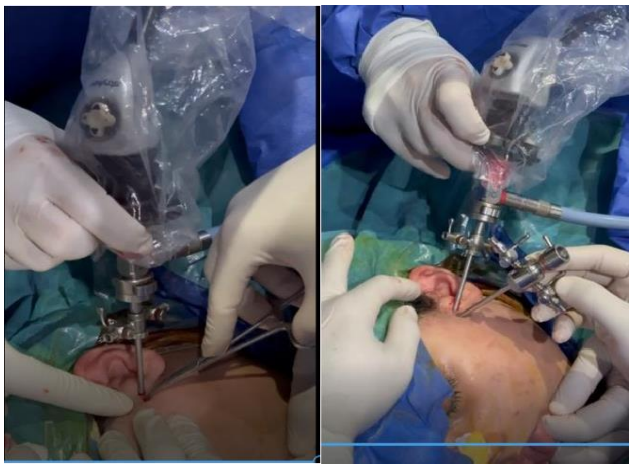


Figure1 a. posterior portal for inflow, arthroscope camera.
Figure1 b. two portals were established inflow and outflow.

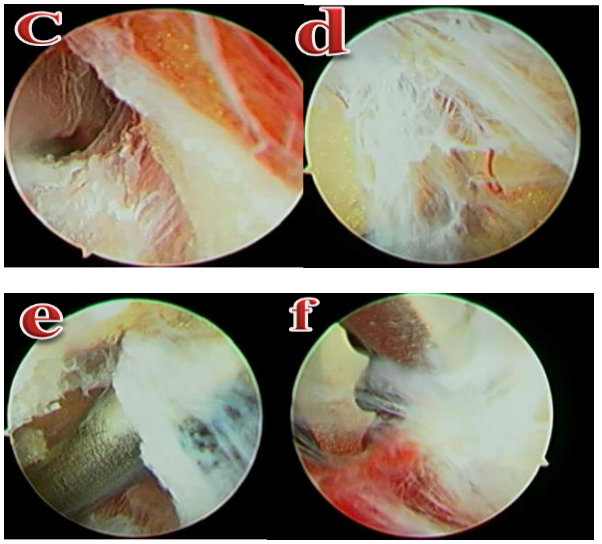


Figure 2 c,d,e,f intra articular image showing poste- rior recess, adhesion and synovitis, outflow sheath and grasper head.

A rigid endoscope with an outer diameter of 2.4mm and a 30° viewing angle (Karl Storz SE & Co. KG, Tuttlingen, Germany) was used for the procedure. All patients underwent arthroscopy under general anesthesia. the portals for inflow and outflow are established along the Holmlund-Hellsing line.(14) (cantho-tragal ligne). After occluding the external auditory ca- nal with sterile cotton, the surgical field was scrubbed and draped using standard sterile tech- niques. Entrance points was located along the canthotragal line, The primary inflow/fossa puncture was marked 10 mm anterior to the tra- gus and 2 mm inferior to the line. The secondary outflow portal was marked 20 mm anterior to the tragus and 10 mm inferior to the line.(21)

In a supine position with the head rotat- ed, the superior joint space was distended (3 mL saline/2% lidocaine) and backwashed. each pa- tient received a double portal puncture (level II arthroscopy), Using a 2.4 mm trocar-cannula sheath, a primary portal was established; place- ment was confirmed by saline fluctuation during jaw movement before inserting a 2.3 mm ar- throscopy. Figure (a) An anterolateral second portal was created for outflow and instrumenta- tion. Figure2(b) Lysis and lavage were per- formed using 500 ml Ringer's lactate, delivered via an infusion pump through the primary can- nula. This maintained continuous pressure to facilitate adhesiolysis and the drainage of inflammatory mediators through the outflow portal.

Control group: Lysis and lavage Ringer's lac- tate alone.

Study group: Lysis and lavage with Ringer's lactate. Deposition of 20 ml of HA post ALL. Stab incision were closed with 5-0 sutures and dressed. Following 5–10 assisted maximal mouth opening repetitions, patients were extu- bated.

Postoperative management

a preauricular pressure dressing was applied for 48 hours. Patients received amoxicil- lin/clavulanic acid (625 mg) and an analgesic complex (ibuprofen 400mg/paracetamol500mg). Cryotherapy was used for 24 hours (20-minute intervals), followed by moist heat. The diet pro- gressed from liquid to soft over three months. Occlusal splint therapy and physiotherapy (ver- tical/lateral exercises) commenced at 24 hours. Sutures were removed after one week

Observation and follow-up

Clinical assessments were conducted at baseline and postoperatively at 1 and 2 weeks, and 1, 3, and 6 months.

Parameters included

- Pain: Evaluated via Visual Analogue Scale (VAS) daily for the first week, then at each follow-up interval.
- Mandibular Kinematics: MIO, lateral excursion, and protrusion were meas- ured using Vernier electronic calipers.
- Functional Outcomes: Chewing efficacy was evaluated using a 3-item food ques- tionnaire (liquid, soft, and hard foods).
- Radiological Evaluation: Preoperative MRI findings were compared with fol- low-up scans obtained at 6 months. Figures (i,g).

Statistical Analysis

Descriptive statistics are reported as mean ± SD, median (IQR), or counts (%). Data normality was confirmed via Kolmogorov-Smirnov test (D=0.13532, p=0.894). Continuous variables were analyzed using independent t-tests for in- ter-group comparisons. Analysis was performed via IBM SPSS v.21, with significance set at $p < 0.05$.

RESULT

Demographic Data

The mean age for Group I was 28.67 years (SD = 10.03), while for Group II, it was 30.17 years (SD = 7.08).The ages range from 21 to 48 and 23 to 41 for both groups respectively. Regarding gender distribution, in Group I, 5 out of 6 participants (83.3%) were female, and 1 (16.7%) was male. In Group II, all 6 participants (100%) were female. There were nonstatically significant between both groups as regard age and gender (table 1). With a P value of 0.771 for age and 0.296 for gander.

Preoperative VAS scores were compa- rable between groups for both right ($p = 0.271$) and left ($p = 0.210$) TMJs. While no significant differences occurred in early follow-ups, Group I (HA) demonstrated significantly lower pain at 3 and 6 months bilaterally (all $p < 0.05$)Table(1). Specifically, at 6 months, HA scores were mark- edly lower for both right (1.33 vs. 4.33, $p = 0.005$) and left TMJs (1.17 vs. 4.00, $p < 0.001$), indicating superior long-term pain reduction with HA injection table 1. Preoperative MIO, lateral excursion, and protru. sion were comparable between groups ($p > 0.05$). For MIO and lateral excursion, no sta- tistically significant differences were observed at any postoperative interval up to 6 months ($p = 0.078$–0.975), despite slight trends favoring Group I at 3 and 6 months.

In contrast, Group I (HA) demonstrated significantly greater protrusion during the early postoperative phase: Day 1 ($p=0.030$), Day 2 ($p=0.001$), and Day 3 ($p=0.045$). However, this advantage diminished over time, with protrusion scores remaining statistically similar from 1 week through 6 months ($p = 0.205$–0.783).

Table 1. Pain comparison between two Groups, VAS)

VAS score for Pain	Group I (n=6)	Group II (n=6)	Test value	P-value
Right				
Pre Op.	8.47±0.59	8.17±0.23	1.166	0.271
1st	9.00±0.89	8.75±0.76	0.522	0.613
2nd	8.10±0.79	8.00±0.63	0.243	0.813
3rd	7.67±0.82	7.17±0.41	1.342	0.209
4th	7.33±1.03	6.85±0.97	0.837	0.422
5th	6.50±1.22	6.83±1.33	-0.452	0.661
6th	6.17±1.17	6.25±0.61	-0.155	0.880
7th	6.00±1.67	6.25±1.08	-0.307	0.765
2w	4.33±1.21	4.83±1.72	-0.483	0.640
1M	3.50±0.98	4.08±1.43	-0.656	0.527
3M	2.00±0.56	4.33±1.03	-2.907	0.016*
6M	1.33±0.37	4.33±1.21	-3.614	0.005*
Left				
Pre Op.	7.92±0.68	7.33±0.82	1.34	0.210
1st	8.25±0.76	8.08±0.66	0.405	0.694
2nd	7.72±0.47	7.50±0.45	0.817	0.433
3rd	7.42±1.02	7.00±0.63	0.85	0.415
4th	6.42±0.49	6.00±1.10	0.85	0.415
5th	6.23±0.43	5.67±1.03	1.24	0.243
6th	6.00±0.00	5.67±1.37	0.598	0.563
7th	4.67±0.74	6.00±1.41	-1.195	0.260
2w	3.33±0.93	4.83±1.33	-1.671	0.126
1M	3.00±0.84	4.00±1.10	-1.225	0.249
3M	1.67±0.47	3.83±1.17	-2.951	0.014*
6M	1.17±0.33	4.00±0.89	-4.715	<0.001**

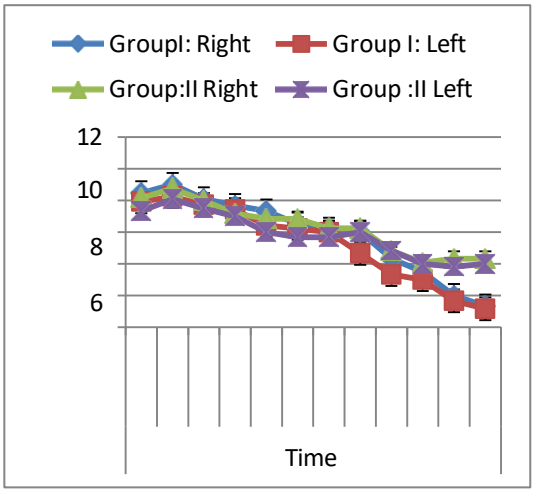


Figure. 3 Comparison between two groups according to VAS score for pain.

Preoperative and early postoperative chewing efficacy were identical, with both groups re- stricted to soft foods at baseline and liquid diets through Day 6 (p = 1.000). By months 2 and 3, Group I (HA) showed a trend toward faster re- turn to hard foods (83.3% and 100%, respective- ly) compared to Group II (50% and 66.7%), though these differences were not statistically significant ($p \geq 0.121$).

Baseline and postoperative MRI find- ings showed no significant differences between groups bilaterally ($p > 0.05$) table2.

Table 2. Comparison between Group I and Group II according to MRI.

MRI find- ing	Group I (n=6)		Group II (n=6)		Test value	P-value
	No.	%	No.	%		
Right						
Pre						
DDWOR	4	66.7%	6	100.0%	2.400	0.121
DDWR	2	33.3%	0	0.0%		
Post						
DDWOR	3	50.0%	4	66.7%	0.343	0.558
DDWR	3	50.0%	2	33.3%		
Left						
Pre						
DDWOR	4	66.7%	2	33.3%	1.333	0.248
DDWR	2	33.3%	4	66.7%		
Post						
DDWOR	1	16.7%	1	16.7%	0.000	1.000
DDWR	5	83.3%	5	83.3%		

Preoperatively, disc displacement with- out reduction (DDWOR) was the predominant finding. Postoperatively, both groups demon- strated similar transitions to disc displacement with reduction (DDWR); on the right side, Group I improved to a 50% DDWR rate com- pared to 33.3% in Group II (p = 0.558), while on the left side, both groups achieved identical out- comes with 83.3% reaching DDWR (p = 1.000). These results indicate that both treatment modal- ities were equally effective in improving disc position

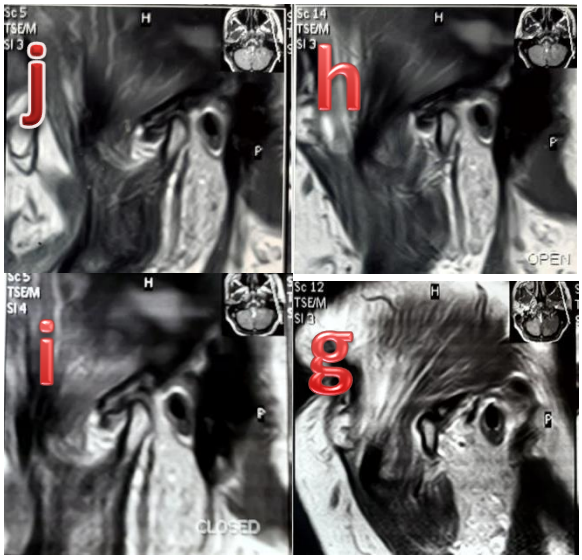


Figure4 j,h MRI closed and open preoperative **Figure 4** i,g MRI closed and open postoperative

DISCUSSION

The primary objective of this research was to assess the efficacy of HA deposition post TMJ ALL versus TMJ ALL alone in achieving superior pain relief, MIO, laterality excursion ,protrusion, chewing efficacy and MRI improvement changes six months post-arthroscopic procedure.

Both groups were demographically comparable, with no significant differences in age, both showed a strong female predilection. This baseline homogeneity ensures that subsequent outcomes are attributable to the intervention rather than demographic variables.

Epidemiological research indicates a significant female predilection in TMJ disorders. Despite extensive investigation into hormonal influences, psychosocial stressors, and genetic predispositions, the exact mechanisms driving this demographic trend remain not fully introstod this result was in accordance of study perfomed by Bagis B.[18] While literature suggests that TMJ disorders peak between the ages of 20 and 40 Manfredini et al.[19].The

results of this study mirrored this distribution, with 83% of participants in their second through fourth decades and an average age of 33.9 years.

In this study using HMW of HA, The HA binds to cell receptors to modulate immune responses and suppress inflammatory cascades, effectively reducing joint pain. Additionally, it acts as a biological shock absorber, cushioning joint structures by distributing mechanical loads [20].

Preoperative pain was comparable across all joints. While most follow-up intervals showed no significant differences, the HA group demonstrated superior long-term pain relief at 3 and 6 months. In both sides, pain scores were significantly decreased. These findings suggest that while arthroscopy provides initial relief for both groups, the addition of HA significantly enhances and sustains pain reduction over time. The HA exerts an analgesic effect by desensitiz- ing intra-articular nerve endings. This finding align with previous controlled studies, which similarly reported significant improvements pain 21.

This was in accordance of Morey-Mas MA [22]. The HA injections following ALL ob- served a significantly enhancement of pain re- duction and TMJ function compared to Ringer's lactate. This finding was not supported across a systematic review performed by Xie et al. [23] In terms of pain reduction, there is no significant difference between HA and placebo, regardless of the follow-up duration.

While both study cohorts experienced a reduction in TMJ pain, the HA group demon- strated significant pain reduction across 3 and 6 month of follow up. These findings reinforce the hypothesis that HA exerts independent analgesic and anti-inflammatory effects that complement
the mechanical benefits of arthroscopic lavage and debridement.

As regard the MIO, and lateral excur- sions improved significantly in both groups with no statistical difference between them. While Group I (HA) experienced a significant boost in protrusive movement during the first three days post-op, this benefit subsided by one week, resulting in similar long-term outcomes for both techniques. this was in agreement with Castaño Joaqui et al.[18] and Morey-Mas et al. [22] who demonstrated tha does not establish the clinical superiority of HA injection post ALL compared with ALL alone. The observed improvements may stem from a multimodal ap- proach involving arthroscopy, adjunctive medi- cations, and physiotherapy.

In contrast, Stasko et al. 24 demonstrated that combining arthroscopy with HA injection significantly reduces pain and restores oral opening. This dual approach effectively debrides adhesions while flushing inflammatory mediators to enhance joint mobility.

HA reduces inflammation and prevents adhesion recurrence. By restoring joint lubrica- tion and protecting cartilage, HA effectively modulates granulation tissue to improve long- term surgical outcomes [25].

Regarding chewing efficiency, findings indicate that Preoperative and early postopera- tive chewing efficiency was identical across groups, with all patients restricted to soft foods at baseline and liquid diets through Day 6. By one month, both groups successfully returned to soft foods . By months 2–3, Group I (HA) showed a clinical trend toward faster recovery, reaching 100% hard food consumption compared to 66.7% in Group II. Although HA may accelerate chewing efficacy, the lack of statisti- cal significance ($p = 0.221$) necessitates larger confirmatory studies.

Chewing efficacy is a key metric for as- sessing TMJ ID and recovery from TMJ arthros- copy. While TMJ ID patients typically suffer from impaired muscle activity and reduced chewing efficacy, Following TMJ arthroscopy, significant improvement typically occurs rapidly within the first 4 to 6 weeks, Most patients can tolerate soft and medium food textures with minimal pain or discomfort during chewing [26].

MRI evaluation demonstrated that both groups had similar types of disc displacement preoperatively. Postoperative imaging showed improved disc positioning (from DDWOR to DDWR) in both groups, with no significant in- ter-group differences, with no statistically signif- icant differences between the groups. This indi- cates that HA injection did not significantly alter the disc position outcomes achieved through TMJ ALL alone. This finding was aligned with that reported Silva et al.[27] He demonstrated that 63% of patients achieved an improved disc position following ALL. Despite the MRI find- ings in this study conflicting with by Gabler, M.J., et al [28]. This suggests that restoring disc mobility and functional dynamics is clinically more significant than achieving anatomical re- positioning of the disc [29].

Regarding intra operative complications, fluid extravasation represents the most common intraoperative finding, minor bleeding is also routine and generally controlled via pressure and irrigation, This outcome corroborates the find- ings of González-García R et al. [51]. Within the study group, neurological complications were documented in two cases, involving numbness in the left temporal region and motor weakness the right eyebrow respectively. Within the control group, one subject of left temporal

paresthesia was documented. Both the sensory deficit and motor weakness achieved complete resolution within 4 to 8 weeks ,the management was fol- lowing a regimen of Vitamin B12, corticosteroids, and physical therapy during the follow-up periods [52]. The close anatomical proximity of the auriculotemporal nerve and the temporal and zygomatic branches of the facial nerve to the arthroscopic portals renders them susceptible to injury. Mechanical compression or direct trauma from the cannula may result in transient neuro- logical deficits, manifesting as paresthesia or paresis [53].

Limitations of this study include a small sample size, which restricts generalizability, and a six- month follow-up, which precludes assessment of long-term joint stability or late-onset degenera- tion. Furthermore, Wilkes stage heterogeneity may have confounded results, necessitating stage-specific stratification in future research.

CONCLUSION

While TMJ arthroscopy with HA offers superior early-term analgesia and acceler- ated protrusive recovery, long-term functional and structural outcomes-including disc posi- tion and chewing efficacy are comparable to standard arthroscopy. Both modalities significantly improve mandibular mobility and edema over six months. Thus, HA serves as a beneficial adjunct for immediate postoperative recovery, but standard arthroscopy remains an equally ef- fective definitive treatment for TMJID.

DECLARATION

Conflict of interest

Authors declare that there is no conflict of interest .

Source of funding

There are no funds procured

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ORIGINAL RESEARCH

THE ACCURACY OF COMPUTER AIDED DETECTION OF PERIAPICAL RADIOLUCENCIES ON CONE BEAM COMPUTED TOMOGRAPHY IMAGES USING ARTIFICIAL INTELLIGENCE: DIAGNOSTIC ACCURACY STUDY.

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ABSTRACT

Objectives: To assess the accuracy of a deep learning model in the automatic detection of periapical radiolucent lesions of upper and lower jaws by comparing it with experienced radiologists' opinion, which represents the ground truth.

Material and methods: CBCT scans of 90 patients were imported into **Blue sky bio** software to be cropped and annotated for detection of periapical Radiolucencies. The annotated data were sent to computer science expert to use the data in training, validation and testing to evaluate the performance of a Bayesian Convolutional Neural Network (Bayesian CNN) model for the automatic detection of periapical radiolucent lesions within maxillary and mandibular cone-beam computed tomography (CBCT) images.

Results: The cross-validated diagnostic performance of the Bayesian ensemble architectures. deep learning model, with ROC-AU values of 0.9839± 0.0139, The PR-AUC values further confirm strong performance, achieving (0.9933 ± 0.0052), achieved high accuracy (0.9441± 0.0283), balanced accuracy (0.9140 ± 0.0458), and F1-scores (0.9616 ± 0.0201), indicating excellent balance between sensitivity and specificity despite class imbalance.

Conclusion: From a clinical perspective, these results suggest that Bayesian ResNet-18 Architecture deep learning model function as balanced diagnostic tools with high sensitivity while maintaining acceptable specificity in computer aided detection of periapical Radiolucencies on CBCT images. ResNet-18 provides also showed an optimal balance between diagnostic performance and computational efficiency, this makes it highly suitable for most clinical deployment scenarios.

Keywords: Artificial intelligence, CBCT, Computer aided detection, Deep learning.

INTRODUCTION

Periapical pathosis can be seen radiographically as periapical Radiolucencies. CBCT creates high-resolution (3D) images without the distortion and superimposition of bone and dental structures seen in conventional radiographs. Cone beam computed tomography scans provide higher diagnostic accuracy compared to digital periapical radiographs in detection of periapical radiolucency[1].In the last few years, there was a revolution in application of artificial intelligence (AI) in the dental field.

Studies show that these AI-powered automated systems performed extremely well in different dental fields[2]. Computer aided diagnosis (CAD) is a non-invasive tool for diagnosis, providing medical professionals with a valuable second opinion and nowadays, many studies are investigating its role in dental application.

The development of computer-aided detection/diagnosis (CAD) systems for dental imaging

is progressing. CAD is also useful in the detection and evaluation of dental and maxillofacial lesions[3].

In recent years the application of artificial intelligence (AI) in the form of deep convolutional neural networks (CNN) have been extensively employed for developing automated tools to achieve an accurate diagnosis[4].

Therefore, this diagnostic accuracy study was designed to evaluate the performance of a Bayesian Convolutional Neural Network (Bayesian CNN) EfficientNet-B0 model for the automatic detection of periapical radiolucent lesions within maxillary and mandibular cone-beam computed tomography (CBCT) images.

MATERIAL AND METHODS

Sample selection and preparation

Sample selection

90 CBCT scans of anonymized retrospective data will be used for research, without the active involvement of patients. Different CBCT machines scans will be used and preliminarily imported into CBCT viewer software program **Blue Sky Bio** to detect the periapical radiolucent lesions.

Inclusion criteria:

- CBCT scans of maxilla and mandible with good quality free pf periapical radiolucent lesions.
- CBCT scans of maxilla and mandible with good quality showing periapical radiolucent lesions.

Exclusion criteria:

- CBCT images of sub-optimal quality or artifacts / high scatter interfering with proper assessment.

Data annotation:

CBCT scans were imported into **Blue sky bio** (open-source free software version 4.12) for data annotation**.** At first the radiologist **navigates the CBCT scans in all cuts (axial, coronal, sagittal and reformatted panorama).**

The radiologist-dependent detection of the periapical area was conducted on **axial cuts** over the apical portion of the root and subsequently identified as either present or absent, with confirmation and consensus from two Oral and Maxillofacial Radiologists (OMFR) with 8 and 15 years of experience. This classification functions as the ground truth **Figure (1).**

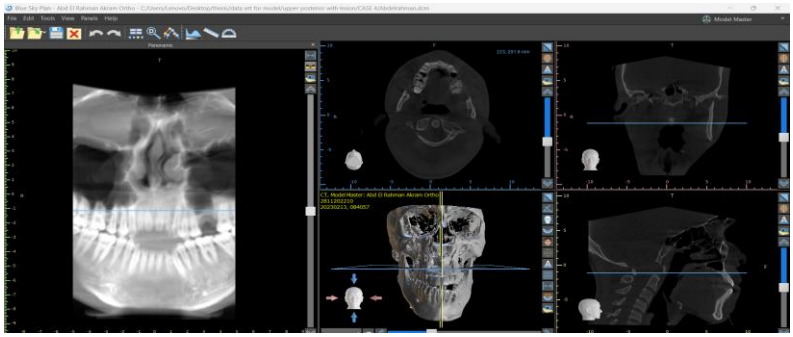


Figure 1. RAW CBCT image in the axial, coronal, and sagittal views on blue sky bio software

The most representative axial cut was selected and 2 cuts above and another two cuts below were selected for a total of 5 cuts in each scan then organized, then scans were cropped in fixed dimensions and organized for easy collaboration with the mathematical engineer for building the model as the following table (1)

Table 1.

Upper arch	**Lower arch**
Upper Anterior Normal **(UAN)**	Lower Anterior Normal **(LAN)**
Upper Anterior with Lesion **(UAL)**	Lower Anterior with Lesion **(LAL)**
Upper Posterior Normal **(UPN)**	Lower posterior Normal **(LPN)**
Upper Posterior with Lesion **(UPL)**	Lower Posterior with Lesion **(LPL)**

Image preprocessing and patch generation

For each category (UAN, UAL, etc.), rectangular axial crops centered on the periapical region were extracted and resized to fixed dimensions. Anterior regions were resized to 275 pixels (height) × 440 pixels (width), whereas posterior regions were resized to 440 pixels (height) × 275 pixels (width), preserving anatomical proportions while standardizing input size across the

Dataset **fig 2**.

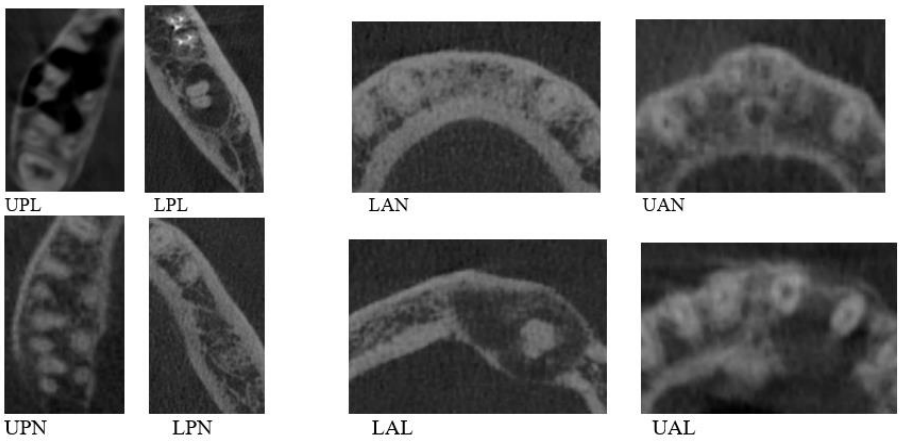


Figure 2. Showing cropped CBCT axial cuts of upper and lower anterior and posterior region

Development of the AI model:
CBCT images were organized into subfolders and preprocessed for uniform cropping and normalization. Model development was conducted in the Python environment (v3.9), utilizing PyTorch and torchvision for diversified data transformations and augmentations (center cropping, random flips, rotation, contrast adjustment) to mitigate overfitting under limited data scenarios [5].
Each ensemble member uses a ResNet-18 backbone with final drop-out layer activated both during training and inference. For each test sample, T stochastic forward passes (typically T = 30) are performed, yielding a predictive distribution rather than a point estimate, as justified by variational Bayesian inference theory[6].
Training, Validation, and Testing A five-fold cross-validation strategy was used to robustly estimate generalization performance.
Training and test splits were maintained at 80:20 per fold and results were aggregated for ensemble prediction. The Bayesian CNN model provides not only a lesion/no-lesion binary label but also a calibrated confidence score, enabling practitioners to assess the reliability of each automated decision[7]. Fig (3)

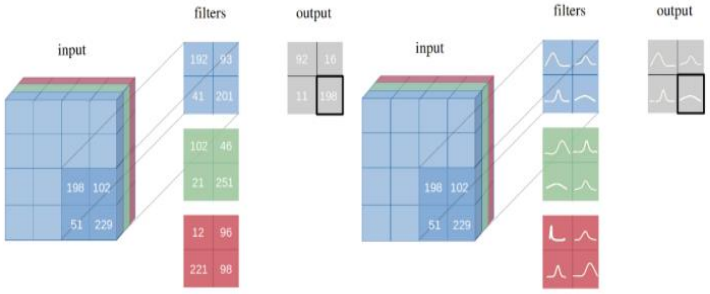


Figure 3. Comparison of conventional and Bayesian CNN architectures
Bayesian ResNet-18 Architecture was included as a mid-complexity baseline. This architecture is based on the residual learning framework, which addresses the degradation problem in deep networks through identity skip connections. The network consists of an initial stem comprising a 7 × 7 convolution with stride 2 andmax pooling, followed by four stages of residual BasicBlock modules with
channel dimensions {64, 128, 256, 512} and down sampling strides. fig (4)

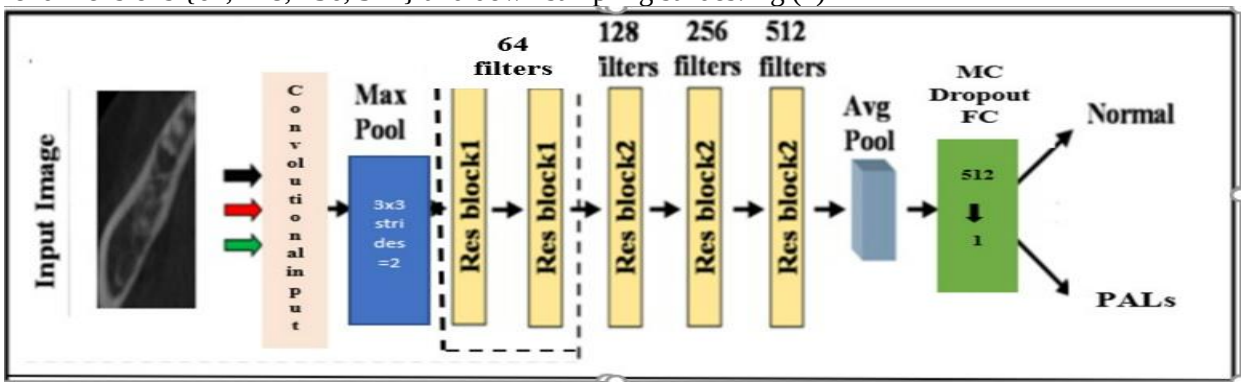


Figure 4. Bayesian ResNet-18 Architecture of Cropped CBCT image in mandibular posterior region.

Statistical analysis
Assessment metrics:
Evaluation
Assessment metrics:
Evaluation

The accuracy of the deep learning model (DLM) versus the Ground truth (GT) was evaluated by the following 2 methods:

1. periapical radiolucent lesion detection accuracy using the classifier DLM:

A dichotomized outcome of "presence of PLAs" and "absence of PLAs" of DLM was compared with GT, where the GT was determined and agreed by two maxillofacial radiologists with eight and 15 years of experience. The results of the test group were put into a confusion matrix of true positive (TP), false positive (FP) and false negative (FN) parameters. Based on this confusion matrix, *Precision*, *Recall (Sensitivity)* and *F1* score were calculated and graded according to the ranking for diagnostic tests by Leonardi Dutra et alwith scores .80% considered excellent outcomes, between 70% and 80% good, between 60% and 69% fair, and below 60% as poor (8)

- **Accuracy** evaluates the correct predictions generated by the model throughout the complete dataset. The calculation is the ratio of true positives (TP) and true negatives (TN) to the total number of samples.
- **Precision,** or positive predictive value, evaluates just true positives among all positive predictions generated by the model. It is determined by the ratio of true positives (TP) to the total of true positives and false positives (FP).
- **Recall**, also referred to as sensitivity or true positive rate, quantifies the ratio of true positive forecasts to all real positive cases, thereby accounting for missed positives. It is determined by the ratio of true positives (TP) to the total of true positives and false negatives (FN).
- **F1 Score** — The F1 Score is a statistic that equilibrates precision and recall. It is computed as the harmonic mean of precision and recall.

Accuracy assesses the overall correctness of the model's predictions, whereas precision and recall concentrate on the quality of positive and negative predictions, respectively. The F1 Score offers an appropriate ratio between precision and recall, rendering it a more balanced indicator for assessing classification models. The area under the curve (AUC) of the receiver-operating characteristic (ROC) curve was calculated as well.

RESULTS

Overall Diagnostic Performance

The cross-validated diagnostic performance of the Bayesian ensemble architectures. Bayesian ResNet-18 Architecture deep learning model, with ROC-AU values of 0.9694±0.0175, The PR-AUC values further confirm strong performance, achieving 0.9828± 0.0125, achieved high accuracy 0.9412± 0.0345 , balanced accuracy 0.9081±0.0561, and F1-scores 0.9597±0.0235, indicating excellent balance between sensitivity and specificity despite class imbalance.

Table 2. Cross-validated diagnostic performance (mean -standard deviation) of the Bayesian ensembles across 5 folds with ensemble and Monte Carlo averaging.

Metric	Bayesian ResNet-18 Architecture
ROC-AU	0.9694±0.0175
PR-AUC	0.9828±0.0125
Accuracy	0.9412±0.0345
Balanced accuracy	0.9081±0.0561
F1-score	0.9597±0.0235
MCC	0.8499±0.0963
Sensitivity	0.9836±0.0163
Specificity	0.8326±0.1011
PPV	0.9373±0.0355
NPV	0.9484±0.0630
Brier score	0.0433 ±0.0236

Confusion Matrix Analysis

EfficientNet-B0 achieving approximately 16.8 true negatives and 47.2–47.4 true positives per fold. False negatives are minimal (0.6 patches), confirming the very high sensitivity. positives are moderate (3.2 patches), resulting in acceptable specificity suitable for clinical deployment where minimizing missed lesions takes priority while avoiding excessive false alarms.

Table 3. Mean confusion matrices (average patch counts per test fold) for model.

TN	FP	FN	TP
16.8	**3.2**	**0.6**	**47.4**

TN = true negatives, FP = false positives, FN = false negatives, TP = true Positives.

Table 4 reports per-image inference time for the three ensemble architectures, measured in milliseconds per image during evaluation. These timing measurements include the complete inference pipeline: loading the image, performing T = 15 Monte Carlo dropout passes for each of Nens = 5 ensemble members, and computing the final averaged prediction.

ResNet-18 achieves a favorable performance-efficiency balance with mean inference time of 17.700. ±34 ms per image (range: 17.36–19.02 ms), maintaining comparable diagnostic performance. This efficiency advantage makes ResNet-18 particularly attractive for clinical deployment scenarios where computational resources are limited or where high-throughput batch processing is required (e.g., retrospective analysis of large CBCT databases).

Table 4. Per-image inference time statistics for ResNet-18 architectures.

Model	Mean (ms/image)	Std (ms/image)	Range (ms/image)
ResNet-18	**17.70**	**0.34**	**17.36–19.02**

DISCUSSION

In detection of periapical pathosis AI have gained much importance, specifically that used CNN and U-Net architecture. Most of the endodontic-related AI studies which are based on CBCT images, dealt with periapical pathosis detection and segmentation.

In a study done by abdolali et al image retrieval (CBIR) was used to assist clinicians in decision making by retrieving the most similar cases to a given query image from a large database. Quantitative results show that the proposed approach is more effective than previous methods in the literature, and it can facilitate the introduction of CBIR in clinical CBCT applications[5].

Complicated assignments like the classification of 2D or 3Dradiographic images lack the ability to elucidate how and why the model operates. Furthermore, in the event of an incorrect diagnosis, it becomes impossible to identify the issue and to thoroughly examine the model's functionality in a step-by-step manner[9].

For detection of periapical radiolucent lesion in dental radiographic images. Despite the growing success of deep learning models, accurate classification remains a significant challenge as medical images same as dental images often exhibit characteristics such as limited spatial resolution, subtle visual differences between disease categories (low inter-class variance), and substantial variation within the same class (high intraclass variability). This will hinder the ability of standard vision models to generalize effectively, frequently resulting in misclassification[10].

These challenges highlight the need for efficient architectures that can focus on critical spatial and contextual features for reliable performance. Therefore, in our study we used Bayesian ResNet-18, providing amid-complexity baseline with proven performance in medical imaging that achieved high accuracy (0.9441± 0.0283), balanced accuracy (0.9140 ±0.0458), sensitivity (0.9836±0.0163), specificity (0.8326±0.1011), positive predictive value (0.9373±0.0355), and negative predictive value (0.9484±0.0630). in comparison to the results of detection of periapical pathosis using CNN and U-Net architecture. CBCT images to assess lesion detection accuracy, achieving excellent ratings for sensitivity (0.93), specificity (0.88), positive predictive value, and negative predictive value (0.93)[11].

On the contrary, Orhan et al. employed a U-Net-like architecture for the detection of periapical lesions in CBCT images, utilizing binary voxel-based intersection and prediction metrics based on the true mask combination (IoU) to assess the model's efficacy in predicting lesion localization. This deep learning model identified 142 out of 153 periapical lesions, yielding a reliability of 92.8%[12].

In our study Bayesian ResNet-18 Architecture model was designed as a supervised binary classifier, categorizing cropped axial CBCT patches as either “lesion” or “normal.” To address the inherent uncertainty in medical image classification, The model incorporated Bayesian inference through MonteCarlo (MC) dropout, which provides quantitative estimates of prediction confidence alongside the classification decision[7].

Another study performed the detection of periapical lesions using the Spatial Configuration-Net based on heatmap Regression and the sensitivity and specificity values of lesion detection were 97.1% and 88.0%, respectively[13].

In other study they found that Relying on the precision metric for comparison may be misleading since, w their datasets have a well-balanced distribution that does not reflect real-world clinical scenarios. The precision metric is sensitive to class distribution, making it less suitable in this context. In terms of sensitivity and specificity, they report a higher number of false negatives and false positives. While their sensitivity and specificity results are lower than those of the closely related and best-performing work by Setzer et al. In our study ResNet-18 demonstrate confusion matrices achieving approximately 16.8 true negatives and 47.2–47.4 true positives per fold. False negatives are minimal 0.8 patches, confirming the very high sensitivity reported in. False positives are moderate (3.2 patches) resulting in acceptable specificity suitable for clinical deployment where

minimizing missed lesions takes priority while avoiding excessive false alarms. From a clinical perspective, these results suggest ResNet-18 function as balanced diagnostic tools with high sensitivity (missing few true lesions) while maintaining acceptable specificity (avoiding excessive false alarms).

In other study group of limitations that was corrected in our study First, the study population was relatively small, which may limit the generalizability of the findings. In our study CBCT scans from different machines were used to account for heterogeneous acquisition parameters, scans were rescaled to a fixed intensity range and normalized per image. Second, the AI tool used in the study was commercially available, and diagnostic performance may vary depending on the specific AI algorithm and training dataset used. Third, the study focused only on PL detection, and other dental pathologies were not considered[14].

Four AI models were evaluated in a study and compared: CBCT-SAM, CBCT-SAM without progressive Prediction Refinement Module (PPR), and two previously developed models: Modified U-Net and PAL-Net. CBCT-SAM achieved an average diagnostic accuracy of 98.92% ± 010.37% and an average[15].

Bayesian ResNet-18 Architecture deep learning model, showed higher results with ROC-AU values of 0.9694±0.0175, The PR-AUC values further confirm strong performance, achieving 0.9828± 0.0125, achieved high accuracy 0.9412± 0.0345, balanced accuracy 0.9081±0.0561, and F1-scores 0.9597±0.0235, indicating excellent balance between sensitivity and specificity despite class imbalance.

When compared to A retrospective study of CBCT scans of 134 molars. PARLs detected by Diagnocat.

Diagnostic performance was assessed at both tooth and root levels showing

demonstrated high sensitivity (teeth: 93.9 %, roots: 86.2 %), moderate specificity (teeth: 65.2 %, roots: 79.9 %), accuracy (teeth: 79.1 %, roots: 82.6 %), PPV (teeth: 71.8 %, roots: 75.8 %), NPV (teeth: 91.8 %, roots: 88.8 %), and F1 score (teeth: 81.3 %, roots: 80.7 %) for PARL detection. The AUC was 0.76 at the tooth level and 0.79 at the root level. Postoperative scans showed significantly lower PPV (teeth: 54.2 %; roots: 46.9 %) and F1 scores (teeth: 67.2 %; roots: 59.2 %)[16].

In other study images under optimal viewing conditions, achieving perfect agreement for axial images of lesion margins (0.98, $P < .001$) and lesion dimensions (length and breadth, 0.98, $P < .001$). Similarly, there was perfect agreement for coronal images of lesion height (1, $P < .001$) and sagittal images of lesion height (0.98, $P < 0.001$)[17].

Our model did not deal with artifacts from in CBCT scans. were excluded from our study; instead, the models were trained solely on cropped images to minimize computational complexity, as advised by the computer scientist, which inevitably impacted the accuracy and generalizability of the model's performance. Furthermore, the normal anatomical periapical radiolucent areas as mental foramen and incisive foramen not considered during evaluation.

CONCLUSION

From a clinical perspective, these results suggest that EfficientNet-B0 deep learning model architecture and function as balanced diagnostic tools with high sensitivity while maintaining acceptable specificity in computer aided detection of periapical Radiolucencies on CBCT images. ResNet-18 provide not only accurate classifications but also reliable confidence estimates through their well calibrated

probabilities and quantifiable uncertainties. This enables sophisticated clinical workflows such as: automatic approval of high-confidence predictions, flagging of high-uncertainty cases for expert review.

DECLARATIONS

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Competing Interests

The authors have no competing interests to declare.

Informed Consent

Not applicable.

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ORIGINAL RESEARCH

DIAGNOSTIC ACCURACY OF ULTRASONOGRAPHY FOR ODONTOGENIC FASCIAL SPACE INFECTIONS COMPARED WITH MRI AS THE REFERENCE STANDARD: A SYSTEMATIC REVIEW AND META-ANALYSIS

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Background: Odontogenic fascial space infections can progress rapidly and may cause airway obstruction, mediastinal spread, or sepsis. Clinical symptoms are often nonspecific and may not reflect disease extent, necessitating imaging for accurate diagnosis. Ultrasonography (USG) and magnetic resonance imaging (MRI) are commonly used modalities, but their comparative diagnostic accuracy remains unclear
Objectives: This systematic review aims to evaluate and compare the diagnostic accuracy of ultrasonography versus magnetic resonance imaging for detecting odontogenic fascial space infections
Methods: Studies directly comparing USG (index test) with MRI (reference standard) in human patients with odontogenic fascial space infections and providing extractable diagnostic accuracy data (true positives (TP), false positives (FP), true negatives (TN), false negatives (FN)) were included. PubMed, Scopus, ProQuest, and Google Scholar were searched from January 2005 to January December 2025. Methodological quality was evaluated using the QUADAS-2 tool. Due to the small number of studies and limited sample sizes, findings were summarized descriptively. No bivariate or hierarchical meta-analysis was performed. This review addressed the question that in patients with odontogenic fascial space infections (Population), how accurately does ultrasonography (Index test) detect infection compared with magnetic resonance imaging (Reference standard), in terms of sensitivity, specificity, and other diagnostic accuracy measures (Outcomes)?
Results: Three studies met the inclusion criteria, totaling 144 infected fascial spaces. The main findings showed that USG had high sensitivity (100%) but low specificity (50%), indicating strong rule-out capability but limited reliability in confirming infection. Diagnostic odds ratios were low and imprecise, with wide confidence intervals. MRI demonstrated higher specificity and superior anatomical detail, particularly for deep or multispace involvement.
Limitations of Evidence: The evidence base is limited by the small number of included studies, observational designs, high risk of selection bias, and imprecision due to small sample sizes, weak DOR, uninformative specificity.
Conclusions: Ultrasonography is a useful initial imaging tool in emergency and resource-limited settings but lacks the specificity needed for definitive diagnosis in complex or deep space infections. MRI remains the preferred modality for accurately mapping such infection spread.

Keywords: Odontogenic infections; Fascial space infections; Ultrasonography; MRI; Diagnostic accuracy

INTRODUCTION

Odontogenic fascial space infections represent one of the most serious maxillofacial emergencies, with the potential for rapid progression into deep cervical spaces.[1,2] If inadequately diagnosed or treated, these infections can lead to airway obstruction, mediastinitis, sepsis, and even death.[1] Early recognition is therefore crucial; however, reliance on clinical findings alone often proves inadequate.[3]

Although symptoms such as swelling, pain, trismus, dysphagia, and fever offer important initial clues, they fail to reliably indicate the depth, boundaries, or severity of the infection.[3] Several factors contribute to this limitation: deep fascial involvement may produce minimal surface signs, rendering early disease difficult to detect visually or by palpation; adjacent anatomical spaces may be affected without visible external swelling, especially in the parapharyngeal, pterygomandibular, or

retropharyngeal spaces; and clinical assessment lacks the ability to determine mediastinal extension, which significantly increases morbidity.[2,21] Because clinical features lack the resolution to differentiate superficial from deep infections imaging becomes essential for accurate diagnosis, risk stratification, and surgical planning.[4]

Magnetic resonance imaging (MRI) is widely considered the most reliable modality for evaluating deep neck infections due to its excellent soft-tissue contrast, multiplanar imaging capability.[4,5] Nevertheless, its use is limited by high cost, reduced availability in emergency settings, prolonged acquisition times, and contraindications in patients with ferromagnetic implants or unstable clinical status.[5] Ultrasonography (USG), on the other hand, is inexpensive, portable, radiation-free, and well-suited for emergency or bedside evaluation, providing real-time dynamic assessment and proving particularly effective for superficial fascial spaces and for guiding aspiration or drainage procedures.[6,7]

While operator dependency remains a recognized limitation of USG, its diagnostic performance improves significantly with familiarity with regional anatomy, standardized scanning protocols, and appropriate probe selection.(8) High-frequency linear probes are useful for superficial spaces, whereas lower-frequency curvilinear probes allow deeper penetration, enabling visualization of some deeper cervical spaces although still with reduced resolution compared to MRI.[8] Thus, USG is not inherently "unable" to assess deeper spaces; its effectiveness depends on operator skill and transducer selection.[6]

Previous research comparing USG and MRI has produced variable results.[9,10,12] Several studies report high sensitivity of USG for detecting odontogenic infections, whereas others demonstrate that MRI more reliably assesses multi-space or deep-space involvement.[7,9,12] Because these investigations differ in methodology, patient selection, and operator experience, their findings are not directly comparable.[11,14] These inconsistencies highlight the need for a structured evidence synthesis.[13,20] Rather than conducting a formal meta-analysis which is not feasible given the small number of available studies and limited sample sizes this review provides a descriptive quantitative comparison of the diagnostic accuracy of ultrasonography relative to MRI in detecting odontogenic fascial space infections.[20]

The objective of this systematic review was to evaluate and compare the diagnostic accuracy of ultrasonography (USG) with magnetic resonance imaging (MRI) in detecting odontogenic fascial space infections.(20) Specifically, it aimed to quantify the sensitivity and specificity of USG against MRI as the reference standard and assess USG's role as a supportive adjunct, particularly where MRI is unavailable.(17,42) This review does not claim USG could replace MRI, given their differing purposes and capabilities, but clarifies USG's performance relative to MRI and its complementary value in practice.[28]

METHODOLOGY

Studies were eligible if they involved human subjects with diagnosed or suspected odontogenic fascial space infections, directly compared USG (index test) with MRI (reference standard) in the same patients, used prospective or retrospective observational designs or clinically documented case series with extractable diagnostic accuracy data - true positives (TP), false positives (FP), true negatives (TN), and false negatives (FN) were required to be extractable or derivable, and were full-text articles in English published between January 2005 and December 2025. Studies were excluded if they contained duplicate or overlapping data, were abstract-only, conference proceedings, posters, letters without sufficient data, non-human research, non-comparative case reports, non-English publications without translation. This review addressed the question as, in patients with odontogenic fascial space infections (Population), how accurately does ultrasonography (Index test) detect infection compared with magnetic resonance imaging (Reference standard), in terms of sensitivity, specificity, and other diagnostic accuracy measures (Outcomes)?. A summary of the PICO components guiding the review question is shown in Table 1.

Table 1. PIRO framework for the review question

Component	Description
Population	Patients with fascial space infections secondary to odontogenic origin
Index test	Ultrasonography
Reference standard	Magnetic Resonance Imaging (MRI)
Outcomes	**Primary outcomes:** Sensitivity, specificity **Secondary outcomes:** Positive predictive value (PPV), negative predictive value (NPV), and diagnostic odds ratio (DOR)

Search Strategy and Information Sources: A comprehensive literature search identified studies comparing ultrasonography (USG) with magnetic resonance imaging (MRI) for diagnosing odontogenic fascial space infections,

following PRISMA-DTA recommendations. Databases searched included PubMed, Scopus, ProQuest, and Google Scholar, covering January 2005 to December 2025.

The strategy combined MeSH and free-text terms with Boolean operators, focusing on odontogenic infection, fascial space infection, deep neck infection, ultrasonography/ultrasound, magnetic resonance imaging/MRI, and diagnostic accuracy, sensitivity, specificity. Search keywords used for example are “Odontogenic fascial space infection” AND “ultrasonography” AND “MRI”; “deep neck infection” AND “diagnostic accuracy”; “ultrasound” AND “magnetic resonance imaging”. Manual searching screened reference lists of included studies and used Google Scholar citation tracking; no additional unpublished/grey literature was included, and no new studies were found. Detailed strategy provided in Table 2

Table 2. Search strategy through different database

Database	Component	Strategy
PubMed (PRISMA-DTA main strategy)	**Population**	("fascial space infection"[MeSH Terms] OR "head and neck"[Title/Abstract] OR "odontogenic infection"[Title/Abstract] OR "cellulitis"[MeSH Terms] OR "facial space"[Title/Abstract] OR "maxillofacial radiology"[MeSH Terms])
	Index test	("ultrasonography"[MeSH Terms] OR "ultrasound"[Title/Abstract] OR "USG"[Title/Abstract] OR "sonography"[Title/Abstract])
	Reference condition	("magnetic resonance imaging"[MeSH Terms] OR "MRI"[Title/Abstract])
	Diseased condition	("Diagnosis AND accuracy"[MeSH Terms] OR "sensitivity"[Title/Abstract] OR "specificity"[Title/Abstract] OR "positive likelihood ratio"[Title/Abstract] OR "negative likelihood ratio"[Title/Abstract] OR "diagnostic odds ratio"[Title/Abstract] OR "summary receiver operating characteristics"[Title/Abstract] OR "comparative study"[MeSH Terms] OR "cross sectional study"[MeSH Terms] OR "randomized controlled trial"[MeSH Terms])
	Combined (with date filter)	(Population terms) AND (Index test terms) AND (Reference condition terms) AND (Diseased condition terms) AND ("2005/01/01"[Date - Publication] : "2025/12/31"[Date - Publication]) *Filters: English; Full text available.*
Scopus	**Population**	TITLE-ABS-KEY(("fascial space infection" OR "head and neck" OR "odontogenic infection" OR cellulitis OR "facial space" OR "maxillofacial radiology"))
	Index test	TITLE-ABS-KEY((ultrasonography OR ultrasound OR USG OR sonography))
	Reference condition	TITLE-ABS-KEY(("magnetic resonance imaging" OR MRI))
	Diseased	TITLE-ABS-KEY(("diagnostic accuracy" OR sensitivity

	condition	OR specificity OR "positive likelihood ratio" OR "negative likelihood ratio" OR "diagnostic odds ratio" OR "summary receiver operating characteristics" OR "comparative study" OR "cross sectional study" OR "randomized controlled trial"))
	Combined	(Population) AND (Index test) AND (Reference condition) AND (Diseased condition) AND PUBYEAR > 2004 AND PUBYEAR < 2026 *Filters: Article or Review; English.*
ProQuest	**Population**	("fascial space infection" OR "head and neck" OR "odontogenic infection" OR cellulitis OR "facial space" OR "maxillofacial radiology")
	Index test	(ultrasonography OR ultrasound OR USG OR sonography)
	Reference condition	("magnetic resonance imaging" OR MRI)
	Diseased condition	("diagnostic accuracy" OR sensitivity OR specificity OR "positive likelihood ratio" OR "negative likelihood ratio" OR "diagnostic odds ratio" OR "summary receiver operating characteristics" OR "comparative study" OR "cross sectional study" OR "randomized controlled trial")
	Combined	(Population) AND (Index test) AND (Reference condition) AND (Diseased condition) *Date range: 2005-01-01 to 2025-12-31; Peer-reviewed; English.*
Google Scholar	**All components combined**	"odontogenic infection" OR "fascial space infection" OR "head and neck infection" ultrasound OR ultrasonography OR USG MRI "diagnostic accuracy" OR sensitivity OR specificity *Advanced search: Date range 2005–2025; English; Articles only.*

Study Selection Process: Two independent reviewers screened titles/abstracts, excluded ineligible articles, and reviewed full texts of potentials. Disagreements were resolved by discussion or a third reviewer.

Data Collection and Extraction: Two reviewers independently extracted data using a standardized, prepiloted form, including study characteristics (author/year, country, design, sample size, setting), USG details (transducer, frequency, protocol, operator experience), MRI details (sequences, field strength, contrast, parameters), and accuracy data (TP, FP, TN, FN derived if needed, author contacted for gaps). Specifically, the missing diagnostic accuracy data (true positive, false positive, false negative, and true negative values) required for quantitative synthesis were not fully reported in several primary studies. Therefore, corresponding authors of these studies were contacted via email.Each author was contacted up to two times at two-week intervals.Disagreements were resolved by discussion or a third reviewer, with independent verification.

Risk of Bias Assessment: Risk of bias was assessed via QUADAS-2(11), per PRISMA-DTA[20], covering patient selection (sampling, criteria, avoiding case-control), index test (USG blinding to MRI, prespecified thresholds), reference standard (MRI appropriateness, blinding), and flow/timing (interval, all tests received, handling missing data). Domains were evaluated for bias and applicability concerns.[11]

Descriptive Evaluation of Diagnostic Performance: With few eligible studies and small samples, no meta-analysis (e.g., HSROC/bivariate) was feasible;[20,36] instead, descriptive quantitative synthesis used TP, FP, TN, FN.[41]

Diagnostic Performance Analysis: We calculated standard diagnostic accuracy metrics for USG detection of superficial and deep odontogenic fascial space infections using MRI as reference standard: sensitivity (ability to detect infection presence), specificity (ability to rule out non-infected spaces), positive likelihood ratio (+LR), negative likelihood ratio (-LR), and diagnostic odds ratio (DOR). All estimates include 95% confidence intervals (95% CI) using Wilson score method for proportions. Due to only 3 studies with heterogeneous populations (superficial vs deep spaces), no formal meta-analysis was performed. Results presented descriptively with forest plots (Figures 4-8). Diagnostic accuracy metrics were computed from true positives, false positives, true negatives, and false negatives using standard formulas. [41]
Likelihood Ratio Interpretation PLR: 10 large increase, 5–10 moderate, 2–5 small, <2 minimal. NLR: <0.1 large decrease, 0.1–0.2 moderate, 0.2–0.5 small, 0.5 minimal.[18]
Heterogeneity and Software: Heterogeneity was not formally assessed (only three studies; I^2 unreliable <10). Calculations were manual, verified in RevMan 5.4/SPSS v27; no random-effects/DerSimonian–Laird used.[16]

RESULTS

Study Selection: A total of 250 records were identified through database searching.(20) After removal of 125 duplicates, 125 unique records underwent title and abstract screening.(20) Of these, 63 were excluded for not meeting inclusion criteria, 62 full texts were sought for retrieval, 21 full-text articles could not be obtained, and following full-text assessment of 41 reports, 38 were excluded for the following reasons as, 15 did not meet eligibility criteria based on full-text review, 7 were identified through reference list screening but did not meet inclusion criteria, and 16 were excluded for not meeting the predefined inclusion criteria.(20) Ultimately, 3 studies met all eligibility criteria and were included in the qualitative and descriptive quantitative synthesis(20) ,As shown in PRISMA-DTA flow diagram (Figure 1).

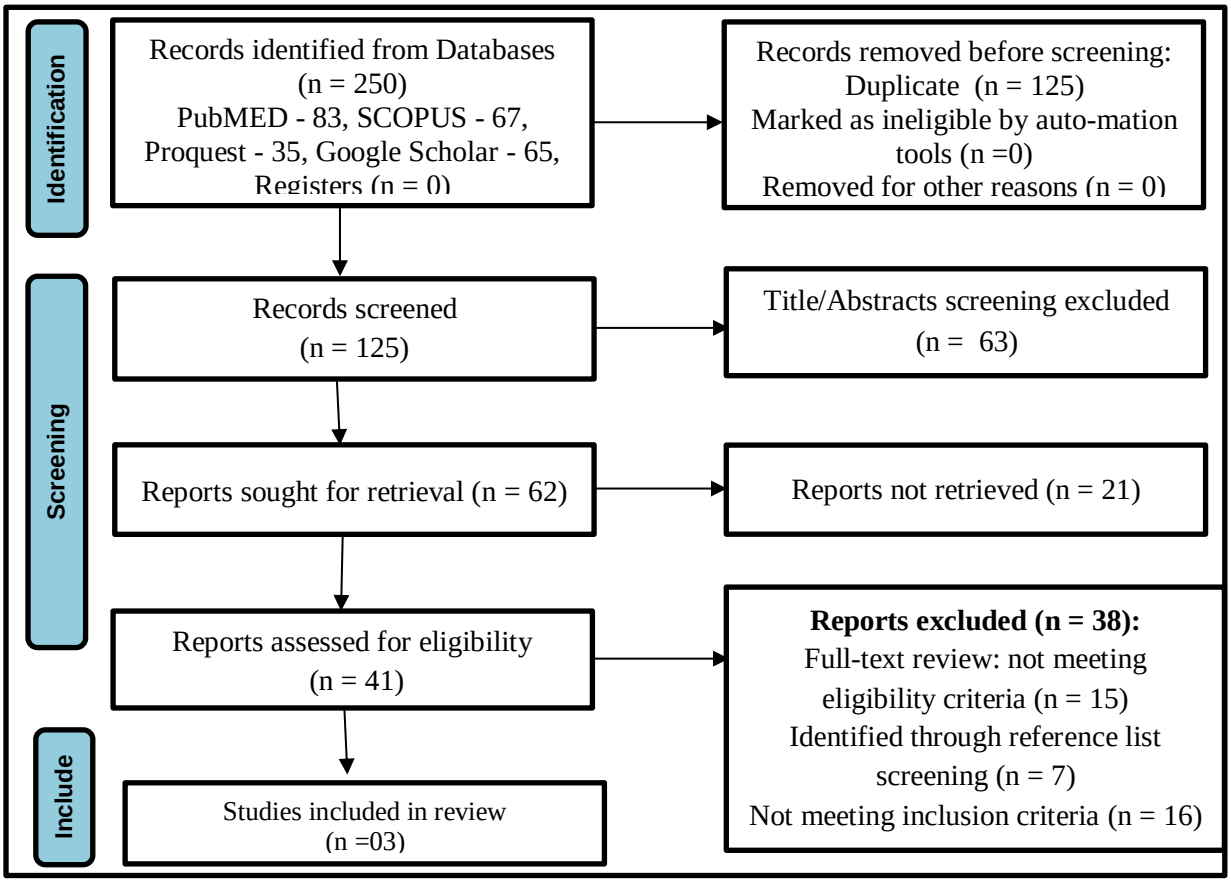


Figure 1. PRISMA 2020 flow diagram

Study Characteristics: The three included studies examined a combined total of 204 odontogenic fascial space infections, confirmed by MRI. Participant ages ranged from young adults to elderly patients, with all subjects presenting with clinical signs of suspected deep or superficial fascial space infection. Summary of included studies provided inTable3

Table 3. Summary of Included Studies

Study	Year	Country	Design	Sample Size	MRI Protocol	USG Probe / Frequency	Main Outcomes Reported
Kapoor et al.	2019	India	Prospective	52 infections	GE HDe Signa 1.5-T unit with a dedicated coil technique which included 3-5 mm axial and coronal T1 weighted images	high-resolution ultrasonography on Toshiba Aplio XG USG Unit (Japan) with 7.5 MHz linear array transducer probe.	Sensitivit, specificity
Ghali et al.	2021	India	Retrospective	50 infections	1.5-t unit(Siemens	linear array probe of 9 MHz	Sensitivit, specificity ,PPV,NPV
Bassiony et al.	2009	UAE	Prospective	42 infections	1.5-T unit (Siemens Magnetom Symphony 1.5T; Siemens, Erlangen, Germany)	7.5-MHz linear array transducer	Sensitivity specificity

Risk of Bias: Overall, studies exhibited low to moderate bias risk, as determined through QUADAS 2 evaluation process. Patient selection presented the most significant concerns, with two studies identified as high risk due to non randomized sampling, case-control design, and restrictive eligibility criteria.[9,12] Comparable methodological challenges have been documented in earlier reviews examining diagnostic accuracy in deep neck infections.[2,13] One study assessed the domain evaluating the index test as uncertain, mainly due to the lack of explicit reporting regarding the blinding of USG interpretation in relation to MRI data.[9]This omission is important, as a lack of blinding is known to overestimate diagnostic performance.[14] In contrast, the flow and timing domains, along with the reference standard (MRI), were repeatedly found to be at low risk of bias, reflecting adequate methodological rigour and appropriate diagnostic sequencing across the studies.[7,9,12] Regarding applicability concerns, the domains for index testing and patient selection were most frequently identified as limitations, whereas the reference standard consistently demonstrated high reliability. Collectively, these findings indicate that although the included studies were methodologically acceptable overall, weaknesses in patient recruitment and incomplete reporting of test interpretation procedures may have introduced subtle evaluative bias. Figures 2-3 illustrate these quality assessments in greater detail.

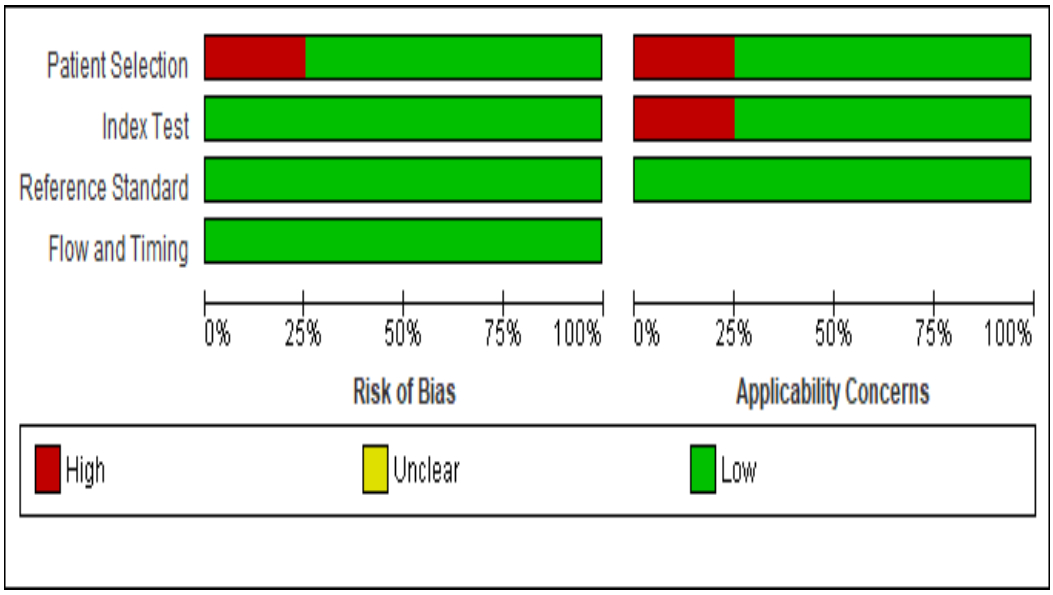


Figure 2. risk of bias graph: presented as percentages across all included studies.

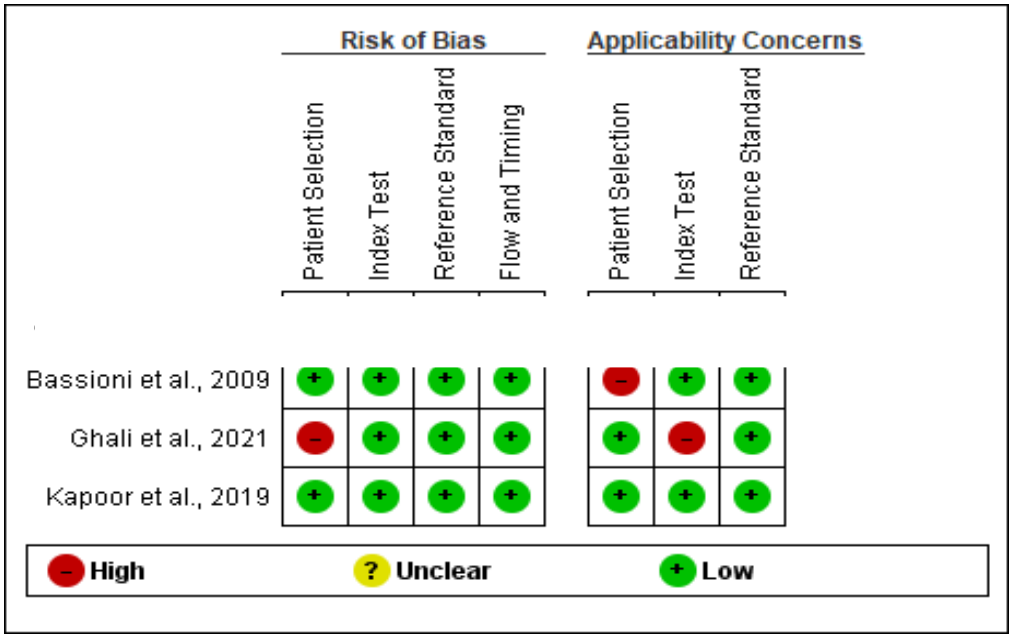


Figure 3. risk of bias summary: for each included study

Ultrasonography (USG) Methods: USG was performed as the index test in all studies using high-frequency linear probes (7-12 MHz) for superficial facial and submandibular spaces and lower-frequency curvilinear probes (3-5 MHz) for deeper cervical spaces when required.[7,9,12] Ultrasonography was used as the index test for identifying odontogenic fascial space involvement. A fascial space was considered positive when ultrasonography demonstrated objective abnormalities within a defined anatomic space, including altered tissue echogenicity, loss of normal fascial plane definition, increased tissue thickness, or the presence of focal hypoechoic or anechoic collections. Bilateral comparison with the contralateral non-infected side was performed to confirm abnormal findings. The analysis was restricted to detection of involvement of superficial and deep fascial spaces, and no staging of infection severity was undertaken.[7,9,12]
Operator experience varied across studies and may have contributed to diagnostic variability.[8,14]
Magnetic Resonance Imaging (MRI) Methods: Magnetic resonance imaging was used as the reference standard for identifying odontogenic fascial space involvement. All included studies used conventional 1.5-Tesla magnetic resonance

imaging systems (Siemens or GE Healthcare) for evaluation of odontogenic fascial space involvement. Imaging was performed using standard head-and-neck protocols with axial and coronal T1- and T2-weighted sequences, with fat-suppressed sequences used where available. A fascial space was considered positive when MRI demonstrated objective abnormalities within a defined anatomic space, including altered signal intensity, loss of normal fat planes, abnormal space expansion, or focal fluid signal compared with the contralateral non-infected side. Involvement of adjacent spaces was determined based on abnormal signal continuity across fascial boundaries. The analysis was restricted to detection of involvement of superficial and deep fascial spaces.[4,7,9,12] MRI consistently confirmed extent, depth, and spread of infections, particularly in deep spaces less accessible to sonography.[4,5]

Detection of Superficial and Deep Space Infections: Across 3 studies (n=204 fascial spaces), pooled sensitivity for USG detection of superficial and deep space infections was 100% (95% CI: 94.9%–100.0%), confirming excellent ability to identify all MRI-confirmed infections. [7,9,12] Pooled specificity was 50% (95% CI: 39.2%–60.8%), indicating frequent false positives, particularly for deep spaces.[7,9,12] +LR 1.28 (95% CI: 1.05–1.56)showed minimal diagnostic gain from positive USG, while -LR 0.72 (95% CI: 0.45–1.15) offered limited reassurance from negative results. DOR 1.77 (95% CI: 0.09–19.95) reflects low overall discriminatory power.It is shown in Figure 4-8.

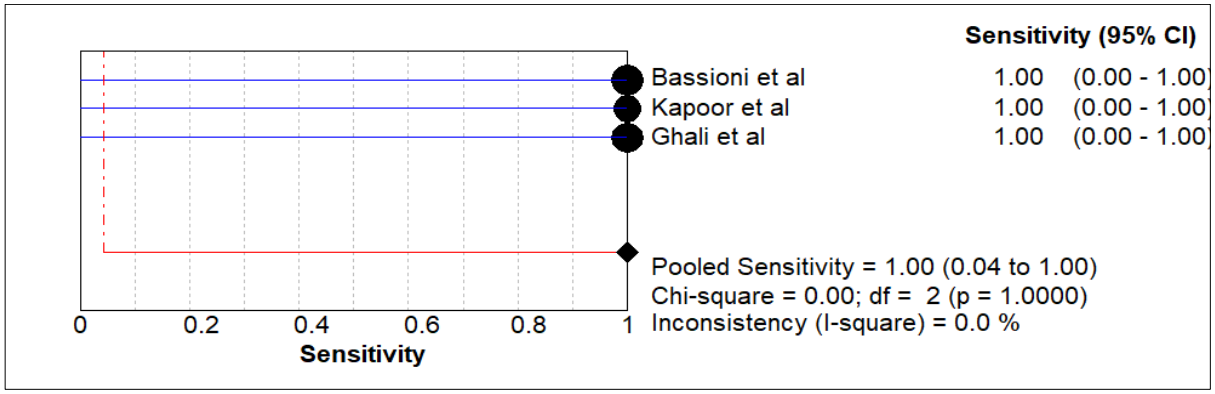


Figure 4. Pooled sensitivity of Ultrasonography for fascial space infection

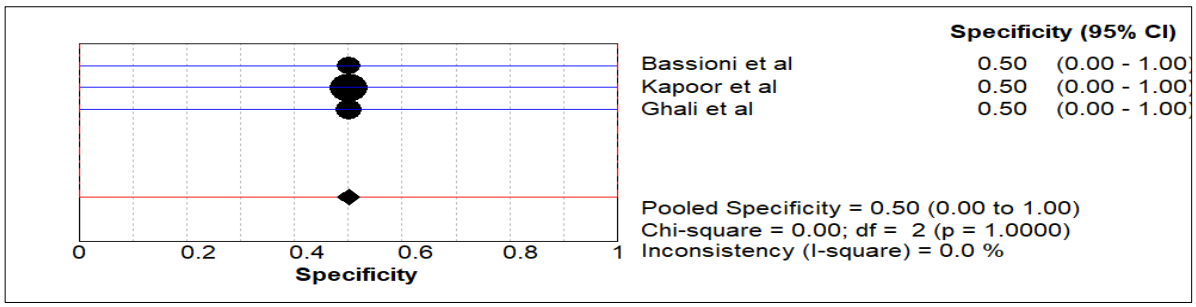


Figure 5. Pooled specificity of Ultrasonography for fascial space infection

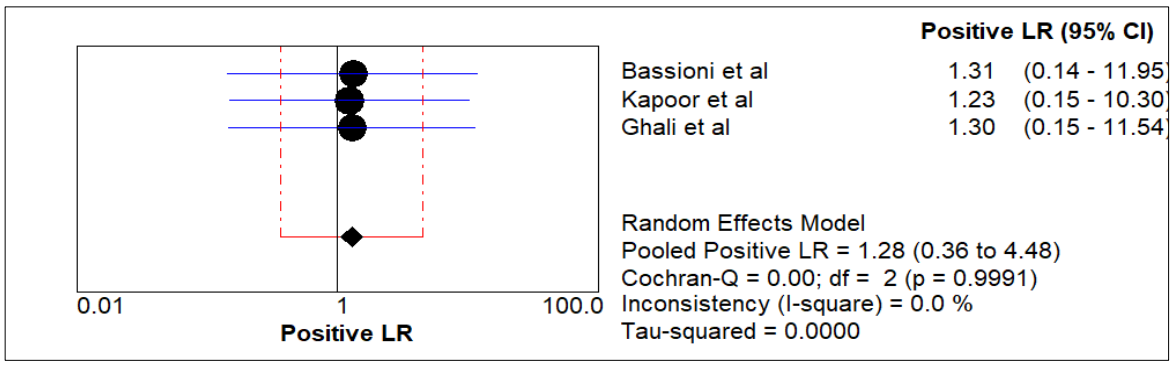


Figure 6. Pooled +LR of Ultrasonography for fascial space infection

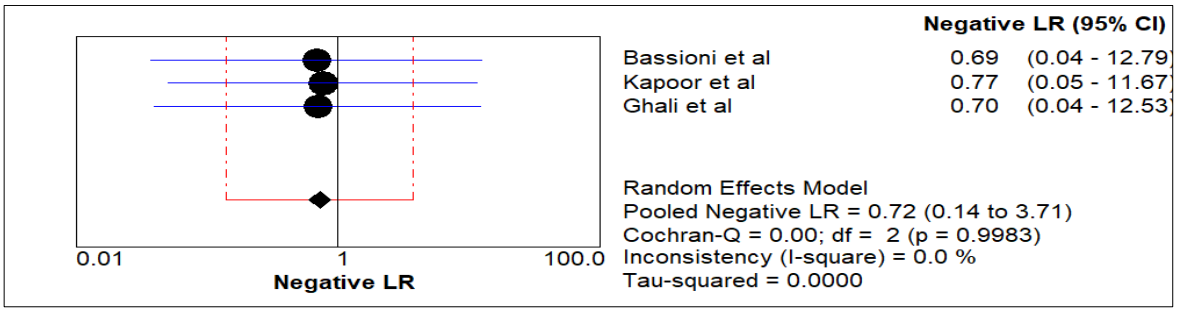


Figure 7. Pooled -LR of Ultrasonography for fascial space infection

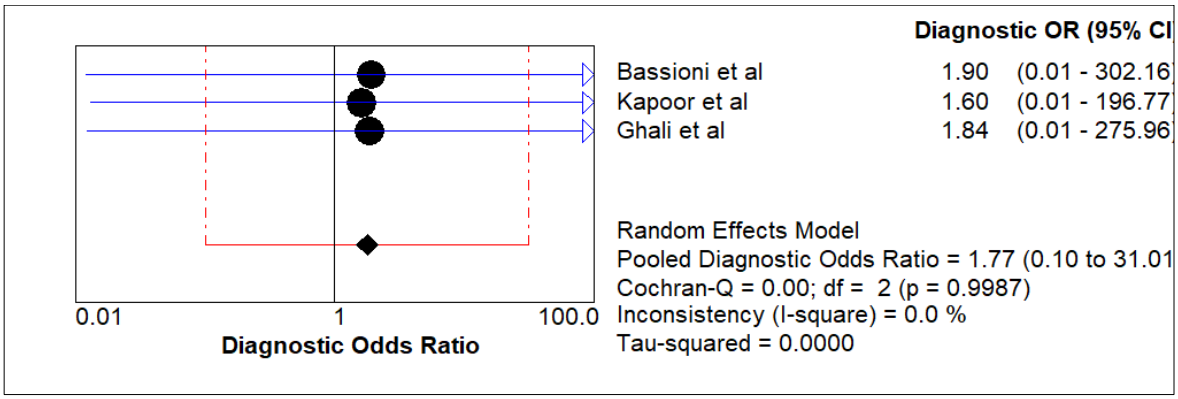


Figure 8. Pooled (DOR) of Ultrasonography for fascial space infections

Likelihood Ratios: The positive likelihood ratio (PLR) was 1.28,[18] representing a minimal increase in likelihood of infection following a positive USG result, while the negative likelihood ratio (NLR) was 0.72[18], representing a minimal decrease in likelihood of infection following a negative USG result. Thus, USG as a standalone test does not meaningfully change post-test probability of disease.(18) It is shown in Figure 6-7

Diagnostic Odds Ratio: The diagnostic odds ratio (DOR) was 1.77 (0.09–19.95)[41], indicating low diagnostic value with wide uncertainty.[41] It is shown in Figure 8

Diagnostic Accuracy Summary: The diagnostic performance of ultrasonography (USG) relative to magnetic resonance imaging (MRI) was synthesized descriptively from the three included studies.[20] MRI was used consistently as the reference standard for confirming infection, depth of involvement, and fascial space extension.[7,9,12]

Sensitivity and Specificity: Across all studies, sensitivity of USG was 100%(7,9,12), indicating that USG successfully identified all cases of confirmed infection [7,9,12], while specificity was 50% [7,9,12], meaning USG incorrectly classified half of non-infected cases as positive.[7,9,12] This pattern shows that USG is most effective as a rule-out tool but has limited ability to rule in infection due to the high false-positive rate.[18]

Predictive Values and Accuracy: Positive predictive value (PPV) varied widely across studies (57.7% to 84.0%)[7,9,12], reflecting differences in patient selection and operator experience.(14) Negative predictive value (NPV) was consistently high at 100% in all studies because sensitivity was perfect and no false-negative cases were reported.[7,9,12] Overall accuracy ranged between 70.3% and 86.2%, influenced primarily by false-positive results.[7,9,12] These findings indicate that USG is reliable for confirming absence of infection when negative, but less reliable when positive.(18) It is shown in Table 5.

Likelihood Ratios: A continuity correction of 0.5 was applied to zero cells for calculation of likelihood ratios. The positive likelihood ratio (PLR) was 1.28[18], representing a minimal increase in the likelihood of infection following a positive USG result, while the negative likelihood ratio (NLR) was 0.72 [18], representing a minimal decrease in the likelihood of infection following a negative USG result. These values fall well below thresholds considered clinically meaningful, confirming that USG does not materially shift post-test probability.[18]

Diagnostic Odds Ratio: The diagnostic odds ratio (DOR) was 1.77 (95% CI: 0.09–19.95).[41] A DOR near 1 indicates no diagnostic effectiveness [41], and the extremely wide confidence interval further highlights the

instability of these pooled estimates.[16] This reflects the small sample size and limited number of studies.(20)
Interpretation: Collectively, these findings indicate that USG is best suited as an initial adjunctive tool for assessing suspected odontogenic fascial space infections.[7,9,12] It provides rapid, bedside assessment and can reliably confirm the presence of infection when negative, owing to its high sensitivity and high negative predictive value.[7,9,12,18] However, USG cannot be relied upon for definitive diagnosis because of poor specificity, minimal likelihood ratio impact.[17,18,42] MRI therefore remains the required modality for accurate mapping of infection extent, particularly in cases involving deep or multispace involvement.[4,5]

DISCUSSION

This systematic review evaluated the diagnostic accuracy of ultrasonography (USG) compared with magnetic resonance imaging (MRI) in detecting odontogenic fascial space infections.(20) Across the three included studies, USG demonstrated consistently high sensitivity, indicating that it reliably identified infected cases when the infection was present.[7,9,12] However, specificity was uniformly low, resulting in frequent false-positive findings.[7,9,12] This limits the utility of USG as a stand-alone diagnostic tool and highlights the necessity of interpreting its findings within the broader clinical context.[18]
Consistency and Discrepancies Across Primary Studies: Across the three included studies, there was marked consistency in the diagnostic performance of ultrasonography compared with MRI for the detection of odontogenic fascial space infections. All studies reported identical sensitivity (100%) and specificity (50%), with no false-negative results observed [7,9,12]. USG has high sensitivity but does not produce a clinically meaningful reduction in post-test probability. (Tables 4 and 5) [7,9,12].

Table 4. Diagnostic Accuracy Metrics of USG Compared to MRI in Included Studies

S. No.	Author, year of study	Index test	Reference standard	True positive (TP)	False positive (FP)	False negative (FN)	True negative (TN)	Sens-itivity (%)	Spec-ificity (%)
1	Bassioni et al., 2009 [1]	USG	MRI	32	10	0	10	100	50
2	Kapoor et al., 2019 [2]	USG	MRI	30	22	0	22	100	50
3	Ghali et al., 2021 [3]	USG	MRI	42	08	0	08	100	50

Table 5. showing descriptive diagnostic accuracy values for USG

Study	Sensitivity	Specificity	PPV	NPV	Accuracy
Bassiony et al., 2009	100%	50%	76.2%	100%	80.8%
Kapoor et al., 2019	100%	50%	57.7%	100%	70.3%
Ghali et al., 2021	100%	50%	84.0%	100%	86.2%

In contrast, positive predictive value (PPV) varied substantially across studies, ranging from 57.7% in Kapoor et al. to

84.0% in Ghali et al. (Table 5) [7,9,12]. This variation is most plausibly explained by differences in disease prevalence and case mix across study populations, with lower infection prevalence in Kapoor et al. and higher prevalence in Ghali et al. As expected, these differences directly influenced PPV despite identical sensitivity and specificity. The uniformly low specificity across studies indicates a consistent tendency toward false-positive findings, reinforcing that positive ultrasonography results should be interpreted in conjunction with clinical assessment and, where available, confirmatory MRI. These findings support the role of ultrasonography as a screening and triage tool for detecting fascial space infection, while MRI remains necessary for definitive confirmation and anatomical delineation [4,5,7,9,12].

Clinical Applicability: Although USG has limited specificity[7,9,12], its strengths lie in accessibility, portability, absence of ionizing radiation, and real-time assessment.(6,8) These characteristics make USG particularly useful in emergency departments, outpatient clinics, and resource-limited environments where MRI is not readily available.(6) USG's high negative predictive value suggests that a negative USG scan can reassure clinicians that a significant collection is unlikely.[7,9,12]

It may, therefore, play a useful role in triage, particularly in differentiating cases requiring urgent imaging or surgical intervention from those suitable for conservative management.[18] However, its diagnostic utility decreases in deeper fascial spaces due to reduced penetration and operator dependency, despite improvements when using lower-frequency probes.[8] For definitive assessment particularly involving retropharyngeal, parapharyngeal, or multiple interconnected fascial spaces MRI while highly accurate, is not a perfect gold standard; lack of surgical or microbiological confirmation may introduce reference standard bias.[4,5]

Impact of Bias and Study Design: An important limitation of the included evidence is the high risk of bias in patient selection, particularly the use of case control designs and restrictive eligibility criteria in two studies. Such pre selected populations, enriched with patients already known or strongly suspected to have infection, are likely to overestimate sensitivity and, to a lesser degree, other measures of test performance. Consequently, the observed 100% sensitivity of USG should be interpreted cautiously, as it may not generalize to unselected clinical populations where the spectrum of disease and non disease is broader.

Comparison with Previous Systematic Reviews: The findings of this review are consistent with broader literature analyzing diagnostic tools for deep neck infections.[2,13] Previous systematic reviews have likewise reported variability in USG performance, emphasizing high sensitivity but limited specificity and operator dependence.[2,23]

In contrast, MRI consistently demonstrates high diagnostic accuracy in delineating fascial boundaries, and assessing deep or multi-space involvement.[4,5]

These observations reinforce that USG should be viewed as complementary rather than competitive to MRI.[28] Notably, other reviews have included larger samples and broader infection categories such as phlegmon, and lymphadenitis, but the conclusions remain similar: USG performs best in superficial infections and as an adjunct for guiding aspiration, whereas MRI is superior for comprehensive diagnostic mapping.[2,13,23]

Future Research Directions: Current evidence is limited by small sample sizes, heterogeneous methodology, and inconsistent reporting of diagnostic parameters.[16,20,29] Future research should focus on multicenter prospective trials with standardized imaging protocols, clear reporting of TP, FP, TN, and FN values to support robust diagnostic accuracy assessment, and standardization of ultrasonography training including probe selection and scanning technique.[11,36]

It should also explore the use of combined imaging pathways to assess how USG and MRI complement each other in clinical workflows [28], integration of artificial intelligence to reduce operator dependency and improve interpretation consistency(33,34), and cost-effectiveness analyses comparing USG-first versus MRI-first diagnostic pathways.[35] Such research would better clarify the appropriate clinical role of USG and inform evidence-based diagnostic algorithms.[20]

LIMITATIONS

This review is limited by the small number of eligible studies and the modest sample sizes available for analysis.[20,29] The included studies demonstrated methodological variability, particularly in patient selection, USG technique, and operator experience.[11,14] Variations in MRI protocols and degree of blinding may also have influenced diagnostic performance.[11]

Because only three studies were available, formal statistical pooling using hierarchical ROC or bivariate meta-analysis models was not possible.[20,36] The resulting descriptive synthesis should therefore be interpreted with caution.[20] Additionally, likelihood ratios and diagnostic odds ratios showed wide confidence intervals, reflecting substantial imprecision.[16,18] These factors limit the generalizability of the findings and highlight the need for higher-quality research to some extent.[13]

CONCLUSION

This systematic review demonstrates that USG, while highly sensitive, lacks the specificity and comprehensive diagnostic accuracy of MRI in evaluating odontogenic deep fascial space infections.[7,9,12,20] USG serves as an excellent point-of-care and triaging modality, particularly in emergency and resource-limited settings.[6,8,18] However, MRI remains essential for definitive diagnosis and surgical planning in deep or complex infection.[4,5] Future multicenter studies with standardised protocols are required to refine diagnostic pathways.[11,36]

Registration: PROSPERO CRD42025642764

DECLARATIONS

Protocol and Registration: The review followed the PRISMA-DTA checklist and was registered in PROSPERO (CRD42025642764),[19] an international registry maintained by National Institute for Health Research supports the University of York's Centre for Reviews and Dissemination in order to avoid duplicate systematic reviews.[37,38]

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Conflicts of Interest: There are no conflicts of interest for the authors.

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REVIEW ARTICLE

RECONSTRUCTION OF ORAL CAVITY DEFECTS AFTER MALIGNANCY RESECTION: A NARRATIVE REVIEW

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Abstract

Malignancies of the oral cavity represent a significant global health burden, with squamous cell carcinoma accounting for the majority of cases. Surgical resection remains the cornerstone of curative treatment; however, removal of malignant lesions often results in complex defects involving bone, soft tissue, mucosa, muscle, and neurovascular structures. These defects can profoundly affect speech, swallowing, mastication, aesthetics, and quality of life. Consequently, reconstruction of oral cavity defects following oncologic resection is a critical component of comprehensive head and neck cancer management.

This review provides a detailed overview of oral cavity anatomy relevant to reconstructive surgery, classification of post-resection defects, and current reconstructive techniques ranging from primary closure and local flaps to regional and microvascular free tissue transfer. Emphasis is placed on flap selection based on defect size, location, and functional requirements. Outcomes related to flap survival, functional rehabilitation, aesthetic restoration, and complication rates are discussed. Advances in microvascular surgery have significantly expanded reconstructive options, enabling restoration of complex composite defects with improved functional outcomes. However, reconstruction must be individualized, considering patient comorbidities, tumor stage, adjuvant therapy requirements, and institutional expertise. Multidisciplinary collaboration between oncologic surgeons, reconstructive surgeons, speech therapists, and rehabilitation specialists is essential to optimize outcomes.

Understanding the anatomical foundations, surgical options, and outcome measures is vital for achieving optimal reconstruction following oral cancer resection. This review synthesizes current evidence to guide reconstructive decision-making and highlights future directions in oral cavity reconstruction.

Keywords: Oral cavity cancer; Reconstruction; Free flaps; Head and neck surgery; Oral anatomy; Oncologic reconstruction; Functional outcomes

1.INTRODUCTION

Cancers of the oral cavity constitute a significant subset of head and neck malignancies worldwide[1]. Squamous cell carcinoma remains the predominant histological subtype and frequently necessitates wide local excision to achieve clear oncologic margins. Advanced lesions often require composite resections involving mucosa, muscle, bone, and adjacent soft tissues. Although surgical extirpation is essential for disease control, it commonly produces substantial functional and aesthetic deficits.

Resection of structures such as the tongue, floor of mouth, buccal mucosa, palate, and mandible can severely impair articulation, bolus formation and propulsion, mastication, airway protection, and facial

symmetry. These deficits profoundly affect nutrition, communication, and psychosocial well-being. Accordingly, reconstruction represents a fundamental component of oncologic management rather than a purely cosmetic adjunct[2].

Historically, reconstruction relied on primary closure and regional pedicled flaps, which were suitable for limited defects but inadequate for complex composite resections. The advent of microvascular free tissue transfer transformed reconstructive practice by enabling simultaneous restoration of soft tissue and osseous components with superior functional outcomes and acceptable morbidity[3,4,5].

2. Anatomical and Functional Considerations

The oral tongue plays a pivotal role in articulation and swallowing. Postoperative functional recovery is closely associated with preserved tongue mobility and reconstructed volume [6]. Pliable, thin tissue is required to facilitate dynamic movement following subtotal or total glossectomy.

The floor of mouth contains critical neurovascular structures, including the lingual nerve and submandibular duct. Reconstruction must maintain tongue mobility and prevent tethering or contracture. Similarly, palatal and buccal mucosal defects demand careful lining restoration to preserve resonance and mastication.

Segmental mandibulectomy presents additional reconstructive challenges. Disruption of mandibular continuity compromises occlusion, mastication, speech intelligibility, and lower facial contour. The classification system proposed by Brown et al.[7] provides a structured framework for reconstructive planning based on defect location and extent. Structural restoration is essential for long-term functional and dental rehabilitation.

3. Evolution of Reconstructive Techniques

Small mucosal defects may be addressed with primary closure or split-thickness skin grafting; however, scar contracture and limited functional restoration restrict their use to early-stage lesions [8].

The pectoralis major myocutaneous flap represented a major advancement before the widespread adoption of microvascular techniques. Although reliable and technically less demanding, its bulk and donor-site morbidity may impair speech and swallowing outcomes. It remains valuable in salvage situations or when free tissue transfer is contraindicated [9].

4. Microvascular Free Tissue Transfer

Microvascular reconstruction is currently regarded as the gold standard for large or composite oral cavity defects. Contemporary high-volume series report flap survival rates exceeding 90–95% [7,10]. These techniques allow precise restoration of both lining and structural components.

The radial forearm free flap, first described for intraoral reconstruction by Soutar et al.[11], remains a workhorse flap due to its thin, pliable characteristics that facilitate articulation and swallowing. Functional assessments demonstrate superior outcomes compared with regional flaps [4].

The anterolateral thigh (ALT) flap offers versatility and variable soft tissue bulk. Wei et al. reported excellent reliability in a landmark series of 672 cases[12]. It is particularly suited for larger defects requiring substantial tissue replacement.

Mandibular reconstruction was revolutionized by Hidalgo's description of the fibula osteocutaneous flap[13]. This technique provides adequate bone stock, allows osseointegrated implant placement, and restores mandibular continuity with favorable aesthetic and functional outcomes[9,14].

5. Functional Outcomes and Quality of Life

Restoration of intelligible speech and safe swallowing remains the primary determinant of reconstructive success. Microvascular free flaps demonstrate superior functional outcomes compared with regional techniques[15].

Health-related quality-of-life (HRQoL) studies highlight the substantial psychosocial burden of oral cancer. Rogers et al. demonstrated strong associations between functional impairment and diminished quality-of-life scores[16].

Long-term follow-up confirms sustained benefits of microvascular reconstruction [17].

Importantly, free flap reconstruction does not compromise oncologic safety. Patel et al. showed that microvascular reconstruction may facilitate more aggressive tumor resection without adversely affecting survival[18].

6. Complications and Risk Factors

Despite high success rates, complications including flap failure, fistula formation, infection, and donor-site morbidity remain clinically significant. Smoking, prior radiotherapy, and systemic comorbidities have been identified as predictors of adverse outcomes[15].

Liao et al. further emphasized advanced tumor stage and vascular compromise as risk factors for flap failure[10]. Careful patient selection and meticulous technique are therefore critical.

7. Multidisciplinary Rehabilitation

Reconstruction extends beyond surgical repair. Early involvement of speech and swallowing therapists, dietitians, and psychosocial support teams significantly enhances recovery. Shaw et al. demonstrated that effective mandibular reconstruction and rehabilitation strongly influence long-term quality of life[19]. A coordinated multidisciplinary approach is essential to optimize outcomes.

8. Future Directions

Technological advances including virtual surgical planning, computer-assisted design, and three-dimensional modeling are improving reconstructive precision. These digital workflows enhance accuracy, reduce operative time, and improve aesthetic symmetry. Emerging regenerative strategies and tissue engineering approaches may further refine reconstruction in the future [7].

CONCLUSION

Reconstruction of oral cavity defects following malignancy resection is a complex yet indispensable component of comprehensive oncologic care. Current evidence strongly supports microvascular free tissue transfer as the preferred modality for large and composite defects. Individualized planning, guided by defect classification and patient-specific factors, combined with multidisciplinary rehabilitation, remains central to optimizing long-term functional and quality-of-life outcomes.

DECLARATIONS

Conflict of Interest

The authors declare no conflict of interest.

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Ethical Approval

Not applicable (Narrative review).

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ORIGINAL ARTICLE

CLINICAL EVALUATION OF THE USE OF SURGICAL TUBE TECHNIQUE VS HYALURONIC ACID GEL INJECTION IN RECONSTRUCTION OF THE INTERPROXIMAL PAPILLA IN PATIENTS WITH CLASS II PAPILLARY DEFICIENCY: A RANDOMIZED CLINICAL TRIAL

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Abstract

Background: Interdental papilla insufficiency is a major concern both aesthetically and functionally. Several invasive techniques have been documented for interdental papilla reconstruction. This study compares the effectiveness of a minimally invasive tube technique to hyaluronic acid gel injection for reconstructing interdental papilla in the esthetic zone, while the long-term success of invasive treatments remains uncertain.

Materials and methods: The study was designed as a randomized, controlled and double-blinded clinical trial. The trial was registered at Cairo University's Faculty of Dentistry between December 2022 and July 2024, and the registration number is (NCT05235477). A total sample size of 20 sites in 16 patients was planned to be recruited. i.e., 10 sites in each group. Patients with deficient interdental papilla class II in the esthetic zone were selected, then these sites in patients were randomized using computer-generated randomization into two equal groups Group I (intervention/surgery group): Patients received the tube technique as recommended by Group II (Control): Patients received a hyaluronic acid (HA) (0.1 mm) injection into the papilla as performed by. Blinding was performed in the selection of patient intervention. The clinical parameters were assessed at baseline, 3months and 6 months and the radiographic parameters were assessed at baseline and 6 months, as well as the patient satisfaction between the two tested groups.

Results: The surgical group showed significant improvement in all clinical parameters at 6 months postoperatively. The findings indicate that although both methods initially decreased the buccal triangle height and surface area as 3 months postoperatively, surgical intervention yielded markedly superior and more enduring results at the six-month follow-up. Specifically, the surgery group demonstrated a consistent reduction in triangle dimensions throughout the study period. In contrast, the hyaluronic acid injection group experienced a statistically significant relapse, indicated by a gradual increase in the black triangle dimensions, between three and six months.

Conclusions: The use of the tube technique is a very effective way for papilla reconstruction when compared to HA injection over the same examination period.

Keywords: Papilla reconstruction, tube technique, hyaluronic acid gel, black triangle

INTRODUCTION

Dental esthetics are considered the most significant determinant in personality development. A minor deviation from community norms can lead to diminished

self-esteem concerning one's appearance resulting a detrimental effect on their quality of life. To develop a professional character, self-confidence is a vital factor in an individual's existence. It also pertains to health and contributes to the experience of achievement [1].

The interdental papilla is a gingival structure that fills the area between neighboring teeth's contact sites. It is supported by the underlying alveolar bone as well as the teeth margins. It is made up of masticatory mucosa, a dense connective tissue covered by oral epithelium and an inner layer coated with junctional and sulcular epithelium [2].

There are numerous factors influencing the interdental papilla, including the vertical and horizontal dimensions of the interdental space, the distance between the contact point and the alveolar crest (CP-BC), and the horizontal inter-radicular distance (HID). Among these factors are also tooth morphology and gingival biotype, fundamental divergence, the location and extent of the contact area, gingival scalloping (gingival angle), periodontal disease, age and traumatic experiences [3].

Treatment options for black triangles encompass both non-surgical and surgical methods. Non-surgical approaches involve strategies that incorporate the correction of traumatic oral hygiene practices, as well as orthodontic and restorative interventions [4]. Tissue engineering and the application of tissue volumizers have been explored as potential approaches for addressing interdental papilla deficiency [5].

Hyaluronic acid, or hyaluronan, is a naturally occurring, non-sulfated, high molecular weight glycosaminoglycan (GAG) that constitutes a vital component of the extracellular matrix (ECM) of connective tissue, synovial fluid, serum, saliva, gingival crevicular fluid, embryonic mesenchyme, vitreous humor, skin, and various other organs and tissues throughout the body [6]. Several studies have evaluated the efficacy of HA in the reconstruction of interdental papilla within the esthetic zone [7,8].

Several conventional surgical techniques employing standard periodontal plastic and augmentation procedures seek to achieve complete papilla fill to address this issue. However, flap design was found to be invasive, associated with increased patient morbidity, limited efficacy, long-term stability, and unpredictability due to confined working spaces and restricted blood supply [4].

Surgical approaches include the pedicle flap technique [9], the semilunar coronally repositioned papilla [10], the envelope flap technique[11], the microsurgical technique with platelet-rich fibrin [12], and the modified semilunar coronally repositioned papilla [13].

The tube technique was recently added in the track of surgical techniques to solve the shortcomings of the other techniques [14]. It was claimed that the tube technique's innovative flap design does not disrupt the graft's blood supply by using apical incisions and containing the graft within a rich vascular contained bed, resulting in consistent and satisfying results.

The integrity of the soft tissue is critical to the effectiveness of this treatment. The tube grafting procedure necessitates technical precision. It is highly susceptible to surgical trauma and tension, especially when the recipient site tissue is delicate.
Based on all proposed advantages of the tube technique over other surgical techniques, as well as the demonstrated efficacy of HA for interdental papilla restoration. The purpose of this study was to compare the clinical efficacy of the surgical tube method versus hyaluronic acid gel injection in reconstructing the interproximal papilla in individuals with class II papillary defeciency.

MATERIALS AND METHODS

Study design:

The present randomized controlled clinical trial encompassed 20 sites in 16 patients exhibiting black triangles in anterior teeth. Participants were enrolled from the outpatient clinic of the Department of Oral Medicine and Periodontology at Cairo University's Faculty of Dentistry between December 2022 and July 2024. Grouping: Group I (intervention/surgery group):

Patients received the tube technique as proposed by [14]. Group II (Control): Patients received a hyaluronic acid (HA) (0.1 mm) injection into the papilla[3].

Ethical Approval:

The research protocol was approved by the Research Ethics Committee of the Faculty of Dentistry, Cairo University, on June 29, 2021. The enrolled patients in this clinical trial received detailed information regarding the procedures and follow-up aspects of the study. Each participant provided a written informed consent and voluntarily consented to take part in the study. The present clinical trial was registered on Clinical Trials with the identifier NCT05235477.

Power and Sample Size:

This power analysis employed interdental papilla loss at six months as the primary endpoint. Based on the findings

of [15], the mean and standard deviation (SD) for the control group were 0.71 (0.74). The minimal clinically significant difference was determined to be 1 mm^2 based on expert consensus. Using an alpha (α) level of 5% and a beta (β) level of 0.8 (Power = 80%), the effect size for the independent samples t-test (d) was 1.32, and the minimum estimated sample size was 10 sites per group. The sample size was expanded to 12 sites per group to account for an anticipated dropout rate of 20% after six months. Sample size determination was conducted utilizing PS Power and Sample Size Calculations Version 3.

Patient Selection:

The study was conducted on 20 sites in 16 patients recruited from the outpatient clinic of the Oral Medicine, Periodontology, and Oral Diagnosis department, Faculty of Dentistry, Cairo University. All new patients of the outpatient clinic were examined by the author and supervisors, and those who met the eligibility criteria were asked to sign a consent after explaining the details of the study and then started the randomization process. The research ethics committee has approved the study (11-6-21) and it was registered retrospectively with the clinical trial registration number (NCT05235477).

Patients were selected based on the following criteria: The patient's age ranged from 25 to 45 years old as done by [3]. Highly motivated patients with papillary deficiency type II, according to the Nordland and Tarnow classification [19], were selected with at least one deficient papilla in the anterior region. Distance between the contact point and interproximal bone crest (CP-BC) was ≤ 7 mm, and probing depth is ≤ 4 mm at the deficient papillary site as done by [3]. Patients with full mouth plaque index (PI) and gingival index (GI) scores between 0 and 1 as recommended by [3], systemically free of any medical condition.

According to [3]: patients with a history of allergic reactions to hyaluronic acid, pregnant or breastfeeding females, smokers and alcoholic patients, and those currently or previously on medication intake that may predispose them to gingival enlargement were excluded from the study.

Patients with cardiovascular diseases patients under orthodontic treatment or who had orthodontic treatment in the past six months, carious teeth, proximal restorations, or fixed prosthesis at the site of treatment also, those with a history of traumatic oral hygiene measures or periodontal surgeries over the last six months in the area of interest or having any scar tissue were not included in the study.

Randomization and Blinding:

The supervisor used computer-generated random numbers to assign patients to the intervention or control groups. Patients were assigned 1:1. The main supervisor, who was not involved in recruitment, conducted a computer-generated randomization list (www.randomizer.org) for concealment. Both groups were equally prepared for surgery or injection. Afterward, the randomized numbers in opaque envelopes would determine which group would receive the hyaluronic acid injection and which would undergo the tube technique. Since the surgical techniques of the two groups were fundamentally different, blinding was only used for the outcome assessor and biostatistician. The lead investigator and participants could not be blinded.

Procedures:

All patients were given stringent dental hygiene instructions, and whole-mouth supra- and subgingival debridement was performed under local anesthesia with hand instruments and ultrasonic scalers. Six to eight weeks after pre-surgical therapy, periodontal re-evaluation was undertaken to establish the suitability of the targeted sites for this study, followed by a baseline assessment of clinical and radiographic data.

Tube Technique: [14].

A semilunar incision was made on the buccal aspect at the MGJ, and a full-thickness flap was elevated using a #15 blade. The flap was 4–5 mm longer mesio-distally than needed for the graft. The buccal flap could freely enter the recession with this expansion. The zenith of another semilunar incision on the palatal aspect was near the alveolar crest. On the buccal aspect, a mucoperiosteal elevator or tunneling knife (smaller than the defect width) was used to carefully reflect the papilla away from the alveolar bone and root surfaces to access the interproximal region to prepare the graft bed. The mucoperiosteal elevator was used to do the same on the palatal aspect. Reflection was done to relax the papilla flap, allowing it to be placed in the new coronal position without stress. At this point, the recipient site resembled a "tube" with two openings: buccal at the mucogingival junction and palatal.

The connective tissue graft (CTG) was harvested by cutting parallel to the gingival margin and 2 mm it. A tiny flap of keratinized tissue was detached, and the second incision was parallel to the gingival edge but perpendicular to the alveolar bone. The graft was raised with the periosteum and freed at its anterior and posterior ends and base using a sharp elevator. Both cases required 12 to 15 mm long, 5 mm wide, and 2 mm thick harvested grafts larger than the interproximal defect side. The needle eye (swage) was passed into the tube from the palate to the buccal with a 6.0 polypropylene suture. A suture needle then engaged a graft end. Another suture was inserted on the CTG's other end. One eye-first suture wound through the tube toward the palatal side. A suture

and periosteal elevator were used to carefully slide the CTG through the buccal end of the tube into the prepared interproximal bed toward the palate. Interproximal was the thickest region of the graft. Buccal and palatal flaps were sutured over the CTG, which was then sutured under them. A 6.0 polypropylene suture with a cutting needle was used. The graft was squeezed from both ends inward for 4–5 minutes using the index finger and thumb to stabilize it.

Injection technique:

Restylane Lidocaine (Galderma S.A., Sweden) was utilized. Three injections were given at each papilla site: baseline, 3, and 6 weeks. For patient blindness, insulin plastic syringes were pre-loaded with hyaluronic acid and saline. The bevel was directed apically, and the needle was inserted 2-3 mm apically to the tip of the interdental papilla and guided coronally with a 45° angle to the tooth's long axis. With gauze, the papilla was lightly molded incisally for 1 minute.

Outcome Assessments:

A-Clinical assessment:

Digital clinical photographs: The surface area of the black triangle (SABT) mm:

The surface area of the black triangle (SABT) was measured using standardized digital clinical images and an image analysis application (Photoshop CS 5, Adobe Systems, San Jose, CA, USA). From baseline and 3- and 6-month postoperative images, the black triangle's surface area was measured and calibrated using a 10 mm William's graduated periodontal probe **[3]** Papilla Presence Index (PPI): according to [16]

Clinical attachment level (CAL):

According to [17], CAL was measured with the periodontal probe from CEJ to the bottom of the pocket to the nearest mm

Probing depth (PD):

The distance from the gingival margin to the base of the periodontal pocket was measured using a William's graduated periodontal probe.

Gingival recession (GR):

The distance from the CEJ to the gingival margin [18]

Gingival Bleeding score:

By gentle probing of the orifice of the gingival crevice using William's graduated periodontal probe. If bleeding occurred within 10 seconds, a positive finding was recorded, and the number of positive sites was recorded and then expressed as a percentage of the number of sites examined [2].

Surface area of black triangle (SABT): Preoperative and postoperative photographs at baseline, 3 months and 6 months intervals were taken perpendicular to teeth of interest. Then the surface area of the black triangle (SABT) was measured. These photos were analyzed using Photoshop CS software. The program was used to measure the height of the selected papillae [3].

B-Radiographic assessment:

Standardized digital periapical radiographs were obtained preoperatively and 6 months postoperative using the long cone paralleling technique using the same equipment, film exposure, and development conditions and using the individualized bite block. The use of a correctly applied X-ray positioner provides a perpendicular alignment of the X-ray cone through the film and consequently a fixed position of the focal spot [20].



Figure 1. showing a 5.5mm distance between the contact point and interproximal bone crest (CP-BC)

C- Patient Satisfaction:

It consists of 3 questions: How satisfied are you with your smile? How satisfied are you with the black space showing between your teeth? Having had this overall experience, would you choose to have the procedure again? [15].

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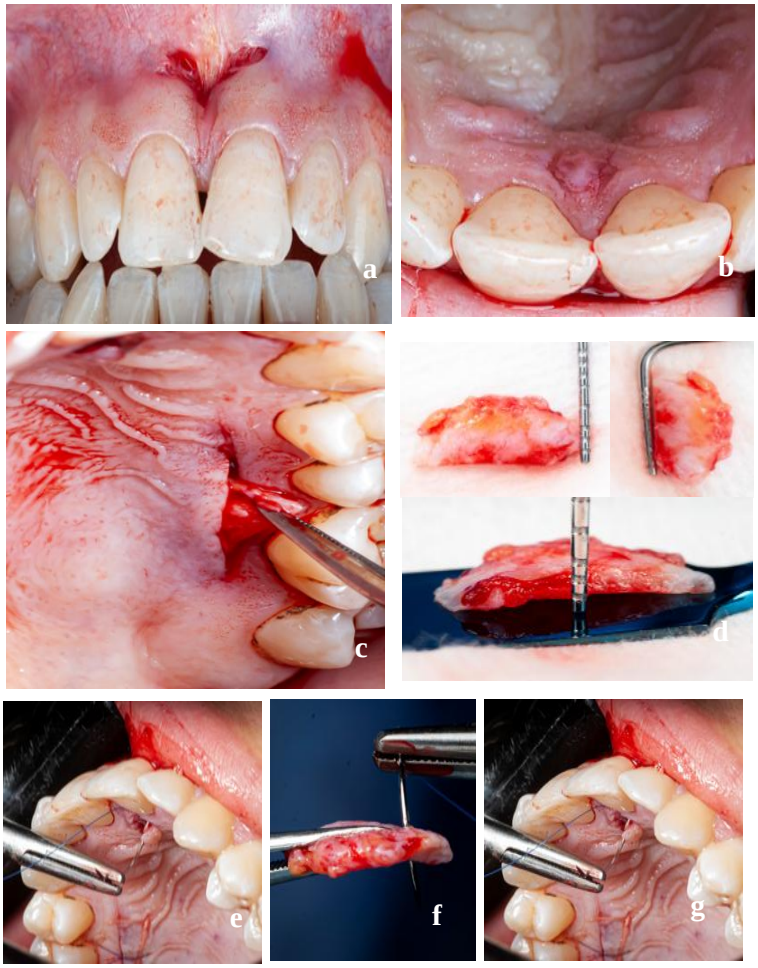


Figure 2. (Intervention): (a) Semilunar flap buccally, **(b)** Semilunar flap palatally, **(c)** Single incision technique for CT graft, **(d)** Showing the length (9 mm), width (4 mm) of the graft, and the thickness of the graft (2 mm), **(e)** inserting the swaged area of the needle palatally in the tube area created, (f) inserting the needle in the graft from one side, and **(g)** adjust the Graft to get into the tube area to raise the papilla to fill the black triangl

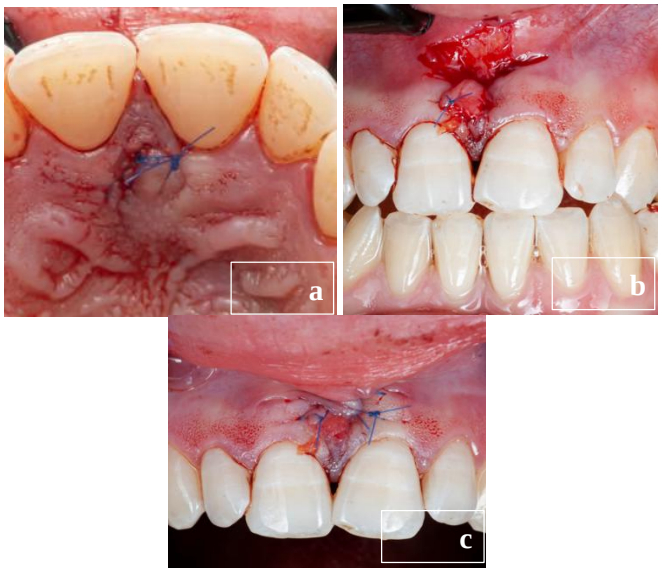


Figure 3. (a) suturing the graft into the tissues and suturing the palatal flap, **(b)** suturing the graft in the buccal tissues**,** and **(c) s**uturing the buccal flap over the graft



Figure 4. (a) Baseline **(b)** 3-month follow-up and **(c)** 6-month follow-up showing absence of black triangle



Figure 5. Control group



Figure 6. **(a)** Baseline **(b)** 3-month follow-up and **(c)** 6-month follow-up showing relapse

Statistical analysis

Numerical data were explored for normality by checking the distribution of data and using tests of normality (Kolmogorov-Smirnov and Shapiro-Wilk tests). All data showed non-normal (non-parametric) distribution except for distance data that showed normal (parametric) distribution. Data were presented as median, range, mean and standard deviation (SD) values. For non-parametric data, Mann-Whitney U test was used to compare between the two groups. Friedman's test was used to study the changes by time within each group. Dunn's test was used for pair-wise comparisons when Friedman's test is significant. For parametric data, the repeated measures ANOVA test was used to compare between the two groups as well as to study the changes by time within each group. Bonferroni's post-hoc test was used for pairwise comparisons when the ANOVA test is significant. Qualitative data were presented as frequencies and percentages. Fisher's exact test was used to compare patient satisfaction results in the two groups. The significance level was set at $P \leq 0.05$. Statistical analysis was performed with IBM SPSS Statistics for Windows, Version 23.0. Armonk, NY: IBM Corp.

RESULTS

Patients' demographic data

Descriptive statistics for gender and age are presented in Table (1).

Table1. Descriptive statistics for baseline characteristics in the two groups

Patients' data	Surgery (n = 10)	Injection (n = 10)
Gender [n, (%)]		
Female	5 (50%)	4 (40%)
Male	5 (50%)	6 (60%)
Age [Mean, SD]	30.4 (3)	32.7 (3.5)

A-Clinical assessment:

Gingival recession (GR in mm)

At baseline, after three as well as after six months, there was no statistically significant difference between the two groups (*P*-value = 1, Effect size = 0), (*P*-value = 0.527, Effect size = 0.238), and (*P*-value = 0.245, Effect size = 0.051), respectively.

Pocket Depth (PD in mm)

At baseline, after three as well as after six months, there was no statistically significant difference between the two groups (*P*-value = 0.662, Effect size = 0.187), (*P*-value = 0.631, Effect size = 0.204), and (*P*-value = 0.071, Effect size = 0.804), respectively.

Clinical Attachment Level (CAL in mm)

At baseline, after three as well as after six months, there was no statistically significant difference between the two groups (*P*-value = 1, Effect size = 0), (*P*-value = 0.542, Effect size = 0.17) and (*P*-value = 0.276, Effect size = 0.343), respectively.

Plaque Index (PI)

At baseline, after three as well as after six months, there was no statistically significant difference between the two groups (*P*-value = 0.317, effect size = 0.17) for each time, respectively.

Gingival Index (GI)

At baseline, after three as well as after six months, there was no statistically significant difference between the two groups (*P*-value = 0.648, Effect size = 0.17), (*P*-value = 0.689, Effect size = 0.136) and (*P*-value = 0.752, Effect size = 0.119), respectively.

Buccal triangle height (mm)

At baseline as well as after three months, there was no statistically significant difference between the two groups (*P*-value = 0.821, Effect size = 0.102) and (*P*-value = 0.384, Effect size = 0.396), respectively. After six months, surgery group showed statistically significantly lower buccal triangle height than injection group (*P*-value = 0.013, Effect size = 1.344).

Table 2. Descriptive statistics and results of Mann-Whitney U test for comparison between buccal triangle height (mm) in the two groups and Friedman's test for the changes within each group

Time	Surgery (n = 10)		Injection (n = 10)		*P*-value	*Effect size (d)*
	Median (Range)	Mean (SD)	Median (Range)	Mean (SD)		
Base line	2.8 (1.37, 4.54) ^{A}	2.75 (0.88)	2.81 (1.95, 3.98) ^{A}	2.89 (0.67)	0.821	0.102
3 months	1.35 (0.44, 2.5) ^{B}	1.47 (0.72)	1.63 (0, 3.26) ^{C}	1.76 (0.58)	0.384	0.396
6 months	0.94 (0, 2.34) ^{C}	1.09 (0.78)	1.99 (1.44, 3.5) ^{B}	2.13 (0.68)	0.013*	1.344
P-value	<0.001*		<0.001*			
Effect size (w)	1		0.833			

**: Significant at P ≤ 0.05, Different superscripts in the same column indicate statistically significant change within group*

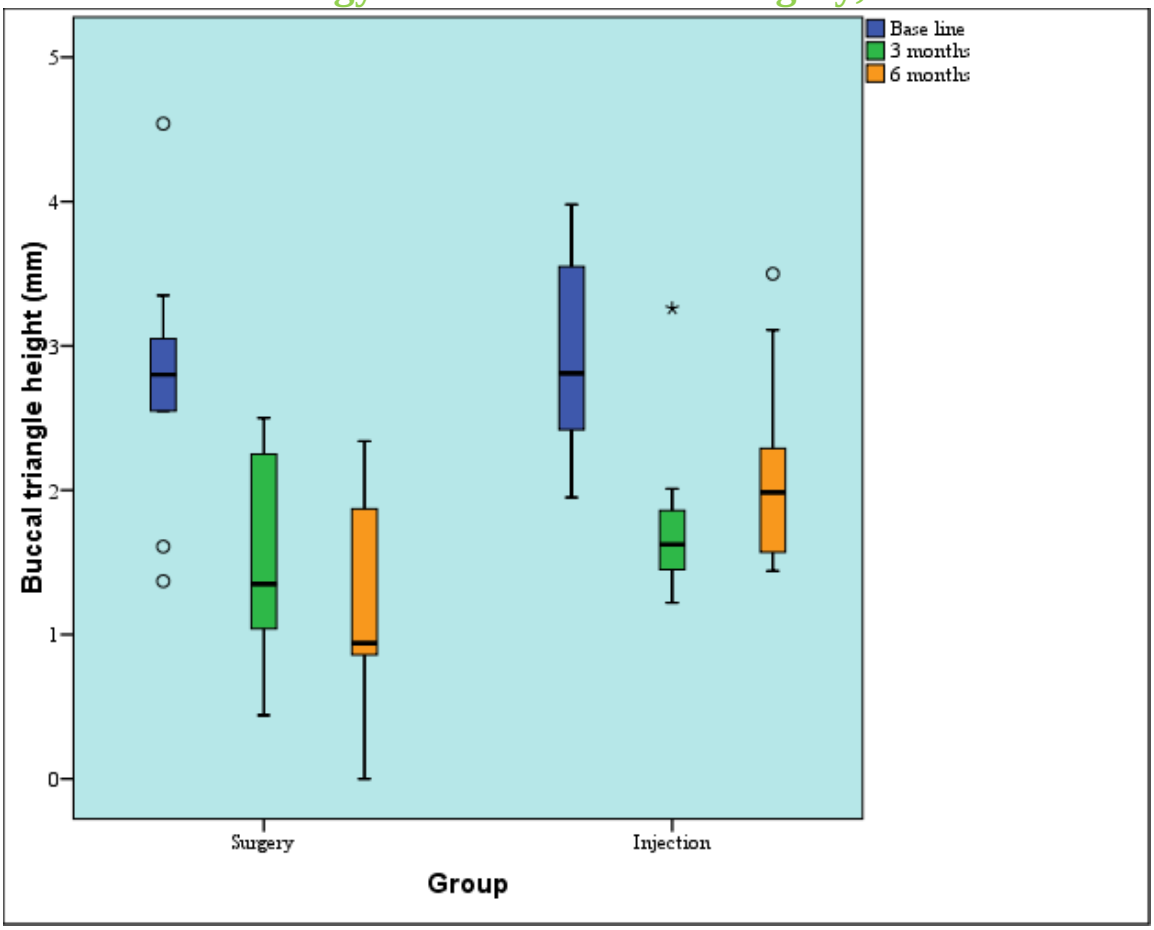


Figure 6. Box plot representing median and range values for buccal triangle height in the two groups (Star and circles representing outliers)

a. Comparison between amounts of reduction in buccal triangle heights in the two groups

The amount of reduction is calculated as the difference between three, six months measurement and base line measurement.

After three months, there was no statistically significant difference between the two groups (*P*-value = 0.820, Effect size = 0.102).

After six months, the tube surgical group showed statistically significantly higher amount of reduction in buccal triangle height than injection group (*P*-value = 0.019, Effect size = 1.23).

Table 3. Descriptive statistics and results of Mann-Whitney U test for comparison between amounts of reduction in buccal triangle height (mm) in the two groups

Time	Surgery (n = 10)		Injection (n = 10)		*P*-value	*Effect size (d)*
	Median (Range)	Mean (SD)	Median (Range)	Mean (SD)		
3 months	1.1 (0.27, 3.33)	1.28 (0.89)	1.11 (0.28, 2)	1.13 (0.54)	0.820	0.102
6 months	1.63 (0.43, 3.68)	1.66 (0.88)	0.56 (0.28, 1.91)	0.76 (0.51)	0.019*	1.23

**: Significant at P ≤ 0.05*

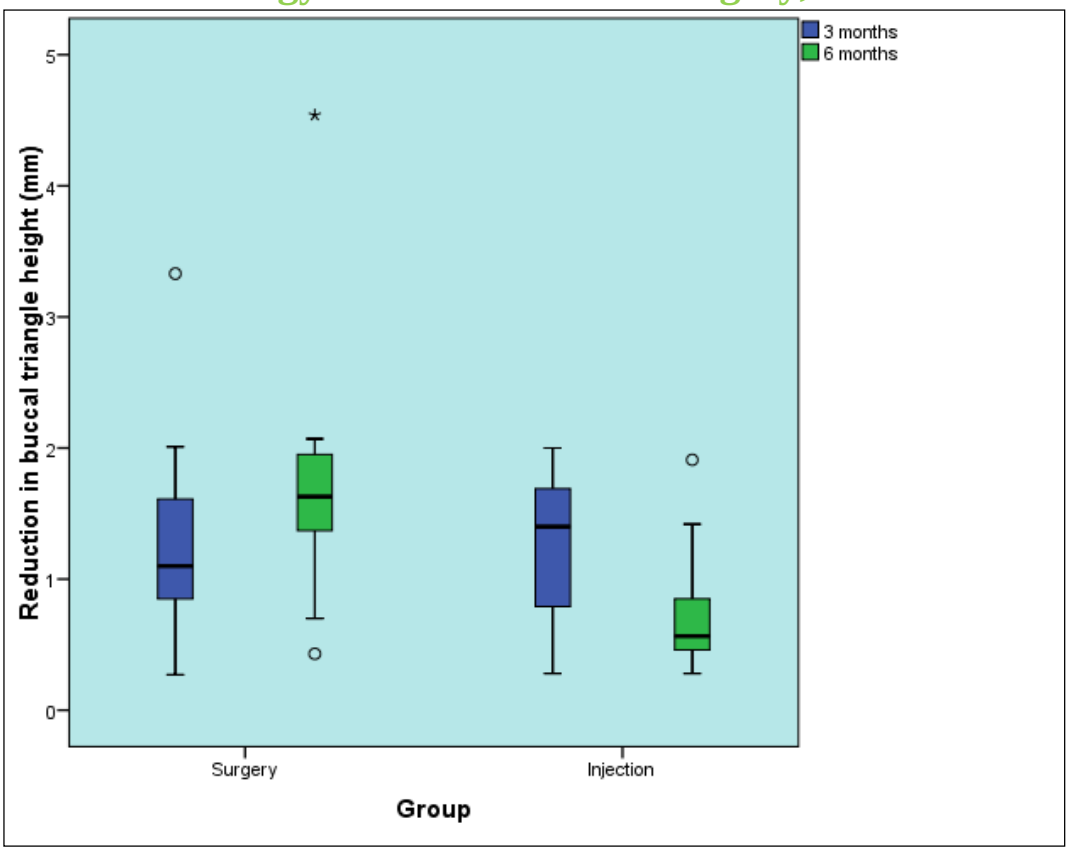


Figure 7. Box plot representing median and range values for reduction in buccal triangle height in the two groups (Stars and circle representing outliers)

Buccal triangle surface area (mm^2)

At baseline as well as after three months, there was no statistically significant difference between the two groups (*P*-value = 0.821, Effect size = 0.102) and (*P*-value = 0.199, Effect size = 0.6), respectively.

After six months, surgery group showed statistically significantly lower buccal triangle surface area than injection group (*P*-value = 0.002, Effect size = 1.835).

Table 4. Descriptive statistics and results of Mann-Whitney U test for comparison between buccal triangle surface area (mm^2) in the two groups and Friedman's test for the changes within each group

Time	Surgery (n = 10)		Injection (n = 10)		*P*-value	*Effect size (d)*
	Median (Range)	Mean (SD)	Median (Range)	Mean (SD)		
Base line	1.77 (0.69, 2.04) ^{A}	1.58 (0.53)	1.59 (0.55, 4.07) ^{A}	1.96 (1.14)	0.821	0.102
3 months	0.58 (0.09, 1.13) ^{B}	0.62 (0.37)	0.93 (0, 1.62) ^{C}	0.89 (0.53)	0.199	0.6
6 months	0.22 (0, 1.45) ^{C}	0.41 (0.51)	1.32 (0.65, 2.86) ^{B}	1.47 (0.71)	0.002*	1.835
P-value	<0.001*		0.002*			
Effect size (w)	0.84		0.63			

**: Significant at P ≤ 0.05, Different superscripts in the same column indicate statistically significant change within group*

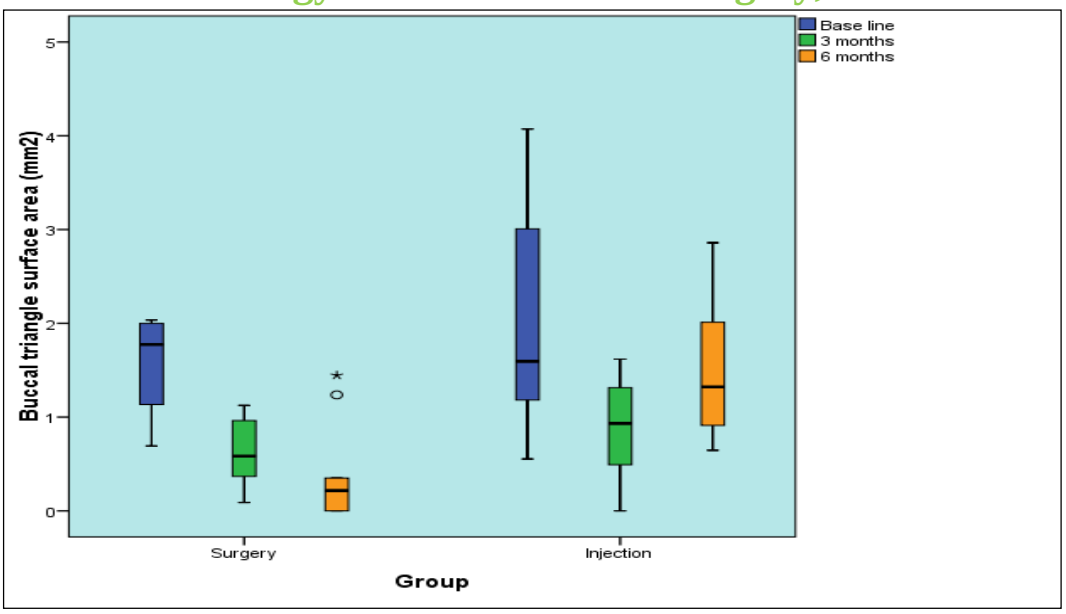


Figure 8. Box plot representing median and range values for buccal triangle surface area in the two groups (Star and circle representing outliers)

a. Comparison between amounts of reduction in buccal triangle surface areas in the two groups

The amount of reduction is calculated as the difference between three, six months measurement and base line measurement.

After three months, there was no statistically significant difference between the two groups (*P*-value = 0.940, Effect size = 0.034).

After six months, the tube surgical group showed statistically significantly higher amount of reduction in buccal triangle surface area than injection group (*P*-value = 0.041, Effect size = 1.026).

Table 5. Descriptive statistics and results of Mann-Whitney U test for comparison between amounts of reduction in buccal triangle surface area (mm^2) in the two groups

Time	Surgery (n = 10)		Injection (n = 10)		*P*-value	*Effect size (d)*
	Median (Range)	Mean (SD)	Median (Range)	Mean (SD)		
3 months	0.96 (0.17, 1.86)	0.97 (0.53)	0.82 (0.06, 2.87)	1.06 (0.89)	0.940	0.034
6 months	1.1 (0.52, 2.04)	1.18 (0.63)	0.39 (-0.09, 2.06)	0.49 (0.66)	0.041*	1.026

**: Significant at P ≤ 0.05*

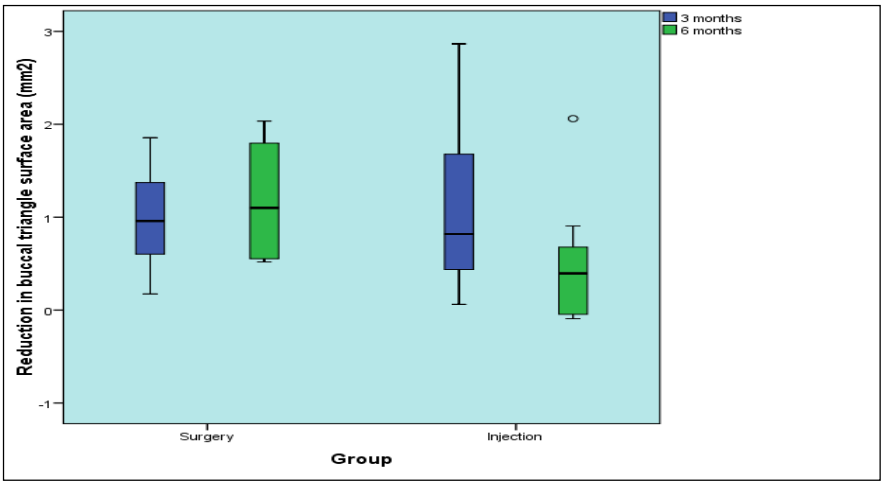


Figure 9. Box plot representing median and range values for reduction in buccal triangle surface area in the two groups (Circle representing outlier)

Radiographic evaluation - Distance (mm)

a. Comparison between the two groups

At base line as well as after six months, there was no statistically significant difference between the two groups (*P*-value = 0.793, Effect size = 0.004) and (*P*-value = 0.593, Effect size = 0.016), respectively.

C- Patient Satisfaction:

At base line, all cases in the two groups were not satisfied at all, so no statistical comparison could be done. After six months regarding Question one as well as Question two, there was a statistically significant difference between groups (*P*-value <0.001, Effect size = 0.872) and (*P*-value <0.001, Effect size = 0.922), respectively. Surgery group showed higher prevalence of extremely satisfied and very satisfied patients than injection group. As regards recommendation of the technique, there was a statistically significant difference between both groups (*P*-value = 0.003, Effect size = 0.745). Injection group showed higher prevalence of definite and probable recommendation of the technique.

DISCUSSION

In modern esthetic dentistry, the interdental papilla constitutes a vital element of an esthetically pleasing smile, and has an impact on patient satisfaction, speech, and long-term periodontal health [2]. The black triangle occurs when the papilla is absent or recedes, creating interproximal gaps that affect pink esthetics and can allow food impaction and space for air or saliva, affecting both appearance and function [21].

The preservation of papillary integrity and flexibility to site-specific anatomy render it especially beneficial for anterior aesthetic restorations, improving patient satisfaction and phonetic function [5].

This randomized clinical trial compared the clinical efficacy of the surgical tube technique versus hyaluronic acid gel injection for the reconstruction of interproximal papilla in patients with class II papillary deficiencies. The tube technique used in this study was chosen as it is considered a minimally invasive surgical method for addressing black triangle abnormalities resulting from the regression of interdental papillae in the gingival aesthetic zone [14].

The tube technique relies on the integrity of soft tissues and that scar tissue should not be present at the recipient site before this procedure. Success also depends on donor tissue thickness. The size of the graft and soft tissue defect can affect the success of this treatment. Dual blood supply improves the success of subepithelial connective tissue grafts [14]. All this was taken into consideration during the choice of the cases in this study.

On the other hand, non-surgical soft tissue augmentation involves injections of various materials. Since hyaluronic acid is the most commonly used soft-tissue augmentation substance, this study used a non-crosslinked form. Biodegradability, biocompatibility, non-immunogenicity, anti-inflammatory properties, and cell proliferation and migration are its biological features. Non-crosslinked hyaluronic acid was mixed with carboxymethyl chitosan (HA-CMC) in the present study to increase its molecular weight and enhance its biological properties, such as water absorption, oxygen permeability, hemostasis, and antibacterial activity. We standardized all shots and recorded measurements in Photoshop CC for each spot at each follow-up photo as done by [3].

The main aim of this study was to evaluate and compare the effectiveness of surgical intervention versus hyaluronic acid injection in the treatment of buccal triangle class II papillary deficiencies. The findings indicated that although both methods initially decreased the buccal triangle height and surface area, surgical intervention yielded markedly superior and more enduring results at the six-month follow-up. Specifically, the surgery group demonstrated a consistent reduction in triangle dimensions over time. In contrast, the hyaluronic acid injection group experienced a statistically significant relapse, indicated by a gradual increase in the black triangle dimensions between three and six months. Conversely, the injection relapse group demonstrated an initial decrease in triangle dimensions at three months, followed by a substantial increase in height and surface area between three and six months. The same finding was reported in a previous study [3].

A statistically significant reduction in the height of the black triangle after 3 months ($p \approx 0.001$) in the HA group compared with the saline group has been reported [3]. Between 3 and 6 months, no statistically significant difference was observed in height-distance measurements. However, the mean height-distance measurements after six months demonstrated a statistically significant reduction compared with baseline measurements, consistent with the findings in our study within the HA group. The HA injection group in the current study showed substantial initial improvement. Hyaluronic acid acted as an immediate space-filler, expanding soft tissue volume through its hydrophilic properties. However, as the present results showed, this initial "swelling" effect diminishes over time as the gel undergoes enzymatic degradation and metabolic turnover.

The present results also coincide with those of previous studies [8,13,15] at two-week and one-month follow-up periods regarding the reduction in the

surface area of the black triangle, but they could maintain their results for six months. The findings of the present study also align with previous findings [15] that revealed mean percentage reductions of 29.52 ± 18.72% from baseline to 3 months and 47.33 ± 20.20% from baseline to 6 months. A case study revealed a mean reduction percentage of 91.1 ± 11.99% after a 25-month follow-up following HA injection [22]. No baseline data on SABT were provided; only the injection of HA gel for minor papillary abnormalities was indicated. The greater percentage of reduction in that study is presumably due to the smaller baseline size of the black triangles and the extended follow-up period. Unlike fillers, surgical techniques such as the advanced papillary flap rely on the anatomical repositioning of the patient's own vascularized tissue. This creates a permanent structural change and a biological seal that are more resistant to relapses typically observed with resorbable materials [15].

Furthermore, the findings of the present study are in accordance with evidence from a systematic review [2], where it seems that the most effective intervention for papilla reconstruction is the use of a subepithelial connective tissue graft. In contrast, nonsurgical interventions, such as hyaluronic acid, appear to offer fewer clear benefits. The integration of surgical flaps allows for a more robust connective tissue attachment and steady blood supply. While injections offer a minimally invasive advantage, they lack the structural support needed to maintain interdental closure in larger defects where the distance to the bone crest is great. In comparing the results of group I with those of group II, HA injection alone was unable to maintain the reduction in the black triangle's width, height, and surface area between 3 to 6-month follow-up

Limitations

There are a few limitations of the present study, including the small sample size and the short follow-up period. A split-mouth design could be preferred to provide a more unbiased comparison of the surgical techniques.

CONCLUSION

• The use of the tube technique is a very effective way for papilla reconstruction when compared to HA injection over the same examination period.
• The use of HA injection for papilla reconstruction is effective but may not allow the long-term structural support provided by the surgical technique.
• The healing after the surgical tube technique is good, with less morbidity of the blood supply and gives better appearance than the hyaluronic acid technique.

DECLARATION

Ethics approval and consent to participate:
.**Consent for publication:**
Availability of data and materials: Research data supporting this publication is available from the corresponding author upon request.
Competing interests: The authors declare no competing interests.
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Author contributions:
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