Low-level laser therapy in temporomandibular joint disorders: a systematic review

Syed Ansar Ahmad¹, Shamimul Hasan²*, Shazina Saeed¹, Ateeba Khan⁴, Munna Khan⁵

Author Affiliations:
1. Department of Oral Surgery, Faculty of Dentistry, Jamia Millia Islamia, New Delhi, India
2. Department of Oral Medicine and Radiology, Faculty of Dentistry, Jamia Millia Islamia, New Delhi, India
3. Laboratory of Disease Dynamics and Molecular Epidemiology, Amity Institute of Public Health, Amity university, Noida, Uttar Pradesh, India
4. Faculty of Dentistry, Jamia Millia Islamia, New Delhi, India
5. Department of Electrical Engineering, Jamia Millia Islamia, New Delhi, India

*Corresponding Author:
Dr. Shamimul Hasan, Professor, Department of Oral Medicine and Radiology, Faculty of Dentistry, Jamia Millia Islamia, New Delhi, India.
Phone: 9953290676
E-mail: shasan1@jmi.ac.in

DOI
10.25122/jml-2020-0169

Dates
Received: 1 November 2020
Accepted: 29 March 2021

ABSTRACT
Temporomandibular joint disorders (TMDs) encompass a wide array of ailments affecting the temporomandibular joint (TMJ), muscles of mastication, and the allied structural framework. Myofascial pain, internal derangement of the joint, and degenerative joint diseases constitute the majority of TMDs. TMDs usually have a multifactorial etiology, and treatment modalities range from conservative therapies to surgical interventions. Low-level laser therapy (LLLT) has evolved as an efficient non-invasive therapeutic modality in TMDs. Previously conducted systematic reviews and meta-analyses have shown variable results regarding the efficiency of LLLT in TMJ disorder patients. Hence, this systematic review was carried out as an attempt to evaluate the efficacy of LLLT in the treatment of temporomandibular joint disorder patients.

KEYWORDS: low-level laser therapy (LLLT), pain intensity, randomized controlled trials (RCTs), temporomandibular joint disorders (TMDs).

INTRODUCTION
TMJ disorders (TMDs) are categorized as degenerative musculoskeletal disorders causing structural and functional abnormalities [1]. Pain, diminished jaw functions and movements, midline deviation, malocclusion, joint noises, and locking constitutes the cardinal signs and symptoms of TMDs [2, 3]. The overall incidence of TMDs ranges from 21.5% to 50.5%, with a female gender predilection [4]. TMDs are categorized into three forms. Myofascial pain is the most typical form, followed by internal derangement of the joint and degenerative joint disease, respectively [5]. TMDs represent a primary cause of non-odontogenic pain in the orofacial region, with 40–75% of the individuals showing at least one TMD sign, such as TMJ noise, and 33% at least one symptom, TMJ or facial pain [6]. Many TMDs may be self-limiting, with periodic remission and exacerbation of symptoms [7].

TMD therapies primarily aim to eliminate pain, joint clicking, restoring TMJ functions and entails dietary and behavioral amendments, pharmacotherapy, physical therapy, occlusal splint therapy, intra-articular injections, arthroscopy, arthrocentesis, Lasers, or open joint surgery [8]. Lasers have gained wide applications in dentistry owing to their therapeutic attributes, such as tissue healing and enhanced local microcirculation [9]. Low-level laser therapy (LLLT) refers to a light-based therapy that produces monochromatic and coherent light of a single wavelength [3].
LLLT may act via numerous mechanisms of action, including facilitating the release of endogenous opioids, augmenting tissue repair and cellular respiration, increasing vasodilatation and pain threshold, and decreasing inflammation [10]. LLLT exerts a photochemical effect, in contrast to the ablative or thermal effects related to medical laser procedures [11].

The current state of knowledge in LLLT as a therapeutic modality in TMDs is primarily based upon previously conducted prospective clinical trials, which have yielded debatable outcomes [12–16]. Few studies have demonstrated higher efficacy of LLLT over placebo [12, 15, 16], while others have shown similar efficiency of LLLT and placebo in the treatment of TMD [13, 14].

Many systematic reviews with or without meta-analyses have also demonstrated contentious results regarding the effectiveness of LLLT in TMDs [17–19]. The meta-analyses by Gam et al. [21], Petrucci et al. [18], and McNeely et al. [22] could not establish the efficacy of LLLT therapy in TMJ pain. However, a meta-analysis conducted by Chang et al. suggested that LLLT has a reasonable analgesic effect on TMJ pain [19]. A meta-analysis by Chen et al. reported that LLLT might substantially enhance the functional outcomes with limited pain amelioration in TMD patients [23]. A systematic review with meta-analyses demonstrated that LLLT is not only effective in pain relief but also improves functional outcomes in TMD patients [4]. Few randomized controlled trials (RCTs) documenting the efficacy of LLLT in TMDs have been conducted since the last published systematic review [5, 11, 24–27].

However, to date, there is still no conclusive validation to substantiate or contradict LLLT for TMDs. Hence, this systematic review was conducted to substantiate and re-validate the efficacy of LLLT as a therapeutic modality in TMDs and review the evidence from previously published literature. The study results are also expected to serve as useful insight and guidelines for clinical practitioners treating patients with TMDs. This review will provide precise and obvious knowledge about the benefits and procedures of laser application, which have already been successfully established in TMD management.

Our objectives were to:

• Ascertain the efficacy of LLLT in pain diminution as the primary outcome and secondary outcome on TMJ functions, masticatory efficiency, psychological and emotional aspects;
• Compare LLLT with placebo and other interventions used in TMD management.

MATERIAL AND METHODS

A systematic literature review was carried out to assess the efficiency of low-level laser therapy in patients with temporomandibular joint disorders.

Research questions

The search for the systematic review was initiated by defining the keywords concerning the population, intervention, control, and outcomes (PICO) format: a) population – “temporomandibular joint disorders (TMDs)”; b) intervention/exposure – “low-level laser therapy (LLLT)”; c) control – “placebo or other interventions like occlusal splints, analgesics, transcutaneous electrical nerve stimulation (TENS) and botulinum toxins”; and d) outcome – “efficacy assessment”. The research question was designed for the above-mentioned keywords: a) “Is low-level laser therapy (LLLT) efficacious in patients with temporomandibular joint disorders?”

Literature search and identification of studies

This search strategy followed the Cochrane guidelines for a systemic review. An extensive hand-searching and electronic searching were made between January 2000 to June 2020 using the combination of controlled vocabulary and free text terms in PubMed and Science direct search engines.

Inclusion criteria

a) RCTs involving LLLT therapy in human subjects with TMDs; b) articles published in the English language between January 2000 to June 2020; c) at least a total of 10 study subjects (both LLLT and placebo categories).

Exclusion criteria

a) Nonrandomized or crossover studies (studies other than RCTs); b) studies conducted on animal models; c) articles published in languages other than English and before January 2000; d) study subjects less than 10; e) studies that fail to provide information on the
outcomes of interest and f) subjects with systemic disorders (i.e., rheumatoid arthritis and fibromyalgia) or non-TMD related pain (i.e., odontogenic pain, neuralgia, and psychological dysfunctions).

Study selection

The titles and abstracts of the identified studies were thoroughly evaluated for potential eligibility. Studies that did not assess the efficacy of LLLT on TMDs were excluded. However, if the abstract of the study was unclear, the full texts of the study were then procured for evaluation. Manual cross-referencing of all the retrieved articles was carried out to identify any study missed previously.

Outcome parameters

The primary outcome parameter was a diminution in the pain intensity in TMDs after LLLT therapy, expressed by the visual analog scale (VAS). The secondary outcome parameters were the effect on TMJ functions (expressed in terms of mouth opening, lateral and protrusive mandibular excursive movements, and TMJ noises), masticatory efficiency, pressure pain threshold (PPT), electromyographic (EMG) activity, quality of life (QoL), psychological and emotional aspects associated with TMDs.

Data extraction

Data extraction was made based on the first author, year of publication, journal name, sample size, treatment design, type and wavelength of laser, dose and power of the used laser, study design, study outcome, and results. The included studies were reviewed by two other authors.

Risk of bias assessment

The risk of publication bias was assessed by using the R-based Robvis software package introduced by the National Institute for Health Research (NIHR) (https://www.riskofbias.info/welcome/robvis-visualization-tool).

RESULTS

Thirty-seven articles were considered eligible for this systematic review. The selection cycle is in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines and is represented as a flowchart in Figure 1.

Based on visual inspection of the figure generated by the Robvis software package, there is no potential publication bias in this study assessing the effectiveness of low-level laser treatment used in various RCTs for TMD patients (Figures 2 and 3). Out of 37 studies, 33 (89.18%) are high methodological studies, which have an overall low risk of bias or with some concerns, while only 4 studies have a high risk of bias. A detailed description of the eligible studies is given in Tables 1 and 2.

Characteristics of the studies

Eighteen studies used the “Research Diagnostic Criteria” (RDC/TMD) for diagnosis of TMDs, followed by VAS in 6 conducted RCTs. 7 studies utilized a combination of these two diagnostic criteria. A wide variety of lasers were used in the included studies. Nineteen studies used a Gallium-aluminum-arsenide laser (GaAlAs). Gallium-arsenide laser (GaAs) was used in 5 studies. Neodymium-doped yttrium aluminum garnet (Nd: YAG), diode lasers, and red and infrared lasers were applied in 2 studies each, followed by Indium-gallium-aluminum-phosphide laser (InGaAlP) and Helium-neon laser (HeNe), which were used in one study each as shown in Table 1. A combination of two laser types was also used in 3 studies, namely that of Shirani et al. [28], Demirkol et al. [29], and Pereira et al. [30].

A single laser type at two different wavelengths (GaAlAs at 650 nm/830 nm) was used in an RCT by Wang et al. [16]. Single laser with two or three laser dosages was employed in 4 studies (Table 1).

The shortest and longest laser wavelengths used among the included studies were 632.8 nm [13] and 1064 nm [29, 31], respectively, except for Altidis et al. [25] and Rodriguez et al. [27], who did not mention the wavelength used in their lasers therapy. Laser dosage ranged between 1.3 J/cm² to 112.5 J/cm² for the majority of the studies. Laser power ranged between 1.76mW [32] to 500mW [33]; 3 studies did not mention the power of the laser [25, 27, 30]. Temporomandibular joint and/or the affected muscles were the primary site of laser application in 18 of the conducted RCTs. Laser therapy was applied specifically at the TMJ in 9 RCTs. In 8 RCTs, the size of laser application was only in the muscles. In most of the conducted studies, laser application was made at pre-decided sites, irrespective of the fact that they were the points of maximum pain or not. However, in other RCTs, only the points of maximum pain intensity were irradiated (Table 2).
Total 1047 studies identified from PubMed and Science Direct search engines
89 studies identified from PubMed
958 studies identified from Science Direct

Applying the inclusion and exclusion criteria, 883 studies were excluded:
• Only Randomized Controlled Trials (RCTs) with Minimum 10 participants were included (nonrandomized/crossover studies were excluded).
• Studies on human subjects were included (systemic diseases, pain other than TMDS, studies on animal models were excluded)
• Studies published in the English language were included (literature in Spanish, Portuguese, Chinese were excluded)
• Studies conducted between January 2000 to June 2020 were included

Total 164 studies included for further assessment
38 studies identified from PubMed
126 studies identified from Science Direct

128 studies were excluded after reading title and abstract of the identified studies

Total 36 studies identified
31 studies identified from PubMed
5 studies identified from Science Direct

2 duplicate studies excluded
3 studies included after cross checking the references of the identified studies

Total 37 studies included for detailed assessment

Figure 1. Selection of studies for the systematic review according to the PRISMA guidelines.
Most of the studies involved a comparison of LLLT and placebo groups. However, seven studies involved comparison of laser with other interventions, namely, botulinum toxin A [9], TENS therapy [11], ibuprofen [15], needling [34], occlusal splints [33, 35], physiotherapeutic and drug protocol (PDP) [36]. Two studies incorporated co-interventions equally to both LLLT and placebo groups. Piroxicam was incorporated with LLLT in one study [37], and in the other study, oral motor (OM) exercises were combined with LLLT [38].

Most of the included studies provided data on the primary outcome of laser therapy, like pain intensity. Eighteen studies focused on secondary outcomes like mouth opening (MO), followed by 13 studies on lateral excursive (LE) mandibular movements, 10 studies on protrusive excursive (PE) mandibular movements, 7 studies on PPT, and 2 studies each on EMG, joint noises, TMD related psychological and emotional aspects, masticatory efficiency (ME), respectively. One study each focused on subjective tinnitus and occlusal contacts distribution (Table 1).

Eighteen studies showed that LLLT was efficacious in diminishing TMD pain, whereas 12 studies showed that LLLT had similar efficacy as of placebo/controls/other intervention in TMD pain diminution. Four studies presented varied effects of LLLT on pain intensity, mandibular motion, EMG activity, and masticatory efficiency. Two studies revealed that LLLT improved the psychological and emotional aspects associated with TMDs, joint noises, masticatory efficiency, and EMG parameters, respectively. One study focused on subjective tinnitus, whereas another study suggested laser acupuncture (LAT) therapy as a suitable alternative to LLLT. The results demonstrate that LLLT appears to be efficient in diminishing TMD pain with variable effects on the outcome of secondary parameters (Table 1).

**DISCUSSION**

Orofacial pain/pain in the stomatognathic system region has a varied pathophysiological basis, and its diagnosis and therapy cover diverse aspects of medicine and dentistry. TMDs are one of the principal causes of orofacial pain. According to the International Association for the Study of Pain, TMDs are defined as an assembly of painful musculoskeletal disorders of the temporomandibular joints, masticatory muscles, and adjacent architecture [39].

The exact etiology of TMDs is still not completely elucidated; however, stress-induced repetitive jaw clenching and grinding accounts as the most important causative factor. Stress also plays a major role in sustaining and augmenting the TMD symptoms. TMDs pose significant diagnostic and therapeutic challenges owing to their multifactorial etiology, lack of investigative guidelines and strategies, and are widely considered as a physical, psychological, and functional disorder [40].

A vast majority of studies assessing TMD therapeutic protocols incorporate only pain scales (VAS) and MO analysis, thereby omitting other imperative characteristics like chronic pain, stress, anxiety, and depression. Dworkin and Le Resche later adopted the Research Diagnostic Criteria (RDC/TMD) in 1992 to overpower these discrepancies, and it also provided the academicians and practitioners with an effective and systematic method of examination, diagnosis, and classification of TMDs [24].

In our systematic review, 18 studies used RDC/TMD to diagnose TMDs. Six RCTs utilized VAS, whereas 7 studies utilized a combination of these two diagnostic criteria. TMDs generally have a gender predisposition, the disease predominantly affecting females (F:M = 2:1–8:1). Patients in the age group of 20 and 50 years are usually affected, an unusual age distribution for a degenerative disorder [1]. In our systematic review, most of the studies revealed a higher prevalence of TMDs among women compared to men with an age range between 20–55 years. Pain is the cardinal manifestation in TMDs. Pain in TMDs accounts for the most probable explanation of these patients seeking treatment. This also serves as a justification for most of the studies focused on assessing the efficacy of a wide range of therapeutic approaches.
### Risk of bias domains

| Study                     | D1 | D2 | D3 | D4 | D5 | Overall |
|---------------------------|----|----|----|----|----|---------|
| Kulekcioglu et al. (2003) | +  | +  | +  | +  | +  | +       |
| Venancio et al. (2005)   | +  | +  | +  | +  | +  | +       |
| Mazzetto et al. (2007)   | +  | +  | +  | +  | +  | +       |
| Cunha et al. (2008)      | +  | -  | -  | X  | +  | -       |
| Emshoff et al. (2008)    | +  | X  | -  | +  | +  | -       |
| Frare et al. (2008)      | +  | +  | +  | +  | X  | +       |
| Carrasco et al. (2008)   | +  | +  | X  | +  | +  | +       |
| Shirani et al. (2009)    | +  | +  | +  | +  | +  | +       |
| Marini et al. (2010)     | +  | +  | +  | +  | +  | +       |
| Mazzetto et al. (2010)   | -  | +  | -  | +  | +  | -       |
| Venezian et al. (2010)   | +  | +  | +  | +  | +  | +       |
| Oz S et al. (2010)       | +  | +  | +  | +  | +  | +       |
| Wang et al. (2011)       | +  | +  | +  | X  | +  | +       |
| Röhlig et al. (2011)     | X  | +  | +  | +  | +  | +       |
| Carli et al. (2012)      | +  | X  | +  | X  | +  | X       |
| Silva et al. (2012)      | +  | X  | +  | +  | +  | -       |

Figure 3. Weighted output for risk bias assessment.
| Study                          | 1 | 2 | 3 | 4 | 5 | 6 |
|-------------------------------|---|---|---|---|---|---|
| Uemoto et al. (2013)          | + | + | + | + | + | + |
| Ferreira et al. (2013)        | + | + | + | + | + | + |
| Ahrari et al. (2014)          | X | + | + | + | + | + |
| Pereira et al. (2014)         | + | - | + | + | + | + |
| Maia et al. (2014)            | X | X | + | + | + | - |
| Demirkol et al. (2015)        | + | + | + | + | + | X |
| Godoy et al. (2015)           | + | + | + | + | + | + |
| Fornaini et al. (2016)        | + | + | + | + | + | X |
| Sancakli et al. (2016)        | + | X | + | + | + | - |
| Machado et al. (2016)         | + | X | X | + | + | + |
| Carli et al. (2016)           | + | + | + | + | + | + |
| Cavalcanti et al. (2016)      | + | + | - | + | + | + |
| Magri et al. (2017)           | + | + | - | + | + | + |
| Costa et al. (2017)           | X | + | - | + | + | X |
| Demirkol et al. (2017)        | - | + | + | + | - | - |
| Shobha et al. (2017)          | - | + | + | + | + | + |
| Brochado et al. (2018)        | - | + | X | + | + | X |

Figure 3. Continued.
array of therapeutic protocols with pain amelioration as the primary outcome [41]. Pain reduction also results in improved jaw motion, chewing, and masticatory efficiency [4]. The results in this systematic review were in coherence with the published literature, as most of the included studies in our review considered pain amelioration as the primary outcome of laser therapy.

Restriction or deflection in the range of mandibular movements (MO, LE and PE mandibular movements) and joint clicking are other frequent manifestations of TMDs. TMD patients also frequently report loss of masticatory efficacy. The masticatory patterns should be evaluated, and a definitive therapeutic protocol should be planned. Surface EMG, myofunctional procedure ratings, and assessment of masticatory efficiency are some of the employed objective approaches [42]. This systematic review also focused on improving the secondary outcomes like MO [5, 9, 10, 14–16, 26, 28, 30, 34, 37, 43–47], LE and PE mandibular movements [10, 14–16, 26, 28, 34, 37, 43–46, 48], PPT [14, 34, 35, 44, 46, 49, 50], EMG parameters [32, 34], joint noises [5, 28], TMD masticatory efficiency (ME) [49, 51], subjective tinnitus [29], and occlusal contacts distribution [48].

The importance of psychological factors (stress, anxiety, depression, and personality changes) has been thoroughly investigated in the etiopathogenesis of TMDs over the years. Published literature has demonstrated that the interrelation between stress, anxiety, depression, and distinct physical manifestations of TMDs is universally in sync with manifestations that are similar to those seen in other chronic musculoskeletal pain disorders [52]. Approximately 75% of TMD patients exhibit chronic features, with detrimental biopsychosocial outcomes like depression and somatization [12]. In our systematic review, two studies emphasized the role of LLLT in improving TMD-related psychological and emotional aspects [24, 27]. The World Association of Laser Therapy came to a consensus in 2004 on the design of clinical trials with LLLT in TMDs. According to the established protocol, the placebo group should compulsorily be a part of the study design [53]. Most of the included RCTs involved a comparison of LLLT and placebo groups. However, 7 RCTs involved a comparison of laser with other interventions or compared co-interventions equally to both LLLT and placebo groups (Table 1).

Therapeutic lasers are generally close to the electromagnetic radiation spectrum and vary from visible (red) to invisible (infrared) light. The most used wavelengths usually range between 600 and 1000 nm, permitting deeper penetration, relatively poor absorption, and easier transmission through the skin and mucous membranes [30].

In this systematic review, most of the studies used lasers with wavelengths within the electromagnetic radiation spectrum. The wavelengths ranged between 632.8 nm and 1064 nm. Only five studies used lasers with wavelengths in the red range (shorter than 780 nm). RCTs conducted by Altindis et al. [25] and Rodriguez et al. [27] did not mention the wavelength of the used lasers. Published literature has ascertained that combining lasers of two wavelengths have furnished positive outcomes. Lasers exert distinct effects in various biological tissues, explaining the variable results of laser therapy with different wavelengths [30]. In our systematic review, a combination of two laser types at different wavelengths was demonstrated by Shirani et al. [28], who used InGaAlP (660 nm) and GaAs (890 nm) lasers, Demirkol et al. [29], who used Nd: YAG (1064 nm) and diode laser (810 nm), and Percira et al. [30], who used red laser (660 nm) and infrared laser (795 nm).

LLLT may show heterogeneity in the dose, power, and application time, with an irradiance of 5 mW/cm² to 5 W/cm², power range between 1 mW up to 10 W, with pulsed or continuous beams, and the application span of 30–60 s/point [54]. The measure of the laser

---

| Study                | D1 | D2 | D3 | D4 | D5 | Judgement   |
|----------------------|----|----|----|----|----|-------------|
| Rodrigues et al. (2019) | + | + | - | + | + | High        |
| Altindis et al. (2019)    | + | - | - | + | + | Some concerns |
| Madani et al. (2020)      | + | + | + | + | - | Low         |
| Chellappa et al. (2020)   | + | + | + | + | + | High        |

Domains:
D1: Bias arising from the randomization process
D2: Bias due to deviations from intended interventions
D3: Bias due to missing outcome data
D4: Bias in measurement of the outcome
D5: Bias in selection of the reported result

Figure 3. Continued.
## Table 1. Characteristics of the included studies.

| Author            | Sample size (n) | Age/gender                  | Treatment design | Type of laser, dose (J/cm²) and power (mw) of laser used | Outcome measures                                                                 | Results                                                                 |
|-------------------|-----------------|-----------------------------|------------------|----------------------------------------------------------|--------------------------------------------------------------------------------|------------------------------------------------------------------------|
| Shobha et al. [5] (2017) | n=40 Group 1 (Laser group n=20) Group 2 (placebo group n=20) | 18–40 yrs Not mentioned | Laser (20) versus placebo (20) | Diode laser (gallium aluminum arsenide, 810 nm, 0.1 W, 6 J/cm²). | PI at function and at rest (VAS), MO and temporomandibular clicking | ↓ pain observed in both active LLLT and placebo groups improvement in clicking |
| Carli et al. [9] (2016) | n=15 Group 1 (Laser group n=8) Group 2 (Botulinum toxin A n=7) | Mean age=28 yrs M: F=2:13 | Laser (8) versus Botulinum toxin A (7) | GaAlAs 890 nm, 100 mw, 80 J/cm² | PI (VAS) and MO | Both Laser and Botulinum toxin A treatments were efficient in reducing pain, but laser therapy was much faster in pain diminution. (LLLT>Botulinum toxin A in pain resolution). However, both treatments showed no statistically significant improvement in MO. |
| Ahrari et al. [10] (2014) | n=20 Group 1 (laser group n=10) Group 2 (placebo group n=10) | Mean age 35.5 yrs, 20 Females | Laser (10) versus placebo (10) | GaAlAs 810 nm, 50 mw, 3.4 J/cm² | PI and mandibular movements | LLLT>placebo |
| Chellappa et al. [11] (2020) | n=60 Group 1 (LLLT group n=30) Group 2 (TENS group n=30) | Not mentioned | LLLT group (30) TENS group (30) n=60 | 672 nm diode laser 50 mw, 3 J/cm² | PI and range of mandibular motion | LLLT>TENS |
| Ferreira et al. [12] (2013) | n=40 Group 1 (laser group n=20) Group 2 (placebo group n=20) | 20–40 yrs 40 females | Laser (20) versus placebo (20) | GaAlAs 780 nm, 112.5 J/cm², 50 mw | PI | LLLT>placebo |
| Emshoff et al. [13] (2008) | n=52 Group 1 (Study group n=26) Group 2 (control-placebo n=26) | 18–58 yrs M: F=10:42 | Laser (26) versus placebo (26) | HeNe 632.8 nm, 1.5 J/cm² and 30 mw | PI | LLLT>placebo |
| Venancio et al. [14] (2005) | n=30 Group 1 (Study group n=15) Group 2 (control-placebo n=15) | Not mentioned M: F=5:25 | Laser (15) versus placebo (15) | GaAlAs 780 nm, 6.3 J/cm² and 30 mw | PI, mandibular function, pain sensitivity | LLLT=placebo |
| Marini et al. [15] (2010) | n=99 Group 1 (Study/laser group n=39) Group 2 (ibuprofen n=30) Group 3 (control-placebo n=30) | Not mentioned | Laser (39) versus ibuprofen (30) versus placebo (30) | GaAlAs 910 nm, 400 mw | PI, mandibular function, morphologic structural analysis of TMJ | LLLT=placebo |
| Wang et al. [16] (2011) | n=42 Group 1 (Study group n=21) Group 2 (control-placebo n=21) | Not mentioned | Laser (21) versus placebo (21) | GaAlAs 650 nm/830 nm, 300 mw | PI, functional examination (MO, lateral and protrusive excursive movements) | LLLT>placebo |
Table 1. Continued.

| Study | n | Group 1 | Group 2 | Group 3 | Protocol Details | Treatment Details | Results |
|-------|---|---------|---------|---------|-----------------|------------------|---------|
| Brochado et al. [24] (2018) | n=51 | Group 1 (photo biomodulation (PBM) group n=18) | Group 2 (Manual therapy group n=16) | Group 3 (Combined group n=17) | PBM group (18) Manual therapy group (16) Combined group (17) | PBM with 808 nm, 100 mW, 13.3 J/cm² | PI, mandibular movements, psychosocial aspects, and anxiety symptoms in TMD patients. All protocols tested were able to promote pain relief, improve mandibular function, and reduce the negative psychosocial aspects and levels of anxiety in TMD patients. However, the combination of PBM and MT did not promote an increase in the effectiveness of both therapies alone. |
| Alhindis et al. [25] (2019) | n=20 | 18–45 yrs | Laser (10) stabilization splint (10) | N/A | PI, muscle sensitivity and the superficial skin temperature differences | Occlusal splint therapy and LLLT were effective in the treatment of MPS, and when thermographic data were considered, LLLT treatments could provide more advantageous results in these patients. |
| Madani A. et al. [26] (2020) | n=45 | Group 1 (LLLT group n=15) | Group 2 (LAT n=15) | Group 3 (Placebo group n=15) | LLLT group (15) LAT group (15) Placebo group (15) | GaAlAs laser 810 nm, 200 mW, 21 J/cm² The mandibular range of motion (Lateral excursive and protrusive movements). PI and Mouth opening | Both LLLT and LAT were effective in reducing pain and increasing excursive and protrusive mandibular motion in TMD patients. LAT could be suggested as a suitable alternative to LLLT, as it provided effective results while taking less chair time. |
| Rodrigues et al. [27] (2019) | N/A | Not mentioned | N/A | N/A | Physical and emotional symptoms in TMD patients | LLLT improved the physical and emotional symptoms of TMD, with results like splint therapy. |
| Shirani et al. [28] (2009) | n=16 | Group 1 (Study group n=8) | Group 2 (control-placebo n=8) | Laser (the combination of two wavelengths, 8) versus placebo (8) | InGaAlP 660 nm and GaAs 890 nm, 6.2 J/cm² and 1.0 J/cm², 17.3 mW and 1.76 mW | PI | LLLT>placebo |
| Demirkol et al. [29] (2017) | n=41 | Group 1 (Nd: YAG laser group n=15) | Group 2 (diode Laser group n=16) | Group 3 (placebo n=15) | Nd: YAG laser (15) versus diode laser (16) versus placebo (15) | Nd: YAG laser (1064 nm), diode laser (810 nm), 250 mW, 8 J/cm² The severity of the tinnitus (VAS) | LLLT>placebo |
| Pereira et al. [30] (2014) | n=19 | 21–55 yrs | N/A | 660 nm (red laser) and 795 nm (infrared) laser 8 J/cm² in Muscles 4 J/cm² in Joint | PI | Both lasers are effective in the treatment and remission of TMD symptoms. |
| Demirkol et al. [31] (2014) | n=30 | Group 1 (laser group n=10) | Group 2 (occlusal splint group n=10) | Group 3 (placebo n=10) | Laser (10) versus occlusal splint (10) versus placebo (10) | Nd: YAG 1064 nm, 250 mW, 8 J/cm² | PI | LLLT>placebo |
| Study | Sample Size | Study Group 1 | Study Group 2 | Laser Parameters | Outcome Measures | Treatment
|-------|-------------|---------------|---------------|-----------------|-----------------|----------------|
| Venezian et al. [32] (2010) | n=48 | Group 1 (Study group n=24) | Group 2 (control-placebo n=24) | Laser (24) versus placebo (24) | PI and EMG Activity | LLLT>placebo (EMG Activity) |
| Cunha et al. [33] (2008) | n=40 | Group 1 (Study group n=20) | Group 2 (control-placebo n=20) | Laser (20) versus placebo (20) | PI and TMD status | LLLT=placebo |
| Uemoto et al. [34] (2013) | n=21 | Group 1 (laser group n=7) | Group 2 (needling group n=7) | Laser (7) versus needling group (7) | PI, EMG activity, mandibular movements | LLLT=placebo (only 4 J/cm²) |
| Oz S et al. [35] (2010) | n=40 | Group 1 (Study group n=20) | Group 2 (control-occlusal splints n=20) | Laser (20) versus PDP (20) versus placebo (20) | PI, mandibular movements and pressure pain threshold | LLLT=occlusal splints |
| Cavalcanti et al. [36] (2016) | n=60 | Group 1 (laser group n=20) | Group 2 (PDP group n=20) | Laser (20) versus PDP (20) versus placebo (20) | GaAlAs 780 nm, 30 mW, 35 J/cm² | Presence/absence of Pain |
| Carli et al. [37] (2012) | n=32 | Group 1 (Laser + piroxicam group n=11) | Group 2 (laser + placebo piroxicam n=11) | Laser + piroxicam (11) versus laser + placebo piroxicam (11) versus placebo laser + piroxicam (10) | GaAs 904 nm, 15 mW, 6 J/cm² | PI, functional examination (MO, lateral and protrusive excursive movements) |
| Fornaini et al. [38] (2015) | n=24 | Group 1 (laser group n=12) | Group 2 (placebo group n=12) | Laser (10) versus placebo (10) | GaAs 904 nm, 15 mW, 6 J/cm² | PI |
| Mazzetto et al. [43] (2010) | n=40 | Group 1 (Study group n=20) | Group 2 (control-placebo n=20) | Laser (20) versus placebo (20) | GaAlAs 830 nm, 5 J/cm² and 40 mW | PI, mandibular movements |
| Röhlöig et al. [44] (2011) | n=40 | Group 1 (laser group n=20) | Group 2 (control-placebo n=20) | Laser (20) versus placebo (20) | GaAs 820 nm, 300 mW, 8J/cm² | PI, functional examination, pain sensitivity | LLLT=placebo |
Table 1. Continued.

| Study (Year) | Group 1 | Group 2 | Group 3 | Laser Type | Power | Source | PI, mandibular movements | LLLT > Placebo |
|--------------|---------|---------|---------|------------|-------|--------|--------------------------|-----------------|
| Silva et al. [45] (2012) | n=45 | Low energy laser (15) versus high energy laser (15) | GaAIAs 780 nm, 52 J/cm² and 105 J/cm², 70 mW | M: F=15:30 | 25–53 yrs | PI, mandibular movements | LLLT-placebo |
| Sancakli et al. [46] (2016) | n=30 | Laser I (10) versus laser II (10) versus placebo (10) | GaAs 820 nm, 30 mW, 3 J/cm² | M: F=15:30 | 18–60 yrs | PI, mandibular mobility, pain sensitivity | LLLT-placebo |
| Costa et al. [47] (2017) | n=60 | Laser II (30) versus placebo group (30) | Referrred pain elicited by palpation and maximum mouth opening | M: F=15:30 | 18–76 yrs | PBMT (830 nm) reduces pain in algic points, but does not influence the extent of mouth opening in patients with myalgia |
| Godoy et al. [48] (2015) | N/A | Laser versus Placebo | Laser type N/A | M: F=15:30 | 14–23 yrs | PI, mandibular range of motion and occlusal contacts | No statistically significant differences were found regarding pain, mandibular range of motion, or the distribution of occlusal contacts after treatment with low-level laser therapy |
| Maia et al. [49] (2014) | n=21 | Laser (10) versus placebo (9) | GaAIAs 808 nm, 50 mW, 33.5 J/cm² | Mean age 27.7±1.44 yrs | Laser (10) versus placebo (9) | PI, masticatory performance, pain sensitivity | LLLT-placebo |
| Magri et al. [50] (2017) | n=91 | Laser (31) versus placebo (30) versus control (30) | GaAIAs 780 nm, TMJ, 20 mW, muscle, 30 mW, 5 or 7.5 J/cm² | M: F=15:30 | 18–60 Yrs | PI, pain sensitivity, the sensory and affective dimensions of pain | LLLT-placebo |
| Carrasco et al. [51] (2008) | n=14 | Laser (7) versus placebo (7) | GaAIAs 780 nm, 105 J/cm² and 70 mW | Laser group n=11 | Laser (7) versus placebo (7) | PI and ME | LLLT-placebo (PI on palpation) LLLT-placebo (ME) |
| Frare et al. [56] (2008) | n=18 | Laser (10) versus placebo (8) | GaAs 904 nm 70 mW, 6 J/cm² | Laser group n=10 | Laser (10) versus placebo (8) | PI | LLLT-placebo |
| Mazzetto et al. [57] (2007) | n=48 | Laser (24) versus placebo (24) | GaAIAs 780 nm 89.7 J/cm² and 70 mW | Laser group n=24 | Laser (24) versus placebo (24) | PI | LLLT-placebo |
Table 1. Continued.

| Author                          | Country of study | Journal                              | Treatment time/number of total sessions/number of sessions/week | Site of laser application | Evaluation/follow-up                        |
|--------------------------------|------------------|--------------------------------------|----------------------------------------------------------------|---------------------------|---------------------------------------------|
| Shobha et al. [5] (2017)       | India            | Indian Journal of Dental research    | 60 s/8/2–3 per week                                            | TMJ and muscles           | Follow-up after 30 days                     |
| Carli et al. [9] (2016)        | Brazil           | Journal of Photochemistry and Photobiology, B: Biology | -7/48 hours interval between each session                      | Muscles                   | N/A                                         |
| Ahrari et al. [10] (2014)      | Iran             | Lasers in Medical Science            | 120 s/12/3                                                     | Muscles                   | Before intervention, after six applications, at the end of treatment, and 1 month after the last application |
| Chellappa et al. [11] (2020)   | India            | Indian Journal of Dental research    | 120 s/12/two sessions/week for 6 weeks                        | TMJ and muscles           | N/A                                         |
| Ferreira et al. [12] (2013)    | Brazil           | Lasers in Medical Science            | 90 s/12/1                                                     | TMJ and Muscles           | Before intervention, monthly until intervention completed |
| Emshoff et al. [13] (2008)     | Austria          | Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontics | 120 s/20/2–3                                                   | TMJ                       | Before treatment and 2, 4, and 8 weeks after the first laser therapy |
| Venancio et al. [14] (2005)    | Brazil           | Journal of Oral Rehabilitation       | 10 s/6/2                                                      | TMJ                       | Immediately before the first, third, and fifth treatment sessions, and at the follow-up appointments after 15, 30, and 60 days of the end of treatment |

F – Female; GaAlAs – Gallium-aluminum-arsenide laser; GaAs – Gallium-arsenide laser; HeNe – Helium-neon laser; LAT – Laser acupuncture therapy; LLLT – Low-level laser therapy; LM – Lateral movements; ND: YAG – Neodymium-doped yttrium aluminum garnet; M – Male; ME – masticatory efficiency; MPS – Myofascial pain syndrome; MO – mouth opening; MT – Manual therapy; N/A: Not Applicable; OM – Oral motor; PBM – Photobiomodulation; PI – Pain intensity; TENS – Transcutaneous electrical nerve stimulation; TMD – temporomandibular joint dysfunction; VAS – visual analog scale.
Table 2. Continued.

| Study                        | Country      | Journal                                | Duration | Target | Follow-up                                                                 |
|------------------------------|--------------|----------------------------------------|----------|--------|---------------------------------------------------------------------------|
| Marini et al. [15] (2010)    | Italy        | Clinical Journal of Pain               | 20 min/10/5 | TMJ    | PI at baseline, 2, 5, 10, and 15 days after treatment. Mandibular function at baseline; 15 days and 1 month after treatment. MRI at baseline and at the end of the treatment. |
| Wang et al. [16] (2011)      | China        | West China Journal                    | 15 min/6/6 | TMJ    | Before treatment, immediately, 1 month and 2 months after treatment.    |
| Brochado et al. [24] (2018)  | Brazil       | Brazilian Oral Research               | 40 s (joint); 21 min (muscle)/72/3 times a week for 4 consecutive weeks | TMJ and muscles | Follow-up after 4 and 8 weeks                                             |
| Altindis et al. [25] (2019)  | Brazil       | Complementary Therapies in Medicine   | N/A      | Muscles | N/A                                                                        |
| Madani A et al. [26] (2020)  | Iran         | Lasers in Medical Science             | 30 s/10/two times a week for 5 weeks | joint, muscles, and acupuncture points | Evaluated before treatment/after 5 sitting/10 sitting and 30 days after therapy |
| Rodrigues et al. 27 (2019)   | Brazil       | Complementary Therapies in Medicine   | N/A      | TMJ and muscles | N/A                                                                        |
| Shirani et al. [28] (2009)   | Iran         | Lasers in Medical Science             | 360 s/6/2 | Muscles | Before and immediately after treatment, 1 week after treatment, and on the day of feeling complete pain relief |
| Demirkol et al. [29] (2017)  | Turkey       | Photomedicine and Laser Surgery       | 20 s or 9 s/10/5 | External Auditory Meatus | Before treatment, immediately and 1 month after treatment |
| Pereira et al. [30] (2014)   | Brazil       | Cranio: The Journal of Craniofacial Surgery | N/A      | TMJ and Muscles | Reassessed at 24 hours and 30 days (short-term assessment), 90 days (medium-term), and 180 days (long-term) |
| Demirkol et al. [31] (2014)  | Turkey       | Lasers in Medical Science             | 20 s/10/5 | Muscles | Before treatment, immediately and 3 weeks after treatment                |
| Venezian et al. [32] (2010)  | Brazil       | Cranio. The Journal of Craniofacial Surgery | 20 or 40 s/8/2 | Muscles | Pt: before treatment, immediately and 30 days after treatment EMG: before and immediately after treatment |
| Cunha et al. [33] (2008)     | Brazil       | International Dental Journal          | 20 s/4/1 | TMJ and/or muscles | Before treatment and after the last treatment                           |
| Uemoto et al. [34] (2013)    | Brazil       | Journal of Oral Science               | 20 s/6/2 | Muscles | Before treatment, after four sessions with intervals ranging between 48 and 72 h |
| Oz S et al. [35] (2010)      | Turkey       | Journal of Craniofacial Surgery       | N/A      | -/10/2 times per week | N/A                                                                       |
| Cavalcanti et al. [36] (2016)| Brazil       | Photomedicine and Laser Surgery       | 20 s/12/3 | TMJ and Muscles | Before treatment, at each week till the fourth week after treatment |
| Carli et al. [37] (2012)     | Brazil       | Journal of Oral Rehabilitation        | 28 s/4/2 | TMJ and Muscles | Before treatment, after the first, second, third, and fourth treatment sessions, and 30 days after last treatment. |
Table 2. Continued.

| Study              | Country     | Journal/Source                                      | Laser Parameters | Treatment/Outcome                                                                 |
|--------------------|-------------|-----------------------------------------------------|------------------|----------------------------------------------------------------------------------|
| Fornaini et al. [38] (2015) | Italy       | Laser Therapy                                      | 15 min/14/7      | Before treatment, 1 and 2 weeks after treatment                                  |
| Mazzetto et al. [43] (2010)  | Brazil      | Brazilian Dental Journal                           | 10 s/8/2         | Before treatment, immediately, 7 and 30 days after applications                  |
| Röhlig et al. [44] (2011)    | Turkey      | Turkish Journal of Physical Medicine and Rehabilitation | 10 s/10/3-4      | Before treatment and after the last applications                               |
| Silva et al. [45] (2012)    | Brazil      | Cranio: The Journal of Craniomandibular and Sleep Practice | 30 s or 60 s/10/2 | Before treatment, immediately, 7 and 30 days after applications                  |
| Sancakli et al. [46] (2016)  | Turkey      | BMC Oral Practice                                  | 10 s/12/3        | Before treatment and after the completion of therapy                           |
| Costa et al. [47] (2017)    | Brazil      | Brazilian Oral Research                            | 28 s/-/-         | Long-term evaluation (6 months)                                                 |
| Godoy et al. [48] (2015)    | Brazil      | Journal of Oral and Maxillofacial Surgery          | 20 s/-/-         |                                                                      |
| Maia et al. [49] (2014)     | Brazil      | Lasers in Medical Science                          | 19 s/8/2         | MP and PPT, before treatment, at the end of treatment and 30 days after treatment, at the same time as above; it was also measured weekly |
| Magri et al. [50] (2017)    | Brazil      | Lasers in Medical Science                          | 10 s/8/2         | Before treatment, after each treatment and 30 days after last treatment         |
| Carrasco et al. [51] (2008) | Brazil      | Cranio: The Journal of Craniomandibular and Sleep Practice | 60 s/8/2        | Before treatment, after the 8th application, 30 days after the last application |
| Frare et al. [56] (2008)    | Brazil      | Revista Brasileira de Fisioterapia                  | 16 s/8/2         | Before and immediately after all sessions of laser applications                 |
| Mazzetto et al. [57] (2007) | Brazil      | Cranio: The Journal of Craniomandibular and Sleep Practice | 10 s/8/2        | Before treatment, after the 4th and 8th applications, and 30 days after the last application. |
| Kulekioglu et al. [58] (2003)| Turkey      | Scandinavian Journal of Rheumatology               | 180 s/15/-       | Before, after, and 1 month after treatment                                       |
| Machado et al. [59] (2016)  | Brazil      | Lasers in Medical Science                          | 45 min/12/1-0.5  | Before treatment, immediately and 1 month after treatment                      |

EMG – electromyography; MRI – magnetic resonance imaging; PI – Pain intensity; PPT – Pressure pain threshold; TMJ – temporomandibular joint; VAS – visual analog scale.

effect is also determined by the laser dose. According to Bjordal et al. [55], the debate on the efficacy of LLLT in TMDs is primarily because of the variability in the laser dose. In our systematic review, laser dosage ranged between 1.5 J/cm² to 112.5 J/cm², except for 5 studies where data was not available (Table 1). Laser power ranged between 1.76 Mw [28] to 500 mW [35].

The included RCTs also showed a wide disparity in the frequency of laser application, the number of sessions/weeks, and the total number of laser sessions. The studies showed that the number of sessions per week ranged from 1–7. Most of the studies argued for 2 sessions per week [5, 11, 13, 14, 26, 28, 32, 33, 35, 37, 43, 45, 49–51, 56, 57]. However, there was no mention of the number of sessions/weeks in a few studies [25–28, 30, 34, 47]. The total number of laser applications also showed great variance, ranging from 4 to 20 sessions. Eight studies argued for a total of 8 sessions [5, 32, 43, 49–51, 56, 57], followed by 12 sessions in 7 studies [10–12, 24, 36, 38, 46], and 10 sessions in 6 studies [15, 26, 29, 31, 44, 45]. However, few studies provided no information on the total number of laser sessions [25, 27, 30, 35, 47, 48]. The time of laser application also varied widely in the included studies.
CONCLUSION

This systematic review aimed to re-validate the efficiency of LLLT in TMDs by thoroughly evaluating the previously conducted research and further compare with placebo and other interventions. The study outcomes are expected to provide useful guidelines for practitioners treating patients with TMDs. The results demonstrate that LLLT appears to be efficient in diminishing TMD pain with variable effects on the outcome parameters. Also, LLLT provides advantages as the therapeutic regimen is non-invasive, reversible, with fewer adverse effects, and may also improve the psychological and emotional aspects associated with TMDs. Therefore, this systematic review highlights the role of LLLT as a promising therapeutic regimen for TMDs.

ACKNOWLEDGMENTS

Conflict of interest

The authors declare that there is no conflict of interest.

REFERENCES

1. Murphy MK, MacBarb RF, Wong ME, Athanasiou KA. Temporomandibular disorders: a review of etiology, clinical management, and tissue engineering strategies. Int J Oral Maxillofac Implants. 2013;28(6):933–941.
2. Ounounou M, Goldberg M, Haas DA. Pharmacotherapy in Temporomandibular Disorders: A Review. J Can Dent Assoc. 2017;83:1–8.
3. Khairnar S, Bhate K, S N SK, Kshirsagar K, Jagtap B, Kulkarni P. Comparative evaluation of low-level laser therapy and ultrasound heat therapy in reducing temporomandibular joint disorder pain. J Dent Assoc Ind. 2017;59(5):289–294.
4. Xu GZ, Jia J, Jin L, Li JH, Wang ZY, Cao DY. Low-Level Laser therapy and ultrasound heat therapy in reducing temporomandibular joint pain. J Phys Ther Sci. 2017;29(7):6341–6343.
5. Alzarea BK. Temporomandibular Disorders [TMD] in Edentulous Patients: A Review and Proposed Classification. J Clin Diagn Res. 2015;9(4):6–9.

7. Romero-Reyes M, Uyanik JM. Orofacial pain management: current perspectives. J Pain Res. 2014;7:99–115.
8. Alexioullida AM, Khalifa AK, Kim YK, Horrya SA. Non-invasive different modalities of treatment for temporomandibular disorders: review of literature. J Korean Assoc Oral Maxillofac Surg. 2018;24(2):43–51.
9. Cariñ JM, Mayrhofer AK, Sonua-Silva RN, Matos FD, Carli JP. Pain in the temporomandibular joint: treatment with platelet-rich plasma and photobiomodulation. J Med Assoc Iran. 2016;159:120–123.
10. AkSU F, Madani AS, Ghafari ZS, Toor S. The efficacy of Low-Level Laser Therapy for the Treatment of Myofascial pain and Myofascial pain, Journal of Photobiomod photobiology. B. 2016;105(4):452–456.
11. Chellappa D, Thirupathy M. Comparative efficacy of low-level laser and TENS in the symptomatic relief of temporomandibular joint disorder. Lasers Med Sci. 2014;29(2):551–557.
12. Ferreira LA, de Oliveira RE, Guimarães JP, Corvalho AC, de Paula MV. Laser acupuncture in patients with temporomandibular dysfunction: a randomized controlled trial. Lasers Med Sci. 2015;30(6):1549–1558.
13. Eshoff R, Bovad R, Pumpl K, Schon H, Strobl H. Low-level laser therapy for treatment of temporomandibular joint pain: a double-blind and placebo-controlled trial.
Esteves SA, Oliveira W. Efficacy of low-level laser therapy on myofascial pain. Lasers Med Sci. 2008;58[4]:213–217.

Craniomandibular & Sleep Practice 2010;28[2]:84–91.

Low-level laser therapy on myofascial pain. Lasers Med Sci. 2014;30[3]:1007–1012.

Low-level laser therapy versus oral clonidine in the treatment of patients with temporomandibular dysfunction. Photomed Laser Surg 2010;24[6]:652–666.

Cacci ML, Guarino MB, Nunes TB, de Marcio RC, de Luca CE, Araujo MC, et al. Peri-implant laser therapy in the treatment of patients with temporomandibular dysfunction. J Oral Rehabil. 2015;42[4]:340–346.

Oliveira D, Adriana Maria Botelho AM, Silva-Pereira TL, Flecha OD, Guimaraes RC, Douglas de Martins MD. Comparative effectiveness of photo biomodulation and manual therapy alone or combined in TMD patients: a randomized clinical trial. Braz Oral Res 2018;32:50.

Auriculotherapy on the Physical and Emotional Aspects of temporomandibular disorders. Cranio. 2007;25[3]:186–192.

Low-level laser therapy and myofascial pain dysfunction syndrome: a randomized controlled clinical trial. Braz Oral Res 2009;23[4]:715–728.

Demirok N, Uzuner A, Demirkol M, Sarf E, Akcay C. Efficacy of low-level laser therapy in subjective tinnitus patients with temporomandibular disorders. Photonmed Laser Surg 2017;5[6]:427–431.

Silva-Peres TL, Flachia OD, Guimarães RC, Douglas de Oliveira D, Azevedo Neto RM. Unilateral auriculotherapy on the Physical and Emotional Aspects in Patients with Temporomandibular Disorders: A Randomized, Controlled Clinical Trial. Complement Ther Med. 2019;42:540–546.

Shitani AM, Guitinneti T, Neghalideh M, Mir M. Low-level laser therapy and myofascial pain dysfunction syndrome: a randomized controlled clinical trial. Braz Oral Res 2009;23[4]:715–728.

Demirok N, Uzuner A, Demirkol M, Sarf E, Akcay C. Efficacy of low-level laser therapy in subjective tinnitus patients with temporomandibular disorders. Photonmed Laser Surg 2017;5[6]:427–431.

Silva-Peres TL, Flachia OD, Guimarães RC, Douglas de Oliveira D, Azevedo Neto RM. Unilateral auriculotherapy on the Physical and Emotional Aspects in Patients with Temporomandibular Disorders: A Randomized, Controlled Clinical Trial. Complement Ther Med. 2019;42:540–546.

Low-level laser therapy on oral mucosal pain: a systematic review of 14 randomized controlled trials. J Oral Rehabil. 2015;42[4]:340–346.

Low-level laser therapy and myofascial pain dysfunction syndrome: a randomized controlled clinical trial. Braz Oral Res 2009;23[4]:715–728.

Demirok N, Uzuner A, Demirkol M, Sarf E, Akcay C. Efficacy of low-level laser therapy in subjective tinnitus patients with temporomandibular disorders. Photonmed Laser Surg 2017;5[6]:427–431.

Silva-Peres TL, Flachia OD, Guimarães RC, Douglas de Oliveira D, Azevedo Neto RM. Unilateral auriculotherapy on the Physical and Emotional Aspects in Patients with Temporomandibular Disorders: A Randomized, Controlled Clinical Trial. Complement Ther Med. 2019;42:540–546.