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Temporomandibular disorders, occlusal splints, and treatment options: a survey-based investigation

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Abstract: Background: The term "temporomandibular disorders" (TMDs) refers to a group of painful conditions that affect both the hard and soft orofacial anatomical structures. The primary objectives of TMD treatment are to lessen pain and enhance mandibular movements, re-establishing proper functioning. One of the widely used treatment options for TMDs pathology is the occlusal splint. This non-invasive intraoral device, determines both the muscle relaxation and reversibly repositions the temporomandibular joint structures. The study aimed to compare the efficacy of different occlusal splint designs or materials in managing TMD symptoms. Methods: Twenty-six patients, nineteen of whom were female and seven of whom were male, ranging in age from twenty to seventy, met the criteria needed participate in this study. Two different questionnaires were formulated: a patient-focused and a clinician-focused questionnaire. The patient's data encompassed general health status and TMD signs and symptoms, whereas the clinician's questions addressed assessment and treatment alternatives, including the particularities of occlusal splint therapy. Results: The majority of the patients were diagnosed with disc displacement with reduction (61.5%), followed by myalgia (26.9%). The only form of treatment preferred by physicians was the Michigan occlusal splint, which was mainly used on the maxillary dental arch (84,6%). After the splint therapy was completed and the intended results were obtained, the treatment plan was finished using selective grinding, prosthetic dental restorations, orthodontic therapy, or a combination of these procedures. The patient was required to continue physical therapy (7,7%), wear a full-arch night guard (42.3%), and undergo rigorous periodic control sessions (34.6%) to maintain the final aesthetic and functional results. Conclusions: Occlusal splints are an efficient and reliable initial therapy preference for patients with temporomandibular disorders. In addition to improving symptoms in the temporomandibular joint, occlusal splints may determine mandibular repositioning, which also implies a variety of treatment approaches, ranging from the minimally invasive to the most complex, to achieve a functional occlusal status.

Keywords: occlusal splint, temporomandibular disorder, facial pain.

1. Introduction

Temporomandibular disorders (TMDs) represent a specific category of musculoskeletal and neuromuscular conditions that affect the hard and soft orofacial anatomical structures, such as masticatory muscles, temporomandibular joints (TMJs) and their adjacent tissues [1]. Acute or chronic pain represents an essential characteristic of this pathology, together with sounds or noises in the TMJs and the limitation of mandibular movements during different functions (chewing, speaking, laughing). Myalgia, arthralgia, internal derangements, and degenerative joint disease are the main TMD conditions [2]. Nevertheless, different painful pathologies, such as neck and shoulder pain or headaches, may be associated with TMDs, which affect the patient's quality of life and social interactions [3]. Although TMDs have multifactorial and complex etiology related to general health issues (hormonal, genetic, or psychologic), dental malocclusion is also considered one of the important risk factors [4].

The clinician must establish a correct diagnosis to develop an accurate and effective treatment plan. Nowadays, the Research Diagnostic Criteria for Temporomandibular Disorders (RDC/TMD) [5] represent the gold standard for evaluating a patient with TMDs. RDC/TMD criteria are used to diagnose the subtypes of painful TMDs. Clinicians may use different clinical approaches, such as non-invasive (occlusal splints, drugs, or physical therapy), minimally invasive (interarticular injections and arthrocentesis), or invasive (arthroplasty or TMJ replacement) [6].

Occlusal splint, a non-invasive intraoral device, is widely used for the conservative treatment of patients diagnosed with TMDs. It is a removable device, mostly applied on the occlusal surfaces of the teeth in one arch, upper or lower, which temporarily eliminates premature contacts and interferences, improving the function of the masticatory system. Occlusal splint improves ~~the~~ neuromuscular activity and determines muscle relaxation and mandibular repositioning [7,8]. Still, the occlusal splint is also used to reposition the temporomandibular joint structures in a reversibly manner, by allowing the condyles to sit correctly in the ideal orthopedically position in the glenoid fossa [9].

The aim of the study was to compare the efficacy of different occlusal splint designs in managing temporomandibular disorders (TMDs) symptoms.

2. Results

A total of twenty-six patients met the requirements to take part in this study, nineteen of whom (73.1%) were female and seven, (24.9%) were male. The participants' ages ranged uniformly from thirty to sixty years old; just seven (26.9%) patients were twenty to thirty, and four (15.4%) were beyond sixty years. Twelve of the participants (46%) reported having facial pain, mainly concentrated around the temporomandibular joint (7.7%) and in the cheeks and temples (11.5%). Most frequently, the patients reported the pain as being intermittent and recurrent (26.9%), occurring in the morning (11.5%) or evening (15.4%), but also during the day (7.7%). When asked to quantify the pain intensity by using a scale from zero (no pain) to ten (the highest intensity of the pain), the majority reported a pain intensity of three (11.5%) and four (11.5%). Associated with facial pain, most frequently, patients reported headaches, 7 (26.9%), and back pain, 8 (30.8%). Only 5 (19.2%) patients had limited mouth opening, while 18 (69.2%) reported noises in the temporomandibular joint (TMJ). Fourteen (53.8%) had sleep bruxism and ten patients (38.5%) reported that their teeth are clenched when they wake up in the morning. Yet, 53.8% of the patients showed tinnitus, and 42.3% reported occlusal discomfort. 19.2% were diagnosed with rheumatoid arthritis or joint inflammation.

In Tables 1 and 2 are represented the masticatory and cervical muscles, which were painful to extraoral and intraoral examination. When assessing the trajectory of the mouth opening, 38.5% of the patients had an "S" shape trajectory, 30.8% showed a unilateral deviation, and 19.2% showed a sinusoidal trajectory. The maximum mouth opening was

less than 40 mm for 15.3% of the participants, between 40 and 50 mm for 80.7% of the subjects, and above 50 mm for 3.8% of the patients. 73.1% of the patients had attrition, 3.8% abfractions, 11.5% abrasion, and 7.7% had fissures or fractures of the dental restorations.

Table 1. Muscle pain at extraoral palpation.

Muscle Type	Right Side			Left Side		
Extraoral Palpation	0 (n%)	1-5 (n%)	>5 (n%)	0 (n%)	1-5 (n%)	>5 (n%)
Temporalis - Anterior fascicle	65.4 %	19.2 %	15.4 %	69.2 %	19.3 %	11.5 %
Temporalis - Middle fascicle	92.3 %	7.7 %	0 %	92.3 %	7.7 %	0 %
Masseter - Superficial fascicle	61.5 %	30.9 %	7.6 %	65.4 %	30.8 %	3.8 %
Masseter - Deep fascicle	92.3 %	7.7 %	0 %	96.2 %	3.8 %	0 %
Medial Pterygoid	69.2 %	27 %	3.8 %	69.2 %	27 %	3.8 %
Sternocleidomastoid	96.2 %	3.8 %	0 %	96.2 %	3.8 %	0 %
Trapezus	92.3 %	0 %	7.7 %	92.3 %	0 %	7.7 %

Table 2. Muscle pain at intraoral palpation. **Diagnosis, treatment options and occlusal splint.**

Muscle Type	**Right Side**			**Left Side**		
Intraoral Palpation	**0 (n%)**	**1-5 (n%)**	**>5 (n%)**	**0 (n%)**	**1-5 (n%)**	**>5 (n%)**
The tendon of the Temporalis	**92.3 %**	**7.7 %**	**0 %**	**92.3 %**	**7.7 %**	**0 %**
Lateral Pterygoid	**38.5 %**	**26.8 %**	**34.7 %**	**42.3 %**	**19.2 %**	**38.5 %**
Masseter - Superficial fascicle Superior Insertion	**80.8 %**	**11.5 %**	**7.7 %**	**80.8 %**	**11.5 %**	**7.7 %**
Masseter - Superficial fascicle Inferior Insertion	**96.2 %**	**3.8 %**	**0 %**	**96.2 %**	**3.8 %**	**0 %**
Medial Pterygoid	**69.2 %**	**19.2 %**	**11.6 %**	**73.1 %**	**19.2 %**	**7.7 %**

The results showed that 96.2% of the patients received no any previous treatments. Anamnesis, clinical examination, and mounting the casts into the semi-adjustable articulator in centric relation position were frequently used by clinicians (30.8%) to assess the diagnosis, followed by CBCT examination (23.1%). CBCT and MRI examinations were only used for patients with TMJ symptoms. The majority of the patients were diagnosed with disc displacement with reduction (61.5%), followed by myalgia (26.9%), arthralgia (3.84%), disc displacement with reduction, and intermittent locking (3.84%), and disc displacement without reduction (3.84%). The physicians' preferred form of treatment was the Michigan occlusal splint, which was applied to the maxillary arch (84.6%). The occlusal splint was fabricated using the digital technique (50%), followed by the conventional manufacturing technique (46.2%).

Of the seven patients diagnosed with myalgia (26.9%), five of them wore the splint for more than six months (71.4%), and only two for some time period between three and six months (28.5%). When considering the effect of the splint therapy, 71.4% reported the muscle pain disappearance, 28.5% claimed that the pain intensity decreased, 85.71% of the patients observed a considerable improvement in the mandibular movements, and all the patients reported changes of the occlusal contacts. One patient diagnosed with arthralgia (3.84%) wore the Michigan occlusal splint between 3 and 6 months months. After the splint therapy, the patient reported the same results (muscle and TMJ pain disappearance, and the change of the occlusal contacts).

For the sixteen patients diagnosed with disc displacement with reduction (DDwR), the treatment option was more diversified; still, occlusal splint therapy (100%) was the primary choice followed by physical therapy (6.5%), arthrocentesis (3.25%), botulinum

toxin injections (3.25%) and laser therapy (6.5%). The clinicians chose the Michigan splint, worn by the patients for different periods according to the severity of the symptoms; eight patients wore the splint between one and three months (50%), three patients between three and six months (18.75%) and five patients more than 6 months (37.5%). When considering the effect of the splint therapy, 87.5% reported muscle and TMJ pain disappearance, and 12.5% claimed that the pain intensity slightly decreased. After wearing the occlusal splint, 56.25% had no TMJ clicking, while 93.75% claimed the change of occlusal contacts. 87.5% of the patients observed a considerable improvement in the amplitude of mouth opening, and 12.5% showed a slight improvement.

Of two patients, one was diagnosed with DDwR and intermittent locking and the other one with disc displacement without reduction (DDwoR); both wore the Michigan occlusal splint some time ~~period~~ between 3 and 6 months, respectively for more than six months (Table 3). When considering the effect of the splint therapy, both of them reported decreased muscle and TMJ pain and TMJ noises (Table 3).

Table 3. Diagnosis, treatment options, and occlusal splint.

Diagnosis (n%)	Treatment options (n%)	Splint type (n%)	Dental arch (n%)	Wear time of the splint (n%)
Myalgia (26.9%)	Occlusal splint (100%)	Michigan (100%)	Maxillary (100%)	More than 6 months (71.4%) Between 3 and 6 months (28.5%)
Arthralgia (3.84%)	Occlusal splint (100%)	Michigan (100%)	Maxillary (100%)	Between 3 and 6 months (100%)
DDwR (61.5%)	Occlusal splint (100%), physical therapy (6.5%), Arthrocentesis (3.25%), Botulinum toxin injections (3.25%), Laser therapy (6.5%)	Michigan (100%)	Maxillary (84.6%) Mandible (15.4%)	Between 1 and 3 months (50%) Between 3 and 6 months (18,75%) More than 6 months (37.5%)
DDwR and intermittent locking (3.84%)	Occlusal splint (100%)	Michigan (100%)	Maxillary (100%)	Between 3 and 6 months (100%)
DDwoR (3.84%)	Occlusal splint (100%)	Michigan (100%)	Maxillary (100%)	More than 6 months (100%)

DDwR – disc displacement with reduction, DDwoR – disc displacement without reduction

After the intended results were obtained by wearing the spint, the treatment plan was completed using selective grinding, prosthetic dental restorations, orthodontic therapy, or a combination of these therapies. Three of the patients diagnosed with myalgia followed an orthodontic treatment (42.8%), three of them a combination of orthodontic therapy and prosthetic dental restorations (42.8%), and only one case was treated by selective grinding (14.2%). The patient diagnosed with arthralgia finished the therapy by receiving orthodontic treatment and prosthetic restorations. Six of the DDwR patients were treated through prosthetic restorations (37.5%). For one patient, selective grinding and prosthetic restorations were created (6.25%), five patients received a combination of orthodontic therapy and prosthetic dental restorations (31.25%), and five patients followed a combined treatment selective grinding, orthodontic therapy and prosthetic dental restorations (31.25%). The patient with DDwR and intermittent locking had orthodontic treatment, and the patient diagnosed with disc displacement without reduction (DDwoR) followed a prosthetic treatment.

Most of the patients (DDwR and DDwoR) were required to use a full-arch night guard (42.3%), to follow the strict periodic control appointments (DDwoR), and engage in physical therapy (DDwoR) to maintain the final aesthetic and functional results. However, more than 53% of the patients reported a great improvement in life quality after the occlusal splint therapy.

The Pearson Chi-Square test was used to assess the correlations between facial pain and its characteristics, as it is recurrent intermittent pain, which appeared mainly in the morning ($p<0.05$), associated with teeth clenching and TMJ noises ($p<0.05$). A significant correlation was also found between the following parameters- the Michigan splint applied on the maxillary arch, and the wearing time of the splint, which had to be longer than three months ($p<0.05$). Another significant statistical result regarding the Michigan splint was reduction of pain, improvement of occlusal contacts, and improvement of articular sounds ($p<0.05$).

3. Discussion

This study aimed to assess the efficiency of occlusal splints when treating patients diagnosed with temporomandibular disorders (TMDs). TMDs are defined by a diversity of clinical particularities, from pain to severe dysfunction of the dental-maxillary apparatus. One of the main symptoms is represented by pain and sounds in the TMJ, pain in the masticatory muscles, limitation of jaw function, and signs of occlusal trauma, which affect the hard and soft tissues of the oral cavity [1].

The results showed that, compared to men, women aged between 30 and 60 years of age were more affected by this pathology. These findings following Warren et al (10), who concluded that the prevalence of TMDs in women is increased because of psychological, hormonal, or chromosomal factors, which enhance the risk of developing TMDs.

For each patient, the signs and symptoms of TMD (such as pain, joint noises, or occlusal status) were assessed both before and after the treatment. When treating patients with TMD, the main goal is to reduce the pain and improve the mandibular movements, reestablishing the correct functions. Occlusal splints represent the first non-invasice treatment option. These occlusal devices have a different design according to the pathology and the desired results. Michigan splint is widely used for the conservative treatment of patients diagnosed with disc displacement with reduction (DDwR) and disc displacement without reduction (DDwoR) [7,11]. The splint was fabricated on semiadjustable articulator in centric relation, from resin with a minimal thickness of 2 mm. In the oral cavity, occlusal splint provided stable occlusal relationships, the teeth contacted simultameously and evenly, and canine and anterior disocclusion of the posterior teeth during eccentric mandibular movements were created.

According to Dawson [9], to obtain the desired results, the patient should wear an occlusal splint, until the pain reliefs, TMJ gains stability, and stable occlusal relationships are achieved.

The patients diagnosed with myalgia reported the presence of intermittent facial pain, mainly localized in cheeks and temples, which appeared primarily in the morning or evening. Using the pain scale, most of the participants in this study graded its severity between three and four. Our results showed that intraoral palpation of the lateral pterygoid muscle and medial pterygoid increased the pain, along with extraoral palpation of the anterior fascicle of the temporalis muscle. The range of mouth opening revealed a limited movement associated with nonfunctional occlusal status. The patients wore the Michigan splint for a minimum of three months, which considerably reduced the muscle pain and improved the mandibular movements.

Regarding the patients diagnosed with arthralgia, our results showed that the splint was used between three and six months, and both masticatory muscle and TMJ pain disappeared. For the initial treatment phase of the patients diagnosed with disc displacement with reduction (DDwR), the Michigan splint was the treatment of choice. However, two patients required other associated treatment options, such as laser therapy and physical therapy, or more advanced ones like botulinum toxin injections or arthrocentesis.

The results revealed that the splint therapy reduced the pain in the muscles and TMJ, but also reduced the clicking and improved the amplitude of mouth opening. The TMDs' symptoms considerably enhanced for the two DDwR patients, who required more advanced treatment options, due to the inefficiency of the splint therapy. After wearing the splint, the patient diagnosed with DDwR and intermittent locking showed reduced pain in the muscles and TMJ, but also reduced the clicking and improved the amplitude of mouth opening. However, the patient diagnosed with disc displacement without reduction (DDwoR) reported only reduced pain in the muscles and TMJ.

Our results revealed the efficiency of the Michigan occlusal splint, by considerably reducing the pain both in the TMJ but also in the masticatory muscles. Similar results were obtained by Oz et al. [12], who concluded that after three months of occlusal splint wearing, muscle pain improved, and mandibular movements were reduced in the case of 40 patients diagnosed with myofascial pain. Similar results were obtained by Ferreira et al. [13], who concluded that occlusal splint significantly reduced muscle pain. Wanman et al. [14], showed that wearing the occlusal splints decreased the pain and improved the symptomatology of disc displacement and sounds in association with physical exercises. In another study, Melo et al. [15] concluded that for patients diagnosed with TMD who have worn occlusal splints, pain, and anxiety were significantly reduced. However, our results showed that occlusal splint therapy significantly improved the life quality of more than 53% of the patients included in this study.

In their study, Hamata et al. [16] indicated the effect of occlusal splints in mandibular repositioning after finishing the initial TMD treatment. They applied twenty occlusal splints to patients diagnosed with TMD, randomly divided into two categories. Ten patients received the occlusal splint fabricated in centric relation position, and the others in maximum intercuspation. Their results showed that regardless of the reference position, at the end of occlusal splint therapy, mandibular repositioning and the reduction of TMD symptoms were achieved.

The occlusal relationship required adjustments, due to relaxation of the masticatory muscles, especially to the inferior fascicle of the lateral pterygoid muscle. The new balanced and physiological muscle contraction allowed the mandibular repositioning and improved the TMD symptoms. Patients have noticed that wearing the splint has altered their occlusal contacts, and experienced difficulties in achieving a functional bite position, especially in the morning after the removal of the splint. To improve the static and dynamic functional status, occlusal changes may be necessary. Nevertheless, our results revealed the efficiency of the Michigan occlusal splint in decreasing the pain symptoms, but it also changed the patients' occlusal contacts, regardless of the TMDs pathology.

However, there are various treatment options, from minimal invasive to the most complex ones, which according to the particularities of the case, may be chosen by the clinicians. The results of our study revealed that selective grinding, prosthetic, orthodontic, or both therapeutic methods were mainly used for oral rehabilitation. The results showed that the patients diagnosed with myalgia mostly followed an orthodontic treatment or a combined treatment- orthodontic therapy and prosthetic dental restorations, while the patients diagnosed with arthralgia received orthodontic treatment

and prosthetic restorations. The DDwR patients were treated by using prosthetic restorations, selective grinding and prosthetic restorations, or a combination of orthodontic therapy, and prosthetic dental restorations; still, some of them followed a combined treatment, represented by selective griding, orthodontic therapy and prosthetic dental restorations. The patient with DDwR and intermittent locking had orthodontic treatment, and the patient diagnosed with disc displacement without reduction (DDwoR) followed a prosthetic treatment.

Nevertheless, to maintain the achieved results, occlusal splints are also used to protect teeth from the harmful effects of bruxism, from grinding or clenching of the teeth during sleeping, which may cause tooth wear, chipping of fractures of the dental restorations. Yet, regular dental check-ups are essential to ensure that the splint continues to fit correctly and provides the desired benefits. However, long-term follow-up will provide valuable data regarding the durability of the orthodontic or prosthodontic treatment and efficacy of the Michigan splint in managing patients diagnosed with temporomandibular disordrs.

4. Materials and Methods

Twenty-six patients were included in this study, who sought treatment at the Department of Prosthodontics, Faculty of Dental Medicine, "Iuliu Haţieganu" University of Medicine and Pharmacy, Cluj-Napoca, Romania. The number of patients included in this study was assessed by using the G* Power software, for an expecting power of 80% and alpha value of 0.05. Yet, the statistical result indicated using a minmal of 23 patients. The approval of the study was in agreement with the Bioethical Committee of the University requirements (number 305/08.12.2022). Each patient received a unique code number and was thoroughly informed about the study's objectives, before signing the consent form.

Only patients with signs and symptoms of TMD were selected, who met the following inclusion criteria: patients suffering from localized or referred pain in the masticatory muscles or TMJ, pain during the mandibular movements, sounds in the TMJ, restricted or exaggerated mandibular movements, bruxism or clenching awareness, complete dental arches, occlusal wear, unstable and non-functional occlusal status. The exclusion criteria were represented by: a history of growth disorders in the facial area, trauma, oncological or neurological diseases, orthodontic or complex prosthetic treatment, partial or complete edentation, history of anti-inflammatory or psychotropic medication, and analgesics. Two types of questionnaires were used for this study: for patients, and one for the clinician.

The patient's questionnaire, formulated according to RDC/TMD criteria, considered the signs and symptoms of TMDs – localized or referred pain and its characteristics (duration, intensity, time of the day when it appears), TMJ pain or noises, the parafunctional habits- grinding or clenching the teeth during the day or the night, but also included questions regarding the evolution of the occlusal splint therapy. The questionnaire addressed to the clinician included data correlated to the clinical examination and history, diagnosis, treatment plan, and the effect of occlusal splint therapy. Clinical assessment included the palpation of masticatory and cervical muscles and TMJ; the amplitude and trajectory of mandibular movements, the static and dynamic occlusion, and parafunction were also evaluated. TMD diagnosis included myalgia (pain in the masticatory muscles, pain during the mandibular functional movements, parafunction), disc displacement with reduction (DDwR – TMJ noises such as clicking, popping, or snapping during mandibular movement or function), disc displacement without reduction (DDwoR – jaw lock or severe limitation in jaw opening), degenerative disorders (TMJ pain, noises, crepitus, during mandibular movement or function), and

subluxation (locking in wide open mouth position). Questions regarding the paraclinical examination techniques, such as cone beam computed tomography (CBCT) or Magnetic Resonance Imaging (MRI) were evaluated (for a definitive diagnosis). The type of the occlusal splint, the fabrication method, the time needed for occlusal stability, the results of the splint therapy, and the final treatment options were assessed.

Statistical analysis was performed using IBM SPSS Statistics 22.0 (Armonk, NY, USA). The normality of data distributions was evaluated using the Shapiro-Wilk test. For the examined hypotheses, a significance level of $p<0.05$ was used. The non-parametric Kolmogorov-Smirnov test was employed since the used variables did not have a normal distribution. The Pearson Chi-Square test was used to identify statistically significant relationships between pain and its characteristics concerning temporomandibular disorder symptoms and the efficiency of occlusal splints.

5. Conclusions

Within the limitations of this study, it can be concluded that Michigan occlusal splints are an efficient and reliable initial treatment option for patients diagnosed with temporomandibular disorders. The Michigan occlusal splints significantly reduced muscle pain. They improved the symptoms in the temporomandibular joint, determined mandibular repositioning, which required various treatment options, from minimally invasive to the most complex, to achieve a functional occlusal status. Future research will focus on assessing the influence of patient related factor, such as age, gender, or severity of TMD, in treatment outcomes and alternative non-invasive treatments options will be investigated.

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Institutional Review Board Statement: The study was conducted by the Declaration of Helsinki and approved by the Institutional Review Board (or Ethics Committee) of "Iuliu Haţieganu" University of Medicine and Pharmacy, Cluj-Napoca, Romania (305/08.12.2022).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Data is available from the corresponding author upon request.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Patient questionnaire, Supplementary Data 1; Doctor questionnaire, Supplementary Data 2.

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