How does a splint work? A systematic review

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Abstract

***Objective*: The mechanisms of action of interocclusal devices have not yet been thoroughly studied, and their true effectiveness remains controversial. A systematic review was conducted to determine how the function of interocclusal devices works in dentate or partially dentate subjects with TMD, with or without associated bruxism.**
***Method*: The review followed the structure required by the guidelines reported in the PRISMA statement. PubMed, EBSCO, SCOPUS, and Web of Science databases were included. The quality of the evidence was evaluated using the GRADE scale.**
***Results*: 881 articles were identified, and 203 duplicates were removed. 49 articles were finally analyzed in this systematic review. 21 of them were controlled clinical trials, and 28 were clinical trials. The studies included aspects of systemic and neurophysiological responses and biomechanical activity. They also assessed the activity of mandibular advancement devices in patients with apnea. After defining the quality of evidence, all studies were analyzed.**
***Conclusion*: The use of interocclusal splints is highly recommended for all patients suffering from any temporomandibular pathology, bruxism, or mild sleep disorders.**

Keywords:Occlusal splint; interocclusal device; oral appliances; night guard

Introduction

Occlusal splints (referred to in literature as “interocclusal appliances,” “oral appliances,” etc.) are common devices used to manage temporomandibular disorders (TMDs) (1). TMD is a broad term encompassing pain and dysfunction of the masticatory muscles, temporomandibular joints (TMJ), and other related structures. The etiology of TMD is multifactorial, and the biopsychosocial model is increasingly supported (2,3). The

primary goals of modern TMD treatment are to reduce or eliminate pain and restore masticatory function. There is debate in the literature regarding the optimal TMD treatment protocol, and treatment choice often depends on the practitioner's experience (4). Besides occlusal splints, treatment options may include pharmacological therapies, exercise therapy, low-level laser therapy, acupuncture, physiotherapy, TMJ lavage, and orthognathic surgery (5). Several studies suggest that patients with TMD improve with a combination of noninvasive treatments, including behavioral therapy, medications, physical therapy, and occlusal appliances. However, more rigorous research is necessary to evaluate these treatments' effectiveness and determine how to personalize treatment for individual patients (6).
Conservative approaches, including the use of oral appliances, are suitable for many patients suffering from TMJ and muscle-related issues (1). For many clinicians, occlusal splints are the first line of treatment for TMD symptoms. The initial management typically involves explaining the problem, pain control, behavioral instructions, and oral splints. General practitioners can administer this approach, which is often successful for most patients with primary TMDs. However, some patients require more complex treatments and specialist consultation (7). A recent study emphasizes that multimodal therapy combining "Counselling" and "hard stabilization splint" is a practical approach for TMD patients (8). There are many occlusal splints (9), each serving different purposes depending on the specific pathology being addressed. These devices are usually made of polymethyl methacrylate (PMMA) and can be fabricated using conventional and digital manufacturing techniques that meet chemical and mechanical standards (10).

Occlusal splint therapy is reversible, non-invasive, and atraumatic. It can promote muscle relaxation, unload the TMJ, and protect teeth from wear caused by bruxism. It is regarded as effective, especially in cases involving limited jaw movement and pain. Various mechanisms have been proposed to explain how these devices work, including: occlusal stabilization, occlusal disengagement, neurophysiological effects on the masticatory system, changes in vertical dimension, the role of the "stress absorber," and placebo effects. Several studies indicate that the thickness of the splint influences its effectiveness (7, 11-17). However, the exact mechanisms of action are not fully understood, and the overall efficacy of occlusal splints remains debated (6,18). There is limited scientific evidence supporting their use for pain relief, TMJ clicking, restricted mouth opening, or bruxism (5,19). Based on these premises, a systematic review was conducted following the PICO criteria to answer the question: "how the interocclusal devices (I) work (O), in dentate or partially dentate subjects with TMD with or without bruxism (P)." No control groups were examined (C).

Methods

Evidence acquisition. In January 2024, a systematic review of the literature was conducted. The authors aligned the paper's structure with the checklist requirements of the guidelines reported by the PRISMA statement (20). PubMed, EBSCO, SCOPUS, and Web of Science databases were included.

Eligibility criteria were:

- Observational studies, clinical trials, or randomized controlled trials involving living subjects.
- Studies include dentate or partially edentulous healthy subjects of any sex, age, or facial type without orthodontic or craniofacial surgery treatment.
- Studies in which the mode of action of the splints was clearly defined.
- Any language is accepted.

Data collection. To identify and select the potentially eligible studies for this review, a search strategy was created for each database. Two semantic fields (interocclusal devices and mode of action) were established to develop the search strategy. Keywords (all fields and MeSH terms) were included in each semantic field (Table 1). Filters applied were years 2014-2024, human, and all languages.

Study identification.__After applying the search strategies for each database, the resulting titles were transferred to the EndNote® application, and then any duplicate titles were manually removed using the same application.

Screening._During the initial screening process, two researchers (RF and LL) independently selected potentially eligible articles by title and abstract. If there was disagreement, a third researcher (DA) participated in selecting the relevant article._In the second stage, the same researchers independently assessed the screened records, and studies that potentially met the eligibility criteria were included. Reasons for excluding

Table 1. Semantic fields and keywords

Semantic field: Interocclusal devices	Semantic field: Mode of action
occlusal splint (MeSH) OR occlusal splints (MeSH) OR inter-occlusal device OR interocclusal device OR night guard OR dental night guard	muscle performance OR muscle pain OR Masticatory muscles OR masticatory performance OR masticatory function OR masticatory force OR temporomandibular OR TMJ OR TMJ pain OR TMJ noise OR pain OR clicking OR click OR crepitus head posture OR body posture OR postural OR postural balance OR stress OR bruxism OR sleep quality OR oral physiology OR cortical masticatory area OR insula activation OR cerebral activation patterns OR rhythmic masticatory activity OR motor coordination OR neurotransmitter

studies were documented. Studies assessed for eligibility were recorded in an Excel® spreadsheet, including author, year, and title information.

Data extraction involved using_PICO criteria. The population included humans of both sexes and all ages, with partial or complete dentition. Intervention consisted of any splint or interocclusal device. Control groups included those with or without a splint or a placebo. Outcomes focused on the mode of action, such as neurophysiological or biomechanical effects. The data were entered into an Excel® spreadsheet.

Quality of evidence. For clinical studies, the GRADE Scale was used (21).

Results

Evidence synthesis. Figure 1 shows the flow chart, which includes identification, selection, and inclusion of articles.

Included articles. 49 articles were finally analyzed in this systematic review (Table 2) (22-70).

Of these, 21 were controlled clinical trials and 28 were clinical studies (15 with a control group and 13 with pre- and post-control groups). The analyzed data were grouped into:

a) Neurophysiological and conductual responses:

- Brain activity (blood oxygenation level-dependent) (25)
- Insular activity (32,36)
- Heart Rate (autonomic nervous system activity (22)
- Heart frequency (29)
- Oxidative stress biomarkers (depressive symptoms) (24)
- GABA and Glu expression (34)
- Hemodynamics: Deoxyhemoglobin (Hb), oxyhemoglobin (HbO2), and OXY (HbO2-Hb) (39)
- Blood lactate (30)
- Cortisol, dehydroepiandrosterone (DHEA), and tumor necrosis factor alpha (TNF-alpha) in the gingival crevicular (40,60)
- Ca level and IL-1β (43)
- Bruxism activity/events (sleep and awake) (29,38,48,52,53,55)
- Rhythmic masticatory muscle activity (22)
- Apnea/hypopnea Index (47,56,63)
- Arousal index (47)
- Respiratory disturbances (47)
- Oxygen saturation (47)

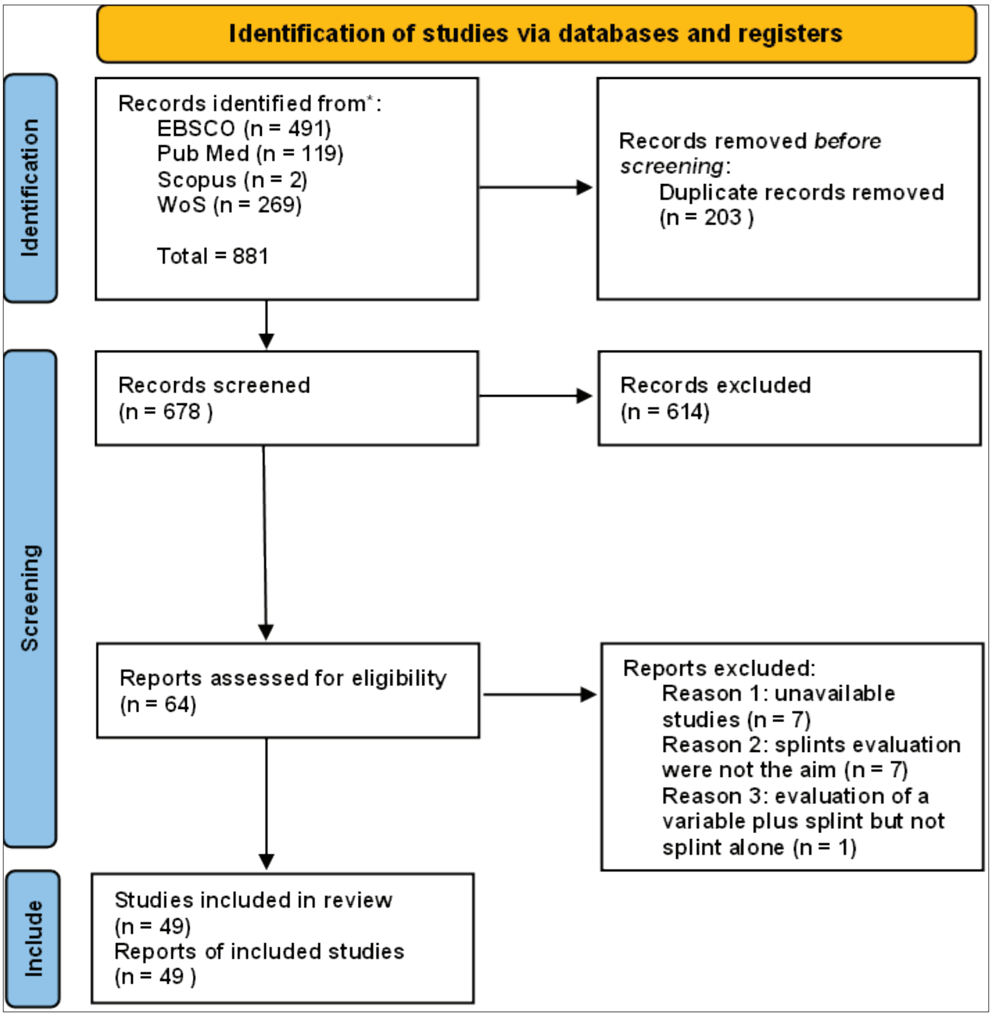

Figure 1. Flow chart drawn according to the PRISMA statement: search methods, identification, selection, and inclusion of retrieved articles.

Table 2. Studies admitted for Systematic Review

Abe S, 2022 [22]	Oral appliances reduce masticatory muscle activity-sleep bruxism metrics independently of changes in heart rate variability
Akat B, 2023 [23]	Ultrasonographic and electromyographic evaluation of three types of occlusal splints on masticatory muscle activity, thickness, and length in patients with bruxism
Alajbeg I, 2020 [24]	Effect of occlusal splint on oxidative stress markers and psychological aspects of chronic temporomandibular pain: a randomized controlled trial
Ariji Y, 2016 [25]	Regional brain activity during jaw clenching with natural teeth and with occlusal splints: a preliminary functional MRI study
Benli M, 2023 [26]	Effect of material type and thickness of occlusal splints on maximum bite force and sleep quality in patients with sleep bruxism: A randomized controlled clinical trial
Camara-Souza MB, 2020 [27]	Tongue force, oral healtherelated quality of life, and sleep index after bruxism management with intraoral devices
Caria P 2014 [28]	Efficiency of occlusal splints on police officers with TMD
Castroflorio T, 2016 [29]	Short-term effects of two different oral devices on sleep bruxism management: a pilot study
Costa D, 2021 [30]	Orofacial evaluation of individuals with temporomandibular disorder after LED therapy associated or not of occlusal splint: a randomized double-blind controlled clinical study
Dalewski B, 2015 [31]	Occlusal splint versus modified nociceptive trigeminal inhibition splint in bruxism therapy: a randomized, controlled trial using surface electromyography
Dammann J, 2020 [32]	Association of decrease in insula fMRI activation with changes in trait T anxiety in patients with craniomandibular disorder (CMD)
Deng H, 2018 [33]	Alteration of occlusal vertical dimension induces signs of neuroplastic changes in corticomotor control of masseter muscles: Preliminary findings
Dharmadhikari S, 2015 [34]	GABA and glutamate levels in occlusal splint-wearing males with possible bruxism
Eriksson PO, 2019 [35]	Instant reduction in postural sway during quiet standing by intraoral dental appliance in patients with Whiplash associated Disorders and non-trauma neck pain
Ernst M, 2020 [36]	Effects of centric mandibular splint therapy on orofacial pain and cerebral activation patterns
Giannakopoulos NN, 2018 [37]	Comparison of device-supported sensorimotor training and splint intervention for myofascial temporomandibular disorder pain patients
Gu W, 2015 [38]	Efficacy of biofeedback therapy via a mini wireless device on sleep bruxism contrasted with occlusal splint: a pilot study
ispirgil E, 2020 [39]	The hemodynamic effects of occlusal splint therapy on the masseter muscle of patients with myofascial pain accompanied by bruxism
Karagozoglu I, 2023 [40]	Evaluation of biochemical changes and treatment efficacy in patients with bruxism following botulinum toxin or splint therapy: a randomized clinical trial.
Karakis D, 2014 [41]	Evaluation of the effect of two different occlusal splints on maximum occlusal force in patients with sleep bruxism: a pilot study
Kolcakoglu K, 2022 [42]	A Comparison of Hard and Soft Occlusal Splints for the Treatment of Nocturnal Bruxism in Children Using the BiteSTRIP®
Kurnikasari E, 2018 [43]	The effect of occlusal splint therapy on masticatory muscles' pressure pain threshold and ca2+ and il-1b level in masticatory myofascial pain syndrome patients
Lässing J, 2021 [44]	The Influence of Customized Mouthguards on the Muscular Activity of the Masticatory Muscles at Maximum Bite and Motor Performance During Static and Dynamic Exercises
Lei Q, 2023 [45]	Neuromuscular and occlusion analysis to evaluate the efficacy of three splints on patients with bruxism

To be continued

Lukic N, 2021 [46]	Short-term effects of NTI-tss and Michigan splint on nocturnal jaw muscle activity: A pilot study
Luz GP, 2023 [47]	Effect of CPAP vs. mandibular advancement device for excessive daytime sleepiness, fatigue, mood, sustained attention, and quality of life in patients with mild OSA
Mainieri VC, 2014 [48]	Analysis of the Effects of a Mandibular Advancement Device on Sleep Bruxism Using Polysomnography, the BiteStrip, the Sleep Assessment Questionnaire, and Occlusal Force
Marc K, 2022 [49]	The effect of a bimaxillary occlusion splint - (Stressbite® dynamic splint system) on postural - control and balance in patients with bruxism
Matsumoto H, 2015 [50]	The effect of intermittent use of occlusal splint devices on sleep bruxism: a 4-week observation with a portable electromyographic recording device
Matsuzaki S, 2021 [51]	Effect of mandibular advancement device on plasticity in corticomotor control of tongue and jaw muscles
Nakamura H, 2019 [52]	Effects of a contingent vibratory stimulus delivered by an intra-oral device on sleep bruxism: a pilot study
Nakazato Y, 2021 [53]	Effect of contingent vibratory stimulus via an oral appliance on sleep bruxism after the splint adaptation period
Ogami S, 2014 [54]	The effectiveness of a mouth guard to protect against strong occlusion caused by modified electroconvulsive therapy
Ohara H, 2022 [55]	Effects of vibratory feedback stimuli through an oral appliance on sleep bruxism: a 6-week intervention trial
Pépin JL, 2019 [56]	Heat-moulded versus custom-made mandibular advancement devices for obstructive sleep apnoea: a randomised non-inferiority trial
Ramachandran A, 2021 [57]	Effect of deprogramming splint and occlusal equilibration on condylar position of TMD patients – A CBCT assessment
Rauer A, 2019 [58]	Physiotherapy home exercises and occlusal splint therapy for myofascial TMD pain A comparative clinical pilot study
Ribeiro AB, 2022 [59]	Effect of short-term increase in occlusal vertical dimension on masticatory muscle electrical activities and pressure-to-pain threshold: A crossover clinical study
Rosar JV, 2017 [60]	Effect of interocclusal appliance on bite force, sleep quality, salivary cortisol levels and signs and symptoms of temporomandibular dysfunction in adults with sleep bruxism
Santander H, 2014 [61]	The effect of a mandibular advancement appliance on cervical lordosis in patients with TMD and cervical pain
Shi X, 2023 [62]	Effects of mandibular advancement devices on upper airway dimensions in obstructive sleep apnea: responders versus non-responders
Shi X, 2023 [63]	Comparisons of the effects of two types of titratable mandibular advancement devices on respiratory parameters and upper airway dimensions in patients with obstructive sleep apnea: a randomized controlled trial
Sjoholm T, 2014 [64]	Long-term use of occlusal appliance has impact on sleep structure
Škaričić J, 2020 [65]	Influence of Occlusal Splint on Mandibular Movements in Patients with Bruxism: a Comparative Pilot Study
Solanki N, 2017 [66]	Effect of mandibular advancement device on sleep bruxism score and sleep quality
Sun J, 2023 [67]	Temporomandibular joint disc repositioning and occlusal splint for adolescents with skeletal class II malocclusion: a single-center, randomized, open-label trial
Tanaka Y, 2020 [68]	The effect of occlusal splints on the mechanical stress on teeth as measured by intraoral sensors
Wasinwasukul P, 2022 [69]	Effects of anterior bite planes fabricated from acrylic resin and thermoplastic material on masticatory muscle responses and maximum bite force in children with a deep bite: A 6-month randomised controlled trial
Zhou J, 2021 [70]	A novel three-dimensional morphological analysis of idiopathic condylar resorption following stabilisation splint treatment

- Sleep quality (26,27,47,48,52,60,66)
- Sleep structure (64)
- Anxiety (32)
- Pain (24,28,29,30,32,36,37,42,43,48,58,59)

b) Craniocervical and postural neurophysiological responses:
- Bite force (26,36,37,45,60,69)
- Occlusal force (41,48,55,66)
- Tongue force (27)
- Muscle activity (EMG) (23,28,29,30,31,36,37,42,44,45,46,50,58,59,69)
- Motor evoked potentials (33,51)
- Motor threshold (51)
- Physical activity (44)
- Postural activity (31)
- Postural sway and balance (35,49)
- Plantar pressure distribution (49)
- Balance (49)

c) Cranio-cervical structural and biomechanical responses:
- Muscle thickness (23)
- Structural Condylar changes (67,70)
- Occlusion (68)
- Malocclusion (67)
- Condylar Position and bone quality (57, 65)
- Upper airway (62,63)
- Mandibular and condylar movement (65)
- TMJ sounds (48)
- TMD signs and symptoms (60)
- Cervical lordosis (61)

Characteristics of participants._Regarding their age, most of the trials were conducted with adults (not elderly). Four trials included children and adolescents. Most studies included males and females; some only females, and a few did not report sex.

Quality assessment. The GRADE scale was used to evaluate selected studies' design, the information quality, and the risk of biases. Table 3 presents the final GRADE rating for the quality of evidence. The authors only regarded ten studies as high quality and 12 as moderate quality. The high-quality studies included the following aspects: Oxidative stress biomarkers (for depressive symptoms and pain) (24), bite force and sleep quality (26,69), muscle activity, heart rate, and bruxism activity (29,30,50,69), pain and blood lactate (30), Apnea/hypopnea Index, Arousal Index, respiratory disturbances, and sleep quality (47,56), motor evoked potentials and motor threshold (51), and structural condylar changes (67). Moderate-quality studies covered the following aspects: rhythmic masticatory muscle activity (22,31), muscle activity (EMG) (23,37,42,46,58), bite force and pain (37,42,58,60), hemodynamics (39), cortisol, dehydroepiandrosterone (DHEA), and tumor necrosis factor alpha (TNF-alpha) in the gingival crevicular fluid (40,60), bruxism activity/events (53), sleep quality (60,66), and occlusal forces (66).

Table 3. Final GRADE assigned for the quality of evidence. High = (+)(+)(+)(+). Moderate = (+)(+)(+). Low = (+)(+). Very low = (+).

Author, year	**Final GRADE assign for quality of evidence**
Abe S, 2022 (22)	(+)(+)(+)
Akat B, 2023 (23)	(+)(+)(+)
Alajbeg I, 2020 (24)	(+)(+)(+)(+)
Ariji Y, 2016 (25)	(+)
Benli M, 2023 (26)	(+)(+)(+)(+)
Camara-Souza MB, 2020 (27)	(+)(+)
Caria P 2014 (28)	(+)(+)
Castroflorio T, 2016 (29)	(+)(+)(+)(+)
Costa D, 2021 (30)	(+)(+)(+)(+)
Dalewski B, 2015 (31)	(+)(+)(+)
Dammann J, 2020 (32)	(+)(+)
Deng H, 2018 (33)	(+)(+)
Dharmadhikari S, 2015 (34)	(+)
Eriksson PO, 2019 (35)	(+)
Ernst M, 2020 (36)	(+)(+)
Giannakopoulos NN, 2018 (37)	(+)(+)(+)
Gu W, 2015 (38)	(+)(+)
ispirgil E, 2020 (39)	(+)(+)(+)
Karagozoglu I, 2023 (40)	(+)(+)(+)
Karakis D, 2014 (41)	(+)(+)
Kolcakoglu K, 2022 (42)	(+)(+)(+)
Kurnikasari E, 2018 (43)	(+)(+)
Lässing J, (44)	(+)
Lei Q, 2023 (45)	(+)
Lukic N, 2021 (46)	(+)(+)(+)
Luz GP, 2023 (47)	(+)(+)(+)(+)
Mainieri VC, 2014 (48)	(+)(+)
Marc K, 2022 (49)	(+)
Matsumoto H, 2015 (50)	(+)(+)(+)(+)
Matsuzaki S, 2021 (51)	(+)(+)(+)(+)
Nakamura H, 2019 (52)	(+)(+)
Nakazato Y, 2021 (53)	(+)(+)(+)
Ogami S, 2014 (54)	(+)
Ohara H, 2022 (55)	(+)(+)
Pépin JL, 2019 (56)	(+)(+)(+)(+)
Ramachandran A, 2021 (57)	(+)
Rauer A, 2019 (58)	(+)(+)(+)
Ribeiro AB, 2022 (59)	(+)(+)

To be continued

Rosar JV, 2017 (60)	(+)(+)(+)
Santander H, 2014 (61)	(+)(+)
Shi X, 2023 (62)	(+)(+)
Shi X, 2023 (63)	(+)(+)
Sjoholm T, 2014 (64)	(+)(+)
Škaričić J, 2020 (65)	(+)
Solanki N, 2017 (66)	(+)(+)(+)
Sun J, 2023 (67)	(+)(+)(+)(+)
Tanaka Y, 2020 (68)	(+)(+)
Wasinwasukul P, 2022 (69)	(+)(+)(+)(+)
Zhou J, 2021 (70)	(+)(+)

Discussion

Studies with good and moderate quality evidence included aspects of systemic and neurophysiological responses and biomechanical activity. They also evaluated the activity of mandibular advancement devices in patients with apnea.

Systemic aspects in studies with high and moderate quality of evidence.

Temporomandibular disorders associated with chronic pain and depression are linked to biomarkers of oxidative stress (71,72). Oxidative stress is the imbalance between the presence of reactive oxygen and nitrogen species and the body's ability to neutralize their effects through the antioxidant system (73), leading to excessive production of reactive oxygen. Antioxidants help reduce oxidative stress, protect DNA from malignant changes, and prevent cellular damage. Under normal conditions, the balance between pro-oxidants and antioxidants slightly favors pro-oxidants, creating a mild oxidative stress that can overwhelm the body's endogenous antioxidant defenses. A decrease in saliva's oxidant/antioxidant ratio suggests that its levels are associated with psychological conditions in patients with TMD (73,74). In the study by Alajbeg et al. (24), the effects of stabilization planes were compared with placebo planes, resulting in significant reductions in pain intensity and disability, which led to increased pain-free mandibular opening. Similarly, Castroflorio shows that intraoral devices reduce orofacial pain (29). Anxiety and especially depression also showed significant improvement when oxidative stress biomarkers were analyzed (73). This could explain the observed decrease in depression related to pain intensity in patients treated with occlusal planes for TMD management. Blood lactate levels have also been studied about pain (30). These studies noted decreased lactate levels, particularly in groups where a plane was combined with infrared light application. Combining these techniques further reduced pain in the masseter and temporal muscles, aiding in modulating the electrical activity of these muscles in individuals with myogenic TMD (without joint involvement). When the body's capacity to eliminate lactate is exceeded, homeostasis is disrupted (75). Lactate is a biomarker for nervous disorders, tissue hypoperfusion (reduced oxygen supply to tissues), physical activity intensity, and muscle fatigue; thus, more intense activity increases oxygen and energy demands, generating more lactate. Lowering circulating lactate likely reduces masticatory muscle pain. Using an occlusal plane may be linked to decreased muscle activity and lower blood lactate levels. Another systemic marker studied is from Karagozoglu et al. (40), who analyzed cortisol levels, dehydroepiandrosterone, and tumor necrosis factor alpha in the gingival fluid of bruxism patients. These stress and inflammation markers are associated with bruxism; cortisol levels also decline when bruxism decreases, suggesting that occlusal planes help reduce stress. Individuals with high stress-coping expectations activate regulatory mechanisms preemptively, which may improve stress response regulation (76). Salivary cortisol, a steroid hormone related to the hypothalamic-pituitary-adrenal axis, increases blood sugar, suppresses immune responses, and enhances fats, proteins, and carbohydrate metabolism. Elevated salivary cortisol levels may result from various conditions like obesity, atopic dermatitis, temporomandibular disorders, bruxism, and psychological issues such as phobias, depression, or anxiety—many of which are directly linked to stress (77).

Regarding tumor necrosis factor alpha, a decrease was observed after bruxism treatment with Botox, but not following treatment with occlusal planes. The reason for this discrepancy remains unclear. Concerning bruxism, reductions in episodes and pain have been reported with specific interocclusal appliances used with particular regimes and/or vibration therapy (29,50,53). Decreasing rhythmic masticatory activity helps reduce bruxism episodes (22). Regarding sleep quality, studies involving patients with apnea and bruxism found that mandibular advancement devices outperform CPAP in improving polysomnographic parameters and quality of life. However, no differences were noted in fatigue and mood (47). Some patients cannot tolerate CPAP, prompting research into alternative mandibular advancement devices, which improve sleep quality but do not significantly affect apnea or hypopnea rates (56,66). For bruxing patients, using an occlusal plane has been shown to enhance sleep quality (60). As mentioned earlier, the reduction in muscular activity among bruxism sufferers using an occlusal plane may be linked to deeper physiological responses reflected by various stress and pain markers (24,29,73,74,30,40).

Local motor and neurophysiological aspects in studies with high and moderate quality of evidence.

Occlusal and bite forces, muscle activity, electromyography, evoked motor potentials, and motor threshold are the neurophysiological aspects analyzed in this group. Regarding maximum bite force, a decrease was observed in subjects using soft planes, while an increase was seen in those using a complex occlusal aircraft (26). This reduction in maximum force with soft planes was attributed to muscle relaxation or increased patient awareness. However, maximum voluntary bite force depends on good muscle health and the absence of fatigue. The question remains: did the maximum bite force decrease in subjects with soft planes due to fatigue caused by constant clenching on the plane? Clenching the jaw with a soft occlusal plane causes fatigue, decreasing bite force and lower electromyographic values (78). This suggests that using a complex occlusal aircraft, rather than a soft one, creates a stable environment allowing the musculature to respond with full strength once stabilized surfaces are managed. Conversely, non-maximal occlusal forces are reduced in patients using a mandibular advancement plane, which produces a protrusive position but still provides a stable surface (66).

Regarding muscular activity observed through electromyography, it has been found that masseter muscle activity decreases after one week of using an occlusal plane. Still, this reduction does not persist after two weeks (50). The authors suggest this is due to peripheral sensory system effects and confirm that intermittent use of stabilization planes enables longer-lasting activity reduction. A similar short-term effect was observed in a study involving children with an anterior bite plane (69). Therefore, this review recommends alternating two or three different planes to prevent peripheral sensory system adaptation to a single occlusal pattern. We refer to stimuli that induce a potential when discussing evoked motor potentials and motor thresholds. Matsuzaki et al. (51) demonstrated that using a mandibular advancement device induces neuroplastic changes in the corticomotor pathways of the tongue and masseter muscles related to the new position. This effect is highly applicable to the long-term use of an occlusal plane over several hours. It provides a basis for studying how planes can manage muscle activity and help identify mandibular centric patterns in patients with occlusal instability.

Studies considered to have low or very low evidence quality were distributed as follows: With low quality of evidence: island activity (32,36), calcium and interleukin levels (43), bruxism (38,48,52,55), evoked motor potentials (33), sleep structure (64), quality of sleep (27,48,52), apnea/hypopnea index (63), upper airway (62), pain (28,32,36,43,48,59), muscle activity (28,59), masticatory force (36), occlusal forces (41,48), lingual force (27), occlusion (68), condylar structural changes (70), and cervical lordosis (61). With very low quality of evidence: brain activity (blood oxygenation level-dependent) (25), GABA and glutamate expression (34), balance and posture (35), muscle activity (44, 45), physical activity (44), masticatory force (45), occlusal force (54), plantar pressure (49), condylar position and bone quality (57,65), and mandibular and condylar movement (65).

The most interesting studies analyze systemic aspects in response to using occlusal planes. Alongside publications with high and moderate levels of evidence (22,24,29,30,40,47,50,53,56,60,66,71-76), there are also noteworthy papers examining calcium and interleukin levels (43), insular activity (32,36), brain activity (blood oxygenation level-dependent) (25), GABA and glutamate expression (34), bruxism (38,48,52,55), evoked motor potentials (33), sleep structure (64), sleep quality (27,48,52), apnea/hypopnea index (63), upper airway (62), and pain (28,32,36,43,48,59). Studies on calcium and interleukin levels (43) have demonstrated that using an occlusal splint for eight weeks in patients with Myofascial Pain Syndrome effectively reduces Ca^{2+} and IL-1β levels and increases the pressure pain threshold of the masseter and temporalis muscles, indicating a decrease in inflammation (43). IL-1β promotes monocyte chemoattractant protein 1 (MCP-1) in synoviocytes, making it a key factor in the inflammatory progression of temporomandibular disorders (TMD). Conversely, calcium regulates skeletal muscle development, homeostasis, and regeneration (84). These molecules are thus important in managing inflammation in joints and muscles. Publications focusing on the insula (32,36) highlight an area of neurophysiological interest where insular activity is studied. The insula contains four functionally distinct regions: 1) sensory-motor in the posterior middle insula; 2) olfactory-gustatory center; 3) socio-emotional in the anterior-ventral insula; and 4) cognitive in the anterodorsal region (79,80). Current research mainly focuses on the granular insula, particularly the dGIrvS2 region (dorsal part of the granular insula, ventral to the somatosensory cortex 2), which exclusively receives proprioceptive inputs from the muscle spindles of the mandibular elevator muscles. Notably, these impulses do not reach the primary somatosensory cortex (S1) or secondary somatosensory cortex (S2), unlike sensory signals from cutaneous, mucosal, or lingual tissues (81). This suggests that dGIrvS2 is a cortical area specialized in proprioception from mandibular elevators (32,36,82), projecting to the somatomotor, somatosensory, basal ganglia, and amygdala nuclei, and indicating that this region processes mandibular muscle information and transmits it to limbic and motor regions (81). This neuronal network is stimulated when a plane is inserted, generating projections to higher-level structures rather than directly to trigeminal motor nuclei. Although these studies are not all high-quality, this neurophysiological basis strongly supports using occlusal planes to manage various temporomandibular disorders. Research on brain activity (blood oxygenation level-dependent) (25) shows that biting with natural teeth or on an occlusal plane influences regional brain activity. In this study, during 6 minutes, activity in the prefrontal cortex was observed during clenching. Implementing a rigid occlusal plane and altering periodontal proprioception induces more widespread brain activation, increasing activity in the supplementary motor area, the temporal association area, and the prefrontal cortex—regions linked to motor coordination, memory, and cognition. This is because the rigid plane modifies vertical dimension and muscle fiber length, affecting occlusal information stored in memory. Such effects might trigger protective reflexes, as acrylic planes have been shown to increase periods of electromyographic silence (85). Regarding GABA and glutamate expression (34), there's evidence that bruxism—associated with teeth clenching and grinding—may involve changes in the GABAergic and glutamatergic systems in the brain. Several mechanisms involved in reducing muscle tone have been described, from sleep onset to the atonia of REM sleep. Brain stem regions (e.g., pontis oralis reticularis, pontis caudalis, parvocellular) and neurochemicals (e.g., serotonin, dopamine, GABA, norepinephrine) play roles in generating rhythmic mandibular movements and modulating muscle tone during sleep (86). Subjects with occlusal splints showing the lowest GABA+ levels in the dorsolateral prefrontal cortex may have inhibited anxiety circuits that influence bruxism. Reduced GABA levels have also been found in the frontal lobe of panic disorder patients, especially in the medial prefrontal cortex rather than the dorsolateral (34). Concerning sleep, studies on sleep structure (64), sleep quality (28,49,53), apnea/hypopnea index (63), and upper airway (62) demonstrate that conventional occlusal planes in bruxers and mandibular advancement devices in sleep apnea patients improve sleep quality and quality of life, reflected partly by reduced muscle activity. Studies on evoked motor potentials (33) and bruxism (38,48,52,55), along with higher-quality evidence (29,30,50,69), indicate that applying interocclusal planes of various types (e.g., feedback devices, mandibular advancement devices) can reduce bruxism episodes to different extents and alter corticomotor potentials due to vertical dimension changes (33,38,48,52,55). These responses are likely linked to central neurophysiological mechanisms discussed earlier. Regarding local motor and neurophysiological factors, numerous studies address muscle activity (28,44,45,59), physical activity (44), masticatory force (36,45), occlusal forces (41,48,54), lingual forces (27), condylar position and bone quality (57,65), condylar structural changes (70), mandibular and condylar movement (65), occlusion (68), cervical lordosis (61), balance and posture (35), plantar pressure (49), and pain (28,32,36,43,48,59). Due to the limited number and low quality of some of these studies, physical activity, occlusion, posture, and plantar pressure analysis remain limited. The other parameters are well documented in higher-quality evidence. Of particular interest is a study on a functional orthopedic device (by Planas) (28). Despite some limitations, it is a randomized controlled trial showing that flat tracks are more effective in reducing pain from myogenic or mixed pathologies. This finding supports using these devices in children and adolescents during growth, as they can accommodate typical morphological changes.

Conclusion

How splints work is a much-debated topic studied in the literature from various aspects, including systemic, neurophysiological, and biomechanical, showing varying levels of evidence quality. The most interesting studies analyze systemic elements in response to using occlusal planes. After a thorough analysis of the effects of the different types of occlusal planes, their use can be highly recommended for all patients suffering from temporomandibular pathology, bruxism, and mild sleep disorders.

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Conflicts of Interest

The authors declare no conflicts of interest.

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