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ORIGINAL ARTICLE

Effectiveness of conservative therapeutic modalities for temporomandibular disorders-related pain: a systematic review

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ABSTRACT

Purpose: The aim of this systematic review was to evaluate the effectiveness of conservative different therapeutic modalities for temporomandibular disorders (TMD) pain.

Materials and methods: An electronic systematic search was conducted in the MEDLINE (PubMed) database to identify the randomized clinical trials (RCTs) published between 2001 and 2021. The following, simple or multiple conjunctions, search keywords were selected: TMD pain, TMD management or conservative treatment or treatment strategies and TMD pain, therapeutic modalities or interventions and TMD. Studies included must have patients older than 18 years, with painful TMD, which diagnosis was performed by Research Diagnostic Criteria for TMD or Diagnostic Criteria for TMD. Outcome variables were pain relief and post treatment pain intensity reduction. Data were analysed with non-parametric tests and the level of significance was set at $p<.05$.

Results: Out of 1599 articles obtained, 28 RCTs fulfilled all selection criteria and were included. The results of this study show that there was a significant decrease in short-term post-treatment TMD pain with the use of occlusal splint alone or in combination with other therapeutic modalities when compared with the control group. Statistically significant differences were also detected between laser and photobiomodulation group and the control, in short-term treatment TMD-related pain.

Conclusions: The primary findings of the present systematic review showed that the occlusal splint alone or combined with other therapeutic intervention presented positive effect on short-term TMD pain reduction. Secondary outcome suggests that laser and photobiomodulation therapy had, also, a significant role in short term pain relief.

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Introduction

The term temporomandibular disorders (TMD) has been defined 'as a collective term involving a number of musculoskeletal and neuromuscular conditions related to the masticatory muscles, the temporomandibular joints (TMJs) and associated structures or both' [1]. It has been reported that the prevalence of TMD in children and adolescents varied widely from 7.3% to 30.4% and the most common TMD diagnosis was myofascial pain [2]. In addition, the most frequent presenting symptom of TMDs is pain, usually located or referred in the jaw muscles, the forehead, the TMJs, the preauricular area and the cervical region of spine or shoulder [3,4].

The aetiology of TMD has been shown to be multifactorial and several risk factors appear to initiate, predispose or prolong TMD-pain [3,5]. Based on a biopsychosocial framework that is valid for muscuskeletal disorders, aetiology of TMD involves structural, neurobiological, trauma, psychosocial factors and parafunctions [6–8]. Although sleep bruxism (SB) and parafunctional activities are generally believed to contribute to the development of TMD pain complaints, increasing evidence suggests that the occurrence of TMD pain is not related to the intensity of SB [9]. However, it is reported that highly stressing conditions like pandemic Covid 19 could be related with bruxism and painful TMD symptoms [10].

Recently, new approaches concerning TMD aetiology were presented. It is supported that TMD aetiology should be investigated in the field of molecular biology and genes [11]. Smith et al. [11] reported that the genetic factors present a great role at chronic and persistent pain conditions, by modulating nociceptive sensitivity, inflammation and autonomic response. Furthermore, Slade et al. [12] investigated several genes and supported their correlation with TMD painful symptoms, identifying them only at patients with such symptoms. The investigation of genetic etiologic factor opens a new therapeutic window for TMD.

Consequently, due to the multiplicity of aetiological factors associated with TMD, several treatment modalities have been proposed [13]. Different therapeutic options, some conservative and reversible, other irreversible, have been clinically used for the management of TMD [8,13,14]. Conservative

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therapeutic modalities that can eliminate the painful symptoms in jaw muscles and TMJs may include occlusal splints, physiotherapy, medications, biofeedback, low-level laser therapy, photobiomodulation, acupuncture, self-care management, ultrasound therapy and counselling [13–15]. Systematic reviews of conducted randomized controlled trials (RCTs) evaluating the effectiveness of different conservative treatment modalities for TMD pain presented conflicting results [13,15–17]. It has been reported that biofeedback can be useful in managing the activity of the masticatory muscles, but there is not sufficient evidence to support its effectiveness in patients with painful TMD [18]. There is also some evidence supporting the use of occlusal appliances, jaw exercises, acupuncture, behavioural therapy and pharmacotherapy for the TMD pain relieving [19]. Furthermore, it has been shown that occlusal splints produced a similar reduction in TMD pain compared to physiotherapy, pharmacological, behavioural medicine and acupuncture treatments [16]. Recent studies did not find sufficient evidence to distinguish the effectiveness of exercise therapy versus occlusal splints for treating painful TMD patients [20]. In contrast to these findings, the placebo effects in alleviating pain have been found to be responsible from 10% to 75% of TMD pain reduction [17]. Additionally, the results of some studies about the efficacy of occlusal appliances demonstrated that there is moderate to very low-quality evidence confirming the effectiveness of occlusal splint therapy in the TMD management [15,19]. However, all types of occlusal splints provide more effective therapy for myogenous or/and arthrogenous TMD when compared to no treatment (untreated control patients) and non-occluding splints use for pain outcome [15].Contradictory results in the literature about the efficacy of therapeutic modalities on TMD pain may be attributable to the heterogeneity of the patient samples included, differences in patients' psychosocial background factors, lack of strict criteria for the diagnosis of TMD and different periods of follow-up [13,14,19].

It is still unclear which therapeutic modality is the most effective in providing TMD pain relief and whether occlusal splint therapy offer additional benefit compared with other TMD treatment approaches. Treatment effectiveness studies are important in dental practice due to their clinical relevance. Subsequently, the aim of this systematic review of RCTs was to assess the effectiveness of conservative different therapeutic modalities in the TMD pain.

Materials and methods

This systematic review protocol was registered at the International Prospective Register of Systematic Reviews (PROSPERO) under the identification number CRD42021252489. The systematic review was conducted following the guidelines of the Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA) [21]. An electronic systematic search was conducted by two independent authors (A.T. and B.S.) in the MEDLINE (PubMed) database to identify the RCTs published between 2001 and 2021. The search was limited to the English language. The focussed question of the search was in a Population, Intervention, Comparison, Outcome (PICO) format as follows: 'in patients with TMDs-related pain, which type or combination of conservative treatment approach is the most effective as far as pain relief and post treatment pain intensity reduction are concerned'? The PICO format justification and Medical Subject Headings (MeSH) terms are presented in Table 1.

Table 1. PICO format justification and search terms.

Population	Patients with TMD-related pain. The diagnosis had to be based on the RDC/TMD or DC/TMD protocol.
Intervention	Conservative different therapeutic modalities for TMD-pain
Comparison	Compared the effectiveness of the different conservative TMD-pain treatments
Outcome	Pain relief and post-treatment pain intensity reduction
Study designs	Randomized clinical trials (RCTs)
MeshTerms for PubMed	TMD pain, TMD management OR conservative treatment OR treatment strategies AND TMD pain, therapeutic modalities OR treatment interventions AND TMD

Initially, based on the type of publication, studies such as reviews, prospective and retrospective studies, case report, systematic reviews and meta-analysis were excluded from the search. Mendeley, a reference manager software program, was used to discard the duplicates files electronically. Studies were then excluded based on data from titles and abstract screening. If title and abstract did not provide sufficient information, the full text was obtained and assessed for eligibility based on the inclusion/exclusion criteria. With regard to inclusion criteria, RCTs included must had patients older than 18 years, with painful TMD, which diagnosis was performed by Research Diagnostic Criteria for TMD (RDC/TMD) [22] or Diagnostic Criteria for TMD (DC/TMD) [23] and were using tools and/or scales (visual analogue scale [VAS], numerical rating scale [NRS], characteristic pain intensity [CPI], pressure pain threshold [PPT]) to assess TMD pain.

In contrast, data were extracted with the following details: articles with age of patients younger than 18 years, articles did not involve painful TMD, articles did not use diagnostic criteria either RDC/TMD or DC/TMD and papers did not use any tools and/or scales to assess TMD pain. Any discrepancies during this search strategy were resolved by analysing the reasons for disagreement by a third author (D.T.), to achieve a consensus.

The assessment of risk of bias was done independently by the two authors (A.T. and B.S.) using the Cochrane risk of bias tool [24] with response options of 'low risk', 'unclear risk', 'high risk' for following criteria: random sequence generation, allocation concealment, blinding of participants, incomplete outcome data, selective outcome reporting and other bias. The potential risk of bias was considered as 'low' if a study provided detailed data on all the parameters. A study was considered to have an 'unclear risk' if it failed to provide information on only one of the parameters. Finally, a study was considered to have a 'high risk' of bias when was failing to provide information regarding $\geq$2 parameters.

Data statistical analysis

Descriptive statistics were used in the initial analysis of the whole data set. The mean values, standard deviations and standard error of mean were estimated using data extracted from the full text of the included articles. Statistical heterogeneity was addressed using the chi-square test. The correlation coefficient, the nonparametric Spearman's rho coefficient, was calculated in an effort to trace any possible relation between parameters and methods outcomes.

Nonparametric tests were applied so as to identify inconsistencies in distribution between the therapeutic modalities outcomes under study. The Kruskal–Wallis *H* test and the Mann–Whitney U test were used to detect any possible differences between therapeutic methods outcomes. The significance level was set at p value$<.05$ throughout the analysis in order to indicate significant statistical difference among the therapeutic modalities. All statistical analyses were carried out with SPSS version 27 statistical software (IBM, Armonk, NY).

Results

Characteristics of included studies

The study search strategy flowchart diagram is shown in Figure 1. A total of 1599 records were identified from databases searches. Only 28 studies succeeded in meeting the inclusion criteria and were included in the present systematic review. The different conservative therapeutic modalities (occlusal splint, biofeedback, cognitive behavioural training, hypnosis, physiotherapy, low-level laser therapy, photobiomodulation, acupuncture, counselling and Botulinum Toxin A) and the characteristics of the included studies (authors, year of publication, study design, therapeutic modality, TMD diagnosis, pain measurement and sample number) are summarized in Figure 2. Follow-up periods for the post-treatment pain reduction were divided into short term ($\leq$5 months) and long term ($\geq$6 months).

Out of the 28 studies, 1 study used biofeedback [25], 3 studies used cognitive behavioural training [25–27], 3 studies evaluated Botulinum Toxin A [28–30], 7 studies used the

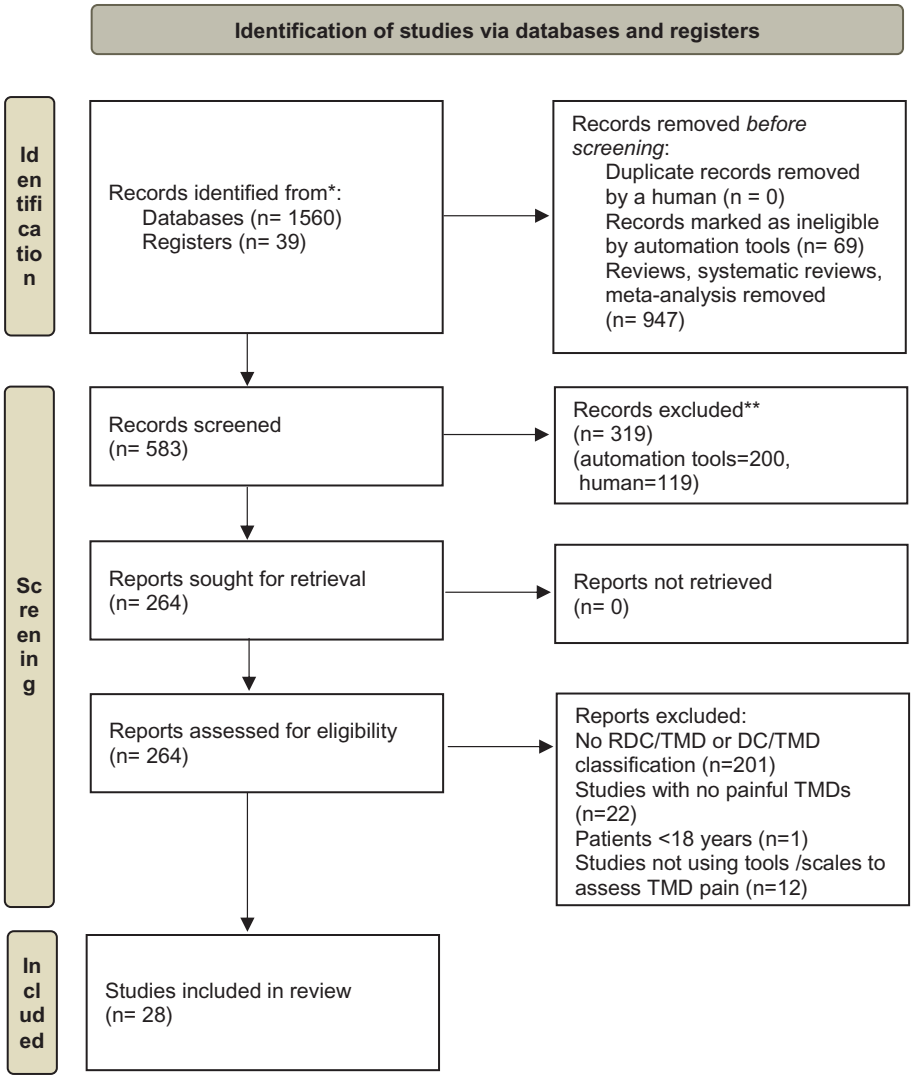

Figure 1. Search strategy PRISMA 2020 flowchart diagram. *Consider, if feasible to do so, reporting the number of records identified from each database or register searched (rather than the total number across all databases/registers). **If automation tools were used, indicate how many records were excluded by a human and how many were excluded by automation tools.

No.	Author/Year	Title	Study Design	Treatment Modality	Diagnosis	Pain Measurement	Sample Number
1	Gardea et al,[25] 2001	Long-term efficacy of biobehavioral treatment of temporomandibular disorders	RCT	Biofeedback, Cognitive Behavioral Training, Combined Treatment, Control	RDC/TMD	CPI	Biofeedback Group (n=27), CBT Group (n=24), Combined Treatment Group (n=29), Control Group (n=28)
2	Dworkin et al,[26] 2002 (1)	A randomized clinical trial using research diagnostic criteria for temporomandibular disorders-axis II to target clinic cases for a tailored self-care TMD treatment program	RCT	Cognitive Behavioral Training, Occlusal Splint + Other Methods	RDC/TMD	CPI	CBT Group (n=61), Occlusal Splint Group (n=63)
3	Dworkin et al,[27] 2002 (2)	A randomized clinical trial of a tailored comprehensive care treatment program for temporomandibular disorders	RCT	Cognitive Behavioral Training, Occlusal Splint + Other Methods	RDC/TMD	CPI	CBT Group (n=59), Occlusal Splint Group (n=58)
4	Nixdorf et al,[28] 2002	Randomized controlled trial of botulinum toxin A for chronic myogenous orofacial pain	RCT	Botulinum Toxin A, Placebo	RDC/TMD	VAS	BTX-A Group (n=15)
5	Ekberg et al,[31] 2003	The efficacy of appliance therapy in patients with temporomandibular disorders of mainly myogenous origin. A randomized, controlled, short-term trial	RCT	Occlusal Splint, Control	RDC/TMD	VAS	Occlusal Splint Group (n=30), Control Group (n=30)
6	Wahlundet al,[47] 2003	Treatment of temporomandibular disorders among adolescents: a comparison between occlusal appliance, relaxation training, and brief information	RCT	Occlusal Splint + Brief Information, Brief information + Relaxation Therapy, Brief Information	RDC/TMD	VAS	Occlusal Splint + Brief Info Group (n=42), Brief Info + Relaxation Group (n=41) Brief Info Group (n=39)

Figure 2. Therapeutic modalities and characteristics of the included studies. RCT: Research Clinical Trial; RDC/TMD: Research Diagnostic Criteria for TMD; DC/TMD: Diagnostic Criteria for TMD; VAS: visual analogue Scale; NRS: numeric rating scale; CPI: characteristic pain intensity; PPT: pressure pain threshold; CBT: cognitive behavioural training; BTX-A: botulinum toxin A; NTI Splint: Nociceptive Trigeminal Inhibition Splint.

7	Ekberg et al,[32] 2004	Treatment outcome of appliance therapy in temporomandibular disorder patients with myofascial pain after 6 and 12 months	RCT	Occlusal Splint, Control	RDC/TMD	VAS	Occlusal Splint Group (n=30), Control Group (n=30)
8	Abrahamsen et al,[45] 2009	Effect of hypnosis on oral function and psychological factors in temporomandibular disorders patients	RCT	Hypnosis, Control	RDC/TMD	NRS	Hypnosis Group (n=21), Control Group (n=22)
9	Li et al,[46] 2009	Clinical effect of a topical herbal ointment on pain in temporomandibular disorders: a randomized placebo-controlled trial	RCT	Ping On Ointment, Placebo	RDC/TMD	VAS	Ping On Ointment Group (n=23), Placebo Group (n=22)
10	Ernberg et al,[29] 2011	Efficacy of botulinum toxin type A for treatment of persistent myofascial TMD pain: a randomized, controlled, double-blind multicenter study	RCT	Botulinum Toxin A, Control	RDC/TMD	CPI	BTX-A Group (n=12), Control Group (n=9)
11	Nilsson et al,[33] 2011	Long-term efficacy of resilient appliance therapy in TMD pain patients: a randomised, controlled trial	RCT	Occlusal Splint, Control (palatal non occluding devise)	RDC/TMD	VAS	Occlusal Splint Group (n=36), Control Group (n=37)
12	Conti et al,[34] 2012	Behavioural changes and occlusal splints are effective in the management of masticatory myofascial pain: a short-term evaluation	RCT	Occlusal Splint + counselling, NTI Splint + counselling, Control (counselling)	RDC/TMD	VAS, PPT	Occlusal Splint Group (n=21), NTI Splint Group (n=16), Control Group (n=14)
13	Guarda-Nardini et al,[30] 2012	Myofascial pain of the jaw muscles: comparison of short-term effectiveness of botulinum toxin injections and fascial manipulation technique	RCT	BotulinumToxin A, Fascial Manipulation	RDC/TMD	VAS	BTX-A Group (n=15), Fascial Manipulation Group (n=15)
14	Niemela et al,[49] 2012	Efficacy of stabilisation splint treatment on temporomandibular disorders	RCT	Occlusal Splint + counselling + muscle exercise, Control (counselling + muscle exercise)	RDC/TMD	VAS	Occlusal Splint Group (n=39), Control Group (n=41)

Figure 2. Continued.

15	Rodrigues et al,[38] 2013	Evaluation of pain, jaw movements, and psychosocial factors in elderly individuals with temporomandibular disorder under laser phototherapy	RCT	Laser Phototherapy	RDC/TMD	VAS	Laser Phototherapy Group (n=10)
16	Shedden Mora et al,[52] 2013	Biofeedback-based cognitive-behavioral treatment compared with occlusal splint for temporomandibular disorder: a randomized controlled trial	RCT	Occlusal Splint, Biofeedback + Cognitive Behavioral Training	RDC/TMD	CPI	Occlusal Splint Group (n=29), Biofeedback + CBT Group (n=29)
17	Demirkol et al,[35] 2013	Effectiveness of occlusal splints and low-level laser therapy on myofascial pain	RCT	Occlusal Splint, Low Level Laser Therapy, Control	RDC/TMD	VAS	Occlusal Splint Group (n=10), Low Level Laser Therapy Group (n=10), Control Group (n=10)
18	Katyayan et al,[50] 2014	Efficacy of appliance therapy on temporomandibular disorder related facial pain and mandibular mobility: a randomized controlled study	RCT	Occlusal Splint + counselling + muscle exercise, Control (counselling + muscle exercise)	RDC/TMD	VAS	Occlusal Splint Group (n=40), Control Group (n=40)
19	Qvintus et al,[39] 2015	Efficacy of stabilisation splint treatment on facial pain - 1-year follow-up	RCT	Occlusal Splint + counselling + muscle exercise, Control (counselling + muscle exercise)	RDC/TMD	VAS	Occlusal Splint Group (n=39), Control Group (n=41)
20	Sancakli et al,[51] 2015	Early results of low-level laser application for masticatory muscle pain: a double-blind randomized clinical study	RCT	Laser Therapy, Placebo	RDC/TMD	VAS	Laser Therapy Group I (n=10), Laser Therapy Group II (n=10), Placebo Group (n=10),
21	Wahlund et al,[36] 2015	Treating temporomandibular disorders in adolescents: a randomized, controlled, sequential	RCT	Occlusal Splint, Relaxation Training	RDC/TMD	NRS	Occlusal Splint Group (n=33), Relaxation Training

Figure 2. Continued.

		comparison of relaxation training and occlusal appliance therapy					Group (n=31)
22	Hasanoglu et al,[48] 2017	Can an NTI-tss device be effective as a first-line therapy in patients with TMD myofascial pain?	RCT	NTI Splint + counselling, Control (counselling)	RDC/TMD	VAS	NTI Splint Group (n=20), Control Group (n=20)
23	Magri et al,[40] 2017	Non-specific effects and clusters of women with painful TMD responders and non-responders to LLLT: double-blind randomized clinical trial	RCT	Low Level Laser Therapy, Placebo, No treatment	RDC/TMD	VAS	Low Level Laser Therapy Group (n=20), Placebo Group (n=21), Control Group (n=23)
24	Manfredini et al,[41] 2017	A comparison trial between three treatment modalities for the management of myofascial pain of jaw muscles: A preliminary study	RCT	Laser Therapy, Occlusal Splint, Counseling	DC/TMD	VAS	Laser Therapy Group (n=10), Occlusal Splint Group (n=10), Counseling Group (n=10),
25	Brochado et al,[42] 2018	Comparative effectiveness of photobiomodulation and manual therapy alone or combined in TMD patients: a randomized clinical trial	RCT	Photobiomodulation, Manual Therapy, Combined Treatment	RDC/TMD	VAS	Photobiomodulation Group (n=18), Manual Therapy Group (n=16), Combined Treatment Group (n=17)
26	Herpich et al,[43] 2019	Intraoral photobiomodulation diminishes pain and improves functioning in women with temporomandibular disorder: a randomized, sham-controlled, double-blind clinical trial	RCT	Photobiomodulation, Placebo	RDC/TMD	VAS	Photobiomodulation Group (n=15), Placebo Group (n=15)

Figure 2. Continued.

occlusal splint as a therapeutic modality [31–37], 5 studies used Laser therapy [35,38–41] and 2 studies used Photobiomodulation [42,43]. Additionally, one study investigated acupuncture [44], one study used hypnosis [45], one study used ping on ointment [46], five studies used counselling [34,37,41,47,48], four studies used manual or relaxation therapy [36,37,42,47], nine studies investigated occlusal splint along with a combination of other methods [26,27,34,37,39,47–50] and seven studies used a combination of other methods [25,35,39,42,47,49,50].

Overall, RDC/TMD was used in 27 out of the 28 studies for the TMD diagnosis whereas DC/TMD was used in only one [41]. In 20 studies, the pain measurement scale used was the VAS [28,30–33,35,37–43,46–51], CPI was used in 5 studies [25–27,29,52], NRS was used in 2 studies [36,45] and in 1 study PPT was used along with VAS [34].

27	Melo et al,[37] 2020	Conservative therapies to treat pain and anxiety associated with temporomandibular disorders: a randomized clinical trial	RCT	Occlusal Splint, Occlusal Splint + Counseling, Counseling, Manual Therapy	RDC/TMD	VAS	Occlusal Splint Group (n=24), Occlusal Splint + Counseling Group (n=25), Counseling Group (n=19), Manual Therapy Group (n=21)
28	Salles-Neto et al,[44] 2020	Acupuncture for pain, mandibular function and oral health-related quality of life in patients with masticatory myofascial pain: A randomised controlled trial	RCT	Acupuncture, Control	RDC/TMD	VAS	Acupuncture Group (n=16), Control Group (n=16)

Figure 2. Continued.

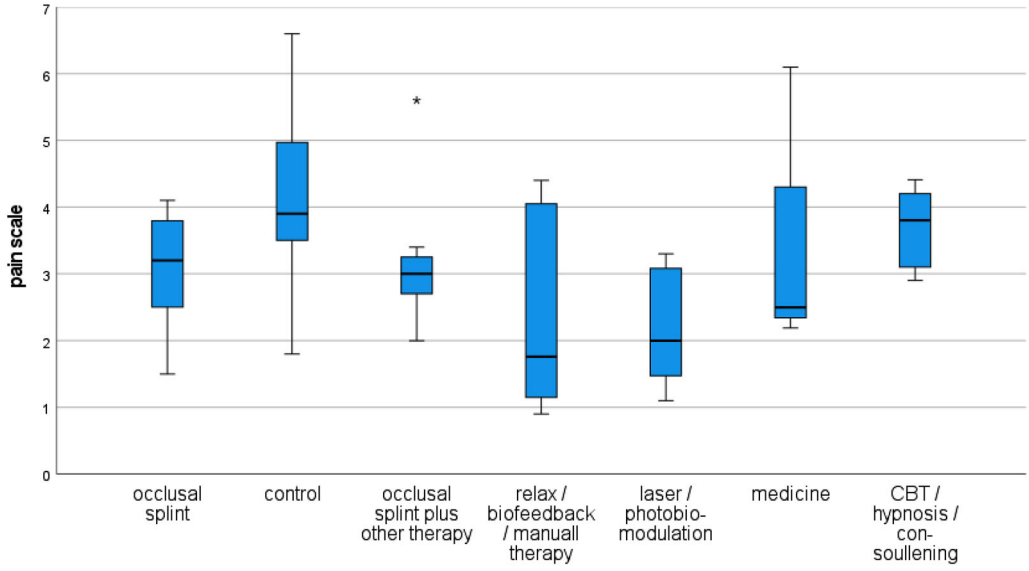

Figure 3. The boxplot showing mean intensity summary statistics of the therapeutic modalities outcomes in short term.

Table 2. Comparisons between therapeutic modalities outcomes in groups.

	Therapeutic modalities	Test performed	*p* Value
1.	Occlusal splint *vs.* occlusal splint plus other therapy *vs.* control *vs.* other therapy	Kruskal–Wallis	.047
2.	Other therapy *vs.* control	Mann–Whitney	.011
3.	Occlusal splint plus other therapy *vs.* control	Mann–Whitney	.019
4.	Laser *vs.* photobiomodulation *vs.* control	Kruskal–Wallis (pairwise comparison)	.033
5.	Occlusal splint *vs.* laser	Mann–Whitney	.035
6.	Control *vs.* laser	Mann–Whitney	.001

According to Cochrane risk of bias tool [24], 8 studies characterized as 'high risk', around 4 had 'unclear risk' for selection bias, while 16 assessed as 'low risk' for performance bias. Statistical analysis of the therapeutic modalities outcomes revealed a statistical significant difference in short-term post-treatment TMD pain with the use of occlusal splint alone or in combination with other therapeutic modality when compared with the control group. The descriptive statistics indices of the studied therapeutic modalities outcomes are presented in Figure 3.

Concerning the effectiveness of treatment regarding pain reduction, occlusal splint group presented statistically significant difference compared to other conservative therapeutic modalities and more specific laser, photobiomodulation and acupuncture (Table 2). Statistically significant differences were also detected between laser and photo-modulation

group and the control group, in short-term post-treatment TMD pain (Table 2).

Discussion

The complexity of the etiopathogenesis of TMD renders its diagnosis rather difficult, while therapeutic approach varies and the recommendation of a 'gold standard' concerning TMD management remains a challenge. As muscle and/or joints, pain is the main complaint of TMD patients, pain relief is the most common reason why these patients seek dental therapy [3,8]. Different conservative and reversible interventions have been suggested for TMD management[53–55]. In every day clinical practice, conservative therapeutic modalities are used more often to restrict or eliminate painful TMD symptoms. Occlusal splint, photomodulation, low-level laser, acupuncture, biofeedback, cognitive behavioural training, hypnosis, botulinum Toxin A, muscle exercise, medications and transcutaneous electrical nerve stimulation (TENS) are some of the proposed appropriate treatment protocols [13,14,53,54].

The main findings of this study regarding the TMD pain reduction showed that occlusal splint and occlusal splint combined with other therapeutic intervention have a superior short-term treatment effect, followed by photobiomodulation and low-level laser therapy. The results revealed a superiority of occlusal splint alone or combined with other therapeutic intervention when compared to control (untreated or patients whose treatment was non-invasive such as counselling and relaxation). Furthermore, the use of occlusal splint was more effective when compared to the other TMD treatment modalities. Significant differences were also detected between low-level laser and photomodulation group and the control group, in short-term post-treatment TMD pain.

The results of this study are in accordance with previous studies comparing the positive outcome of occlusal splints with that of a control group and with those RCTs studies that have shown stabilisation splints are more effective than other TMD treatments [13,31–34]. Occlusal splints, especially stabilisation splint (also known as the Michigan splint) are the most recommended therapeutic modality for painful TMD patients of both myogenous and arthrogenus origin [13,19,31,32]. Stabilisation splints have been widely used to protect the teeth from tooth wear, to restore the neuromuscular balance and to reduce pain in TMD patients [16,31,56].

On the other hand, the findings of this study are in contrast with those RCTs that have shown stabilisation splint therapy does not offer any additional benefit compared with other conservative treatment interventions [37,54]. Furthermore, Fricton [16] found that stabilisation splints were equally effective in short-term TMD pain reduction compared to physical and behavioural medicine and acupuncture therapy. Additionally, comparable results concerning pain intensity reduction were reported for occlusal splint therapy and biofeedback method [55]. Wieckiewicz et al. [14] stated that the various non-invasive and conservative treatments including counselling, exercises, occlusal splint, massage, manual therapy should be considered as a first choice therapy for TMD pain because of their low risk of side effects.

Although these clinical studies evaluated the effectiveness of different treatment approaches, sample sizes, diagnostic criteria for TMD, degree of pain perception, psychological factors and experimental therapeutic strategies, duration of follow-up differ significantly. The variety in these parameters of the proposed protocols renders their comparison difficult. Additionally, a key point at these studies was the observation time. Short-term results may not detect differences concerning the efficacy of conservative treatment modalities. A systematic review of existed RCTs could provide the evidence to establish which conservative TMD pain therapeutic modality is the most effective in short-term follow-up.

The results of this study are in agreement with previous studies that have shown the effectiveness of photobiomodulation, low-level laser therapy and occlusal splint in reducing TMD pain [35,50,51]. Photobiomodulation is a general term, used as an umbrella including low level laser treatment. Low-level laser therapy was used in TMDs management, presenting satisfying results in pain control and function/jaw movement [57]. Although, laser irradiation reported to be effective on pain control, its effectiveness was under doubt as Herpich et al. [43] supported that laser treatment group presented comparable results with laser placebo group. Other conservative treatment modalities such acupuncture, dry needling and substance injection were also applied for TMD myalgia management [37]. A systematic review investigating acupuncture (traditional, trigger point and laser) provided evidence that their effectiveness in muscle TMD pain were similar to stabilisation splint [58]. Furthermore, it has been reported only short-term improvement in TMD muscle pain. At the same study, the authors reported that acupuncture effectiveness in muscle pain was comparable to placebo acupuncture [58]. Additionally, comparable results concerning pain intensity and disability were reported for occlusal splint therapy and biofeedback conservative method [55]. These findings reveal that in case of application of modern treatment modalities psychological factors play a significant role to the final result. Although many studies supported the efficacy of different conservative treatments (exercises, laser and phototherapy), none of them was proved to be more beneficial than occlusal splint [59]. Moreover, it is widely supported that the predictable treatment protocol application could download or even eliminate TMD painful signs and symptoms [60].

In case of investigations studying the efficacy of occlusal splint only, there were no placebo group, while in case of studies comparing different conservative treatment approaches which including placebo group, statistical significance reported between occlusal splint group and placebo group. This is a major difference between occlusal splint group and groups of non-invasive therapies including laser or acupuncture, indicating that occlusal splints have the potential to be more effective in TMD pain management [57].

The painful TMD symptoms were supported to affect quality of life [61]. Dahlström and Carlsson [61] reported that there was a controversy concerning TMD impact on oral health-related quality of life [OHRQoL]. Although some investigators supported that TMD effect on quality of life was

greater than that of periodontal, dental [62] or neurologic/vascular orofacial pain conditions [63,64] others found this impact to be similar to that of other dental conditions [63,64]. It seems that pain is rather an unpleasant and annoying symptom that could compromize the quality of life. The degree that TMD affect quality of life depends on the severity and duration of pain and restriction of function [61]. That is why, controlling the severity of pain or reducing pain symptoms is crucial in clinical practice and many studies have been contacted in order to establish the appropriate protocol for TMD pain management. It has been reported that the therapeutic protocol should be based on the medical history, the aetiology and the severity of pain symptoms [65]. Investigators tried to identify markers of pain using physical examination and questionnaires, in order to open a new therapeutic window to the clinicians [65]. Detection of biomarkers associated with painful TMDs based on neural recordings could allow the prediction of the severity of pain at TMD patients. Identification of such biomarkers could be helpful in understanding of TMD pain pattern [66].This finding could be the first step in order to establish combined effective treatment protocols on TMD painful symptoms, satisfying patients and improving their quality of life. It is supported that more research is needed before establishing global interpretations of management efficacy [15,56].

Some limitations of this systematic review should be addressed. Methodological problems in the majority of studies that were reviewed complicated definitive conclusions and point to the need for more well-controlled RCTs with appropriate methods. Heterogeneity among the number of studies concerning the different TMD subgroups was a major drawback. The myogenous or arthrogenous TMD sub-groups also presented heterogeneity rendering difficult the analysis of the result of the articles included. Additionally, the measurement of TMD pain influenced by the patient's subjective experiences and may have introduced bias into this study. Also, due to the multifactorial aetiology of TMD, the majority of the patients report psychosocial complications. However, none of the included studies focussed on other treatment outcomes such as psychological impairment and depression therapy.

Conclusion

Systematic review of RCTs investigating the effectiveness of different TMD pain treatment modalities could reveal the superiority of some therapeutic protocols compared to others.

Based on the results of this systematic review it could be concluded that:

- The primary findings of this systematic review showed that the occlusal splint alone or combined with other therapeutic modality was the most effective treatment option for TMD pain reduction in short-term follow-up.
- Secondary outcome suggest that low-level laser and photomodulation treatment options had, also, a significant role in short-term pain relief, despite the fact that their effectiveness was rank lower than the occlusal splint therapy.

However, the efficacy of the occlusal splint therapy and other treatment modalities on TMD pain in long-term follow-up remains to be confirmed.

Disclosure statement

No potential conflict of interest was reported by the authors.

References

[1] Peck CC, Goulet JP, Lobbezoo F, et al. Expanding the taxonomy of the diagnostic criteria for temporomandibular disorders. J Oral Rehabil. 2014;41(1):2–23.

[2] Christidis N, Lindström Ndanshau E, Sandberg A, et al. Prevalence and treatment strategies regarding temporomandibular disorders in children and adolescents-A systematic review. J Oral Rehabil. 2019;46(3):291–301.

[3] Fernandes G, van Selms MKA, Gonçalves DAG, et al. Factors associated with temporomandibular disorders pain in adolescents. J Oral Rehabil. 2015;42(2):113–119.

[4] Wieckiewicz M, Grychowska N, Nahajowski M, et al. Prevalence and overlaps of headaches and Pain-Related temporomandibular disorders among the polish urban population. J Oral Facial Pain Headache. 2020;34(1):31–39–39.

[5] Greene CS. The etiology of temporomandibular disorders: implications for treatment. J Orofac Pain. 2001;15(2):93–105.

[6] Suvinen TI, Reade PC, Kemppainen P, et al. Review of aetiological concepts of temporomandibular pain disorders: towards a biopsychosocial model for integration of physical disorder factors with psychological and psychosocial illness impact factors. Eur J Pain. 2005;9(6):613–633.

[7] Tournavitis A, Tortopidis D, Fountoulakis K, et al. PsychopathologicProfiles of TMD patients with different pain locations. Int J Prosthodont. 2017;30(3):251–257.

[8] List T, Jensen RH. Temporomandibular disorders: old ideas and new concepts. Cephalalgia. 2017;37(7):692–704.

[9] Smardz J, Martynowicz H, Michalek-Zrabkowska M, et al. Sleep bruxism and occurrence of temporomandibular Disorders-Related pain: a polysomnographic study. Front Neurol. 2019;10:168.

[10] Emodi-Perlman A, Eli I, Smardz J, et al. Temporomandibular disorders and bruxism outbreak as a possible factor of orofacial pain worsening during the COVID-19 Pandemic-Concomitant research in two countries. J Clin Med. 2020;9(10):3250.

[11] Smith SB, Maixner DW, Greenspan JD, et al. Potential genetic risk factors for chronic TMD: genetic associations from the OPPERA case control study. J Pain. 2011;12(11):T92–101.

[12] Slade GD, Ohrbach R, Greenspan JD, et al. Painful temporomandibular disorder: decade of discovery from OPPERA studies. J Dent Res. 2016;95(10):1084–1092.

[13] List T, Axelsson S. Management of TMD: evidence from systematic reviews and metaanalyses. J Oral Rehabil. 2010;37(6):430–451.

[14] Wieckiewicz M, Boening K, Wiland P, et al. Reported concepts for the treatment modalities and management of temporomandibular disorders. J Headache Pain. 2015;16:106.

[15] Al-Moraissi EA, Farea R, Qasem KA, et al. Effectiveness of occlusal splint therapy in the management of temporomandibular disorders: network meta-analysis of randomized controlled trials. Int J Oral Maxillofac Surg. 2020;49(8):1042–1056.

[16] Fricton J. Current evidence providing clarity in management of temporomandibular disorders: summary of a systematic review of randomized clinical trials for intra-oral appliances and occlusal therapies. J Evid Based Dent Pract. 2006;6(1):48–52.

[17] Porporatti AL, Costa YM, Réus JC, et al. Placebo and nocebo response magnitude on temporomandibular disorder related-pain: a systematic review and meta-analysis. J Oral Rehabil. 2019;46(9):862–882. Sep

[18] Florjanski W, Malysa A, Orzeszek S, et al. Evaluation of biofeedback usefulness in masticatory muscle activity Management-A systematic review. J Clin Med. 2019;8(6):766.
[19] Ebrahim S, Montoya L, Busse JW, et al. The effectiveness of splint therapy in patients with temporomandibular disorders: a systematic review and meta-analysis. J Am Dent Assoc. 2012;143(8):847–857.
[20] Zhang L, Xu L, Wu D, et al. Effectiveness of exercise therapy versus occlusal splint therapy for the treatment of painful temporomandibular disorders: a systematic review and meta-analysis. Ann Palliat Med. 2021;10(6):6122–6132.
[21] Page MJ, McKenzie JE, Bossuyt PM, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ. 2021;372:n71.
[22] Dworkin SF, LeResche L. Research diagnostic criteria for temporomandibular disorders: review, criteria, examinations and specifications, critique. J Craniomandib Disord. 1992;6(4):301–355.
[23] Schiffman E, Ohrbach R, Truelove E, et al. Diagnostic criteria for temporomandibular disorders (DC/TMD) for clinical and research applications: recommendations of the international RDC/TMD consortium network* and orofacial pain special interest group. J Oral Facial Pain Headache. 2014;28(1):6–27.
[24] Higgins JT, Green S. Cochrane handbook for systematic reviews of interventions. Version 5.1.0. London: The Cochrane Collaboration; 2011.
[25] Gardea MA, Gatchel RJ, Mishra KD. Long-term efficacy of biobehavioral treatment of temporomandibular disorders. J Behav Med. 2001;24(4):341–359.
[26] Dworkin SF, Huggins KH, Wilson L, et al. A randomized clinical trial using research diagnostic criteria for temporomandibular disorders-axis II to target clinic cases for a tailored self-care TMD treatment program. J Orofac Pain. 2002;16(1):48–63.
[27] Dworkin SF, Turner JA, Mancl L, et al. A randomized clinical trial of a tailored comprehensive care treatment program for temporomandibular disorders. J Orofac Pain. 2002;16(4):259–276.
[28] Nixdorf DR, Heo G, Major PW. Randomized controlled trial of botulinum toxin A for chronic myogenous orofacial pain. Pain. 2002;99(3):465–473.
[29] Ernberg M, Hedenberg-Magnusson B, List T, et al. Efficacy of botulinum toxin type A for treatment of persistent myofascial TMD pain: a randomized, controlled, double-blind multicenter study. Pain. 2011;152(9):1988–1996.
[30] Guarda-Nardini L, Stecco A, Stecco C, et al. Myofascial pain of the jaw muscles: comparison of short-term effectiveness of botulinum toxin injections and fascial manipulation technique. Cranio. 2012; 30(2):95–102.
[31] Ekberg E, Vallon D, Nilner M. The efficacy of appliance therapy in patients with temporomandibular disorders of mainly myogenous origin. A randomized, controlled, short-term trial. J Orofac Pain. 2003;17(2):133–139.
[32] Ekberg E, Nilner M. Treatment outcome of appliance therapy in temporomandibular disorder patients with myofascial pain after 6 and 12 months. Acta Odontol Scand. 2004;62(6):343–349.
[33] Nilsson H, Vallon D, Ekberg EC. Long-term efficacy of resilient appliance therapy in TMD pain patients: a randomised, controlled trial. J Oral Rehabil. 2011;38(10):713–721.
[34] Conti PC, de Alencar EN, da MotaCorrêa AS, et al. Behavioural changes and occlusal splints are effective in the management of masticatory myofascial pain: a short-term evaluation. J Oral Rehabil. 2012;39(10):754–760.
[35] Demirkol N, Sari F, Bulbul M, et al. Effectiveness of occlusal splints and low-level laser therapy on myofascial pain. Lasers Med Sci. 2015;30(3):1007–1012.
[36] Wahlund K, Nilsson IM, Larsson B. Treating temporomandibular disorders in adolescents: a randomized, controlled, sequential comparison of relaxation training and occlusal appliance therapy. J Oral Facial Pain Headache. 2015;29(1):41–50.
[37] Melo RA, de Resende CMBM, Rêgo CRF, et al. Conservative therapies to treat pain and anxiety associated with temporomandibular disorders: a randomized clinical trial. Int Dent J. 2020;70(4): 245–253.
[38] Rodrigues JH, Marques MM, Biasotto-Gonzalez DA, et al. Evaluation of pain, jaw movements, and psychosocial factors in elderly individuals with temporomandibular disorder under laser phototherapy. Lasers Med Sci. 2015;30(3):953–959.
[39] Qvintus V, Suominen AL, Huttunen J, et al. Efficacy of stabilisation splint treatment on facial pain - 1-year follow-up. J Oral Rehabil. 2015;42(6):439–446. Jun
[40] Magri LV, Carvalho VA, Rodrigues FCC, et al. Non-specific effects and clusters of women with painful TMD responders and non-responders to LLLT: double-blind randomized clinical trial. Lasers Med Sci. 2018;33(2):385–392.
[41] Manfredini D, Favero L, Cocilovo F, et al. A comparison trial between three treatment modalities for the management of myofascial pain of jaw muscles: a preliminary study. Cranio. 2018;36(5):327–331.
[42] Brochado FT, Jesus LH, Carrard VC, et al. Comparative effectiveness of photobiomodulation and manual therapy alone or combined in TMD patients: a randomized clinical trial. Braz Oral Res. 2018;32:e50.
[43] Herpich CM, Leal-Junior ECP, Politti F, et al. Intraoral photobiomodulation diminishes pain and improves functioning in women with temporomandibular disorder: a randomized, sham-controlled, double-blind clinical trial: intraoral photobiomodulation diminishes pain in women with temporomandibular disorder. Lasers Med Sci. 2020;35(2):439–445. Mar
[44] de Salles-Neto FT, de Paula JS, Romero D A J, et al. Acupuncture for pain, mandibular function and oral health-related quality of life in patients with masticatory myofascial pain: a randomised controlled trial. J Oral Rehabil. 2020;47(10):1193–1201.
[45] Abrahamsen R, Zachariae R, Svensson P. Effect of hypnosis on oral function and psychological factors in temporomandibular disorders patients. J Oral Rehabil. 2009;36(8):556–570.
[46] Li LC, Wong RW, Rabie AB. Clinical effect of a topical herbal ointment on pain in temporomandibular disorders: a randomized placebo-controlled trial. J Altern Complement Med. 2009;15(12):1311–1317.
[47] Wahlund K, List T, Larsson B. Treatment of temporomandibular disorders among adolescents: a comparison between occlusal appliance, relaxation training, and brief information. Acta Odontol Scand. 2003;61(4):203–211.
[48] Hasanoglu Erbasar GN, Alpaslan C, Eroglu Inan G. Can an NTI-tss device be effective as a first-line therapy in patients with TMD myofascial pain? J Oral Rehabil. 2017;44(8):589–593.
[49] Niemelä K, Korpela M, Raustia A, et al. Efficacy of stabilisation splint treatment on temporomandibular disorders. J Oral Rehabil. 2012;39(11):799–804.
[50] Katyayan PA, Katyayan MK, Shah RJ, et al. Efficacy of appliance therapy on temporomandibular disorder related facial pain and mandibular mobility: a randomized controlled study. J Indian Prosthodont Soc. 2014;14(3):251–261.
[51] Sancakli E, Gökçen-Röhlıg B, Balık A, et al. Early results of low-level laser application for masticatory muscle pain: a double-blind randomized clinical study. BMC Oral Health. 2015;15(1):131.
[52] Shedden Mora MC, Weber D, Neff A, et al. Biofeedback-based cognitive-behavioral treatment compared with occlusal splint for temporomandibular disorder: a randomized controlled trial. Clin J Pain. 2013;29(12):1057–1065.
[53] Kapos FP, Exposto FG, Oyarzo JF, et al. Temporomandibular disorders: a review of current concepts in aetiology, diagnosis and management. Oral Surg. 2020;13(4):321–334. Nov
[54] Al-Moraissi EA, Conti PCR, Alyahya A, et al. The hierarchy of different treatments for myogenous temporomandibular disorders: a systematic review and network meta-analysis of randomized clinical trials. Oral Maxillofac Surg. 2021.
[55] Shaffer SM, Brismée JM, Sizer PS, et al. Temporomandibular disorders. Part 2: conservative management. J Man Manip Ther. 2014; 22(1):13–23. Feb
[56] Alkhutari AS, Alyahya A, Conti PCR, et al. Is the therapeutic effect of occlusal stabilization appliances more than just placebo effect in the management of painful temporomandibular disorders? A network meta-analysis of randomized clinical trials. J Prosthet Dent. 2021;126(1):24–32.

[57] Brochado FT, de Jesus LH, Chaves KD, et al. Non-invasive therapies for management of temporomandibular disorders: a systematic review. Clin Biomed Res. 2019;39(3):238–243.
[58] List T, Helkimo M, Andersson S, et al. Acupuncture and occlusal splint therapy in the treatment of craniomandibular disorders. Part I. A comparative study. Swed Dent J. 1992;16(4):125–141.
[59] Stechman-Neto J, Porporatti AL, Porto de Toledo I, et al. Effect of temporomandibular disorder therapy on otologic signs and symptoms: a systematic review. J Oral Rehabil. 2016;43(6):468–479. Jun
[60] Gil-Martínez A, Paris-Alemany A, López-de-Uralde-Villanueva I, et al. Management of pain in patients with temporomandibular disorder (TMD): challenges and solutions. J Pain Res. 2018;11:571–587.
[61] Dahlström L, Carlsson GE. Temporomandibular disorders and oral health-related quality of life. A systematic review. Acta Odontol Scand. 2010;68(2):80–85.
[62] Reisine ST, Fertig J, Weber J, et al. Impact of dental conditions on patients' quality of life. Community Dent Oral Epidemiol. 1989; 17(1):7–10.
[63] Luo Y, McMillan AS, Wong MC, et al. Orofacial pain conditions and impact on quality of life in community-dwelling elderly people in Hong Kong. J Orofac Pain. Winter. 2007; 21(1):63–71.
[64] Reissmann DR, John MT, Schierz O, et al. Functional and psychosocial impact related to specific temporomandibular disorder diagnoses. J Dent. 2007;35(8):643–650.
[65] Harper DE, Schrepf A, Clauw DJ. Pain mechanisms and centralized pain in temporomandibular disorders. J Dent Res. 2016;95(10): 1102–1108.
[66] Shrivastava M, Battaglino R, Ye L. A comprehensive review on biomarkers associated with painful temporomandibular disorders. Int J Oral Sci. 2021;13(1):23.