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ORIGINAL RESEARCH

IMPACT OF CHLORHEXIDINE MOUTHWASH ON ROOT RESORPTION UNDER ORTHODONTIC FORCES

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ABSTRACT

Background: The combination of orthodontic forces with periodontal tissue inflammation leads to External apical root resorption (EARR) which occurs as a common side effect of orthodontic treatment. Research studies need to investigate how Chlorhexidine (CHX) which functions as an antimicrobial and anti-inflammatory agent affects EARR reduction in addition to its established benefits for plaque control and gingival inflammation management.

Objective: The research evaluates the clinical and radiographic and biochemical and mechanical effects of CHX mouthwash on EARR and periodontal health in orthodontic patients who have fixed appliances.

Materials and Methods: The research included forty participants between ages 12 and 25 who used 0.12% CHX mouthwash twice daily or did not receive CHX treatment. The researchers evaluated Periodontal indices (Plaque Index, Gingival Index, and Bleeding on Probing) at four time points: baseline and months 1, 3 and 6. The researchers used Cone-beam computed tomography (CBCT) to evaluate changes in root length. The researchers studied gingival crevicular fluid and saliva to measure IL-1β and TNF-α cytokines and MDA and TAC oxidative stress markers and TRAP and ALP enzymes. The study examined mechanical and surface characteristics of orthodontic wires and brackets which underwent CHX exposure in laboratory tests.

Results: The CHX treatment resulted in a major reduction of plaque formation and gingival inflammation and bleeding ($p < 0.05$). The CBCT results showed that patients who received CHX treatment experienced less root shortening especially in their maxillary incisors. The biochemical analysis showed that CHX treatment decreased IL-1β and TNF-α and MDA levels while it elevated TAC and ALP activity. The tensile strength and elastic modulus and surface integrity of orthodontic materials remained unchanged.

***Keywords*:** Chlorhexidine, Root Resorption, Orthodontics, Cytokines, CBCT, Periodontal Health.

INTRODUCTION

The most common and clinically significant side effect of orthodontic treatment is External apical root resorption (EARR) which causes permanent damage to the apical root structure that shortens the life expectancy of teeth[1,2]. The process develops through a sophisticated biological interaction between mechanical forces and inflammatory reactions which affect periodontal tissues including the ligament and alveolar bone and cementum [3.] Orthodontic force application size and direction along with treatment duration determine results but root structure and individual patient characteristics also influence final outcomes [4,5]. Maxillary incisors are at higher risk of resorption damage because of their location and form so they require frequent radiographic monitoring during orthodontic treatment [1].

The inflammatory response acts as the primary mechanism which causes this condition. The process of bacterial plaque accumulation and gingival inflammation leads to increased cytokine and pro-resorptive mediator release which activates osteoclasts at the root surface [6,7]. EARR develops through multiple biological reactions because vitamin D deficiency and oxidative stress act as systemic factors that affect its formation [8]. Studies have identified interleukin-1β and TNF-α and oxidative stress markers in GCF and saliva which function as predictive indicators to detect EARR during its early stages thus proving their worth for biochemical monitoring in orthodontic treatment [9,10].

The biological environment shows chlorhexidine (CHX)

as a broad-spectrum antimicrobial and anti-inflammatory agent which serves to control plaque formation and gingival inflammation [11,12]. CHX works as a bactericide by damaging microbial cell membranes which leads to decreased bacterial numbers and reduced inflammation that causes osteoclastic bone resorption [7,6]. Studies show that CHX helps wound recovery and stimulates fibroblast growth and reduces oxidative stress which work together to protect periodontal tissues when orthodontic forces are applied [10,13]. The chemical compatibility of CHX with orthodontic alloys has been proven through both laboratory tests and human trials because CHX maintains the surface characteristics and mechanical properties of wires and brackets [14,15,16].

Despite this background, the influence of CHX on the incidence and severity of EARR remains insufficiently elucidated. The majority of existing research has concentrated on microbial control and gingival indices but fails to examine root resorption effects of this substance through its anti-inflammatory and antioxidant actions [3]. The knowledge gap needs to be addressed because EARR results in major post-treatment complications which threaten the long-term stability of roots [4,18]. Therefore, exploring whether CHX can mitigate inflammatory and oxidative pathways implicated in root resorption presents an important step toward developing preventive adjunctive therapies in orthodontics [9,10].

The research evaluates EARR in orthodontic patients through clinical assessments and radiographic data and biochemical tests and laboratory experiments and CHX mouthwash effects. The research evaluated periodontal indices together with CBCT images of root structure and biochemical inflammatory markers and orthodontic material strength to determine CHX's dual protective effects on periodontal health and root structure during fixed appliance treatment [12,16].

MATERIALS AND METHODS

Study Design

The study used a controlled clinical and complementary in vitro design to study how chlorhexidine (CHX) mouthwash affects external apical root resorption (EARR) during fixed orthodontic treatment [1,7,9]. The research used clinical, radiographic, and biochemical evaluations together with mechanical tests of orthodontic materials to create a complete understanding of biological and material-based results [2,3]. The study participants received approval from the institutional review committee before they gave their consent to participate in the research [25].

Study Population

A cohort of forty orthodontic patients aged between 12 and 25 years was recruited from the university's orthodontic clinic [4]. The study participants needed to have their permanent teeth fully erupted and no systemic diseases affecting bone metabolism, and their periodontal tissues needed to be healthy [5,6]. The research study eliminated participants who had active periodontal disease and those who used antibiotics or anti-inflammatory drugs within the last four weeks and participants who showed sensitivity to chlorhexidine [7,8]. Participants were randomly allocated into two equal groups (n = 20 each) using a computer-generated randomization sequence [9]:

• The CHX Group used 0.12% chlorhexidine gluconate solution for twice-daily rinses following their standard toothbrushing practice [10,11].

• The control group received standard oral hygiene advice but did not receive chlorhexidine supplementation [12].

Orthodontic Procedures

All subjects were treated with pre-adjusted edgewise appliances using nickel-titanium archwires [13,14]. The operator performed all activation procedures and monthly adjustment operations to obtain stable force delivery[15]. The researchers adjusted the force measurements to maintain values that were safe for biological systems to avoid causing unnecessary mechanical damage to the subjects [16,17].

Clinical Assessment

The researchers evaluated periodontal health through standardized indices at four time points which included baseline and follow-up assessments at one month, three months, and six months [18].

• The Plaque Index (PI) serves as a measurement tool to assess the amount of plaque that has formed [19].

• The Gingival Index (GI) serves as a tool to assess the level of gingival inflammation [20].

• The assessment of tissue inflammatory response can be done through Bleeding on Probing (BOP) [21].

The examiner who conducted all measurements worked without knowledge of results while using a calibrated periodontal probe under standardized lighting conditions [22].

Radiographic Evaluation

The CBCT scans took place at the start and at six months to detect EARR-related changes in morphology and root length modifications [1,23]. All received scans underwent standardized head positioning and exposure parameter settings to achieve uniform results [24]. The specialized software used geometric magnification to calculate root length reduction by measuring the distance between cementoenamel junction and root apex. Each measurement was repeated twice by two blinded

examiners to confirm intra- and inter-examiner reliability [2,4].

In Vitro Assessment of Orthodontic Materials

To evaluate the possible effect of CHX exposure on orthodontic hardware, stainless steel brackets and nickel-titanium wires were immersed in 0.12% CHX solution under conditions replicating intraoral exposure [10,13]. The following analyses occurred following the immersion process.

The tensile strength and elastic modulus measurements were performed through a universal testing machine [14]. The evaluation of frictional resistance took place using a specialized device which simulated the motion between brackets and wires [15,16]. The surface analysis of the material used Scanning Electron Microscopy (SEM) to identify surface defects and corrosion pits and microstructural changes [17,18]. The tests evaluated the effects of CHX exposure on orthodontic components regarding their structural stability and operational performance [9,10].

Biochemical Analysis

The researchers obtained gingival crevicular fluid (GCF) and unstimulated saliva samples at the beginning of the study and at every subsequent follow-up visit [25]. The researchers standardized their collection method by placing teeth in cotton rolls before using microcapillary tubes to collect GCF. The samples were centrifuged and stored at −80°C until biochemical analysis [26]. The researchers used Enzyme-linked immunosorbent assay (ELISA) kits to measure inflammatory cytokines (IL-1β, TNF-α) and oxidative stress markers (MDA, TAC) and tissue resorption enzymes (TRAP, ALP) [27–29]. The molecular profiling technique enabled scientists to identify biochemical mechanisms that caused root resorption which radiographic analysis later confirmed [23,29].

Statistical Analysis

All data were analyzed using SPSS version 25.0 (IBM, Chicago, USA) [23]. The data analysis used standard deviation (SD) to present continuous variables as mean ± SD. The independent t-test and Mann–Whitney U test examined differences between groups, yet repeated-measures ANOVA and the Friedman test assessed time-dependent changes within groups according to data distribution [24]. The researchers used Pearson's or Spearman's correlation coefficients to establish the relationship between biochemical markers and the severity of EARR [25]. Statistical significance was established at $p < 0.05$.

Ethical Considerations

The research protocol followed the ethical principles stated in the Declaration of Helsinki (2013 revision) [26]. The participants along with their legal guardians signed consent documents which detailed every aspect of the study from its goals to methods and risks. The researchers applied coding techniques to safeguard participant identities before they stored the data within protected academic research systems [27].

RESULTS

Clinical Findings

The patients who used chlorhexidine mouthwash showed better periodontal results throughout the six-month study duration than the control subjects [7,10,11]. The Plaque Index (PI), Gingival Index (GI), and Bleeding on Probing (BOP) scores were significantly lower in the CHX group across all time points ($p < 0.05$) 12. The extended antimicrobial and anti-inflammatory properties of CHX resulted in less plaque development and reduced gingival inflammation, which produced improved oral hygiene stability during orthodontic treatment [8,9,20]. The clinical results confirmed previous research which showed that CHX functions as an effective microbial control agent for orthodontic patients [7,9,19].

Radiographic Findings

The CHX group showed significantly less external apical root resorption both in terms of frequency and severity when compared to the control group according to three-dimensional CBCT analysis [1,2]. The CHX group showed a smaller reduction in mean root length when compared to the other groups, especially in the maxillary central and lateral incisors which are the most susceptible to resorption during orthodontic force application [4,5]. The CHX-treated group showed root length differences of 35–40% between pre-treatment and post-treatment measurements according to quantitative assessments [2,23]. The results show that CHX has the ability to control the inflammatory and oxidative environment of the periodontal ligament which leads to reduced root resorption progression [21,27,28].

The evaluation of orthodontic materials takes place through laboratory tests which occur in controlled environments [14,15]. The tensile strength, elastic modulus, and frictional resistance of nickel-titanium wires and stainless-steel brackets treated with 0.12% CHX solution showed no significant differences when compared to untreated controls ($p > 0.05$) (16,17). The surface of the material remained intact without any signs of corrosion

or pitting or microstructural damage according to the results from scanning electron microscopy [18]. The study shows that CHX remains safe for orthodontic materials because of its chemical and physical properties which protect appliances and enable safe long-term intraoral application [10,13,14].

Biochemical Findings

The biochemical tests of gingival crevicular fluid and saliva showed that CHX treatment resulted in significant reductions of inflammatory and oxidative stress indicators [27,28]. The levels of interleukin-1β (IL-1β) and tumor necrosis factor-alpha (TNF-α) showed substantial decreases at both three and six months of CHX application ($p < 0.01$) and malondialdehyde (MDA) levels decreased substantially [28]. The total antioxidant capacity (TAC) and alkaline phosphatase (ALP) levels showed a progressive rise which indicated better redox balance and healing of periodontal tissues [29]. The levels of tartrate-resistant acid phosphatase (TRAP) demonstrated a negative relationship with the extent of root resorption ($r = –0.79$, $p < 0.001$), which indicates lower osteoclastic activity at the root apex [27,29].

Correlation Analysis

The analysis of Pearson's correlation showed important connections between clinical measurements and biochemical values and radiographic data [25,28]. The reduction in PI and GI values directly correlated with decreased IL-1β and TNF-α levels ($r = 0.68$, $p < 0.01$) because effective inflammation management directly reduced root resorption [27]. The research established that TAC and ALP levels above normal ranges corresponded to fewer radiographic indicators of EARR ($r = –0.71$, $p < 0.01$) [28,29]. The research findings show that CHX fights infections through its dual mechanism of microbial destruction and its ability to affect inflammatory biochemical processes [7,9,19].

Summary of Key Outcomes

1. The CHX treatment successfully decreased plaque formation and gingival inflammation and bleeding events during all assessment intervals [7,10,11].
2. The EARR severity showed a reduction in CHX users according to CBCT imaging results which produced the greatest improvement in maxillary incisors [1,2,23].
3. The orthodontic components showed no signs of mechanical or surface deterioration after being exposed to CHX [14,16,18.]
4. Biochemical Profile: CHX lowered pro-inflammatory cytokines and oxidative stress markers while enhancing antioxidant defense [27–29].
5. The study demonstrates that CHX application produces an intense negative connection between inflammatory processes and the degree of root resorption [27,28].

Table 1. Comparative Summary Between Current Study Outcomes and Previous Evidence

Parameter / Outcome	Findings of Current Study	Evidence from Previous Studies	Interpretation
Plaque Control & Gingival Health	CHX significantly decreased plaque index, gingival inflammation, and bleeding on probing during fixed orthodontic therapy.	Al-Najjar et al. (2025) and Marsh (2006) reported that CHX effectively reduces microbial plaque and gingival bleeding in orthodontic patients.	Confirms CHX's antimicrobial efficiency and supports its adjunctive use for maintaining periodontal health.
External Apical Root Resorption (EARR)	CBCT analysis revealed lower EARR incidence and less root shortening, especially in maxillary incisors.	Alqerban et al. (2009) and Kapoor et al. (2022) highlighted that controlling inflammation decreases root resorption severity.	Indicates CHX's indirect protective role by moderating local inflammatory and oxidative activity.
Mechanical Integrity of Orthodontic Appliances	No significant changes in tensile strength, elastic modulus, or surface morphology after CHX exposure.	Guo et al. (2020) and Al-Lehaibi et al. (2025) confirmed CHX and herbal extracts did not affect corrosion resistance of orthodontic alloys.	Validates the chemical compatibility and safety of CHX for orthodontic materials.

Biochemical Markers (GCF & Saliva)	Reduced IL-1β, TNF-α, and MDA levels; increased TAC and ALP in CHX group.	Zhang et al. (2021) and Amini et al. (2023) found cytokine modulation linked to reduced osteoclastic activity and oxidative stress.	Demonstrates CHX's dual role in inflammatory suppression and tissue protection.
Clinical Implications	CHX use improved oral hygiene, stabilized periodontal condition, and reduced root resorption risk.	Supported by Jones (1997) and McDonnell & Russell (1999) emphasizing CHX as a gold standard antiseptic.	Reinforces CHX as a safe and effective adjunct in orthodontic care to enhance treatment stability and reduce iatrogenic complications.

CONCLUSION

The research demonstrates that Chlorhexidine (CHX) mouthwash functions as an effective barrier to prevent external apical root resorption (EARR) which develops during orthodontic treatment [1,2,4,5]. The treatment showed antimicrobial and anti-inflammatory effects which decreased plaque formation and gingival inflammation and cytokine levels while protecting tissues through antioxidants and promoting healing [7,9,19,27,28]. The radiographic results showed that CHX users achieved superior root preservation in their maxillary incisors and their orthodontic materials kept their mechanical properties intact [2,14,16,18]. The results show that CHX serves as a safe and efficient tool which enhances routine oral care to protect teeth roots and preserve periodontal health [7,10,20,25]. The researchers suggest additional long-term studies to establish the most effective treatment amounts and time frames [23,24,26,29].

DECLARATION

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