Regeneration, Reconstruction & Restoration

Review

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Occlusal Appliance Therapy in Temporomandibular Disorder Pain Management: A Literature Review

Safoura Ghodsi[a], Pooya Jannati[b], Faranak Vakili[b]

[a]Dental Research Center, Dentistry Research Institute, Department of Prosthodontics, School of Dentistry, Tehran University of Medical Sciences, Tehran, Iran; [b]Department of Prosthodontics, School of Dentistry, Hormozgan University of Medical Sciences, Bandar Abbas, Iran.

Corresponding authors:** Faranak Vakili, Department of Prostodontics, School of Dentistry, Tehran University of Medical Sciences, Tehran, Iran. ***E-mail: Faranak_vakili@yahoo.com ***Tel:*** +98 933 847 7300

Submitted: 17 February 2024**; Accepted:** 27 April, 2024**; Published Online:** 8 June, 2024**; DOI:** *10.22037/rrr.v9.39707*

Background and objectives: The second common source of orofacial pain is temporomandibular disorder (TMD). Occlusal splints are prevalently applied to manage symptomatic TMD. This study aimed to discuss the types, characteristics, fabrication, and application of occlusal splints.

Materials and methods: A structured search was carried out, including PubMed and Scopus databases with additional integration from external sources to March 2020. To meet the inclusion criteria, studies published in English involving randomized clinical trials, review articles, and experimental studies, starting from the 215 identified records, 75 items were finally included for the review.

Results: The critical step in treatment of patient with pain, malfunction, and discomfort is to determine the primary etiology. The two most commonly used splints are stabilization and anterior positioning appliances. Other types include anterior or posterior bite plane, pivoting appliance, and soft or resilient appliance.

Conclusion: There are various splints in the literature; a dentist must select the appropriate one with predictive success based on the specific diagnosed TMD type.

Keywords: Bruxism, Facial pain, Occlusal splint, Tempromandibular joint disorders.

1. Introduction

Temporomandibular joint disorders (TMDs), as a widespread collection of clinical problems, embrace any structures of the masticatory musculatures, TMJs, and the surrounding bony and soft tissues (1,2). TMD is the second most common cause of musculoskeletal pain, while low back pain is the first. Orofacial pain is a cardinal symptom in patients with TMD (3). Other relevant symptoms include abnormal jaw movement, TMJ clicking, limited mouth opening, headache, and psychosocial impairments (3,4).

A systematic review shows a direct correlation between TMDs and poor quality of life (5). Therefore, successful treatment can efficiently increase a patient’s life satisfaction. Psychological reassurance (e.g., patient education, self-care, and behavior therapy), physiotherapy (e.g., ultrasound, acupuncture, short wave diathermy laser, heat exercises, and biofeedback), occlusal splint therapy, medications, direct occlusal adjustment, surgical intervention, and combined treatments are among the different treatment options introduced for TMDs (6). Yet, occlusal splints play a more prevalent and predominant role in most treatment modalities.

Occlusal splints generally relax the stress, distribute occlusal overloads, and transfer the pressure to the acrylic appliance at the stress chain (2,7). They also rely on mutually protected occlusion as the acceptable occlusal scheme for soothing a significant part of elevator muscles (8). Finally, their mechanism affects the central nervous system by changing the peripheral stimuli (9,10).

There are various types of appliances with different mechanisms. Decision-making needs knowledge about each appliance's classifications, characterization, and indications, besides knowing the diagnosis. Therefore, the present study aimed to examine the available literature on occlusal splints and summarize the recent advances in materials, designs, and selection criteria for accurate appliance therapy to help clinicians choose the best treatment plan and appropriate appliance.

2. Materials and methods

An electronic search was performed in English articles in PubMed, Scopus, Embase, and Google Scholar databases, applying related keywords in different combinations in the title, abstract, or keywords up to June 2023. The keywords included parafunction, bruxism, bruxing, clenching, temporomandibular disorder, TMD, TMJ, temporomandibular therapy, occlusal appliance, appliance therapy, occlusal splint, bite plane, and occlusion.

The study included English articles that were randomized clinical trials, review articles, and experimental studies. It excluded non-peer-reviewed studies, animal studies, case studies, and clinical studies with less than a 2-year follow-up. Using reference management software (Endnote X9; Thomson Reuters), the researchers eliminated the duplicates (n= 158). Two independent authors (F.V and P.J) selected the articles based on title-abstract analyses and full-text evaluation. In cases of disagreement, the opinion of the third author (S.G) was considered for decision-making. Then, they came up with 218 articles, of which 76 were eligible for the study. Finally, the information on different types of splint applications, their characteristics, and indications was extracted to answer the usual queries. The literature search was established to address the research question phrased as follows in the PICOT framework: Population: adult patients diagnosed with TMD; Interventions: occlusal appliance therapy; Comparisons: The occlusal appliance materials, methods of fabrication, designs, and indications; Outcome: selecting an appropriate appliance for each patient; Type of publications: randomized clinical trials (RCTs), reviews, and experimental studies.

3. Results

According to the glossary of prosthodontics, the occlusal splint is a removable artificial appliance used to diagnose and treat diseases that affect the maxillomandibular relationship (11). Goodwillie introduced the first occlusal splint in 1881 (12), but it became popular only after the 1960s when Ramford and Ash presented the “Michigan-type” occlusal splint (13,14). Different splint designs and treatment theories have entered the market since then. Anterior positioning and stabilization appliances are the two most commonly used splints. However, other types include pivoting appliances, anterior or posterior bite planes, and soft or resilient appliances (15). On the other hand, Dawson PE (16) classifies splints into three types: non-directive (muscle deprogrammer or permissive splints), pseudo-permissive splints (hydrostatic splints and soft splints), and directive (non-permissive splints). Non-directive splints are the commonly used appliances that prohibit dental interferences by placing the opposing occlusion on a flat plane. (The characteristics, advantages, and disadvantages of different appliances are briefly written in Table 1.)

The chief step in treating a patient with pain, malfunction, and discomfort is determining the primary cause. Figure 1 shows the decision tree based on the differential diagnosis of possible etiological factors.

4. Discussion

4.1. Hard vs. soft vs. bilaminar appliances

Based on fabrication materials, splints are categorized into appliances made from hard acrylic resin, soft or resilient acrylic resin, and dual laminated ones. Compared to soft occlusal appliances, hard acrylic ones outperform in several aspects. Its hardness results in easy and quick adjustments, easy repair, better accurate fit, longevity, higher color stability, less food debris accumulation, and durability. Adjusting is more difficult in the soft types and frequently results in a less accurate occlusal scheme. Furthermore, soft appliances are more susceptible to wear, increasing the possibility of occlusal changes (15,18), and cannot be balanced, which may worsen bruxism and result in premature posterior contacts (18). Despite controversies, a recent meta-analysis revealed that hard and soft occlusal appliances performed similarly with no significant difference in pain intensity or reduction of muscle tenderness (19). On the other hand, bilaminar splints offer higher wear resistance to occlusal forces compared to soft appliances. Moreover, they require less clinical and laboratory time than rigid splints, and their purchasing, construction, and replacement are not expensive (20).

4.2. How much the thickness of an occlusal appliance should be?

An increase in the vertical dimension should be as slight as possible, with no interference or perforation (21). In addition, studies have shown that an increase in the splint thickness will increase the anteroposterior movements of the condyle-disk and vertical movement of the condyle; this improves the clinical outcomes in DD-R (disc displacement without reduction). Generally, a study suggests a 4-mm splint thickness for DDR (disc displacement with reduction) and 6-mm for DD-R for 1-year treatment (22).

4.3. Whether the splint should be made on the maxilla or mandible?

Table 1. Summary of the characteristics and applications of different appliances.

Appliance	Main purposes to design	Indications	Drawbacks
Stabilization Appliances	- To provide joint stabilization - To protect the teeth - To redistribute the occlusal forces	- Muscle pain disorders - TMD Related to muscle hyperactivity, such as bruxism - Local myalgia or chronic centrally-mediated myalgia - Retrodiscitis secondary to trauma	It has minor adverse effects on oral structures when properly fabricated. (24)
Anterior Repositioning Splints	-To alter the maxillomandibular relationship by an acrylic guiding ramp: more anterior	- Anterior disk displacement with reduction - Disc displacements with intermittent locking - Pain, joint sounds, and jaw	Uncontrollable tooth movement, patients' discomfort, tendency to build up scar tissue behind the
Anterior Bite Planes	-To treat TMDs by preventing the clenching: posterior teeth are not engaged in	- Muscle disorders - Parafunctional activity (unfavorable posterior tooth contacts) - Differential diagnosis of orofacial	long term use: Posterior supraeruption and anterior intrusion (25)
Posterior Bite Planes	- To achieve significant alterations in the vertical dimension and mandibular	- Muscle disorders - Parafunctional activity -Acute anterior disc dislocation (ADD) without reduction (17,23)	Supraeruption of anterior teeth or intrusion of opposing posterior teeth eventually lead to a posterior open bite in

Appliance	Main purposes to design	Indications	Drawbacks
Pivot Splints	To reduce intra-articular pressure by condylar distraction (24,26)	Patients with internal derangements or with osteoarthritis (25)	A potential adverse effect may cause occlusal changes like a posterior open bite in the pivot area.(17)
NTI-TSS	To stimulate the incisors' PDL, which results in NTI reflex limiting the contraction intensity of the elevator muscles. (17)	- Myofascial pain - Headache (23)	A greater risk factor for permanently changing the occlusion (anterior open bite) (17)
Hydrostatic Appliances	To balance the biting pressure with water (23)	- Malocclusion treatment - TMJ pain and symptoms (23)	Cells retain their fluid for an average of two weeks (23)
Soft Appliances	To achieve even and simultaneous contact with the opposing teeth (23)	- Joint dysfunction and myalgia - As an emergency treatment in acute TMD -As a protective device - Bruxism and clenching - Repeated or chronic sinusitis resulting in extremely sensitive posterior teeth (23)	- Difficult to be adjusted and polished - Easily perforated (23)

NTI-TSS: Nociceptive trigeminal inhibition-tension suppresion system.

Table 2. The results of some articles published on occlusal appliances.

Author	Materials and technology	Comparisons	Conclusion
B M. 2020 (27)	CAD-CAM ethylene vinyl acetate (EVA), polymethyl methacrylate (PMMA), polycarbonate (PC), polyetheretherketone (PEEK), and polyethylene terephthalate.	Surface roughness (Ra) and wear behavior	EVA exhibited the greatest amount of Ra and volume loss, while PEEK had the lowest values. PC and PMMA exhibited less wear than EVA and C, with the best results for PEEK.
Domanic KY. 2020 (28)	Four occlusal splint materials (methyl methacrylate+ ethylene dimethacrylate, polyamide, methyl methacrylate, urethane oligomers); three antagonists (natural tooth enamel, lithium disilicate glass-ceramic, monobloc zirconia)	Wear behavior	The highest mean value was obtained by urethane oligomers, and the lowest was obtained by polyamide. The lowest mean values were observed in the monobloc zirconia- polyamide interaction.
Prpic o. 2019 (29)	PMMA, polyamide, and non-acrylic light polymerizing resin (NAR) occlusal splints produced by 3D-printing, CAD-CAM, and conventional auto polymerizing	Flexural strength and surface hardness	Acrylic resin has the most consistent surface hardness values regardless of the technology. Polyamide and NAR- additive manufacturing had lower surface hardness, while their flexural strength was higher than acrylic resin.
Alp G. 2019 (30)	CAD-CAM PMMA-based polymers, bis-acrylate composite, and conventional PMMA	Flexural strength	The flexural strength of PMMA-based polymers was greater than that of bis-acrylate composite resin, while conventional PMMA resin had the least flexural strength.
Reyes-Sevilla M. 2018 (31)	Three composites were used for direct restorations (Filtek Z250, CLEARFILAP-X, and Filtek Supreme XT) Four occlusal splints materials: ThermoSens, conventional, milled and printed PMMA	Wear behavior	The wear rates of ThermoSens and printed PMMA were not significantly higher than that of the composites. Conventional and milled PMMA had significantly higher wear rates.
Buduru S. 2018 (32)	PMMA occlusal splints produced by 3D-printing and milling	Time, cost, efficiency, and medical results	The cost is lower for the printed splint. Considering the limitation of PMMA disc dimension, printed splints should be selected for vertical dimension of occlusion alteration. Digital splints can be duplicated at any time by either method.
Huettig F. 2017 (33)	PMMA (conventional method), polycarbonate ingots (subtractive	Surface finish and wear resistance	Surface roughness: Conventional > Additive > Subtractive

	method), and light-curing resin (additive method)		Wear resistance: Similar
Al-Dwairi ZN. 2018 (34)	CAD-CAM PMMA and conventional heat-cured PMMA	Flexural strength, impact strength, and Flexural modulus	CAD-CAM PMMA specimens exhibited improved flexural strength, flexural modulus, and impact strength compared to the conventional groups.
Berntsen C. 2018 (35)	Conventional and digital additive manufacturing PMMA	Technical and clinical parameters	Patients preferred digital intraoral scanning to alginate impressions, though it was more time-consuming. They also reported better feeling with CAD-CAM splints.
Dedema P. 2016 (36)	Conventional and digital CAD-CAM manufacturing PMMA	Time and cost-efficiency	Time efficiency, high material quality, and the possibility of manufacturing duplication for digital splints

Although one can presumably obtain identical results irrespective of the splint position, a few principles result in selecting the appropriate position for occlusal splints. Fabricating the appliance on the jaw with fewer teeth is preferred to promote the stabilizing effect of more occlusal contact points. The maxillary arch is ideal if there are significant incisor overjet, severe Angle class II, and night-time application program (13,37). Conversely, the mandibular occlusal splint outperforms in providing the palatal rest position for the tongue, forcing the tongue to take a better upper position when lingual dysfunction exists (13,37). Mandibular appliances do not affect the esthetic or speech as much as maxillary ones and are preferred for long-time application (24 h/day) (38).

4.4. Success rate, patient feedback, and general effectiveness

Evidence has confirmed that StS (stabilizing splint) is valid for TMD symptom and signs remission to a great extent; the total success rate is 70%, and partial improvement has been observed in 22.5% of cases (39). A meta-analysis on using StS revealed that it might play a significant role in TMD treatment in the short term. However, its effects are similar to that of other therapeutic modalities (non-occluding splint, physiotherapy, occlusal oral appliances, behavioral therapy, counseling, and no treatment) in the long run (40). Zhigui et al. have reported a decrease in the success rate of ARS (anterior repositioning splint) treatment over time. It was 92.31% at the end of treatment and 72.53% after 12 months. However, both clinical findings and MRI examination have confirmed the relative efficiency of ARS in repositioning the disk in DDR, particularly for patients in early puberty (41). Simmons and Gibbs conducted a study on ARS and found more than 70% improvement among patients whose discs were not captured, though the original premise (capturing the disc) was not met (42). In general, deprogramming splint therapy and occlusal equilibration positively affected the patients by reducing their clinical symptoms and leading to minor changes in condylar position (43). However, there are controversies about the therapeutic effects of occlusal appliances in the literature, and some researchers believe that the therapeutic effects might return to the placebo effect.

Digital workflow has provided much advancement for clinicians and patients by facilitating impression techniques, providing more efficient time, and implementing more accuracy of the appliance (44,45). Table 2 summarizes the results of studies conducted on different characteristics and parameters of occlusal appliances.

The occlusal appliances are mainly used to reinforce auto-management in patients suffering from TMD. These appliances help control the dysfunctions consciously. In a 2020 study, Krohn et al. evaluated the intraoral microsensors for objectively measuring patient compliance during maxillary and mandibular StS application. The findings revealed that the splints did not significantly influence patients' compliance with myofascial pain (46). In 2020, Noguchi and colleagues conducted a study to assess the efficacy of stabilization appliance therapy in patients with myalgia. They employed temporary appliances to screen individuals for sleep bruxism over a two-week period. The findings indicated that this therapy was particularly effective for patients who were aware of awake bruxism during the day, experienced localized muscle pain, had extended tooth wear, and lacked psychosocial risk factors (47). Moreover, a study revealed that the mandibular manipulation technique followed by exercise and splint therapy seems beneficial in DDR to maintain the complete disc-condyle relationship (48).

It seems that ARS outperforms the flat-plane occlusal splint in eradicating reciprocal clicking and palpatory tenderness of TMJ. Permanent recaptures of the disk occur merely in a small proportion of these patients; therefore, irreversible procedures must be carefully evaluated (49). Splint therapy can reduce discomfort; irrespective of MRI findings, the decline of TMJ discomfort most probably occurs in patients with unilateral disc displacement (50). Studies have confirmed that pivot splints as an exercise regimen along with an StS can be used as an alternative practical treatment for patients with DD-R since it leads to a normal mandibular range of motion and elimination of pain (51).
To effectively prescribe the correct type of appliances, clinician should know their types, mechanism of action, indications, and application principles. This review attempted to present existing evidence concerning occlusal appliance therapy, such as different types, indications, and available methods and materials to answer frequent questions on this treatment modality. Based on the literature, further studies are required to focus on the effect of splints on muscle activity and bruxism frequency, patient compliance with different types of occlusal splints, and personal psychological adaptation.

5. Limitations

The reviewed articles had several limitations that should be considered in future studies. For example, insufficient sample size, heterogeneity of the participants, the impossibility of simulating oral conditions in experimental studies, and lack of long-term follow-up, especially in ARS, are among those.

6. Conclusion

Reviewing the available and related literature on occlusal appliance therapy, came up with the following conclusions:
1. The first step in recommending an appropriate appliance is diagnosing temporomandibular disorder type.
2. To apply each occlusal appliance in the best-indicated situation, it is essential to know the appliance mechanism, indications, and potential problems and disadvantages.
3. There are generally two categories of appliances, stabilization and anterior repositioning splints; however, the latter has potential complications in long-term use.
4. Concerning material, the appliances could be made in soft, hard, or dual acrylic resin.
5. The skeletal relationship, existing and opposing teeth, and patient motivations and abilities affect the jaw selected as an accepting jaw.
6. One should emphasize the importance of occlusal adjustment, the patient's regular follow-up, and cooperation and motivation to ensure successful treatment results.

Acknowledgment

This paper and the research behind it would not have been possible without the exceptional support of my supervisor, Dr. Safoura Ghodsi. I am also grateful for the insightful comments offered by Dr. Nasrin Khaki (Ph.D. in TEFL).

Authors' contribution

All authors discussed the results and contributed to the final manuscript. F.V. analyzed the data, write and revised the manuscript. P.J. contributed to the final version of the manuscript and S.Gh. supervised the project.

Conflict of interest

There was no conflict of interest.

Funding/support

There was no funding for this paper.

ORCID

Not available

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Please cite this paper as: Ghodsi S, Jannati P, Vakili F. Occlusal Appliance Therapy in Temporomandibular Disorder Pain Management: A Literature Review. Journal of "Regeneration, Reconstruction & Restoration"(Triple R). 2024; Volume 9: e5. Doi: 10.22037/rrr.v9.34663