



Effectiveness of Laser Photobiomodulation Therapy (LPBMT) in TMD patients on different sites: masticatory muscles and TMJ/masticatory muscles

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Abstract

Purposes Temporomandibular joint disorders (TMD) are the common disorders related to the mandibular joint and nervous systems, which can affect the quality of the patient's life. The aim of this study is to evaluate the effect of Laser Photobiomodulation Therapy (LPBMT) on different points of the masticatory muscles and temporomandibular joint (TMJ); with digital occlusal splint (DOS) as two conservative treatment options in TMD.

Materials and methods In this study, 24 TMD patients were randomly divided into three equal groups. The first group A ($n = 8$) was under treatment of LPBMT on the masticatory muscles and the TMJ. The second group B ($n = 8$) was under treatment of LPBMT only on the masticatory muscles; and the last group C ($n = 8$) was a placebo group. All patients received DOS after the LPBMT. Clinical examination was performed before, right after, and 1 month after LPBMT. Subsequently, the patient's symptoms were evaluated 2 weeks, 1, and 3 months after using DOS. Comparisons of data were analyzed by SPSS software with a significance level of $p < 0.05$.

Result In spite of showing no significant group differences ($p = 0.110$), the results revealed within time all the three groups had a significant improvement in pain intensity and mandibular functions ($p < 0.001$).

Conclusion This study showed that a combination of LPBMT and DOS has better clinical results in comparison with DOS alone in the treatment of TMD patients over time.

Keywords Laser Photobiomodulation Therapy (LPBMT) · Occlusal splint · Temporomandibular disorder (TMD) · Masticatory muscles · Temporomandibular joint (TMJ)

Introduction

TMDs are the most widespread disorders related to the temporomandibular joint and the nervous system. According to epidemiological studies, approximately 10.5 to 54% of the general population suffer from these disorders [1] and are more common in females [2]. Occlusal abnormalities such

as cross bite, open bite, crowding, habitual para-functions, and psychological factors can lead to TMD [3].

According to the Diagnostic Criteria for Temporomandibular Disorder (DC/TMD) and Research Diagnostic Criteria for Temporomandibular Disorder (RDC/TMD), the common symptoms of TMD include clicking, pain, limitation of the

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jaw movements, arthralgia, myalgia, and referred myofascial pain, which all can affect the patient's quality of life [1].

There are two comprehensive treatment options for TMD: non-aggressive and reversible or aggressive and irreversible methods. Conventionally, reversible treatment plans include medical therapy, physical therapy, and occlusal splint [3]. Irreversible methods can be separated into two categories: minimally invasive and invasive approaches. Intra articular injection and arthrocentesis treatment are sorted into the minimally invasive group, while permanent amendments in the occlusal surface of the teeth [3], arthroplasty, and TMJ replacement are classified in the invasive group [1]. Reversible treatment plans are commonly used due to their safety, patient comfort, and affordability [1]. Occlusal splints, which are advantageous tools in diagnostic methods, are in the first line of non-invasive treatment approaches. The therapeutic effects of these appliances include occlusal deprogramming, elimination of occlusal discrepancies, muscle relaxation, reduction of trauma to TMJ, and acceleration of its restoration [3]. Use of occlusal splints increases jaw movements awareness and changes the mandibular rest position to a more comfortable and open position. As mentioned, stabilization splints are also beneficial for diagnostic purposes. These appliances can promote the position of the mandible before prosthetic or orthodontic treatment [4]. Traditional processes used to manufacture splints have several cons, such as technique sensitivity and poor appliance fitness, needing longer chair side time to create passive fit and occlusion adjustment. Furthermore, in the course of use, these appliances tend to fracture and fail.

Occlusal splints, manufactured by CAD-CAM overtake conventional techniques by eliminating human errors, resulting in higher material quality appliances and less manufacturing time [2].

Another non-invasive therapeutic intervention that has recently been proposed for the treatment of TMD is Laser Photobiomodulation Therapy (LPBMT) [5]. In this treatment method, laser light is emitted in the range of 600 to 1100 nm (red to near infrared) with irradiance between 5 mW/cm² to 5 W/cm² and power of less than 1 mW to 10 W, and pulse or continuous emission up to 60 s in each point can be used [6]. The therapeutic effect of LPBMT includes adjusting physiological functions of cells, treating the inflammatory process, promoting tissue healing, and increasing the analgesic effect in the treatment of chronic and acute pain. In fact, LPBMT is reported to be effective in removing waste production of cellular metabolisms [7, 8]. The main cellular target of LPBMT is mitochondrial cyclooxygenase with resulting production of prostaglandins, which in turn act as the key mediator of the acute inflammatory response. LPBMT can replace systemic drugs without risk of allergy, drug toxicity, or drug addiction. Generally in dentistry, the treatment target tissues of PBM are located in the superficial range up to 10 mm. Due to strong absorption of these

wavelengths by biological tissue, LPBMT can only penetrate to a certain depth of the tissue [9]. TMD are divided into two categories of intra-capsular and muscular disorders. The muscular disorders are regarded as a background of the intra-capsular disorders [10]. There are a number of studies in the field of laser irradiation at the TMJ [8, 11, 12], the masticatory muscle site [13], and both of them [14, 15]. Thus, the aim of this study is to evaluate the effectiveness of DOS and LPBMT on different points of TMJ and masticatory muscles in TMD patients.

Methods and materials

This study was performed in randomized clinical trial. The protocol was approved by the Ethics Committee of Iranian Registry of Clinical Trial under process number 1401.024.

At the beginning of the study, all complications and benefits of the treatment were explained to the participants, and they signed an informed consent statement.

Subject

TMD: Patients who were referred to the dental prosthetic department of Shahid-Beheshti Faculty of Dentistry (Tehran, Iran), in 2022–2023.

Inclusion criteria

The inclusion criteria for selecting patients are as follows:

- (1) Ages of 20 to 50 years old [16]
- (2) The diagnosis of TMD (muscle disorder type) based on DC/TMD and RDC/TMD [7]

Exclusion criteria

Patients with the following specifications were removed from the study:

- (1) History of recent facial trauma [8, 17]
- (2) Congenital or developmental disorders [17]
- (3) History of recent fracture of facial bone [8]
- (4) History or existence of systemic rheumatologic disease [8, 16]
- (5) Malignancy [18]
- (6) Previous or current skin lesions in head and neck area [17]
- (7) Pregnancy [18]
- (8) Previous treatment for TMDs in the last month [8]
- (9) History of psychiatric disorders or neurological deficit [18]
- (10) Completely edentulous [15]
- (11) Existence of dental pain or periodontal problems [17]
- (12) Patient with diagnosis of disc displacement or dislocation

Procedures

Prior to any intervention, a TMD questionnaire based on (DC/TMD) and (RDC/TMD) [7] was provided to the participants. In addition, clinical examination was performed by a previously trained clinician. This examination included palpation of masticatory muscles and TMJs, evaluation of mandibular movements by using a specific ruler to measure maximum mouth opening, horizontal movements such as left and right movements by using a periodontal probe and to use a stethoscope to check the clicking sound of TMJs. The following items were analyzed: frequency of headache, fatigue, difficulty in chewing, presence of habitual parafunctions such as bruxism and clenching and the patients' psychological state. After these steps, the patients were randomly divided into two groups; two groups received LPBMT and one received a placebo treatment. Laser radiation on both sides was performed as follows:

- (1) Three points on the masseter (origin, body, and insertion), one point on the anterior temporal [13] and two points on the sternocleidomastoid (origin and insertion) muscles [11].
- (2) Three points on the masseter (origin, body and insertion), one point on the anterior temporal [13], two points on the sternocleidomastoid (origin and insertion) muscles [11] and three points around the TMJs (superior, anterior, and posterior) [8, 11, 12].
- (3) Placebo treatment: the dental light curing equipment which has a blue light and a warning sound.

Two sessions per week of LPBMT or placebo treatment completed over 6 weeks, a total 12 sessions [19].

The GaAlAs diode laser device (Diode D5; 808 nm, LAMBDA; Italy) was measured with a power of 300 mW, energy density of 7.89 J/cm², and spot size of 0.38 cm² and was used to irradiate 10 s per point [20], resulting in a total

energy of 3J per point, (3J divided by 0.38 = 7.89 J/cm²) (Table 1). During the laser application process, the patient was positioned in a way that the Frankfurt plane is parallel to the ground. The active tip of the laser device was covered to prevent cross contamination. For a better penetration depth, the point of the skin was cleaned with 70% alcohol and both the patients and operator wore protective glasses. The probe was kept in firm contact with the tissue.

It is possible to estimate the amount of laser radiation in terms of cm², by calculating the surface that is exposed to laser radiation. The depth of penetration of the 808-nm diode laser is approximately 10 mm [21]. A Visual Analog Scale (VAS), which is a numeric rating scale that works from 0 to 10 [12] was used before, right after, and 1 month after LPBMT to record TMJ or masticatory muscle pain [22–24]. Moreover, the amount of mandibular movements, based on the scale of International Association for Dental Research (IADR) [18], was measured before, immediately after, and 1 month after completion of the laser treatment sessions [18].

Plaster models of the dentition were made from alginate impressions and were mounted in the CR position. They were converted into 3D Model by using the 3shape Multi Die scanning table laser (3shape A/S, Denmark). This indirect method was selected because of more accuracy than intraoral scanning process. In this way, occlusal splints were manufactured by CAD-CAM method [4]. Digital occlusal splints were delivered to the patients, and necessary training was presented. The patient was advised to use these appliances 6 h per 24 h (every night) (Table 2) [25]. The appliance was cleaned every morning with toothbrush and water [4]. Evaluation of the pain and mandibular movements was performed based on VAS and IADR before occlusal splint construction, 14 days, 1, and 3 months after using [26]. Finally, data was analyzed by SPSS software (Fig. 1).

Table 1 Treatment parameters

Parameter (unit)	Value	Description
Beam spot size (cm ²)	0.38	
Irradiance (mW/cm ²)	300	
Exposure duration (s)	10	Per point
Radiant exposure (J/cm ²)	7.89	Per point
Number of points irradiated	3	Around TMJ (superior, anterior and posterior)
	6	Masseter (3 points), Sternocleidomastoid (2 points) and anterior temporal (1 point)
Area irradiated (cm ²)	0.38 × 9 points	
Application technique	Skin contact	Firm pressure applied
Number and frequency of treatment sessions	2 sessions per week over 6 weeks (12 total)	

Table 2 Summary of experimental conditions

Group	Laser application site	Therapeutic intervention
A	TMJ and masticatory muscles	LPBMT and DOS
B	Masticatory muscles	LPBMT and DOS
C	TMJ and masticatory muscles	Placebo and DOS

Results

Thirty patients were included at the beginning of the study ($n = 10$ in each group). Two patients of group A and one from group B were lost during follow-up. To equalize the samples, the number of patients decreased to 8 for each. Tukey HSD and Kruskal-Wallis tests were accomplished

to analyze the quantitative variables. The qualitative variables were analyzed by Fisher's exact test.

There were no statistically significant differences in pretreatment pain intensity (Fig. 2), maximum mouth opening, mandibular protrusive, and left and right movements between the experimental groups according to the one way ANOVA (Table 3).

The results showed statistically significant differences after therapeutic intervention in pain intensity value in all three groups ($p < 0.001$). However, there were no significant differences between the three groups ($p = 0.110$) according to the Kruskal-Wallis test. But the pattern of pain reduction was different, and it seemed that the greatest reduction value was for group A (Fig. 2).

Also, the results were the same for the maximum mouth opening (MMO) in all the three groups. Based on

Fig. 1 Flow chart of experimental design

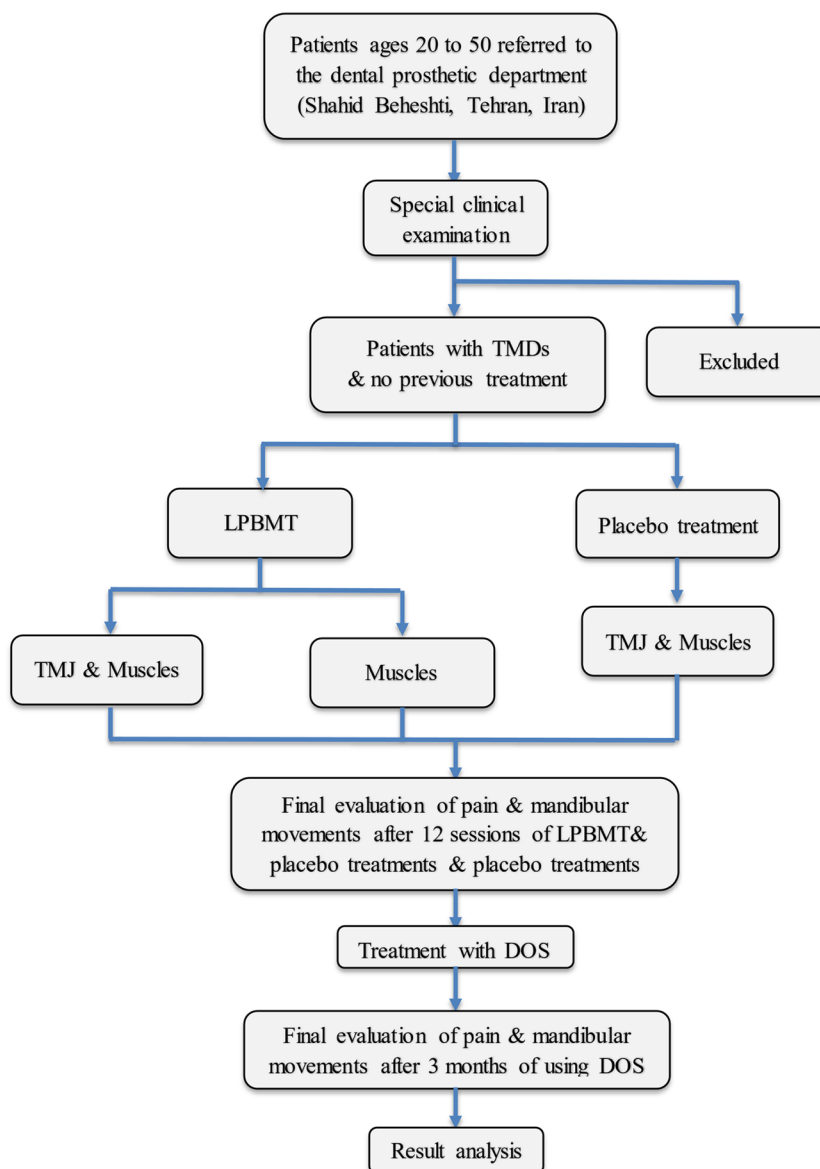


Fig. 2 Graphs showing the mean pain intensity in time of the three groups

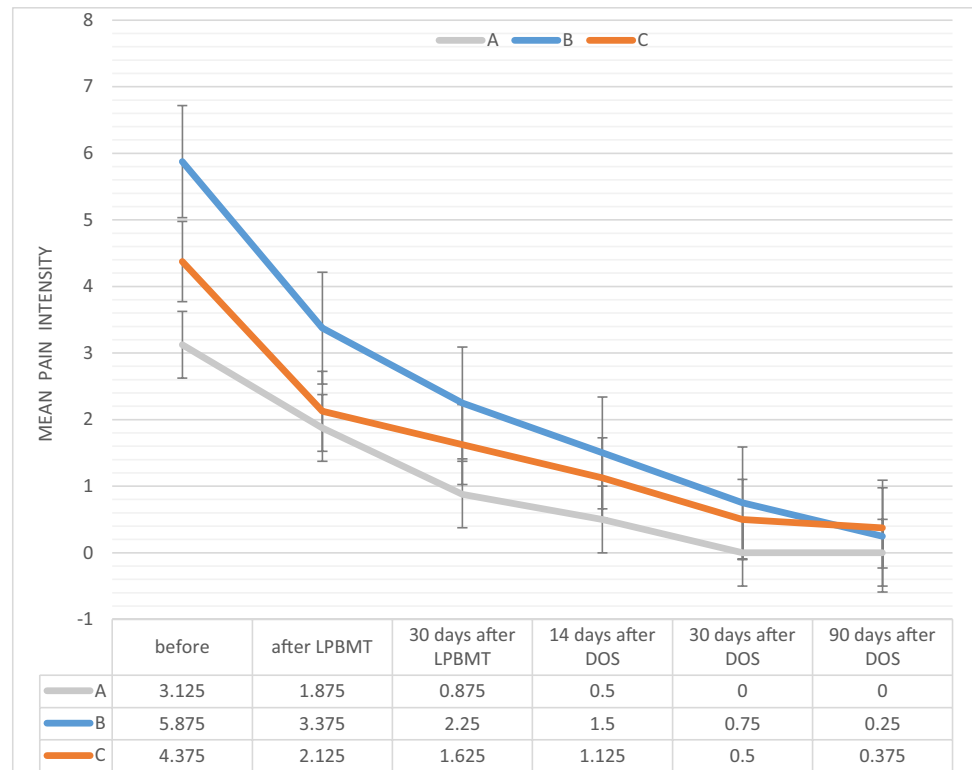


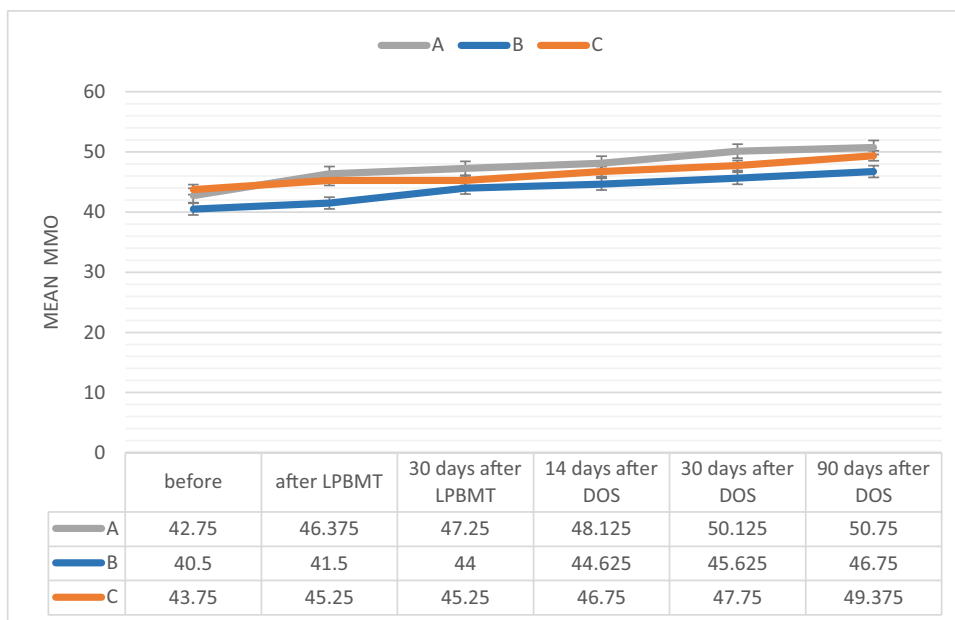
Table 3 Statistical indicators of dependent variables at the base time by group

		N	Mean	Std. deviation	Minimum	Maximum	p-value
Pain intensity	A	8	3.12	2.748	0	8	0.206
	B	8	5.87	3.482	0	10	
	C	8	4.37	2.774	2	10	
	Total	24	4.45	3.242	0	10	
Maximum mouth opening	A	8	42.75	5.392	35	53	0.803
	B	8	40.50	6.990	32	52	
	C	8	43.75	8.940	30	56	
	Total	24	42.33	6.774	30	56	
Protrusive movement	A	8	6.87	2.232	4	10	0.367
	B	8	5.87	1.457	4	8	
	C	8	6.62	1.685	4	9	
	Total	24	6.45	1.874	4	10	
Left movement	A	8	5.87	1.356	4	8	0.548
	B	8	5.25	1.752	3	8	
	C	8	5.12	2.474	0	8	
	Total	24	5.41	1.538	0	8	
Right movement	A	8	6.37	1.303	5	8	0.321
	B	8	5.5	1.690	3	8	
	C	8	5.87	1.642	3	8	
	Total	24	5.91	1.500	3	8	

Fig. 3, a significant increase in MMO was revealed over the time ($p < 0.001$). Although there were no statistically significant differences between the groups ($p < 0.189$),

the interaction between group and time was significant ($p < 0.001$), and the highest improvement was related to group A.

Fig. 3 Graph showing maximum mouth opening (in mm) in the three groups over time



Protrusive, left, and right lateral movements were measured during treatment and follow-up for the evaluation of the ability of mandibular movements. The differences between the study groups were significant 14 days after DOS. According to the results, the maximum amount of mandibular movement ability was related to group A, and the minimum amount was for group C. The differences between groups A and C were statistically significant, but these differences were not significant between groups A and B or between groups B and C (Figs. 4 and 5).

Regarding the TMJ noise, the results were reported as zero and one. Fisher exact test revealed that over time, the

effect of therapeutic intervention in group A was statistically significant, compared to group C ($p = 0.001$) (Table 4).

Discussion

There are various treatment plans for TMD due to their high prevalence in human societies. These treatments are divided into two general categories: invasive and non-invasive, out of which the second one is more accepted by the patients because of its low risk and cost benefit. The first generation of laser devices was introduced in the 1960s for diagnostic

Fig. 4 Graph showing mean protrusive movement (in mm) in the three groups over time

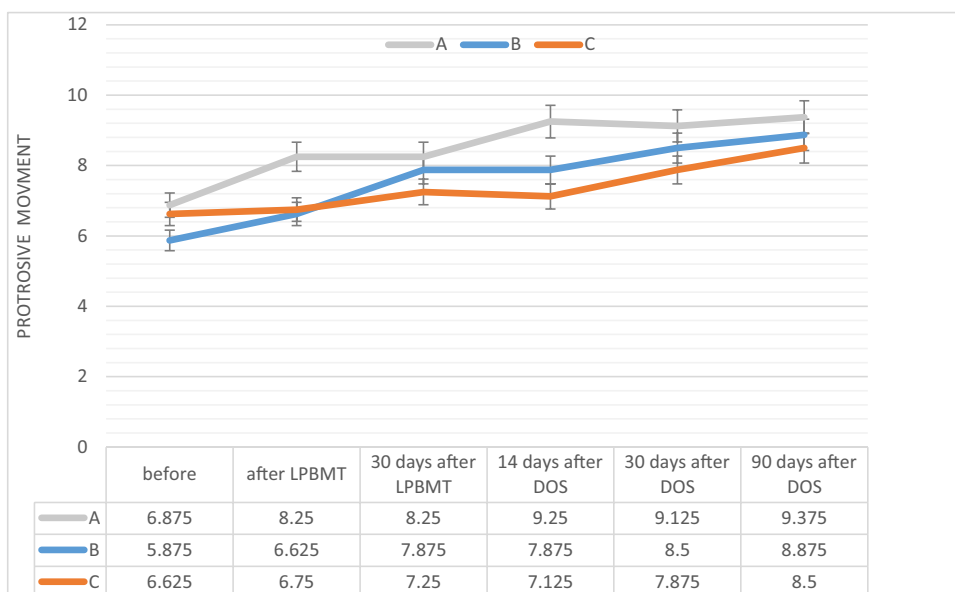


Fig. 5 Graph showing mean left lateral movement (in mm) in the three groups over time

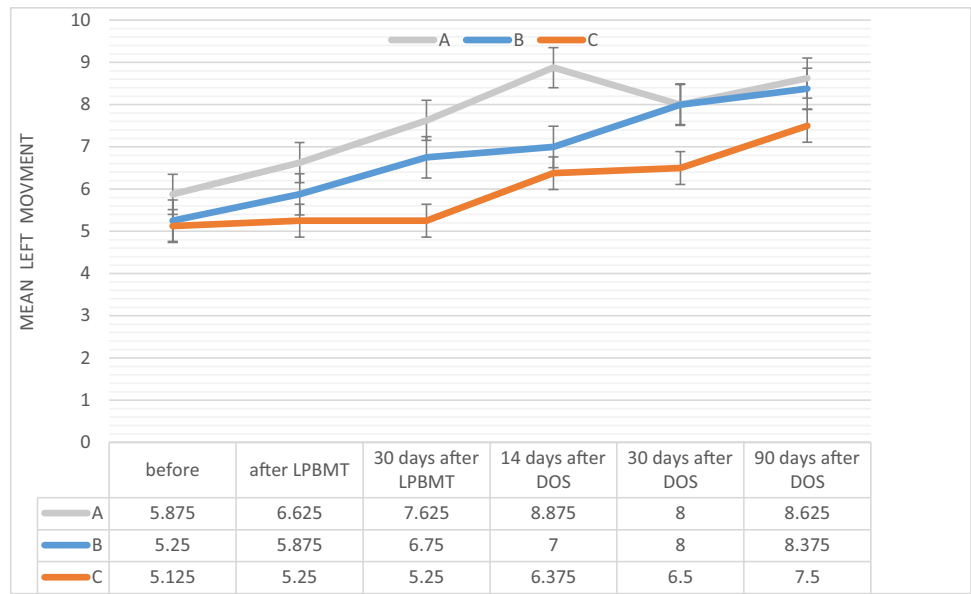


Table 4 Distribution of TMJ noise at different times by treatment groups

			Group A	Group B	Group C	Total	p-value
Before	0*	N [±]	1	2	2	5	1.000
		% [£]	12.50%	25%	25%	20.80%	
	1**	N	7	6	6	19	0.854
		%	87.50%	75%	75%	79.20%	
After LPBMT	0	N	3	6	4	13	0.854
		%	37.50%	75%	50%	54.20%	
	1	N	5	2	4	11	1.000
		%	62.50%	25%	50%	45.80%	
30 days after LPBMT	0	N	5	6	4	15	1.000
		%	62.50%	75%	50%	62.50%	
	1	N	3	2	4	9	0.263
		%	37.50%	25%	50%	37.70%	
14 days after DOS	0	N	5	8	6	19	0.263
		%	62.50%	100%	75%	79.20%	
	1	N	3	0	2	5	0.079
		%	37.70%	0%	25%	20.80%	
30 days after DOS	0	N	5	8	8	21	0.079
		%	62.50%	100%	100%	87.50%	
	1	N	3	0	0	3	0.079
		%	37.70%	0%	0%	12.50%	
90 days after DOS	0	N	5	8	8	21	0.079
		%	62.50%	100%	100%	87.50%	
	1	N	3	0	0	3	
		%	37.70%	0%	0%	12.50%	

* 0 means “not having click noise”, ** 1 means “existence of click sound”

± N means “the number in each group”

£ % means “percentage of existence or not existence of click sound”

and therapeutic purposes [27]. The low intensity laser suggested a non-invasive innovative therapeutic method for TMD. For instance, Ahrari et al. [13] and Marini et al. [18] found that PBM is efficient in improving myofascial pain, functional mandibular movements, and clinical symptoms of the temporomandibular joint disc displacement. Another interesting matter was different sites of irradiation, which some authors concentrated on. The diode laser was utilized in different sites of painful muscles and points around the condyles in Rodrigues's study [15], which reported positive effects in reducing pain and improvement of maximum mouth opening. As mentioned earlier, another conservative treatment for TMD is the occlusal appliance therapy. Among the studies in this field, Chao-Zhang's meta-analyses showed that occlusal splints have a positive effect on the increase of maximum mouth opening, improvement of temporomandibular joint clicking sound, and locking of the jaws. Moreover, this treatment is reported to reduce the intensity of pain and frequency of painful episode for TMD patients [1, 7]. Studies on different types of occlusal splints have also been performed, including Amin's study to compare the effect of three different types of occlusal splints (soft, liquid, and hard) in the treatment of Myofascial Pain Dysfunction Syndrome. The results of that RCT pointed out that hard splints were effective in a shorter period of time, while liquid and soft splints were meant to be used for longer time to be effective in TMD treatment [28]. Nowadays, CAD-CAM technology has had extensive advertising, claiming that it can be used instead of traditional lab technique, improving mechanical properties of materials and eliminating human errors. There are several studies in comparison between digital occlusal splints and conventional occlusal splints. It has been proved that digital occlusal splints lead to statistically significantly lower pain in TMD, tension of face and chair side time for adjusting the appliance, compared to conventional occlusal splints [2].

A combination of the two methods of low intensity laser and occlusal splint was the other discussable subject for researchers, which indicated this was more efficient than a solitary method [29]. Moreover, several studies have been comparing these two treatment approaches [20, 30].

Favorable results have been achieved in various studies based on different points of radiation therapy; therefore, the aim of the present study was to evaluate the efficacy of LPBMT and DOS in the management of patients with TMD, using two different PBM protocols.

The null hypothesis, which LPBMT along with DOS is more effective than DOS alone and laser irradiation at the combined TMJ and muscle sites is effective than muscles alone, was not completely accepted. In the present study, the control group revealed significant relief in clinical symptoms in the 4th follow-up session. The results were similar to the findings of da Cunha et al. [31], Shirani et al.

[32], and Emshoff et al. [33], who reported a significant reduction in pain intensity in three experimental groups, which corroborates the placebo effect of LPBMT. However, the findings of this study differs from Carrasco et al. [34], Cetiner et al. [35], Mazzetto et al. [12], Santos et al. [36], Conti [37], and Ahrari et al. [13], who reported significant reduction in clinical symptoms of TMD patients treated with the active laser probe but not for the placebo application. Despite the lack of statistically significant differences between the studied groups, group A has had clinical significant differences from the others. Thirty days after splint therapy, pain intensity in group A was decreased to 0 and remained in this status for 90 days. But this condition was not spotted in other groups. Moreover in the 3rd follow-up session (14 days after splint therapy), there were obvious clinical differences in the mandibular movement's scale between groups.

As reported in a previous article, radiation of laser has neural effects in the reduction of pain intensity. Impacts of PBM on the peripheral nervous system incorporate the inflammatory cytokines' immune cell modulation and activation or deactivation of neural signals [38].

According to the experimental study by Anders et al. [39], red (623 nm) and infrared (830 nm) irradiation has an advantageous impact on functional recovery of damaged peripheral nerves.

Various degrees of absorption, scattering, and reflection occur in biological tissue in different wavelengths of light. Including that neural tissue is opulent of mitochondria, and mitochondrial cytochrome C oxidase (CCO) is known as one of the most important biological chromophores, CCO plays a necessary role in action mechanism of LPBMT [40]. Absorption of sent photons by PBM can increase available electrons and also reduces molecular oxygen of the center of CCO catalyzer and increases grades of the mitochondrial membrane potential (MMP), adenosine three phosphate (ATP), cyclic adenosine monophosphate (cAMP), and reactive oxygen species (ROS). Briefly, the red and infrared radiation can enhance mitochondrial activities and trigger the cellular signaling it produces. For instance, Mancebo et al. [41] reported that the amount of ATP of mouse primary cortical neurons was approximately two times higher than in the cortical group (810 nm, 25 mW/cm², and 5 min, 3J). Also, in Oron et al. [39], PBM caused a significant increase in ATP productions in normal human neural progenitors (808 nm, 50 mW/cm², 1 s, and 0.05 J/cm²).

Myalgia, which is defined as muscle weakness and muscle fatigue, is one of the main TMD's symptoms. It can be explained by decreased intra-muscular blood flow and hazardous metabolite accumulation. Another beneficial PBM is promotion of vascularization, causing vasodilation, reduction of edema, and oxygen provision to hypoxic cells in painful tissue. In addition, reduction in the release of histamine,

acetylcholine, and synthesis of bradykinin causes muscular pain relief [42].

A biphasic or negative parabolic curve of dose-response has been displayed in several PBM studies. Based on these scientific results, lights have no significant therapeutic effect at very low doses, and much higher doses of PBM can be deterrent or have harmful impacts [40].

The variety in results of different investigations might be related to the different laser wavelength, frequency, energy dosage, and numerosity laser applying session based on the study design. It was attempted to assimilate the radiation parameters to neural LPBM therapy studies, for example, the wavelength was 808 nm (600 to 850 nm that was mentioned in mitochondrial electron transfer chain and nerves' respiratory capacity control), energy density of 7.89 J/cm² (4.8 to 9.6 J/cm²). However, the power density of 300 mW/cm (5 to 100 mW/cm), frequency (40 to 1000 Hz) and irradiation time was 10 s (48 s to 16 min) is greatly higher in transcranial PBM [39, 41].

One of the limitations of the present study is subjectivity of the pain scales (VAS), in that results almost depend on the patient's pain threshold. If a study can be designed to merge clinical symptoms with cellular and molecular findings, the effect of LPBMT on disc or TMJ can be more precisely explained. Despite lack of cellular data laser effects in TMJ treatment, an elimination of clicking in group A was observed in most cases at the 3rd follow-up session. Furthermore, due to combination of PBM and occlusal splint therapy, according to Sam et al. [43], occlusal splints stabilize the dysfunction of TMJ and in long-term can lead to semi-permanent result.

Another limitation of this study is the short-term follow-up duration and lack of cases. It is recommended to use more patients and longer follow-ups in future studies to analyze long-term effects of a combined treatment with LPBMT and occlusal splint.

Conclusion

Based on the findings of this study, it was observed that over a period of 30 and 90 days, all 24 treated patients experience a satisfactory improvement. There was no statistical significant difference between three treated groups but combination therapy (LPBMT and DOS) can be suggested as the treatment choice for treating TMJ and masticatory muscle's disorders.

Declarations

Ethics approval The questionnaire and methodology for this study were approved by the Human Research Ethics committee of the Ira-

nian Registry of Clinical Trials (IRCT) (Ethics approval number: IRCT20220613055160N1).

Consent to participate Informed consent was obtained from all the individual participants included in the study.

Consent for publication The patients signed the informed consent regarding publishing their data and photographs.

Conflict of interest The authors declare no competing interests.

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