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ORIGINAL RESEARCH

ASSESSMENT OF 3D-PRINTED OCCLUSAL SPLINT USED IN THE TREATMENT OF TEMPOROMANDIBULAR DISORDER IN FEMALE PATIENTS.

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Background: This study aimed to assess 3D-printed occlusal splint, used in the treatment of patients with Temporomandibular disorder (TMD), comparing with conventional occlusal splints regarding radiographic evaluation using CBCT and patient satisfaction.
Materials and Methods: A prospective crossover design was conducted at The Outpatient's Clinic of The Prosthesis Department, Faculty of Dental Medicine for Girls, Al-Azhar University, Egypt. 12 female patients were diagnosed to have TMD without disc displacement using ultrasound. There were two categories for each case: Splints made of traditional heat-cured acrylic resin (PMMA) were given to six patients in Group A for their maxillary occlusal joints, then they went through a 1-month washout period, after that they received maxillary occlusal splint constructed by 3D printed technique. Group B: received maxillary occlusal splints constructed by 3D Printed technique, they went through a 1-month washout period, after that they received maxillary occlusal splints constructed by the conventional method.
Results: the results of the study showed that, both types of splints led to change at the condylar position. However, the 3D printed splint demonstrated statistically significant changes, particularly on the left side, while the conventional splint showed non-significant changes. Patient satisfaction significantly improved in both groups, with higher scores reported in the 3D printed splint group.
Conclusion: According to the results of the study, the 3D printed occlusal splint demonstrated notable clinical effectiveness in the management of TMD

Keywords*:* TMD, Patient Satisfaction, 3D Printed Splint, Stent, CBCT.

INTRODUCTION

When the masticatory muscles, the temporomandibular joints (TMJ), and other structures in the jaw are affected by a variety of musculoskeletal problems, it may lead to dysfunction and discomfort. Among the many non-odontogenic causes of orofacial discomfort, jaw pain, limited mobility, and joint noises, TMD is by far the most frequent. [1-5]

Bruxism which is one of the most important causes of TMD, has a multifactorial etiology involving occlusal, psychological, and neurological influences. It can generate forces several times greater than normal chewing, resulting in teeth wear, fractures, periodontal damage, and TMD. [6]

The previous studies revealed that, TMD prevalence reached 73.4%, with 57% classified as mild with significantly higher rates in females (73.3%) than males (26.7%). TMD is also linked to psychological comorbidities such as depression and causing a significant economic and social load.[7,8]

Orofacial discomfort and dysfunction are often caused by TMDs. To ease discomfort and preserve teeth from deterioration, occlusal splints are commonly used in treatment. Modern digital dentistry has led to a dramatic shift away from the use of traditional methods of fabrication for these splints and toward the use of computer-aided manufacturing (CAD/CAM) processes like milling and 3D printing. [8]

The etiology of this disorder is multifactorial, combining structural, functional, and psychological factors. Pain is the most common symptom, though TMD may also present without pain (9).

Diagnosis should follow structured protocols, including the diagnostic criteria of temporomandibular disorder (DC/TMD), psychological assessment, and CBCT imaging, to guide individualized treatment (10, 11). Management typically favors occlusal therapy which is reversible, conservative approaches such as medications, physiotherapy, occlusal splints, self-care, and cognitive-behavioral strategies.

Occlusal therapy is conservative and reversible and one component of treatment. Splints are widely used to relieve muscle tension, reduce parafunctional forces, and promote neuromuscular balance, aiding in both diagnosis and therapy. Their design varies in coverage, retention, material, and thickness, allowing mandibular stability and functional harmony (12-15).

Occlusal splint therapy remains a cornerstone in the conservative management of TMDs, aiming to reduce intra-articular loading, redistribute occlusal forces, and promote neuromuscular balance. With the using of digital technologies, the use of CAD/CAM and 3D-printing in splint fabrication has gained prominence due to its reported advantages in precision, fit, and reduced clinical time. However, limited clinical evidence directly compares these techniques in terms of objective radiographic outcomes and patient satisfaction scale (15). Traditional splints commonly fabricated from polyethylene or acrylic resins have limitations such as instability, discoloration, fracture risk, and allergenicity, in addition to labor-intensive fabrication (16,17). Recent advances in CAD/CAM digital workflows have improved splint fabrication, offered greater precision, efficiency, reproducibility, and patient comfort while overcame many drawbacks of conventional methods (18).

Since 3D printing allows for the efficient production of more complicated geometries at a lower cost and in less time than the conventional milling method, it is quickly gaining popularity in the dental field. More and more stabilizing splints are being made utilizing 3D printing because of these benefits related to manufacture. Nevertheless, it is still unclear whether these stabilizing splints made of 3D printing are clinically as effective as more traditional options. (19).

So, the study was conducted to address the following question; Would the digital design and fabrication of the occlusal splint provide improvement, compared to conventional occlusal splint in terms of patient satisfaction and condylar position?

Study design

This study was designed to be a parallel randomized controlled crossover trials, with the conventional acrylic resin splint served as the control for comparison with the 3D printed splint. All twelve patients were randomly and blindly assigned to either one of the following groups:

Group A: Six patients, each received conventional stabilization occlusal splint for 3 months, then they went through one-month washout period, after that they received a 3D printed occlusal splint.

Group B: Six patients, each received 3D printed stabilization occlusal splint for 3 months, then they went through one-month washup period, after that received conventional occlusal splint.

The following ethical authorization code was assigned to the research once it was authorized by the Faculty of Dental Medicine for Girls' Ethical Committee: (REC-PR-25-03)

Sample size calculation

According to G*Power software version 3.1.9.7. Twelve patients were selected from the Outpatient Clinic of Removable Prosthodontics Department, Faculty of Dental Medicine for Girls, Al-Azhar University. All the patients in this study were informed about the steps of treatment, methodology and a written consent were signed by each one of them.

MATERIAL AND METHODS

All the patients received thorough TMJ clinical examinations supported by CBCT and ultrasound for diagnosis. The patient diagnosed clinically according to signs and symptoms: Bruxism and clenching, Pain, Headache, Tenderness in muscles and Clicking in TMJ with no functional mouth limitations. All the patient were chosen to be:

1. Female, cooperative patient with age ranged between (20-50).
2. The patient should be physically and psychologically able to tolerate procedures.
3. Absence of any substantial dental or periodontal disease with good oral hygiene.
4. Absence of prior psychological or occlusal splint therapy.
5. Patients had Angle class I without any malocclusion.

The splints design:

Twelve occlusal splints were fabricated with parameters, focused on occlusal contact, anatomical extension, and thickness to ensure function, comfort, and efficacy. Posterior occlusal contact in centric relation was directed to the supporting cusps (mandibular buccal cusps), avoiding premature contacts. To prevent back teeth from getting in the way while moving laterally or protruding, anterior guiding was used. To reduce parafunctional loads and interferences, the occlusal surface was smoothed and flattened.

Each maxillary splint extended to cover all occlusal surfaces, wrapping slightly beyond buccal cusps and incisal edges, and extending palatally to ensure full coverage and stability.

Splint thickness was standardized at 2 mm, providing strength while limiting bulk for comfort. Relief was applied along gingival margins to avoid irritation.

Construction of Conventional Occlusal Splint

Primary impressions were taken with rubber base material (Zeta Plus, Zhermack, Italy) and poured in dental stone (Zeta Dental Stone, Zeus, UK.) to create diagnostic casts. Special trays of heat cured resin (Acrostone, Heat cured, Egypt) were fabricated for secondary impressions which was poured to obtain master casts. Master casts were surveyed (Ney Dental Surveyor, USA) to detect undercuts. A facebow record was used for (Bioart Elite Face Bow A7 Plus, Sao Paulo, Brazil.) mounting the upper cast on a semi-adjustable articulator (Bioart Arcon articulator A7 Plus, Sao Paulo, Brazil), albeit a central occlusion record was used to mount the bottom cast.

Splints were designed with flat occlusal surfaces, uniform posterior contacts, anterior guidance during excursions, and a standardized 2 mm thickness using modeling wax (Cavex Wax Set Up, Netherlands).

Wax pattern from modeling wax (Cavex Wax Set Up, Netherlands) was made with extension covered occlusal surfaces, wrapping beyond buccal cusps/incisal edges for retention. The splints were flasked, wax-eliminated by boiling out, and processed with heat-cured acrylic resin (Acrostone, Heat cured, Egypt) following manufacturer's instructions. The cured splints were deflasked, finished, polished, and adjusted intraorally using articulating paper to eliminate occlusal interferences. Following three months of receiving their splints, individuals were to return for a follow-up appointment.

Construction of 3D Printed Occlusal Splint

Same steps were followed as conventional occlusal splint. Scanning for the mounted casts were made using a Ceramill map 400 scanner (Ceramill map400 Scanner, Austria) to generate STL files. Before designing the splint, digital surveying was performed on the scanned casts to determine the most suitable path of insertion for the occlusal splints.

The digital survey line was established using the Exocad Dental software (Exocad Dental CAD, Germany) to identify the height of contour and undercut areas on the abutment teeth. This process allowed accurate visualization and adjustment of the design before fabrication. The digital approach provided enhanced precision and repeatability compared to conventional mechanical surveying, ensuring optimal retention and stability of the final splint. The STL files were imported into dental Exo CAD dental software.

Digital design of the splints was performed using Exocad Dental CAD software. The design included uniform posterior occlusal contacts, anterior guidance to ensure disocclusion during mandibular movements, and an anatomical extension covering the occlusal surfaces with slight wrapping onto buccal and palatal aspects. The thickness of occlusal splint was standardized at 2 mm to balance strength and patient comfort, as shown in figure (1, 2)

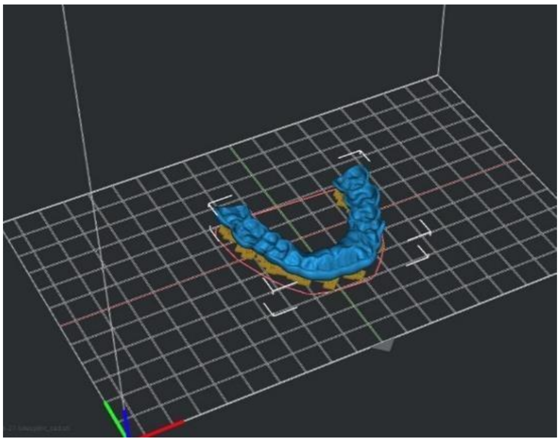

Figure 1. Initial digital design of the occlusal splint on the Exocad dental software

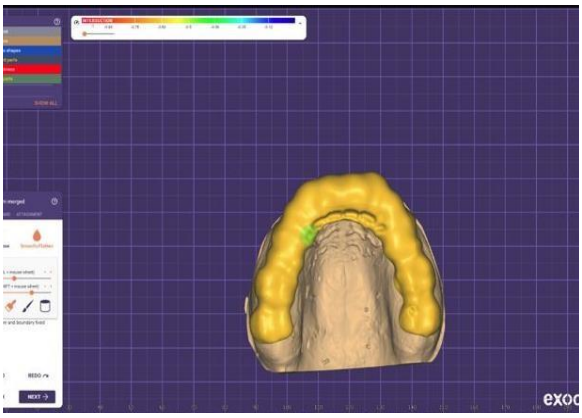

Figure 2. Maxillary arch digital scan imported into Exocad for splint design.

The splints were fabricated using a DLP 3D printer with HARZ Labs Dental Clear resin (Harz Labs 3D resin for dental splint, Russia). The thickness was carefully controlled to ensure sufficient strength while minimizing bulk to maintain patient comfort, following manufacturer-recommended settings. Post-processing involved cleaning in isopropyl alcohol, air drying, and UV curing to ensure complete polymerization. The printed splints were then finished and polished using rotary instruments to refine the surface and achieve a smooth, comfortable fit.

For both splints, they were evaluated intraorally for clinical fit, retention, and occlusion. Necessary adjustments were made chairside to optimize comfort and function. The patient was advised to wear the splint while sleeping and to follow certain cleaning procedures.

Washout period for a month was followed between the two splints for each patient, the patient's satisfaction was measured at baseline and 3 months. The CBCT records were also evaluated one and three months after delivery.

For each patient right and left condyles were subjected to a pre-treatment CBCT scan and also 3 months after delivery, while the patients were instructed to close their teeth at centric occlusion during imaging. With the help of CS 3D imaging software (version 3.5.18.0), With the help of CS 3D imaging software (version 3.5.18.0), the linear measures were taken. Millimeters were used to determine the linear dimensions of the radiographic joint spaces, which include the anterior, posterior, and superior spaces.

After measuring the maximal condylar width from the coronal slice, the image's sagittal plane was positioned at its midway. It was thought that the middle cut of the joint was the matching sagittal slice. From the center incision, 3.5 mm to the medial and 3.5 mm to the lateral were the measures recorded. To improve precision, the three cuts were used to measure the anterior, superior, and posterior spaces, and the mean of these measurements was then computed. Referring to figure (3)

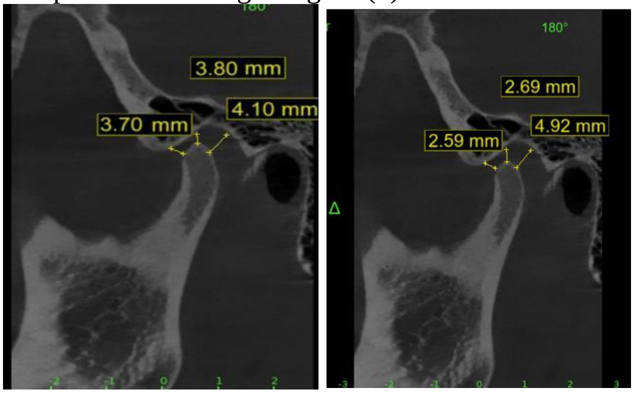

Figure 3. Sagittal CBCT slice before and after using splint demonstrating measurement of the anterior, superior, and posterior joint spaces at the central cut of the condyle.

Diagnostic tools:

Patient satisfaction was assessed using the Numeric Analogue Scale (NAS), a validated subjective measure commonly used. The NAS questionnaire included ten items evaluating various symptoms associated with TMD, such as facial pain, joint clicking, mastication difficulty, headache, neck pain, teeth sensitivity, joint pain, mouth opening limitation, face tension and neck tension. Each item was scored on a 10-point scale, with 0 indicating no complaint and 10 indicating the worst symptom severity.

Satisfaction data were collected at two time points: baseline (prior to treatment) and three months after delivery. Patients were instructed to mark their responses independently without clinician influence to avoid bias. The results were analyzed to compare the effectiveness of conventional versus 3D printed occlusal splints in improving patient-perceived outcome.

Using scores:

Scores of 0–3: Mild symptoms or high satisfaction.

Scores of 4–6: Moderate symptoms/satisfaction.

Scores of 7–10: Poor/Severe dissatisfaction or symptoms.

Statistical analysis

All analyses of the collected data were conducted using SPSS software (version 25, IBM Corp., USA), The Shapiro-Wilk test was applied to assess data normality, numerical variables were expressed as mean and slandered deviation, independent T test and Mann Whitney test were used for comparison of different splint type and side for parametric and non-parametric variables respectively.

Paired T test and Wilcoxon Signed-Rank Test were used for comparisons between parametric and non-parametric related variables respectively. A statistically significant result was defined as a value of $P < 0.05$, a very significant result as a P- value ≤ 0.001, and a result that was not significant as a value of $P > 0.05$.

RESULTS

This crossover study included 12 female patients aged between 20 and 50 years. Each participant received both conventional and digital occlusal splints, resulting in a total of 24 splints (12 per group). All patients completed a three-months follow-up period with one-month washout period between the two types of splints.

Radiographic assessment (CBCT Results):-

Evaluation was done regarding effect of evaluation period and splint type.

I-Effect of evaluation period on the condylar position under the same splint type and the same measuring side.

1-Conventional Splint:

a- When the conventional splint was used first, CBCT measurements revealed no significant compared to baseline.

In the Left side, the mean condylar position decreased from 3.75 ± 0.42 mm at to 3.50 ± 0.44 mm after 3 months. In the right side, the mean value decreased from 3.74 ± 0.55 mm to 3.46 ± 0.60 mm after 3 months. (table 1)

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Table 1. Comparison of condylar position between the two-time intervals and the two sides for the different splint types. When each splint used as first splint.

1st splint	Conventional			Digital		
Time interval	At baseline	After 3 months	P-value*	At baseline	After 3 months	P-value*
Left	3.75±0.42	3.5±0.44	0.357NS	3.72±0.94	2.91±0.86	0.006S
Right	3.74±0.55	3.46±0.6	0.266NS	4.49±0.49	3.69±0.48	0.095NS
P-value**	0.976NS	0.903NS		0.058NS	0.042S	

b- When the conventional splint was used second, CBCT measurements revealed no significant compared to baseline.
For both left and right sides, the mean condylar position showed a slight decrease after 3 months, however, paired t-test analysis revealed these changes were not statistically significant for either side ($p > 0.05$), (table 2)

Table 2. Comparison of condylar position between the two-time intervals and the two sides for the different splint types. When each splint used as second splint.

2nd splint type	Conventional			Digital		
Time interval	At baseline	After 3 months	P-value*	At baseline	After 3 months	P-value*
Left	3.29±0.47	3.03±0.5	0.302NS	3.56±0.58	2.78±0.49	0.012S
Right	3.88±0.72	3.57±0.67	0.395NS	3.73±0.49	2.96±0.37	0.003S
P-value**	0.072NS	0.087NS		0.522NS	0.417NS	

2- Digital Splint (3D Printed):
a- When the 3D printed splint was used first, CBCT measurements were statistically significant compared to baseline.
In the Left side, the mean condylar position decreased from (3.72±0.94 mm) to (2.91±0.86 mm) after 3 months. In the Right side, the mean condylar position decreased from (4.49±0.49 mm) to (3.69±0.48 mm) after 3 months, (table 1).
b- When the 3D printed splint was used second, CBCT measurements were statistically significant compared to baseline.
The digital splint demonstrated a similar trend to the conventional splint, with bilateral reductions in condylar position. The left side decreased from 3.56±0.58 mm to 2.78±0.49 mm, while the right side showed a reduction from 3.73±0.49 mm to 2.96±0.37 mm after 3 months. (table 2).
Regardless of the splint type, the CBCT results indicated decreasing in the mean of condylar position after 3 months of delivery. The difference was not significant in the Conventional splint regardless measuring side when it was used first, and statistically significant with the Digital splint left and non-significant in the Digital splint right, when it was used first, (table 2)
Both splint types showed after 3 months of delivery decreases in condylar position when used as a second splint, only the digital splint produced statistically significant changes at baseline and after 3-months follow-up. The conventional splint's positional changes, though observable, did not reach statistical significance at both periods, as shown in table (2)
II- Effect of splint type on the condylar position at the same time interval and the same measuring side:
a- The first assigned splint:
On the left side, the conventional splint showed higher mean condylar position values than the digital splint at both time intervals, at baseline and after 3 months; however, there were no statistically significant differences between

the two groups at baseline or after 3 months, (table 3).
On the right side, the digital splint recorded the highest mean values at both time points, with a statistically significant difference between groups at baseline, though this significance was not maintained after 3 months (table 3).

Table 3. Mean ±SD, and comparison of condylar position between the two splints at different time intervals for both sides, when each splint was used as first splint.

Side	Left		Right	
Time interval	At base line	After 3 months	At base line	After 3 months
Conventional	3.75±0.42	3.5±0.44	3.74±0.55	3.46±0.6
Digital	3.72±0.94	2.91±0.86	4.49±0.49	3.69±0.48
P-value**	0.935NS	0.109NS	0.012S	0.417NS

B- During the second used splint:

On the left side, digital splints showed higher pretreatment values, while conventional splints demonstrated superior values after 3 months measurements. Differences were non-significant at both time points (p>0.05), (table 4)

On the right side, conventional splints maintained higher mean values both at baseline and after 3 months, yet similarly showed no statistically significant differences compared to digital splints at either evaluation period, (table 4).

Table 4, Mean ±SD, and comparison of condylar position between the two groups at different time intervals for both sides when the splint was used secondly after the washout period.

side	Left		Right	
Time	At baseline	After 3 months	At baseline	After 3 months
Conventional	3.29±0.47	3.03±0.5	3.88±0.72	3.57±0.67
Digital	3.56±0.58	2.78±0.49	3.73±0.49	2.96±0.37
P-value**	0.316NS	0.342NS	0.649NS	0.042S

Assessment of CBCT results regardless of washing out period (Overall results):

Comparison between conventional and digital splints on the condylar position

Conventional Splint

The difference between the time intervals was not statistically significant (P-value > 0.05)

In the Left side, the mean condylar position decreased from (3.64±0.78 mm) to (3.26±0.54 mm) after 3 months. In the Right side, the mean condylar position decreased from (3.81±0.65 mm) to (3.52±0.64 mm) after 3 months, (table 5).

Digital Splint

Difference between the time intervals was statistically significant (P-value < 0.05) at left side and statistically highly significant at the right side (P-value < 0.001)

In the Left side, the mean condylar position decreased from (3.53±0.51 mm) to (2.85±0.7 mm) after 3 months. In the Right side, the mean condylar position decreased from (4.11±0.63 mm) to (3.33±0.58mm) after 3 months, (table 5).

Regardless of the splint type, the CBCT results indicated decreasing in the mean of condylar position after 3 months of delivery. The difference was not significant in the Conventional splint regardless measuring side, and statistically significant with the Digital splint left and highly significant in the Digital splint right, (table 5).

Table 5. Comparison of condylar position between time intervals at baseline and after 3 months, for the right and left sides, using different splint types.

Splint		Conventional			Digital		
Time interval		At baseline	After 3 months	P**	At baseline	After 3 months	P**
Overall	Left	3.64±0.78	3.26±0.54	0.163NS	3.53±0.51	2.85±0.7	0.004S
	Right	3.81±0.65	3.52±0.64	0.196NS	4.11±0.63	3.33±0.58	0.001HS
	P**	0.152NS	0.213NS		0.061NS	0.037S	

Effect of Splint type on the condylar position under the same period and same measuring side

Left Side

No significant difference between the groups either at baseline or after 3 months, (table 6)

Right side

The Digital splint achieved the highest mean at baseline, while Conventional achieved the highest one after 3 months and yet the difference between the two groups was not significant at the two-time intervals, (table 6)

Table 6. Mean ±SD, and comparison of condylar position between the two groups at different time intervals for both sides.

	Left		Right	
	At baseline	After 3 months	At baseline	After 3 months
Conventional	3.64±0.78	3.26±0.54	3.81±0.65	3.52±0.64
Digital	3.53±0.51	2.85±0.7	4.11±0.63	3.33±0.58
P-value**	0.594NS	0.062NS	0.176NS	0.369NS

Assessment of patient satisfaction via Numerical Analogue Scale (NAS)

Assessment of NAS score during the first used splint

Both splint types showed significant improvements in NAS scores after 3 months (Conventional: 6±0.89 to 4±1.1; Digital: 5.83±1.17 to 2.83±0.75). Those decreases were statistically significant ($p<0.05$) for conventional and highly statistically significant for digital group ($p<0.001$).

Patients who used conventional splint reported higher baseline NAS scores (mean difference = 0.17) than those using digital splint. This difference was not statistically significant ($p>0.05$).

After 3 months of evaluation digital splint patients showed significantly higher satisfaction scores ($p<0.001$), (table 7)

Table 7. Mean ±SD, comparison of NAS scale for different groups at the two-time intervals when each splint was used as the first one.

	At baseline	After 3 months	P-value*
Conventional	6±0.89	4±1.1	0.006S
Digital	5.83±1.17	2.83±0.75	< 0.001HS
P-value**	0.843NS	0.007S	

-* Overall P-value for comparison between the two-time intervals (Wilcoxon signed-rank Test).-** Overall P-value for comparison between the two groups (Mann-Whitney U Test).- S= Statistically significant at $P \leq 0.05$ - NS=

Non-significant P <0.05.- HS= Highly significant at P ≤ 0.001

Assessment of NAS score during splint was used after washout period (secondly used splint)

Both splint types showed highly significant improvements in NAS scores after 3 months (Conventional: 5±0.89 to 1.67±0.82; Digital: 3.67±0.52 to 1.17±0.98). both splint types demonstrated highly significant improvements in NAS scores after 3 months (increased patient's satisfaction) ($p<0.001$), (table 8).

At baseline, NAS scores were significantly decreasing in the digital splint group (more satisfaction) compared to the conventional splint group ($p<0.05$). While this pattern persisted after 3 months with conventional splints maintaining higher mean scores, the difference between splint types at follow-up was no longer statistically significant ($p>0.05$), (table 8).

Table 8. Mean ±SD, comparison of NAS scale for different groups at the two-time intervals when the splints were used secondly after the washout period.

	At baseline	After 3 months	P-value*
Conventional	5±0.89	1.67±0.82	< 0.001HS
Digital	3.67±0.52	1.17±0.98	< 0.001HS
P-value**	0.003S	0.419NS	

Assessment of NAS score regardless of washout period (Overall results)

Regarding conventional Splint, the mean NAS score was decreased from (4.83±1.40) to (2.58±1.8) after 3 months (more satisfaction), While digital Splint, the mean condylar position was decreased from (5.42±1.08) at baseline, to (2.21±0.96) after 3 months. The differences were statistically highly significant in both splint types, (table 9).

NAS score comparisons showed directional differences with no statistical significance: Digital splint patients demonstrated moderately higher at baseline scores (4.83±1.40 vs 5.42±1.08), while conventional splint patients showed slightly superior after 3 months scores (2.58±1.8 vs 2.21±0.96). The difference between the two groups at both time intervals was not significant, (table 9)

Table 9. Mean ±SD, comparison of Overall NAS scale for different groups at the two-time intervals.

	At baseline	After 3 months	P-value*
Conventional	4.83±1.40	2.58±1.8	< 0.001HS
Digital	5.42±1.08	2.21±0.96	< 0.001HS
P-value**	0.291NS	0.513NS	

4. DISCUSSION

In this research, we aimed to compare the effects of 3D printed occlusal splints to those of traditionally made splints in terms of patient satisfaction, condylar position as measured by CBCT, and overall treatment outcomes for female patients with TMDs.

Symptoms of temporomandibular disorders (TMDs) include noises made by the temporomandibular joints (TMJ) or the jaw muscles, discomfort felt in the jaw muscles or the TMJ, and changes in the way the mouth opens, such as narrowing, widening, or deflecting [20].

The present study compared the effects of conventionally fabricated heat-cured PMMA splints and digitally manufactured 3D printed stabilization splints on condylar position and patient satisfaction in female patients diagnosed with TMD. The methodological framework used in this investigation played a central role in ensuring the precision, reproducibility, and clinical validity of the findings [21].

In designing the study, patient selection adhered strictly to clearly defined inclusion and exclusion criteria for ensuring a diagnostically homogeneous sample. Restricting the selected participants to cooperative females aged 20–50 was essential for controlling biological variability, as hormonal fluctuations during reproductive years have been widely reported to influence pain perception and TMJ biomechanics. This justification is supported by established evidence demonstrating the increased prevalence and symptom intensity of TMD in women within this age range [22].

Limiting the sample to patients without systemic joint-affecting diseases further minimized confounding factors that could influence TMJ positional changes. Within this controlled population, the use of maxillary full-coverage stabilization splints was methodologically justified, as full-arch appliances consistently demonstrate superior neuromuscular stabilization and load redistribution compared with partial-coverage designs, which carry documented risks of posterior extrusion and occlusal alteration if used long term [23,24].

The contrasting fabrication workflows represented a key methodological strength. The conventional pathway involved conventional acrylic processing. Conversely, the digital workflow comprising indirect scanning of casts, CAD-based design, and DLP printing eliminated many of these operator-dependent errors [25].

Indirect scanning was intentionally selected over intraoral scanning to avoid common clinical challenges such as saliva contamination, limited posterior access, and patient movement. Previous investigations have confirmed that cast scanning yields greater trueness and precision in full-arch models, thereby enhancing the fit and predictability of the digitally fabricated splints.

Furthermore, integrating CBCT with ultrasound imaging provided a multimodal diagnostic approach consistent with current TMJ assessment recommendations, with CBCT offering high-resolution evaluation of condylar morphology while ultrasound supplied complementary soft-tissue insights [26].

CBCT analysis revealed that both splint types produced changes in condylar position; however, only the 3D printed splint demonstrated statistically significant reductions, particularly on the left side and bilaterally after three months. This finding aligns with cumulative evidence that digitally fabricated appliances provide more accurate and uniform occlusal contacts, thereby modulating joint loading more effectively [27].

The enhanced precision of CAD/CAM splint design minimizes discrepancies between the virtual and delivered appliances, allowing more predictable mandibular repositioning. Interestingly, the persistence of higher mean positional values on the right condyle, though often non-significant, is consistent with literature indicating that functional dominance and habitual chewing patterns may influence side-specific adaptation. Such asymmetry reinforces the need for individualized splint therapy informed by functional analysis rather than assuming bilateral symmetry of response [28].

Parallel to the radiographic findings, patient satisfaction measured via the Numerical Analogue Scale demonstrated significant clinical improvement across both groups. Nonetheless, patients using the 3D printed splints consistently exhibited lower post-treatment NAS scores indicating greater symptom relief during the initial phase. This difference gradually diminished over time but remained clinically notable [29].

The CBCT findings showed a general reduction in the mean condylar position after three months in both splint types. This reduction was not statistically significant in the conventional splint group, suggesting minimal positional changes over the follow-up period. In contrast, the digital splint demonstrated significant reduction on both sides, indicating a measurable improvement in condylar positioning with continuing use. This finding reflected a more pronounced effect of the digital splint. [23]

The superiority of digital splints in early symptom reduction may be attributed to their enhanced fit, smoother surfaces, and minimized need for chairside adjustment. These characteristics collectively support improved comfort, greater compliance, and more stable intraoral retention. Previous studies consistently highlight that the precision inherent to digital workflows translates into reduced occlusal interferences and more efficient neuromuscular deprogramming, all of which contribute to improved patient satisfaction. [30]

Both groups showed observable reduction in NAS scores at the baseline scores which indicates an early clinical improvement upon using the first splint before washout period. After 3 months, the improvement became highly significant in both groups, reflecting a decrease of symptoms over time. These findings maybe because of using of either splint type leads to a meaningful and statistically significant reduction in patient discomfort, with the digital splint maintaining a more favorable trend throughout the follow-up period. [1]

Although the clinical advantages of digital splints are increasingly evident, the higher fabrication cost remains a practical consideration. However, as digital technologies continue to evolve and become more widely available, economic limitations may diminish, further supporting the integration of digital splints into routine TMD management. [31]

The clinical findings demonstrate that 3D printed splints offer measurable advantages in precision, patient comfort, and condylar position, while conventional PMMA splints remain reliable stabilizing devices. These insights contribute meaningfully to the growing evidence supporting the transition toward digital workflows in contemporary TMD therapy. [32]

CONCLUSION

According to the results of the study, the 3D printed occlusal splint demonstrated notable clinical effectiveness in the management of TMD as evidenced by improvement of condylar position and marked increase in patient satisfaction.

LIMITATION

Further longitudinal studies with larger sample sizes, inclusion of male patients, and evaluation of muscle activity with electromyography are recommended to confirm these findings and establish reliable clinical guidelines for integrating 3D printing technologies in TMD management.

DECLARATION

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No other sources of funding were used for this study.

Conflict of interest

No conflict of interest exists, according to the authors.

Competeting interest

No conflict of interest has been disclosed by the writers. The study's procedure was approved by the Research Ethics Committee at Al-Azhar University's Faculty of Dental Medicine for Girls in Cairo, Egypt. In order to get informed permission, we had a thorough discussion with the patient about the treatments, their advantages, and any potential risks.

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