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ORIGINAL ARTICLE

Effects of oral motor exercises and laser therapy on chronic temporomandibular disorders: a randomized study with follow-up

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Abstract This study investigated the efficacy of combining low-level laser therapy (LLLT) with oral motor exercises (OM-exercises) for rehabilitation of patients with chronic temporomandibular disorders (TMDs). Eighty-two patients with chronic TMD and 20 healthy subjects (control group) participated in the study. Patients were randomly assigned to treatment groups: GI (LLLT + OM exercises), GII (orofacial myofunctional therapy—OMT—which contains pain relief strategies and OM-exercises), and GIII (LLLT placebo + OM-exercises) and GIV (LLLT). LLLT (AsGaAl; 780-nm wavelength; average power of 60 mW, 40 s, and 60 ± 1.0 J/cm²) was used to promote analgesia, while OM-exercises were used to reestablish the orofacial functions. Evaluations at baseline (T1), after treatment immediate (T2), and at follow-up (T3) were muscle and joint tenderness to palpation, TMD severity, and orofacial myofunctional status. There was a significant improvement in outcome measures in all treated groups with stability at follow-up (Friedman test, $P < 0.05$), but GIV did not show difference in orofacial functions after LLLT ($P > 0.05$). Intergroup comparisons showed that all treated groups had no difference in tenderness to palpation of temporal muscle compared to GC at follow-up (Kruskal-Wallis test, $P < 0.01$). Moreover, GI, GII, and GIII showed no difference from GC in orofacial functional condition (T2 and T3) while they differed significantly from GIV ($P < 0.01$). In conclusion, LLLT combined with OM-exercises was more effective in promoting TMD rehabilitation than LLLT alone was. Similar treatment results were verified with the OMT protocol.

Keywords Temporomandibular disorders · Oral motor therapy · Low-level laser therapy · Rehabilitation · Orofacial functions

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Introduction

Orofacial pain affects muscle activity, movements, and oral motor functions [1–3]. Temporomandibular disorders (TMDs), a group of musculoskeletal disorders, are the most common chronic orofacial pain condition, with higher prevalence in women than in men [4, 5].

Several conservative and reversible treatments are proposed for TMD [6, 7], with the primary goal of reducing the symptom intensity and thus improving the function of the maxillomandibular unit [5].

Occlusal splint is the most popular therapy for TMD [4, 8–10], but effects of other modalities have been investigated. Many studies have shown that approaches as counseling and physical therapy, including relaxation, massage, masticatory muscle exercises [8–13], and low-level laser therapy (LLLT) [6, 14–19], alone or in combined form, result in pain relief and improvement of jaw movements in TMD patients.

In particular, the effects of LLLT on TMDs have been linked to modulation of the inflammatory process and analgesic action [6, 20]. However, a few of these studies have compared patient's outcomes after treatment with healthy subjects [9, 10, 16] and reported the effect size [9]. Additionally,

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functional outcomes have been limited to the range of motion of mandible assessment.

Despite the relevance of human jaw movements, mainly in mastication and speech, greater amplitude does not necessarily mean better functionality. Orofacial functions are complex and involve coordinated activation of multiple subsystems of muscles, including those of the face, jaw, tongue, palate, pharynx, and larynx under the control of the central nervous system [21].

From this viewpoint, LLLT has not proved to be more effective than are other therapies for simultaneously solving both pain and impairment of orofacial functions in TMD [16, 22]. Pain reduction contributes for ameliorating jaw motion [17], difficulty in chewing [15], and masticatory performance [6]. Although, these changes does not ensure that mastication and other functions occur without the compensations, which are frequent in patients with chronic TMD [1, 3]. Motor behavior adaptations may be beneficial but may also be a maladaptation leading to abnormal tissue loading and injury that ultimately stimulates nociceptors and that may result in susceptibility to develop a variety of chronic sensorimotor dysfunctions [21, 23]. Thus, altered motor performance may be a factor for the maintenance of pain [24].

Previously, a program of orofacial myofunctional therapy (denoted by OMT protocol in this study) including oral motor exercises (OM-exercises) for the stomatognathic system components and mastication/deglutition improvement, besides counseling and pain relief strategies showed promising results for functional rehabilitation of TMD patients [25, 26].

The hypothesis of the present study was that LLLT combined with OM-exercises would potentiate TMD rehabilitation better than would either LLLT alone or OM-exercises associated with pain relief techniques of the previously described OMT protocol.

The rationale for such effect is based on previous findings about the analgesic role of LLLT [3, 6, 16, 17, 19] and the fact that motor rehabilitation is a potential approach to treat musculoskeletal pain disorders [24, 27].

Therefore, the aims of this study were to investigate (1) the efficacy of combining LLLT and OM-exercises for the treatment of TMD compared to the OMT protocol and the treatment with LLLT only, as well as with placebo (inactive laser) combined to OM-exercises and a healthy group and (2) the effects of each one program immediately after treatment and at follow-up.

Methods

The participants of this study were selected from 247 patients who came to our University for treatment of orofacial pain and TMD. Among these, 116 showed chronic pain and diagnosis of TMD, according to the Research Diagnosis Criteria for Temporomandibular Disorder (RDC/TMD)—Axis I [28], and 104 subjects agreed to participate. They were randomly assigned to four treatment groups using GraphPad software (Graphpad Software, Inc). Five participants dropped out prior to the start of treatment, and 16 ceased participation during treatment (discontinued, failed to perform the exercises at home, or attend therapy) and 1 did not attended the follow-up. Eighty-two patients (76 women and 6 men) completed the treatment and follow-up. Twenty healthy subjects, without TMD, paired by age and sex (18 women and 2 men; mean age 30 ± 9.6 years), were recruited for the control group (group C) (Fig. 1).

All patients and subjects had permanent dentition; none had dental pain or periodontal problems, neurological or cognitive deficit, previous or current tumor or trauma in the head and neck region, current or prior orthodontic, orofacial myofunctional or TMD treatment, or current use of analgesic, anti-inflammatory, and psychiatric drugs. Additionally, all women declared they were not pregnant.

The study was approved by the institutional ethics committee (Process N. 4118/2013) and all the exams were undertaken with the understanding and written consent of each subject according to the ethical principles.

Demographic characteristics and range of jaw motions (mean ± standard deviation) of patients with TMD in the diagnostic phase are listed in Table 1 and TMD classification in Table 2.

Outcome measures

Three indicators were used to assess the treatment results:

1. Self-judgment of TMD severity*:* we applied the ProTMDmulti—part II questionnaire using a numerical scale and validated to determine the perception of the severity of TMD signs and symptoms such as muscular pain, joint pain, neck pain, earache, tinnitus, ear fullness, tooth sensitivity, joint noise, and difficulty to swallow and speak. The questionnaire enabled us to differentiate control subjects from TMD patients. The reliability and validity of this measure have been demonstrated previously [29].
2. Tenderness to palpation: pressure was applied to the masseter, temporal muscles, and to temporomandibular joint disorders (TMJs) bilaterally. A numerical scale (0–10) was used to assess pain intensity, with 0 indicating no pain and 10 the worst pain.
3. Orofacial myofunctional status: the appearance/posture, mobility, and performance during the functions of stomatognathic system components were evaluated according to the Orofacial Myofunctional Evaluation with Scores (OMES) Protocol [26], which has been

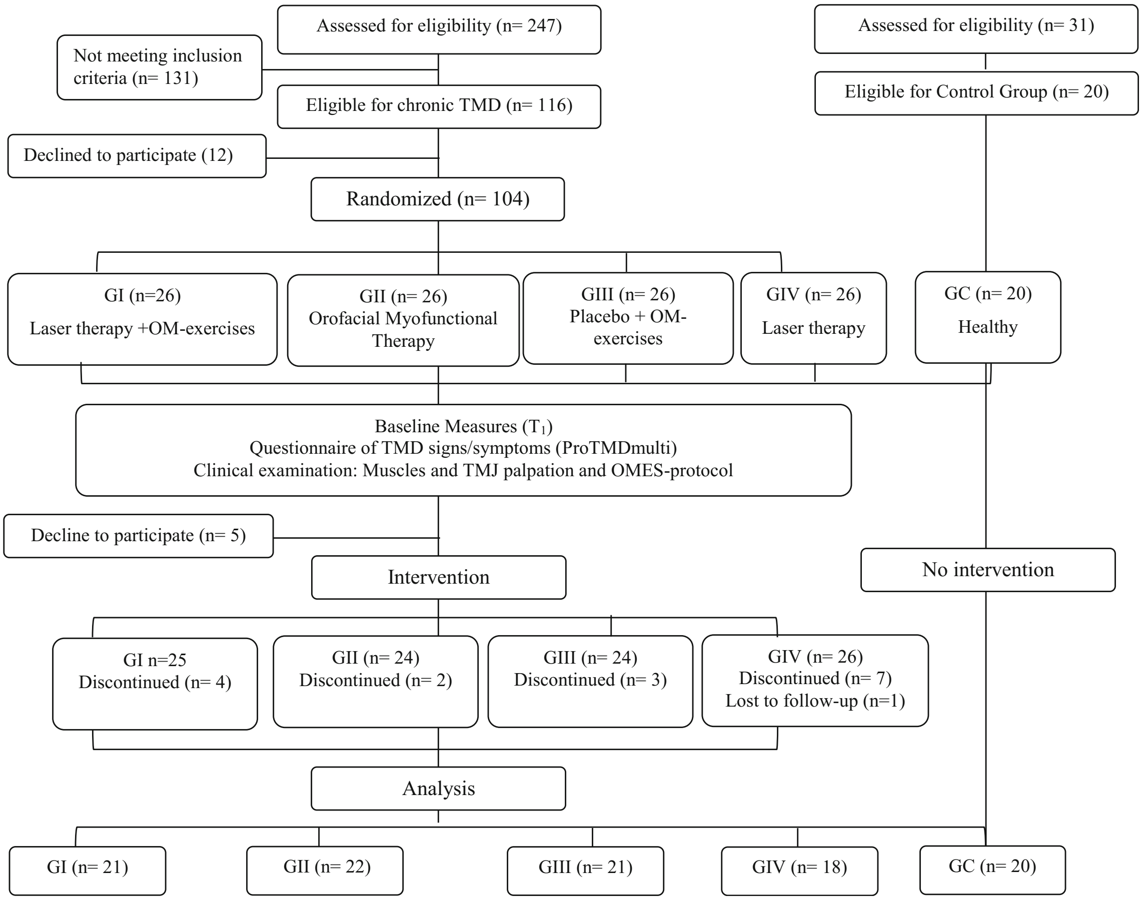

Fig. 1 Flow chart of method and participants

validated for young and adult subjects including TMD patients and showed both sensitivity and specificity of 0.80.

All procedures were performed during the diagnostic phase (baseline = T_1) and were repeated immediately after treatment (T_2) and 3 months in average after completing the treatment (T_3). The speech therapist responsible for the treatment did not participate in the evaluations.

The similarity in age or outcome measures between the TMD groups was determined at baseline before any intervention.

Table 1 Group characteristics: demographic data, TMD duration, and range of movements

		GC (*N* = 20)	GI (*N* = 21)	GII (*N* = 22)	GIII (*N* = 21)	GIV (*N* = 18)
Female participants	n	18	21	21	19	15
Male participants	n	2	0	1	2	3
Mean age (SD)	Mean (SD)	30 (9)	36 (13)	33 (12)	32 (14)	34 (12)
TMD duration (month)	Mean (SD)	–	87 (97)	67 (56)	53 (45)	109 (97)
Range of jaw movements						
Mouth opening (mm)	Mean (SD)	52.4 (3.7)	45.1 (6.7)	44.7 (8.5)	50.0 (9.1)	50.0 (7.1)
Right laterality (mm)	Mean (SD)	9.5 (2.8)	6.8 (2.2)	7.9 (2.7)	7.4 (2.5)	8.9 (2.2)
Left laterality (mm)	Mean (SD)	9.2 (1.6)	7.7 (2.3)	7.2 (2.9)	7.8 (2.7)	9.6 (1.5)
Protrusion (mm)	Mean (SD)	8.0 (1.5)	6.1 (1.6)	7.1 (2.2)	7.1 (2.4)	8.4 (1.7)

SD standard deviation, *mm* millimeters, *GC* healthy control group, *GI* low-level laser therapy + oral-motor exercises, *GII* orofacial myofunctional therapy, *GIII* placebo + oral-motor exercises, *GIV* low-level laser therapy

Table 2 TMD classification according to DC/TMD

TMD classification			GI ($N=21$)	GII ($N=22$)	GIII ($N=21$)	GIV ($N=18$)
Intra-articular	Myalgia	Arthralgia				
DDwR—B	B	B	6	4	3	4
	B	U	1		1	3
	U	U	1			1
	U	-				1
	B	-		1		
	–	B			1	
DDwR - U	B	B	1	5	5	1
	U	B			1	
	B	-			1	
	U	U	1	1		
	________	B		1		
DDwoR—B	B	B	1	4	3	
DDwoR—U	U	U	1			
DJD—B	B	B		1	1	
	B	U				1
DJD—U	B	B	2		1	1
	B	U		1		
–	B	B	6	3	3	4
–	B	U	1	1	1	1
–	U	U				1

DDwR disk displacement with reduction, *DDwoR* disk displacement without reduction, *DJD* degenerative joint disease, *B* Bilateral side *U* Unilateral side, *GC* healthy control group, *GI* low-level laser therapy + oral-motor exercises, *GII* orofacial myofunctional therapy, *GIII* placebo + oral-motor exercises, *GIV* low-level laser therapy

Treatment procedures

TMD treatment consisted of one or more modalities, according to group.

In the LLLT, an AsGaAl semiconductor diode infrared laser device (Model Twin Flex Evolution Laser; MM Optics Ltda, São Carlos, São Paulo) with continuous emission at 780-nm wavelength, a power of 60 mW for 40 s, and energy density of 60 ± 1.0 J/cm^2 was used. Bilateral laser application was done locally with light skin contact at five sites in the TMJ region: lateral pole; superior, anterior, posterior, and inferior points of the condylar position; and on the painful sites of the masseter and temporal muscles reported by the subjects. For the purposes of the study, two identical tips were produced by the laser equipment manufacturer, i.e., an active one and an inactive (placebo) one. The study was blinded, with the subjects not knowing which tip was active until the analysis of the data.

Briefly, the OMT protocol for TMD consisted of the following: (1) instructions to the patients about TMD, myofunctional disorders, and care needed to avoid system overloading; (2) strategies for pain relief such as thermotherapy, massage, and relaxation training; (3) OM-exercises, i.e., (3.1) exercises for tongue, lips, and cheeks and jaw muscles (mobility, endurance, muscle strength) and (3.2) orofacial function training [25, 26].The OMT protocol for TMD therapy was adopted in full or in part in three treatment groups, as described below:

Group I ($n=21$): instructions (1), LLLT, followed by OM-exercises (3.1 and 3.2).The specific pain relief strategies of the OMT protocol were not included
Group II ($n=22$): complete OMT protocol for TMD (1, 2, 3.1, 3.2) [25]
Group III ($n=21$): instructions (1), placebo (laser application performed with an inactive tip, without energy output) plus OM-exercise (3.1 and 3.2)
Group IV ($n=18$): instructions (1) and LLLT

The treatment sessions lasted for 45 min and were held on a weekly basis during the first 60 days and on a biweekly basis thereafter for a total of 12 sessions, totaling a maximum of 9 h in the 120-day period. Patient adherence to the treatment program was tracked based on attendance to the scheduled sessions and for groups I, II, III, it was included a control card on which patients listed the techniques and exercises practiced at home with dates and times and handed over on each return. Failure to attend therapy or reevaluation sessions or failure to perform the exercises at home led to patient exclusion from the study.

Measurement reliability

A randomly selected percentage of the subjects ($n = 20$) was reevaluated by examiner (E1) and by a second blinded examiner (E2). Evaluations performed by the same examiner were scheduled with an interval of at least 30 days to avoid memory effects. These data were used to determine intra and interexaminer reliability.

Statistical analysis

Descriptive statistics were computed for all variables and were shown as the mean and standard deviation (SD) of scores for ProTMDmulti, pain during palpation, and OMES protocol.

The Kruskal-Wallis test was used to intergroup comparisons at each time point separately (T_1, T_2, and T_3), and posttest was applied to compare the difference in the sum of ranks between groups. Intragroup comparisons were performed by Friedman test. Post-test was used to identify the significant difference between evaluations performed before (T_1) and after intervention (T_2 or T_3) as well as between T_2 and T_3.

Interexaminer agreement was determined by intraclass correlation coefficients (ICCs) and weighted kappa coefficient (*Kw*'). Effect sizes for statistically significant differences between T_1 and T_3 were calculated using the Cohen's d statistic. The effect interpretation was based on Cohen [30]: small, $d = 0.2$; medium, $d = 0.5$; and large, $d = 0.8$. These analyses were made using MedCalc Statistical Software version 15.5 (MedCalc Software bvba, Ostend, Belgium; https://www.medcalc.org; 2015).

Consistency and stability of the intraexaminer (reliability coefficient) were determined by the Split-half method, using the Statistica software (StatSoft Inc., Tulsa, OK, USA).

To decrease the risk of false-positive conclusion about group comparisons, significance was set at 1 % ($P \leq 0.01$) and the remaining analyses at 5 % ($P < 0.05$).

Results

Reliability and agreement

The reliability coefficient test and retest performed by E1 were as follows: palpation = 0.93; algometry according to the site ranged from 0.82 to 0.95; and OMES-protocol = 0.98. Intraexaminer ICCs were found: tenderness to palpation = 0.95, ProTMDmulti = 0.95, and OMES-protocol = 0.89. The weighted kappa coefficient (*Kw*') of 0.71 (95 % IC = 0.58-0.85) showed good interexaminer agreement for evaluation with OMES-protocol.

Descriptive statistic (mean values and SD) for outcome measures and results of intergroup and intragroup comparisons are shown in Tables 2, 3, and 4.

Intergroup comparisons of outcome measures

Before intervention

At baseline, intergroup comparisons indicated significant differences ($P \leq 0.001$) with TMD groups showing higher symptom scores (ProTMDmulti) and tenderness to palpation, as well as lower OMES scores than did the control group (GC). There was no statistical difference among TMD groups.

After intervention

Immediately after intervention (T_2) and on follow-up (T_3), significant group differences occurred. All TMD groups still had significantly higher ProTMDmulti scores and tenderness to palpation of masseter muscle (T_2 and T_3) and TMJ (T_2) than those of the GC. Also, the groups GIII and GIV showed higher tenderness to palpation of temporal muscle than did GC in T_2, but not in T_3.There was no statistical difference between GC and GI or GII for palpation of temporal muscle (T_2 and T_3). Moreover, there was no statistical difference between GI and GC for TMJ pain on follow-up (T_3). Analysis of the OMES total score revealed significant group differences during both T_2 and T_3 ($P < 0.001$). According to the posttest, GIV exhibited lower scores than did GC and the other TMD groups that performed OM-exercises.

Intragroup comparisons of outcome measures

All treatments promoted beneficial effects, but with a few particularities, according to modality. In general, outcome measure improvement in T_2, compared to T_1, and positive results were maintained at follow-up ($P < 0.01$, Friedman test). An exception was observed for oral motor function, that is, GIV did not present difference after laser therapy.

The effect size (Cohen d) were large for all outcome measures in groups treated with both pain relief strategy and OME-exercises (GI and GII), except for function category of OMES-protocol in GI that was medium. The groups GIII (placebo + OM-exercises) and GIV (LLLT) showed large effect sizes in ProTMDmulti total score and tenderness to palpation of TMJ. Additionally, large effect size occurred in GIII for mobility of stomatognathic components and OMES-score total.

Table 3 Severity of TMD symptoms and tenderness to palpation (mean and standard deviation), intergroup comparisons, intragroup comparison, and effect size

Variables			GC (N=20)	GI (N=21)	GII (N=22)	GIII (N=21)	GIV (N=18)	P value KW-test
ProTMDmulti total score	T_1	Mean	1.45[a]	145.1[b]	123.2[b]	105.5[b]	118.4[b]	<0.0001
		SD	1.89	86.9	63.2	78.9	64.7	
	T_2	Mean		31.0[b]	24.2[b]	27.6[b]	25.3[b]	<0.0001
		SD		35.3	26.1	30.0	22.7	
	T_3	Mean		28.5[b]	30.9[b]	33.0[b]	35.5[b]	<0.0001
		SD		27.3	33.5	43.5	33.4	
P value Friedman test				<0.001	<0.001	<0.001	<0.001	
Effect size (d) $T_1 \times T_3$				−1.8	−1.8	−1.1	−1.6	
Tenderness to Palpation								
Temporalis	T_1	Mean	0.2[a]	3.7[b]	4.2[b]	3.2[b]	3.4[b]	<0.0001
		SD	0.5	3.3	3.0	2.9	3.0	
	T_2	Mean		1.1[a,b]	1.3[a,b]	1.8[b]	1.4[b]	0.0004
		SD		1.4	1.7	1.7	2.2	
	T_3	Mean		1.1	1.6	1.4	1.3	NS
		SD		1.8	1.7	2.2	1.7	
P value Friedman test				<0.001	<0.001	0.004	0.039	
Effect size (d) $T_1 \times T_3$				−1.0	−1.1	−0.6	−0.7	
Masseter	T_1	Mean	0.8[a]	6.4[b]	6.0[b]	4.6[b]	4.6[b]	<0.0001
		SD	1.0	2.4	2.7	2.5	2.5	
	T_2	Mean		3.2[b, c]	2.4[b]	3.2[b, c]	2.6[c]	<0.0001
		SD		2.2	2.3	1.8	2.2	
	T_3	Mean		3.6[b]	3.0[b]	2.9[b]	3.2[b]	0.0002
		SD		2.4	2.1	2.2	2.4	
P value Friedman test				<0.001	<0.001	0.005	<0.001	
Effect size (d) $T_1 \times T_3$				−1.1	−1.3	−0.7	−0.6	
TMJ	T_1	Mean	0.4[a]	6.4[b]	6.5[b]	5.8[b]	4.7[b]	<0.0001
		SD	0.9	2.8	2.9	3.0	2.6	
	T_2	Mean		3.1[b]	2.6[b]	2.8[b]	2.3[b]	<0.0001
		SD		3.0	2.3	2.3	2.4	
	T_3	Mean		3.0	2.7[b]	2.8[b]	2.5[b]	0.0002
		SD		2.6	2.2	2.3	2.3	
P value Friedman test				<0.001	<0.001	<0.001	0.008	
Effect size (d) $T_1 \times T_3$				−1.3	−1.5	−1.1	−0.9	

P value KW (Kruskal-Wallis) test: intergroup comparisons; P value Friedman test: intragroup comparison; All $P \leq 0.01$ are significant. Means with different superscript letters indicate significant difference between groups in the post-test. Effect sizes for statistically significant intragroup differences before (T_1) × after treatment (T_3) (Cohen's d statistic)

GC healthy control group, *GI* low-level laser therapy + oral-motor exercises, *GII* orofacial myofunctional therapy, *GIII* placebo + oral-motor exercises, *GIV* low-level laser therapy, *SD* standard deviation

Discussion

The main findings of this study were that all treatments promoted favorable changes, although those with combined pain relief strategies and OM-exercises (GI and GII) were more efficient in reducing TMD symptoms (ProTMDmulti), tenderness to palpation, as well as in the functional orofacial rehabilitation. Between the GIII (placebo + OM-exercises) and GIV (LLLT), the first produced better results in OMES-score and the second in symptoms (ProTMDmulti score).

Therefore, the hypothesis that LLLT combined with OM-exercises would be more effective in promoting TMD rehabilitation (decreasing signs/symptoms and functional recovery) compared to LLLT alone was confirmed, but it was not better than complete OMT protocol (OM-exercises associated

Table 4 Orofacial condition

OMES protocol			GC ($N=20$)	GI ($N=21$)	GII ($N=22$)	GIII ($N=21$)	GIV ($N=18$)	P value KW-test
Appearance/posture	T_1	Mean	16.45[a]	13.4[b]	12.9[b]	13.1[b]	12.6[b]	<0.0001
		SD	1.19	1.6	1.7	1.4	1.5	
	T_2	Mean		14.8[b, c]	14.7[b]	14.2[b, c]	13.2[c]	<0.0001
		SD		1.4	1.8	1.7	1.8	
	T_3	Mean		15.0[b]	15.3[b, c]	14.1[c, d]	13.3[d]	<0.0001
		SD		1.1	1.5	1.7	1.3	
P value Friedman test				<0.001	<0.001	<0.001	NS	
Effect size (d) $T_1 \times T_3$				1.1	1.5	0.6	0.5	
Mobility	T_1	Mean	52.40[a]	46.3[b]	47.1[b]	47.4[b]	46.7[b]	<0.0001
		SD	3.14	5.5	4.6	4.8	2.4	
	T_2	Mean		52.9[a]	54.1[a]	55.0[b]	48.8[c]	<0.0001
		SD		3.7	2.3	1.8	3.9	
	T_3	Mean		52.7[a]	54.2[a]	53.6[a]	49.0[b]	<0.0001
		SD		4.4	1.7	3.2	3.8	
P value Friedman test				<0.001	<0.001	<0.001	NS	
Effect size (d) $T_1 \times T_3$				1.2	2.0	1.5	0.7	
Functions	T_1	Mean	26.55[a]	23.9[b]	24.1[b]	24.2[b]	23.9[b]	<0.0001
		SD	1.50	2.1	1.8	3.5	1.8	
	T_2	Mean		25.7[a]	26.4[a]	25.8[a]	23.6[b]	<0.0001
		SD		1.3	1.3	1.7	1.8	
	T_3	Mean		25.1[a]	26.2[a]	26.0[a]	23.4[b]	<0.0001
		SD		1.6	2.1	1.9	1.9	
P value Friedman test				0.021	<0.001	0.001	NS	
Effect size (d) $T_1 \times T_3$				0.6	1.1	0.6	–	
OMES total score	T_1	Mean	95.4[a]	83.6[b]	84.2[b]	84.7[b]	83.1[b]	<0.0001
		SD	4.2	7.0	6.8	8.2	4.1	
	T_2	Mean		93.5[a]	95.2[a]	95.0[a]	85.3[b]	<0.0001
		SD		5.2	3.9	4.1	5.1	
	T_3	Mean		92.9[a]	95.7[a]	93.7[a]	85.7[b]	0.0001
		SD		5.9	3.4	5.4	4.8	
P value Friedman test				<0.001	<0.001	<0.001	0.0031	
Effect size (d) $T_1 \times T_3$				1.4	2.1	1.3	0.6	

P value KW (Kruskal-Wallis) test: intergroup comparisons; *P* value Friedman test: intragroup comparisons. All $P \leq 0.01$ are significant. Means with different superscript letters indicate significant difference between groups in the post-test. Effect sizes for statistically significant intragroup differences before (T_1) × after treatment (T_3) (Cohen's d statistic). Intergroup comparisons of OMES-total score (mean and standard deviation), intragroup comparison, and effect size of categories and total scores of OMES-protocol

GC healthy control group, *GI* low-level laser therapy + oral-motor exercises; *GII* orofacial myofunctional therapy; *GIII* placebo + oral-motor exercises; *GIV* low-level laser therapy, *SD* standard deviation

with strategies as relaxation, hot compress, and massage techniques).

This study also shows that, compared to control group, treated groups no longer showed a significant difference for the tenderness to palpation of temporal muscle. Furthermore, the groups with OM-exercises achieve healthy functional orofacial conditions. However, in all the other comparisons, differences between treated groups and C group were still observed.

In literature, it has been documented that LLLT promotes positive effects on TMD, despite differences due to wavelength and energy density (dose) for which there is no evidence regarding what the amount required to TMD is [5]. Previous studies reported changes in tenderness to palpation, pressure pain threshold [6, 15, 16, 19, 22], self-perception of pain [6, 14, 20, 31, 32], and range of jaw movements [15, 16, 20, 32] immediately after TMD treatment.

Some of these also reported which effects were maintained at 1-month follow-up [6, 15, 19].

Among the previously quoted papers, only one compared healthy group and TMD patients after LLLT. According to authors, the TMD group values after the treatment were still significantly different from those of healthy individuals [16], as verified in the present study with respect to all treated groups.

Additionally, some reported better results of LLLT treatment compared to placebo [6, 15, 19] while others did not observe differences between groups [14, 20, 31, 32]. In a recent meta-analysis, Chen et al. [5] concluded that the LLLT has limited efficacy in reducing pain, but it can significantly improve the range of jaw movements of patients with TMDs.

Our results showed that LLLT (GIV) provides pain and other symptoms relief, as well as placebo and OM-exercises (GIII), although these modalities had been less efficient compared to the other two treatments with combined pain relief strategies and OM-exercises (GI and GII).

Placebo, according to literature, is not the inert treatment alone, but rather, it is the whole ritual of the therapeutic act that tells the patient that beneficial therapy is being given [33]. Thus, the placebo may be inherent to all clinician-patient contact. There are many placebo procedures, with different responses and mechanisms implicated in various conditions. Factors such as patient expectations and the wish to relieve pain are important in placebo analgesia [34].

However, LLLT alone was not sufficient for TMD rehabilitation. Thus, another aspect of the present investigation involves exercise effects. Exercise therapy is relevant for the rehabilitation of patients with musculoskeletal disorders, and it is widely used in a variety of painful conditions [24, 27]. Authors explained that exercise-induced hypoalgesia is characterized by diminished sensitivity to noxious stimulation or a decrease in pain perception, possibly due to the stimulated release of pain-relieving peptides that include non-opioid compounds (e.g., serotonin, norepinephrine) and endogenous opioid substances, typically measured by changes in plasma β-endorphin levels [27, 35].

Improvement of the major symptoms of TMD, self-perception of functional impairment, and range of jaw movement in TMD patients (muscular or intra-articular) have also been associated with exercise therapy for joint mobilization and massage for mandibular muscles [11, 12], massage alone, or massage associated to conventional occlusal splint [9, 10]. Nonetheless, a recent paper does not support additional effect of occlusal splint compared to physical therapy [13].

In general, several studies reported functional recovery after diverse therapeutic modalities, such as laser therapy and exercises; however, analyses comprised the range of movements and self-assessing scales as difficult to chew. When orofacial functions were evaluated after LLLT, no change occurred [16, 22], as also verified in our patients.

Results showed that OM-exercises were essential to functional reorganization [25]. This approach differs from other physical therapies for TMD, because in addition to jaw mobilization, it includes strategies for lips and tongue cheeks aiming to develop independent voluntary contraction ability and mobility of each component, coordination between them, and thus, mastication and deglutition training, whenever appropriate.

There are relevant physiologic linkages among jaw, tongue, and lip functions [36], with sophisticated central coordination and adaptation for the orofacial functions [21], which has not been considered in most proposals for TMD treatment.

This investigation is the first to evaluate the effects of combining LLLT and OM-exercises in TMD treatment and the first to monitor OMT protocol results after an average of 3 months of follow-up.

In general, OM-exercises have not been applied to relieve pain, but to rehabilitate orofacial movements and functions such as swallowing [37, 38] and mastication [39, 40]. Orofacial muscle training can improve tongue strength and accuracy [38], lip-closing force [41], masticatory muscle activity, and masticatory pattern [40]. It can also promote a reduction in the time necessary to reintroduce oral feeding [39] and penetration-aspiration in patients with dysphagia [38].

Moreover, OM-exercises perhaps may provide training and learning of motor skills, and they are likely to promote neuroplasticity to the primary motor area (MI) and the primary somatosensory area (SI) that are involved in sensorimotor integration and control of orofacial motor functions [21].

Studies have disclosed that standardized motor task training is associated with corticomotor excitability and neuroplasticity in corticomotor control of tongue [42, 43] and jaw muscles [44, 45].Thus, this type of training may potentially improve motor behavior performance, which is essential for treating patients with musculoskeletal pain disorders [24]. Nevertheless, all these possibilities require further investigation.

Study limitations

A potential limitation of our study was heterogeneity of the sample with several TMD classifications, which could have effects on the treatment outcomes [5]. Nevertheless, the randomization was successful, and the baseline distribution of TMD type and the side of involvement (unilateral or bilateral) was similar across the four patient groups making the comparisons between them unbiased. Moreover, Chantaracherd et al. [7] have not verified an association between intra-articular status (stages of intra-articular disorders: normal joint structure, DDwR, DDwoR, and DJD) and TMD impact (a variable composed of scales for self-assessment of pain intensity, jaw function, and jaw disability). These scales seem to have some similarity with outcome measures of the present study.

Our study did not include psychological factor analysis that may clarify not only the placebo effect but also the influence of this variable in all treated groups.

Conclusion

LLLT and OM-exercises combined was more effective than LLLT alone was in promoting TMD rehabilitation, with decreasing of signs/symptoms and functional recovery, but it was not better than complete OMT protocol. Treatments combining pain relief strategies (LLLT or traditional techniques) and OM-exercises are promising for rehabilitation of patients with TMD.

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Compliance with ethical standards The study was approved by the institutional ethics committee (Process N. 4118/2013) and all the exams were undertaken with the understanding and written consent of each subject according to the ethical principles.

Conflict of interest The authors declare that they have no conflict of interest.

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