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"JÚLIO DE MESQUITA FILHO"
Instituto de Ciência e Tecnologia
Campus de São José dos Campos

ORIGINAL ARTICLE

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Relief of signs and symptoms in patients with tempromandibular disorders using occlusal stabilization splints equilibrated by T-scan versus articulating foil: a randomized clinical trial

Alívio dos sinais e sintomas em pacientes com disfunção temporomandibular utilizando placas oclusais estabilizadoras ajustadas com T-scan versus papel carbono: um ensaio clínico randomizado

Sara Eman Abdelsalam[1], **Ashraf Emil ESKANDAR**[1], **Ramy Maher GHALY**[2], **Mohamed Amr Mohamed EL KHASHAB**[1]

1 - Cairo University, Faculty of Dentistry. Cairo, Egypt.
2 - Ain Shams University, Faculty of Dentistry. Cairo, Egypt.

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ABSTRACT

Objective: To evaluate the relief of signs and symptoms of temporomandibular disorders (TMDs) after splint equilibration via two methods: articulating foil and T-scan. **Material and Methods:** Twenty-eight patients with myofascial TMD were selected and divided into two groups. Each group were treated with additive CAD/CAM stabilization splints equilibrated using either articulating foil or T-scan. Pain reduction percentage, improvement in jaw function and pain free range of movements were assessed after 1 and 3 months. The data were analyzed by the repeated measures one-way ANOVA test followed by the Tukey's post hoc test and the independent t- test. **Results:** There was a significant reduction in pain improvement in jaw function and pain free maximum opening within each group, without statistically significant differences ($p>0.05$) between both groups after 1 and 3 months. **Conclusion:** T-scan and articulating foil are both effective in stabilization splint equilibration.

KEYWORDS

Articulating foil; Occlusal splint; Pain; TMD; T-scan.

RESUMO

Objetivo: Avaliar o alívio dos sinais e sintomas das disfunções temporomandibulares (DTMs) após o ajuste de placas por dois métodos: papel carbono e T-scan. **Material e Métodos:** Vinte e oito pacientes com DTM miofascial foram selecionados e divididos em dois grupos. Cada grupo foi tratado com placas estabilizadoras CAD/CAM do tipo aditiva, ajustadas com papel carbono ou T-scan. A porcentagem de redução da dor, a melhora da função mandibular e a amplitude de movimentos sem dor foram avaliadas após 1 e 3 meses. Os dados foram analisados por meio do teste ANOVA de uma via para medidas repetidas, seguido do teste post hoc de Tukey e do teste t independente. **Resultados:** Houve redução significativa da dor, melhora da função mandibular e da abertura máxima sem dor dentro de cada grupo, sem diferenças estatisticamente significativas ($p > 0,05$) entre os grupos após 1 e 3 meses. **Conclusão:** O T-scan e o papel carbono são eficazes no ajuste de placas estabilizadoras.

PALAVRAS-CHAVE

Papel carbono; Placa oclusal; Dor; DTM; T-scan.

INTRODUCTION

Temporomandibular disorders (TMDs) are general terms that include various disorders that involve the temporomandibular joint, the masticatory muscles and associated structures. TMDs have become one of the most prevalent disorders that influence patient's quality-of-life and daily functional activities in current populations [1,2]. Patients experiencing TMD typically present with a range of symptoms, including pain during opening and closing, crepitus, limited mouth opening and morning stagnation [3].

Controversial opinions have dominated the literature concerning the etiology, diagnosis, and treatment of TMD. Given the challenge of pinpointing a single primary cause for these symptoms, the etiology of this disorder is considered multifactorial. However, the relationship between dental occlusion and TMD remains a topic of debate among researchers [4].

The effectiveness of pain reduction through splint therapy is well-documented in the literature. Numerous studies have reported the resolution of symptoms following the insertion of occlusal splints (OS) [5-7]. The stabilization splint, with its characteristic occlusion scheme, is among the most commonly used occlusal splints for managing symptoms of TMD [8]. To attain the desired occlusal scheme objectives, the occlusal splint should be adjusted using occlusal detection methods.

Various occlusal indicators, including Mylar paper strips, polyether rubber impression bites, wax, articulation foil, occlusal sprays, foils, occlusal sonography, and T-Scan are employed in clinical practice [9]. Among these, articulating foil is the most commonly used indicator in dental practice. Previous studies were mainly concerned with analyzing its physical properties, such as thickness, composition, ink and substrate, as well as plastic deformation. However, clinical studies analyzing the size and characteristics of the foil marks have shown no correlation between the size of articulating foil markings and the applied occlusal force [10].

On the other hand, the T-Scan occlusal analysis system is a Microsoft system that has dominated researches once it evolved. It is capable of recording occlusal contacts within 0.01-s increments. The T-Scan system is composed of a recording handle which houses an autoclavable sensor support and a disposable Mylar-encased 100 μm sensor that registers occlusal contact at 5-10 μm. It is regarded as the most accurate occlusal detection method regarding quantity and timing of occlusal contacts in the literature which remain unaffected by changing the sensor or repeating the measurements, as well as the presence of saliva [11-13].

Although marked occlusal load imbalance was found in conventionally adjusted stabilization splints when tested with the T-Scan, no therapeutic effects of the conventionally adjusted and T-Scan adjusted splints were studied in spite of its importance for clarifying the effectiveness of a well-balanced stabilization splint in symptom resolutions [14].

Therefore, the objective of the present study was to evaluate the relief of signs and symptoms of TMD after using occlusal stabilization splints equilibrated using T-scan versus articulating foil. Despite the documented accuracy of the T-scan in comparison to articulating foil, it is hypothesized that there will be no difference between them regarding the relief of TMD signs and symptoms.

MATERIAL AND METHODS

A randomized clinical trial with a preoperatively defined treatment protocol was conducted on twenty-eight patients with TMDs. The research proposal was reviewed and approved by the research ethics committee and the study protocol was registered on ClinicalTrials.gov (NCT04661670).

Sample size calculation was performed by comparing the reduction in pain score that denotes relief of symptoms and signs in TMD patients. As reported in a previous publication [15], the mean ± SD pain score reduction in the conventional group was approximately 91.9 ± 21%, and it was assumed that the new intervention would achieve at least 25% improvement in pain reduction [14]. Accordingly, we calculated that the minimum proper sample size was 14 patients in each group to be able to reject the null hypothesis with 80% power at $\alpha = 0.05$ level using the Student's t- test for independent samples. Sample size calculations were performed using PS Power and Sample Size Calculations software, version 3.0.11 for MS Windows (William D. DuPont and Walton D., Vanderbilt University, Nashville, Tennessee, USA).

The patient selection process adhered to predetermined inclusion and exclusion criteria. All enrolled patients met the following criteria: fully or partially dentate male and female compliant adult patients with no more than one missing tooth per quadrant (excluding third molars) and who experienced signs and symptoms of TMD (diffuse pain in the head and neck, headache, pain exaggeration by jaw movements and restricted jaw movements), which was confirmed using the diagnostic criteria for temporomandibular disorders (DC/TMD) Axis I. Patients who were diagnosed with other TMD disorders such as degenerative diseases were excluded from the study. All participants were informed of the nature of the research study and were allowed to sign an informed consent form.

The base line pain scale score and range of pain free jaw movements (mm) were recorded before starting the treatment. Patients were randomly divided into two parallel groups at a 1:1 ratio after diagnosis. Each group was composed of 14 patients; Group A received occlusal stabilization splints equilibrated using articulating foil, while Group B received occlusal stabilization splints equilibrated using T-scan (Figure 1).

Two computer-generated column tables of random numbers were established using www.random.org to produce the random allocation sequence of the participants. Every participant grasped an opaque sealed envelope from a box. Being sealed and opaque ensured allocation concealment. Blinding of the patients and the care provider regarding the interventions was not feasible; however, the outcome assessor and statistician were blinded.

Primary impressions were made using irreversible hydrocolloid impression material (Zhermac Hydrogum 5), and the obtained study casts were used for the mounting procedures and final occlusal adjustments of the occlusal splints. A maxillary face-bow transfer was mounted on a semi-adjustable articulator (A7-Plus Bio Art semi-adjustable articulator), followed by a jaw relation record using Futar D, Ultra Rigid, Kettenbach LP in the centric relation after deprogramming the muscles using leaf gauges. A protrusive record was made at 6 mm mandibular protrusion to set the horizontal condylar guidance, while the lateral condylar guidance was adjusted at a fixed value of 15 degrees. The centric relation record was verified by comparing the first point of contact intraorally and the first point of contact on the articulator after mounting.

The mounted casts were scanned using an extraoral scanner (DOF Freedom UHD Desktop) to produce virtual 3D models on which occlusal splints were designed. Occlusal appliances were fabricated on mandibular arches for all patients with the aid of a specialized computer aided designing software (Exocad-Dental CAD software). Firstly, virtual surveying was carried out to detect the teeth height of contour. The extension of the occlusal splint was determined at a slightly occlusal level to the height of the contour buccally while 1-2 mm beyond the gingival margin lingually. A complete arch coverage design was performed and shaped to be flat occlusally. Aided by the virtual articular which was adjusted based on the previously adjusted angles and color-coding feature in the software, balanced anterior and posterior bilateral contacts with posterior disocclusion on excursive movements was achieved (Figure 2).

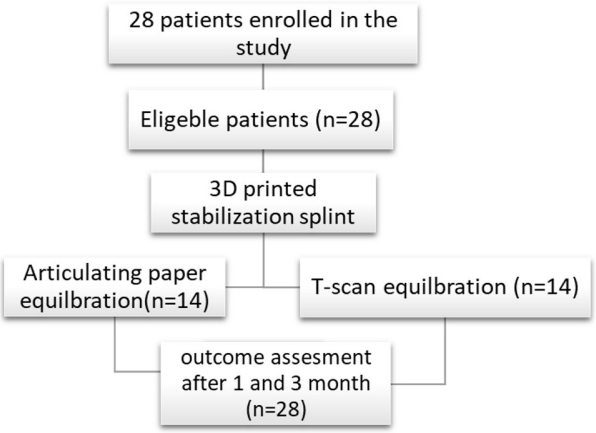

Figure 1 - Patients enrollment and distribution.

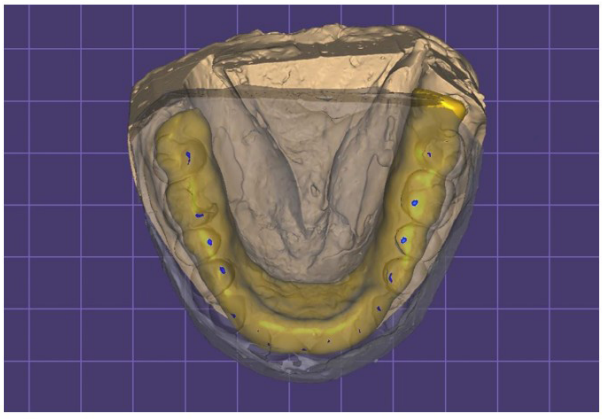

Figure 2 - Stabilization splint design.

The STL files of the finished CAD splints were subsequently transferred to a 3D slicing software (Chitubox 1.9.3) to produce twenty-eight occlusal splints using an occlusal splint resin material (Harz Labs Dental Splint, Russia) and a DLP, LCD printer (AnyCubic Photon s, ANYCUBIC, China). The files were sliced at a zero-degree print orientation with a 0.05 mm layer height, bottom layer count of 8, 1.7s exposure time, 1.7 mm/s lift speed, and a 1s wait before printing .

After completion of the printing procedure, all the splints were cleaned for 3 minutes in 96% reusable ethanol solution followed by an additional 2 minutes in 96% fresh ethanol solution. The cleaned splints were then sprayed with ethanol and scrubbed with a brush soaked in ethanol to rinse off any remaining residual resin. The study samples were then prepared for post curing by removing the support structures using a side cutter. The splints were checked for fit and then subjected to a post-curing process of 80 °C in an oven for 30 minutes followed by 3-5 minutes of 405 nm UV light in a light curing box (AnyCubic Wash& Cure 2.0 Curing Box, ANYCUBIC, China) (Figure 3).

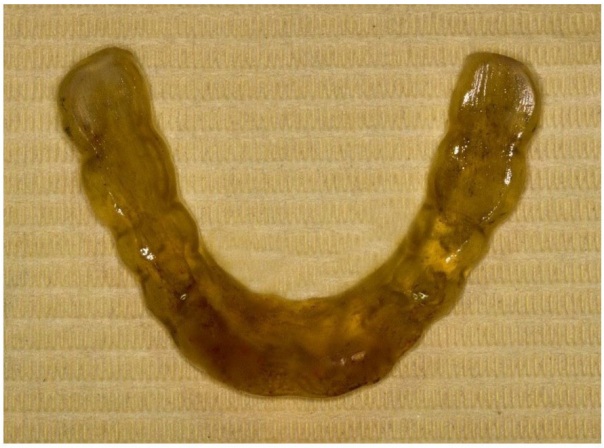

Figure 3 - 3D printed stabilization splint.

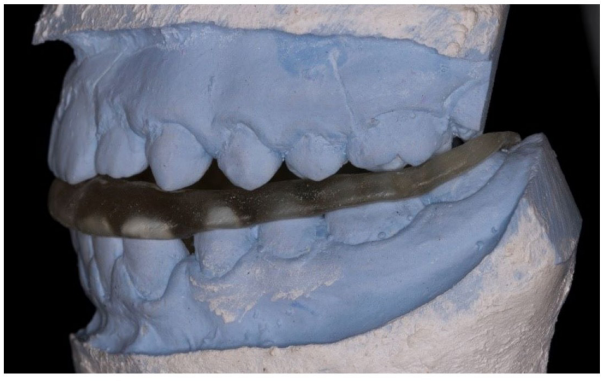

Figure 4 - Stabilization splint adjusted on the articulator.

Occlusal refinement of the constructed splints was carried out on the previously mounted articulator using 20 μm thick articulating foil (AccuFilm, Parkell, USA) (Figure 4). At the next clinical visit, all splints were inserted and checked for stability and comfort before initiating the intraoral occlusal adjustment.

For Group A; the final occlusal correction was performed while the patient was in the supine position using 20 μm thickness articulating foil and 8 μm thickness shim stock (DENU Shim Stock, HDI Inc.) The patient was asked to tap 3 times on the articulating foil and occlusal correction was performed using a carbide laboratory bur and rubber cone until a uniform contact on all teeth was achieved in centric relation. This was illustrated on the splint by a series of uniformly appearing articulating foil marks. The patient was subsequently asked to perform protrusive, right and left excursions to ensure smooth anterior guidance and posterior disocclusion (Figure 5).

For Group B; occlusal equilibration was performed using the T-Scan III (software version 8.0) computerized occlusal analysis; where the same adjustment sequence was used as in Group A. The T- Scan dental arch size was adjusted to fit the patient's arch by measuring the width of the central incisor using a periodontal probe. A centric occlusion scan in turbo mode (0.003 second incremental scanning) was selected. The sensor was placed intraorally so that the midline 'V' of its support contacts the midline of the central incisors, followed by a

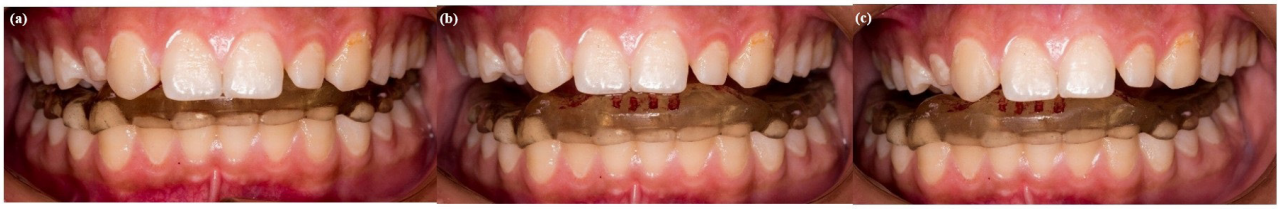

Figure 5 - (a) Centric relation contact; (b) Protrusive movement contact; (c) Lateral excursive contact.

conditioning process in which the patient was allowed to strongly bite on the sensor 2-3 times. At this point it is important to calibrate the sensitivity level in the software to fit the patient's biting force. The patient was asked to gently occlude on the posterior teeth, then clench firmly for one to three seconds. This procedure was repeated until 1-3 pink spots were evident on the T scan graph. Skipping this procedure will result in a hyper or hypo responsive sensor. The splint was then inserted intraorally and the patient was asked to clench to record the occlusal force. Guided by the articulating foil marks, areas requiring adjustments were ground using a carbide laboratory bur until the occlusal force distribution was bilaterally balanced on the software and the center of force (COF) icon sits close to the midline (Figure 6).

Mandibular excursions were then adjusted in a similar maneuver. The appropriate excursion scan label was chosen, after which the patient was asked to clench on their posterior teeth for one to three seconds, and then move in a lateral or protrusive excursion to the full extent of the border movement. Contacts other than the anterior and canine guidance were eliminated until achieving anterior guidance and posterior disocclusion in a time less than 0.5 seconds (Figures 7 to 9).

Finally, all patients in both groups were allowed to occlude comfortably in an upright position to ensure that all teeth were in contact evenly, with no anterior teeth contacting harder than the posterior ones. No finishing or polishing was performed following the final occlusal adjustments to maintain the achieved refined occlusal contacts.

All patients were instructed to wear the occlusal splints during sleep and were initially scheduled for weekly occlusal refinement appointments until no longer needed. The patients were then recalled after 1 (T1) and 3

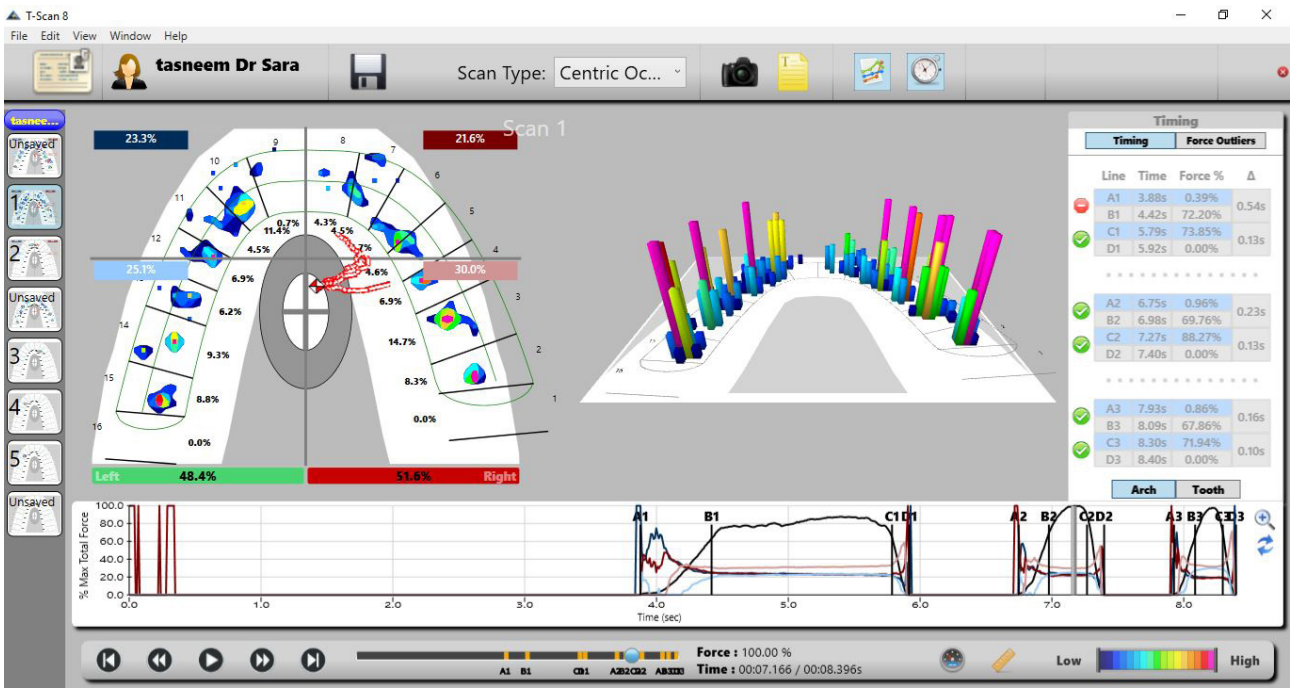

Figure 6 - Centric relation T-scan record.

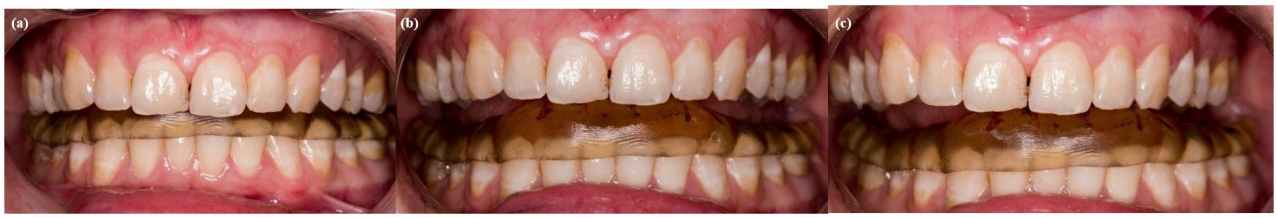

Figure 7 - (a) Centric relation contact; (b) Protrusive movement contact; (c) Lateral excursive contact.

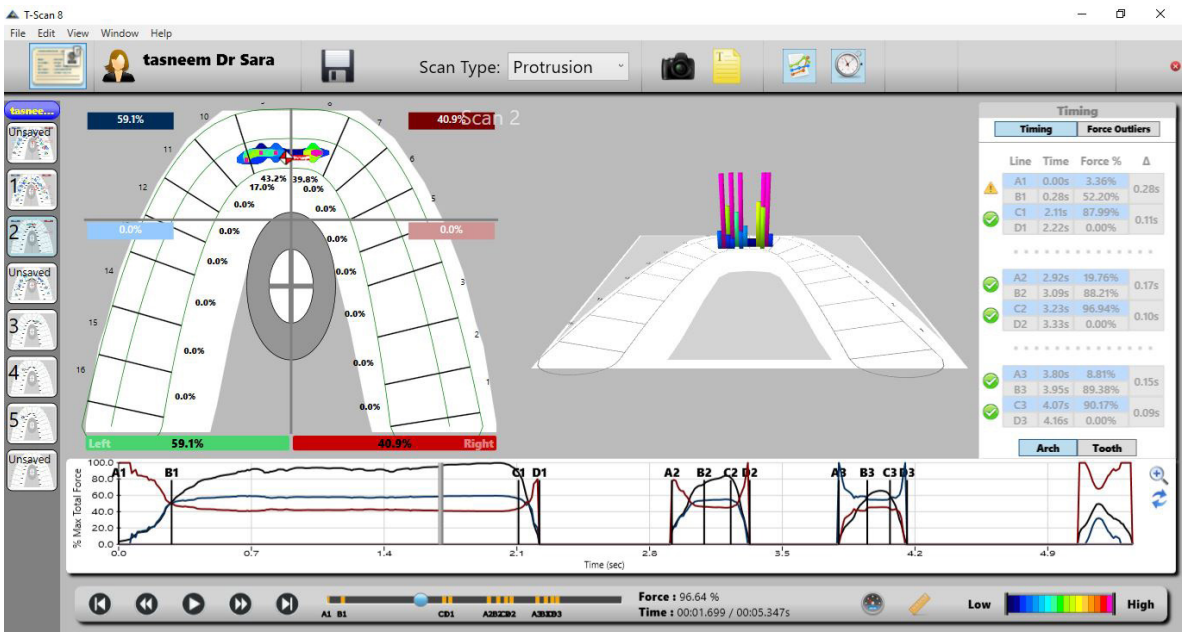

Figure 8 - Protrusive movement T-scan record.

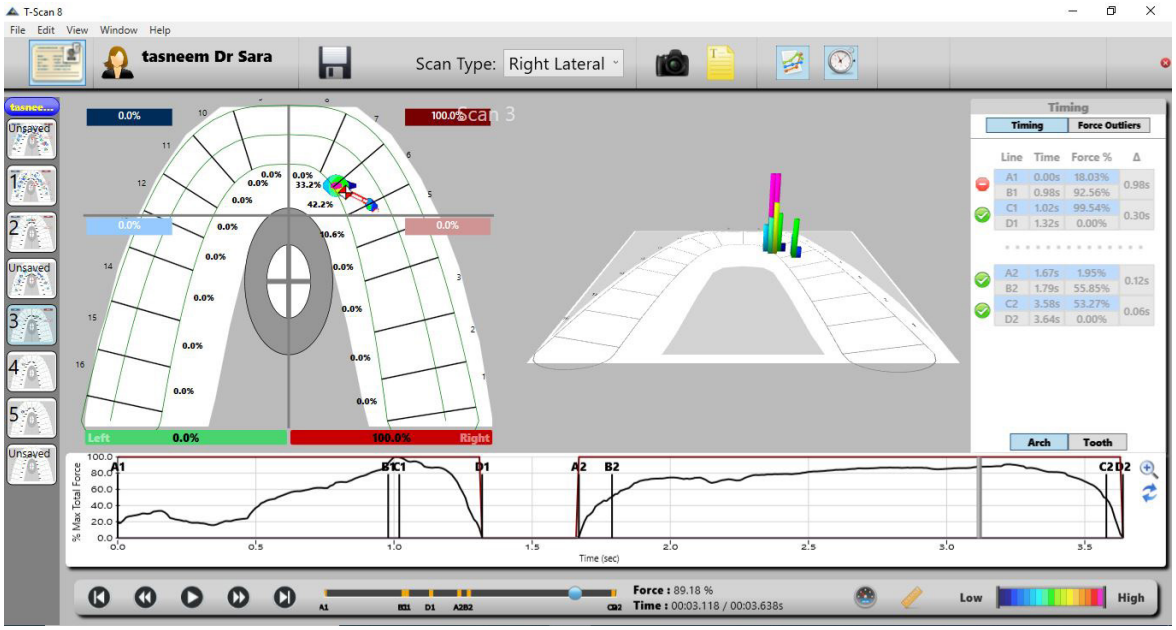

Figure 9 - Lateral excursive T-scan record.

months (T2) to evaluate the change in TMD pain symptoms using questionnaires, in addition to the change in range of pain free jaw movements using a ruler (Figure 10). Both questionnaires: The Graded Chronic Pain Scale and Jaw Functional Limitation Scale questionnaire were used in the participant's native language version provided by the International Network of Orofacial Pain and Related Disorders methodology website [16].

Statistical methods: Data was analyzed using the IBM SPSS advanced statistics (Statistical Package for Social Science), version 20 software (SPSS Inc., Chicago, IL, USA). Numerical data was described as mean and standard deviation or median and range. Data was explored for normality using the Shapiro Wilk and Kolmogorov Normality tests. For the parametric data, the independent t- test was used for comparison between both groups. Repeated Measures One-Way ANOVA followed by the Tukey's Post Hoc test was used for comparison between different intervals. A p-value less than or equal to 0.05 was considered statistically significant. All tests were two tailed.

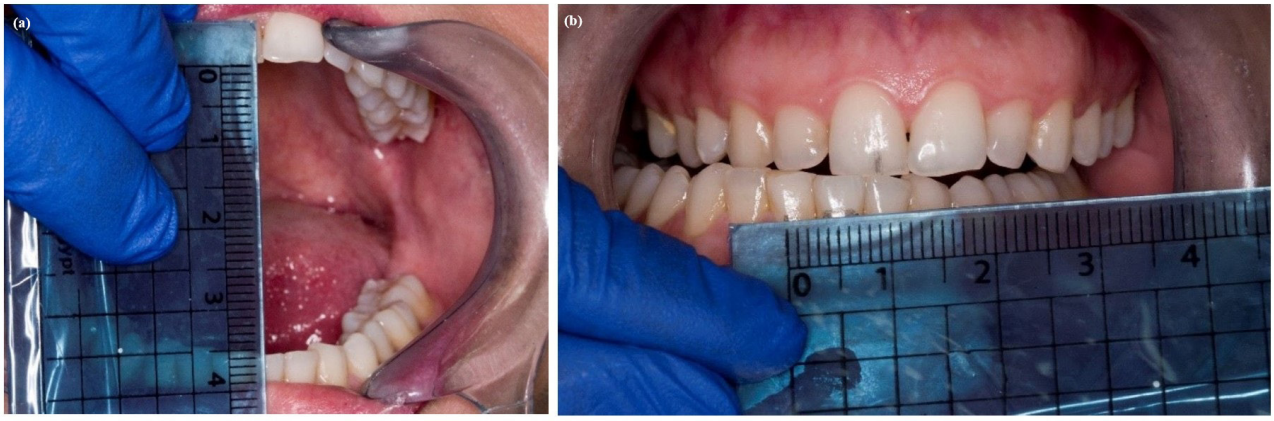

Figure 10 - Range of movement assessment: (a) Maximum pain free opening; (b) Lateral excursive movement measurement.

RESULTS

The normality test revealed that the significance level (P-value) was insignificant at P-value > 0.05, which indicated that the data originated from a normal distribution (parametric data) resembling a normal bell curve in both groups for all parameters. The baseline characteristics of both groups are shown in Table I.

Pain intensity and percentage of pain intensity reduction: For both groups, there was a statistically significant difference between the different intervals (P<0.05). The percentage of pain intensity reduction was calculated and revealed to be 28% and 39% in the articulating foil group and T-scan group, respectively. In the T-scan group, pain intensity was significantly greater at baseline and significantly lower, while T2 revealed an insignificant difference from the other intervals. On the other hand, in the articulating foil group, the pain intensity at baseline and T1 was significantly greater than that at T2 (P>0.05), while at T2, it was significantly lower. A comparison between the two groups in Table II at different intervals revealed a statistically insignificant difference between them regarding baseline, T1 and T2.

Jaw Functional Limitation scale (JFL)

For the T-scan group, there was a statistically significant difference between the different intervals (P<0.05). The JFL score at baseline was significantly the highest, while at T1, it was significantly the lowest, and at T2, revealed a statistically insignificant difference with the other intervals. For the articulating foil group, there was an insignificant difference between different intervals as P>0.05. A comparison of the two groups in Table III revealed a statistically insignificant difference between them regarding baseline, T1 and T2.

Table I - Baseline characteristics

Characteristics		T-scan equilibration group	Conventional equilibration group
Age		18-35 years old	17-40 years old
Gender	Males	0	2
	Females	14	12
Medical history	Colitis	2	4
	Sinusitis	6	3
	Sleep problems	4	6
	Neck and back pain	2	1
	Stress	6	7

Range of pain free jaw movements: For both groups, there was a statistically insignificant difference between different intervals regarding protrusion, right and left excursion. Regarding pain free maximum opening, in the T-scan group, there was a significant difference between baseline and T1 (P=0.01) and an insignificant difference between T1 and T2. In the articulating foil group, there was a significant difference between baseline and T2 (P=0.007), while T1 revealed insignificant differences with the other intervals. A comparison of the data between the two groups at different intervals in Table IV revealed that the differences were not statistically significant (P >0.05), and revealed statistically insignificant differences at all intervals of opening, protrusion, right or left excursion.

In Table V, a summary with a P value difference between baseline, T1 and T2 with each group for each outcome.

Table II - Pain intensity score at different intervals between both groups and percentage of pain intensity reduction

		Study group (T-scan group)		Control group (Articulating foil group)		P value
		Mean	Standard Deviation	Mean	Standard Deviation	
Pain intensity score	Baseline	63.00	23.92	53.00	21.66	0.23
	T1= 1M	50.57	24.91	47.86	28.66	0.78
	T2=3M	52.29	23.89	43.57	24.85	0.33
Percentage of pain intensity reduction		39	44	28	33	

Table III - Jaw Function Limitation Scale at different intervals between both groups

Jaw Function Limitation Scale	Study group (T-scan)		Control group (Articulating foil)		P value
	Mean	Standard Deviation	Mean	Standard Deviation	
Baseline	32.86	19.00	28.14	22.09	0.53
T1= 1M	18.71	13.44	23.29	16.77	0.41
T2=3M	21.29	12.24	22.86	16.58	0.76

Table IV - Pain free jaw movements (in mm) at different intervals between both groups

Pain free jaw movements		Study group (T-scan)		Control group (Articulating foil)		P value
		Mean	Standard Deviation	Mean	Standard Deviation	
Opening	Baseline	35.71	2.70	34.71	9.01	.580
	T1= 1M	40.00	7.17	36.43	8.50	.240
	T2=3M	39.86	6.29	37.71	8.50	.455
Protrusion	Baseline	6.86	.66	6.29	1.54	.214
	T1= 1M	7.29	.99	6.29	1.54	0.051
	T2=3M	7.29	1.20	6.71	1.82	.335
Right excursion	Baseline	7.43	2.59	8.57	2.06	.208
	T1= 1M	8.00	2.22	7.57	2.34	.623
	T2=3M	7.86	2.25	7.86	1.79	1.000
Left excursion	Baseline	8.43	2.21	7.86	2.80	.554
	T1= 1M	8.14	1.79	7.43	2.53	.397
	T2=3M	8.43	1.91	7.86	1.88	.432

Table V - P value difference between baseline, T1 and T2 within each group

Control group (Articulating foil)	Study group (T-scan)	Outcome	
0.008*	0.02*	Pain intensity score	
0.1	0.008*	Jaw Functional Limitation Scale	
0.007*	0.01*	Pain free opening	Pain free jaw movements in (mm)
0.23	0.34	Protrusion	
0.14	0.06	Right excursion	
0.31	0.27	Left excursion	

* p<0.05 statistically significant

DISCUSSION

The present study was designed to compare two methods of stabilization splint equilibration techniques which were the use of articulating foil or shim stock versus T-scan regarding pain intensity reduction, jaw function limitation and range of pain free mandibular movements. Based on the results of the present study, there was a significant reduction in pain and improvement in jaw function and pain free maximum opening within each group, without statistically significant differences ($p>0.05$) between the two groups after 1 and 3 months. Maxillary and mandibular occlusal splints have been shown to be equally effective at relieving temporomandibular disorder (TMD) signs and symptoms [8,17,18]. However, in the current study, the selection of the mandibular occlusal splint design was based on the authors' perspective of it being more esthetically acceptable with less speech disturbance, thus potentially increasing patient compliance. The included patients were from both sexes, but the majority were females due to the greater sex predilection nature of TMD. Only disorders of myofascial origin were included in the present study to avoid the confounding effect of different diagnoses and variable stages of derangement on the study outcomes.

The effectiveness of stabilization splints in reducing pain and improving jaw function depends on various factors, including the persistence of multi-systemic etiologies, the diagnostic origin of TMD, patient compliance with wearing the appliance, and the method of appliance fabrication. The beneficial effect of using a stabilization splint in TMD management has been justified by many theories ranging from occlusal disengagement, raising of vertical dimension, improving the condyle-fossa relation, improving cognitive awareness of harmful behavior up to reducing the load on masticatory components or exerting placebo effects [19].

In an attempt to eliminate the covariant factors in the present study, patient selection criteria, splint design, duration of wearing the appliance and fabrication method were standardized and controlled among both groups. Additionally, patients were ensured not to use any complementary pain-relieving factors such as medications or physiotherapy throughout the study timeline.

For both groups, occlusal equilibration of the stabilization splint was performed until bilateral simultaneous contact was established on all teeth in the centric relation position, anterior guidance in protrusive movements and canine guidance on lateral excursive movements with complete posterior teeth disocclusion. In the T-scan group, the disocclusion time reduction of all molars and premolars was adjusted to be < 0.5 seconds per lateral excursion. This approach was proven to reduce muscle hyperactivity levels and their related myogenous symptoms as indicated by Poovani and Thumati [20]

Pain reduction and jaw function limitation were subjectively measured using validated questionnaires, while the pain-free range of mandibular movements was objectively evaluated by a blinded assessor. The assessor took an average of three measurements for each pain-free opening, protrusion, left and right lateral excursions at each time interval. This combination of subjective and objective outcomes was intended to ensure that the patient's responses were not biased by the effect of using a digital device in the test group.

Most treatment outcome studies conducted on temporomandibular disorders (TMDs) have been based on comparison of the mean values of different treatment groups. However, it would be more beneficial for clinicians to relate these mean values to the smallest detectable difference of an outcome variable. This approach provides insight into the level of improvement required for a treatment approach to be considered therapeutically successful or preferred over another treatment approach. In the literature, the reported smallest detectable difference in actual pain intensity on a 0-100 visual analog scale is 25 [21]. Accordingly, by comparing the mean pain intensity reduction percentage in the T-scan group and articulating foil group (39 and 28, respectively), with the reported smallest detectable difference in pain intensity, it can be concluded that both equilibration techniques are considered equally successful in treating TMD patients with stabilization splints.

Pain is reflected in jaw function and range of pain free movements. The results of the present study showed that pain reduction, improvement in jaw function and maximum pain free opening were more pronounced at T1 (after 1 month) than at T2 (after 3 months) in the T-scan group,

revealing a statistically significant difference between baseline and 1 month while there was no significant difference between 1 and 3 months. Conversely, in the articulating foil group, the maximum improvement in outcomes occurred at T2, and there was no significant difference between baseline and 1 month.

These findings could be attributed to the accurate equilibration obtained by the T-scan as indicated by Kerstein et al. [14], thus resulting in accelerated improvement occurring at 1 month compared to that in the other group, which showed significant improvement after 3 months. The insignificant difference between the two groups after 3 months was possibly due to the effect of clenching and progressive splint wear. This finding suggests that any initially unapparent premature contact present in the articulating foil group may have self-corrected over time due to the aging of the splint.

Despite maintaining the occlusal contacts in the T-scan group, a rebound in pain intensity was evident after 3 months. Although being statistically insignificant, this finding is noteworthy as it supports the notion that TMD is a multifactorial condition and other contributing factors such as stress or sleep problems may lead to increase in pain levels again. This improvement fluctuation within a short period of time is reported in the literature to be associated with high impact more than low impact TMD cases [22].

One of the mechanisms of action of stabilization splints is minimizing muscle hyperactivity and promoting muscle relaxation which alleviate pain, improve jaw function and increase pain free movements. The lateral pterygoid muscle, being a depressor muscle, is often the most hyperactive muscle in patients with TMD [23]. This phenomenon could potentially explain the significant improvement in pain-free jaw opening observed in the current study in comparison to the protrusive and lateral excursion movements which didn't show any significant improvement.

Various studies have sought to provide scientific evidence on the effect of wearing stabilization splints on brain cerebral activity using functional MRI to correlate with the improvement in signs and symptoms. According to Lotz et al. [24], a well-adjusted Michigan splint reduced the activation in primary sensorimotor areas, which was associated with a decrease in electromyographic activity in the masticatory muscles. On the other hand, Otsuka et al. [25], reported that a malfunctioning splint leads to additional activation in the anterior cingulate cortex and the amygdala which was positively associated with scores of discomfort. Additionally, splint therapy was found to decrease the activation in the anterior insula cortex; an area that is highly involved in autonomic reactions, affective motivational functions, and the association of emotions with former painful experiences [26].

It is worth mentioning that the reliability of functional MRI studies is questionable, as they are subject to an uncontrollable margin of error due to factors such as thermal noise, system noise, physiological noise and non-task-related cognitive processes [27,28]. This suggests that stimulation of neural activity responsible for pain, attributed to other factors such as stress, can counteract the effect of stabilization splints on neural activity. This may explain the diversity of results observed in the present study over time.

The limitation of the present study is mainly represented in the limited number of participants who are characterized with variable muscle strength, pain threshold perception, stress levels and emotional status. All these factors possibly led to inconsistent pain level improvement and eventually were reflected on their jaw functions and range of movements. In considering the feasibility of incorporating the T-scan into daily clinical practice, it's important to note that despite its apparent accuracy in detecting occlusal discrepancies, patients from both groups exhibited similar outcomes after 3 months. Furthermore, the cost of the T-scan device should be taken into account, along with the fact that multiple sensors are typically required to complete the equilibration process for each patient.

CONCLUSION

Within the limitations of the present study, it can be concluded that both the T-scan and articulating foil are equally effective in stabilization splint equilibration, reducing pain intensity and improving the range of pain-free mouth opening in patients with temporomandibular disorders (TMDs).

Clinical implications

Both the T-scan and articulating foil are regarded as equally effective in guiding the

splint equilibration process. However, the cost and availability of articulating foil render this approach more convenient.

Author's Contributions

SEA: Funding Acquisition, Investigation, Methodology and Writing – Original Draft Preparation. AEE: Conceptualization, Data Curation and Supervision. RMG: Validation. MAMEK: Formal analysis and Writing – Review & Editing

Conflict of Interest

The authors have no conflicts of interest to declare.

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Regulatory Statement

The present study was conducted in accordance with all the provisions of the local human subject oversight committee guidelines and policies of Cairo University. The present study protocol was reviewed and approved by [The Research Ethics Committee, School of Dentistry, Cairo University], approval number (NCT04661670).

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Sara Eman Abdelsalam
(Corresponding address)
Cairo University, Faculty of Dentistry, Cairo, Egypt.
Email: sara.eman@dentistry.cu.edu.eg

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