Disability and Rehabilitation

ISSN: 0963-8288 (Print) 1464-5165 (Online) Journal homepage: http://www.tandfonline.com/loi/idre20

Immediate and short-term effects of phototherapy on pain, muscle activity, and joint mobility in women with temporomandibular disorder: a randomized, double-blind, placebo-controlled, clinical trial

Carolina Marciela Herpich, Ernesto Cesar Pinto Leal-Junior, Cid Andre Fidelis de Paula Gomes, Igor Phillip dos Santos Gloria, Ana Paula Amaral, Maitê de Freitas de Rocha Souza Amaral, Fabiano Politti & Daniela Aparecida Biasotto-Gonzalez

To cite this article: Carolina Marciela Herpich, Ernesto Cesar Pinto Leal-Junior, Cid Andre Fidelis de Paula Gomes, Igor Phillip dos Santos Gloria, Ana Paula Amaral, Maitê de Freitas de Rocha Souza Amaral, Fabiano Politti & Daniela Aparecida Biasotto-Gonzalez (2017): Immediate and short-term effects of phototherapy on pain, muscle activity, and joint mobility in women with temporomandibular disorder: a randomized, double-blind, placebo-controlled, clinical trial, Disability and Rehabilitation, DOI: 10.1080/09638288.2017.1336648

To link to this article: http://dx.doi.org/10.1080/09638288.2017.1336648

Published online: 11 Jun 2017.

DISABILITY AND REHABILITATION, 2017
https://doi.org/10.1080/09638288.2017.1336648

Taylor & Francis
Taylor & Francis Group

ORIGINAL ARTICLE

Immediate and short-term effects of phototherapy on pain, muscle activity, and joint mobility in women with temporomandibular disorder: a randomized, double-blind, placebo-controlled, clinical trial

Carolina Marciela Herpich[a], Ernesto Cesar Pinto Leal-Junior[a], Cid Andre Fidelis de Paula Gomes[b], Igor Phillip dos Santos Gloria[a], Ana Paula Amaral[a], Maitê de Freitas de Rocha Souza Amaral[a], Fabiano Politti[a] and Daniela Aparecida Biasotto-Gonzalez[a]

[a]Postgraduate Program in Rehabilitation Sciences, Center for Support to Research on Movement Analysis, University Nove de Julho (UNINOVE), São Paulo, Brazil; [b]Department of Physical Therapy, University Nove de Julho (UNINOVE), São Paulo, Brazil

ABSTRACT

Objectives: The aim of the present study was to evaluate the immediate and short-term effects of phototherapy on pain intensity, the pressure pain threshold (PPT), maximum vertical mandibular movement, and the electrical activity of the masseter and temporal muscles in women with temporomandibular disorder (TMD).

Methods: Sixty women were randomly allocated to four different groups and submitted to phototherapy with a combination of super-pulsed laser (905 nm), red (640 nm), and infrared (875 nm) light emitting diodes in the same equipment on the masseter (three points) and temporal (two points) muscles bilaterally in a single session. The following doses were used in each point of application: Group 1 – 2.62 J; Group 2 – 5.24 J; Group 3 – 7.86 J; placebo group. Pain intensity was determined using the visual analog scale. The PPT was analyzed using a digital algometer. Vertical mandibular movement was measured using digital calipers. Myoelectrical activity of the masseter and temporal muscles was measured using electromyography. Four evaluations were performed: pre-intervention, immediately after, 24 and 48 hours after phototherapy.

Outcomes: A significant reduction in pain intensity during the post-treatment evaluations in comparison to the pretreatment evaluation was observed in group 1 (Median difference = 2.60 [95% CI = 1.35–3.85]) and group 2 (Median difference = 2.2 [95% CI = 0.98–3.42]) especially after 48 hours and group 3 (Median difference = 2.50 [95% CI: 0.56–4.46]) especially after 24 hours, with a moderate effect size, but no effect was found regarding the other variables.

Conclusions: A single session of combined phototherapy was capable of reducing pain intensity in individuals patients with TMD.

ClinicalTrials.gov (NCT02018770).

➤ IMPLICATIONS FOR REHABILITATION

- Phototherapy device combining two light sources (LED and laser), and different densities in the same device is a novelty in the rehabilitation market, and has proved to be a useful intervention for people with temporomandibular disorders.
- This mode of phototherapy is another option that assists in the rapid intervention in pain symptoms, promoting a considerable degree of comfort to the patient moments after its application.

ARTICLE HISTORY
Received 17 October 2016
Revised 22 March 2017
Accepted 27 May 2017

KEYWORDS
Temporomandibular joint disorder; electromyography; physical therapy modalities; lasers; phototherapy

Introduction

Temporomandibular disorder (TMD) is a collective term embracing all the problems relating to the temporomandibular joint (TMJ) and related musculoskeletal structures, characterized by pain or discomfort in the TMJ, masticatory muscles and limited or deviated mandibular movements and chewing difficulty, with pain considered the most common and limiting clinical manifestation of this condition [1,2]. According to Gonçalves et al. [3], 39.2% of patients report at least symptom of TDM and females are twofold more likely to complain of pain symptoms in comparison to males [4]. Direct or indirect trauma to the mandible or TMJ, occlusal interferences, malocclusion, muscle disorders, and microtrauma caused by continual parafunctional habits [1] may be related to the etiology of TMD.

Different non-surgical approaches can be used for the treatment of TMD, such as pharmaceuticals [5], physical therapy [2], phototherapy [6], manual therapy and should be occlusal therapy [7]. The principal aim of all non-surgical treatments used for the

CONTACT Carolina Marciela Herpich carolinaherpich12@hotmail.com 124 Street, Cabo Jõao Teruel Fregoni, Apartment 161 F, Ponte Grande, 07032000 Guarulhos, SP, Brazil

management of this disorder is to reduce the intensity of the symptoms, especially pain, thereby providing an improvement in jaw function.

Phototherapy, such as low-level laser therapy (LLLT), has been used for the treatment of TMD. LLLT involves a monochromatic, coherent light source that preserves collimation during propagation [8]. The action of LLLT has been described to modulate the inflammatory process in cases of acute pain by reducing the influx of neutrophils, oxidative stress, swelling, and hemorrhage [9]. This differs from a light-emitting diode (LED), which covers a broad gamut of wavelengths and has also been used as treatment option for individuals with TMD [10], achieving similar results with the advantages of a lower cost and better durability of the equipment [11].

Clinical studies have demonstrated that LLLT can lead to a reduction in muscle and joint pain [6,10], a reduction in the number of trigger point, and improvement in jaw movements and chewing function. However, conflicting results are reported, likely due to differences in laser irradiation parameters or the criteria used for the classification and evaluation of TMD, which indicates limited efficacy with regard to reducing pain [12]. Moreover, only one light source is employed. Thus, the combined use of multiple light sources could represent a therapeutic advantage [13], as a single session could lead to different effects on tissues when the energy delivery rate is varied [14,15]. Thus, there is a need for investigations that address the joint use of LLLT and LED therapy in a single device, following a tendency of previous studies in which this combination has been employed for other treatments [15,16].

The aim of the present study was to determine the immediate and short-term effects of phototherapy on such variables in patients with TMD and compare to the placebo group.

The hypothesis tested herein is that phototherapy with a combination of super-pulsed laser (905 nm) as well as both red (640 nm) and infrared (875 nm) diodes in the same device will lead to immediate improvements in pain intensity, the pressure pain threshold (PPT), maximum vertical mandibular movement and electrical activity in the masseter and temporal muscle in patients women with TMD.

Methods

Design

A prospective, randomized, placebo-controlled, double-blind (patients and examiner) study was conducted. The methods were previously specified in a published protocol study [17]. Two physiotherapists who were blinded to the allocation of the patient to the different groups were in charge of evaluating the subjects to confirm the eligibility criteria. This evaluation consisted of a detailed history on TMD, the confirmation of the diagnosis through the use of the Research Diagnostic Criteria for Temporomandibular Disorders (RDC/TMD) [18] and a physical examination. Those eligible for the study received clarifications regarding the objective and procedures and signed a statement of informed consent agreeing to participate, in compliance with Resolution 466/2012. This study received approval from the local human research ethics committee under process number 18032013.4.0000.5511 and is registered with ClinicalTrials.gov (NCT02018770).

The patients participating in the study were randomized into groups according to a spread sheet generated in a computer program by a researcher who was not involved in the selection of patients. Randomization occurred in the order in which each patient was enrolled in the study: Group 1 – 2.62 J/point; Group 2 – 5.24 J/point; Group 3 – 7.86 J/point; and Group 4 – placebo. The randomization procedure was performed by a researcher who was not involved in the recruitment, evaluation, or treatment of the participants. Four physiotherapists (one per group) with at least three years of experience and having undergone a two-month training period for administration of the procedures were designated to conduct the treatments. On the day of treatment, a researcher who was unaware of the volunteers scheduled the equipment according to the result described in randomization. The physiotherapists who then performed the treatment were blinded to the parameters programed into the equipment.

A blinded examiner evaluated the clinical outcomes before, immediately after as well as 24 and 48 h after phototherapy. The participants were informed that they would receive treatment involving phototherapy and were blinded to whether the treatment was active or placebo.

Participants

The RDC/TMD [18] was used to diagnose the participants with myofascial pain (Ia) or myofascial pain with limited opening (Ib) and pain and/or fatigue in the masticatory muscles during functional activities for more than six months bilaterally. Concomitant diagnoses were permitted, such as arthralgia and disc displacement, as reported in precision study conducted by Manfredini et al. [19]. Only women were selected due to the high prevalence rate of TMD in this gender [4].

The following were the exclusion criteria: age less than 18 years or more than 40 years; body mass index (BMI) greater than 25 kg/m^2 to standardize the relationship between muscle surface and the electromyographic electrode, currently undergoing orthodontic physiotherapeutic, psychological, or medicinal (analgesic, anti-inflammatory agent, or muscle relaxant) treatment; pregnancy; the use of a complete or partial dentures; use of a bite plate; history of trauma to the face or TMJ; a history of luxation or subluxation of the TMJ; missing teeth (except for third molars); a diagnosis of osteoarthritis (IIIb) or osteoarthrosis (IIIc), and Psychological disorder and/or psychological treatment using the RDC/TMD.

The clinical trial was conducted at a physical therapy clinic in the city of Sao Paulo, Brazil. The participants were recruited with the use of posters and flyers at physical therapy and dentistry clinics between February and November 2014.

Sample size calculation

The sample size was calculated considering $\alpha = 0.05$, $1 - \beta = 0.9$ from the data on the VAS described in a study conducted by Pereira et al. [20]. The calculation was performed using the G*Power program, which determined 15 patients for each group.

Intervention

Phototherapy was administered to the anterior, middle, and posterior temporal muscle (three points) as well as the upper and lower masseter muscles (two points) bilaterally in all groups, totaling 10 points on each volunteer with a radiance area of 4 cm^2 per point. Treatment was administered with a portable nine diode cluster (PainAway^{TM}, Multi Radiance Medical, Solon, OH), with one 905-nm diode super-pulsed laser (frequency: 1000 Hz: average optical output: 0.9 mW; peak power: 8.5 W; and spot size: 0.4 cm^2), four 640-nm infrared LEDs (frequency: 2 Hz; average optical output of each: 15 mW; and spot size: 0.9 cm^2), and four 875-nm red LEDs

(frequency: 16 Hz; average optical output of each: 17.5 mW; and spot size: 0.9 cm^2). Radiance time in each time point of application was 20 s (Group 1), 40 s (Group 2), or 60 s (Groups 3 and 4), with energy per quadrant of 2.62 J (Group 1), 5.24 J (Group 2), 7.86 J (Group 3), or 0 J (Group 4), generating a total energy of 26.20 J (Group 1), 52.40 J (Group 2), 78.60 J (Group 3), or 0 J (placebo group) (Table 1). Two devices furnished by the manufacture were used: one active (Groups 1, 2, and 3) and one inactive (without the delivery of energy, used for placebo group). Both devices have identical sound and light. During the administration, both the therapist and volunteer wore eye protection, which was also supplied by the manufacturer.

Table 1. Parameters of phototherapy.

Number of super-pulsed lasers	1 Super-pulsed laser
Wavelength (nm)	905
Frequency (Hz)	1000
Average optical output (mW)	0.9
Peak Power (W)	8.5
Dose (J) total per group (G1: 20 s; G2: 40 s; G3: 60 s)	0.018; 0.036; 0.054
Spot size (cm^2)	0.4
Number of red LEDs	4 Red
Wavelength (nm)	640 (±10 nm)
Frequency (Hz)	2
Average optical output (mW)-each	15
Dose (J) each emitter per group (G1: 20 s; G2: 40 s; G3: 60 s)	0.3; 0.6; 0.9
Dose (J) total per group (G1: 20 s; G2: 40 s; G3: 60 s)	1.2; 2.4; 3.6
Spot size (cm^2) – each	0.9
Number of infrared LEDs	4 Infrared
Wavelength (nm)	875 (±10 nm)
Frequency (Hz)	16
Average optical output (mW) – each	17.5
Dose (J) each emitter per group (G1: 20 s; G2: 40 s; G3: 60 s)	0.35; 0.70; 1.05
Dose (J) total per group (G1: 20 s; G2: 40 s; G3: 60 s)	1.4; 2.8; 4.2
Spot size (cm^2) – each	0.9
Magnetic field (mT)	35
Treatment time (s)	20; 40; or 60
Aperture of device (cm^2)	4
Total delivered energy (J) per point (G1: 20 s; G2: 40 s; G3: 60 s)	2.62; 5.24; or 7.86
Total delivered energy (J) per individual (G1: 20 s; G2: 40 s; G3: 60 s)	26.20; 52.40; or 78.60

A total of 98 individuals were screened for the present study. Thirty-eight were excluded for the reasons presented in Figure 1. The remaining 60 patients divided into four groups (15 patients in each group) were all evaluated before and immediately after as well as 24 and 48 h after phototherapy.

Measures

Four outcome measures were analyzed: pain intensity using the visual analog scale (VAS); the PPT using a digital algometer; maximum vertical mandibular movement using calipers; and myoelectrical activity of the masseter and temporal muscles using electromyography (EMG). Pain intensity was the primary outcome and the remaining measures were the secondary outcomes. Evaluations were performed before and immediately after as well as 24 and 48 h after phototherapy.

Pain intensity

The VAS is a simple, efficient, reliable, and valid method for measuring pain intensity and is widely employed in both clinical practice and research [21]. This scale consists of a 10-cm line with "no pain" printed at one end and "worst pain ever felt" printed at the other end. Each participant was asked to report her pain intensity based on the previous 24 h by marking a perpendicular line between the two extremes of the scale [21].

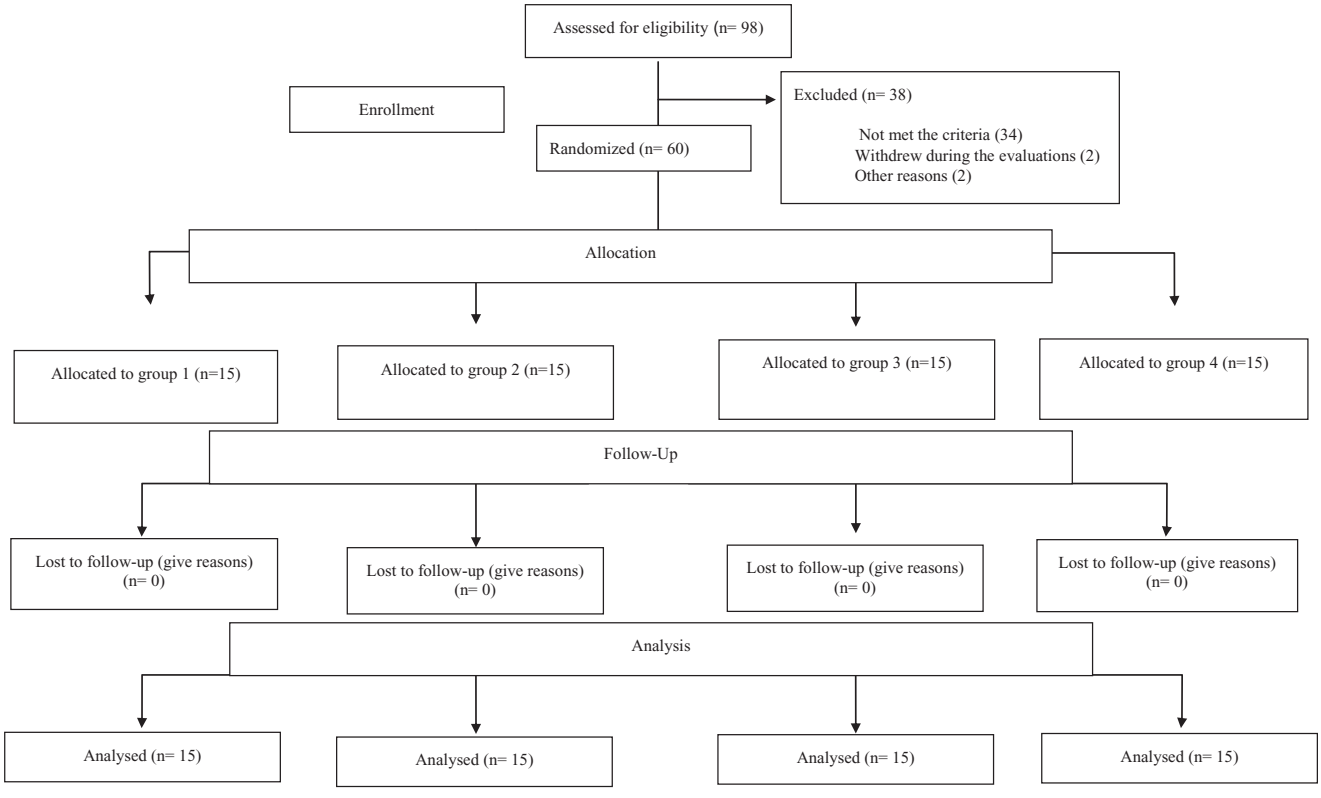

Figure 1. Flow diagram.

Pressure pain threshold

A digital algometer (DD-200 model, Instrutherm®, São Paulo, Brazil) was used to determine the PPT. For such, the volunteer remained seated in a chair with the trunk erect and back supported, feet planted on the floor and hands resting on the thighs, with the Frankfurt plane parallel to the floor. The examiner positioned the algometer and exerted gradual pressure at three points of the masseter (upper, middle, and lower) and anterior temporal (posterior, middle, and anterior) muscles, bilaterally, determined through palpation following the guidelines of RDC/TMD clinical exam. All points received pressure until the volunteer reported the sensation of pain, at which time the value on the display of the equipment was recorded [22]. If the volunteer did not experience pain, pressure was ceased upon reaching 4 kgf. Pressure was exerted using the rubber tip (1 cm^2) of the device in direct contact with the skin at the "fast" velocity on the "peak hold" function (specification of the digital DD-200 algometer from Instrutherm®). Prior to the first session, readings were taken on the individual's arm to familiarize the volunteer with the test. The volunteer was instructed to raise one of her hands when the pressure became painful, at which point the researcher interrupted the test. The algometer was only applied once to each of the aforementioned points and a 30-rest period was respected before the next reading was made. A single research assistant performed the clinical PPT measure. The intratester reproducibility of the PPT measurements was satisfactory to good (intraclass correlation coefficient (ICC 0.78–0.93) [22].

Range of movement

The evaluation of maximum vertical mandibular movement was performed using two measures: maximum opening without pain, for which the volunteer was instructed to place the mandible in a comfortable position and open her mouth as wide as possible without pain and without assistance; and maximum opening even with pain, for which the volunteer was instructed to place the mandible in a comfortable position and open her mouth as wide as possible even if feeling pain. All measurements were recorded in millimeters with the aid of digital calipers (Starrett®, Athol, MA) positioned between the maxillary and mandibular central incisors. The same procedure was performed three times, with a one-minute interval between readings. The mean of the three readings was used for the comparison between baseline and post-treatment evaluations.

Electromyography

The right and left masseter and anterior temporal muscles were analyzed with surface EMG. After cleaning the skin with 70% alcohol, disposable surface electrodes (Ag/AgCl – Noraxon® Ltd., Scottsdale, AZ) measuring 10 mm in diameter were placed on the masseter and anterior temporal muscles with a center-to-center distance of 20 mm. The electrodes were attached over the belly of the muscle in the region with the greatest tonus after the volunteer performed moderate intercuspation. When necessary, hair was shaven from the appropriate sites to ensure adherence of the electrodes [23]. A rectangular metal electrode was attached to the left wrist to serve as reference. The participants remained seated in a chair with hands lying on the thighs. EMG signals were obtained using an eight-channel module (EMG System do Brasil Ltda®, São Bernardo do Campo, Brazil) with a 20–1000 Hz band pass filter and a common mode rejection ratio >120 dB. All data were acquired and processed using a 16-bit analog to digital converter (EMG System do Brasil Ltda®, São Bernardo do Campo, Brazil) with a sampling frequency 2 kHz. The EMG signals were captured under the following conditions: (1) rest for 15 s; (2) maximum voluntary contraction (MVC) for five seconds with Parafilm M® placed between the upper and lower molars on each side; (3) voluntary contraction with maximum habitual intercuspation (MHI) for five seconds with no material placed between the teeth. Three readings were made under each condition, with a two-minute rest period respected between readings. Electrode placement between evaluations was standardized by marking the sites with a black marker and instructing the participant not to remove the marks in the two days following the first readings.

EMG signal processing was performed using specific routines carried out using the Matlab program, version 7.1 (The MathWorks Inc., Natick, MA). The root mean square (RMS) of the EMG signal (expressed in μV) captured at rest (total of 15 s) and during MHI (total of three seconds; the first and fifth seconds were discarded) were normalized by the RMS of the highest value obtained during the three MVC readings (μmV/μV × 100: % MVC).

Statistical analysis

The Shapiro–Wilk test was used to determine the distribution of the data. As the VAS was not normally distributed, the data were analyzed using nonparametric tests and expressed as median and inter-quartile range (25% and 75%). Friedman's test and Dunn's *post hoc* test were used for the comparison of VAS scores at the different evaluation times before and after phototherapy. The Kruskal–Wallis test was used for the inter-group comparisons at each evaluation. The PPT, myoelectrical activity of the masseter and temporal muscles and maximum vertical mandibular movement exhibited normal distribution. Thus, repeated-measures analysis of variance (ANOVA) was used to determine the influence of phototherapy on each of these variables. The SPSS 20.0 program (SPSS Inc., Chicago, IL) was used for all analyses and the level of significance was set to 5% ($p < 0.05$) for all interactions.

Cohen's *d* and partial eta squared (ηp2) were used to calculate the effect size [24]. The interpretation was based on the values established by Cohen: small effect (less than d = 0.2 and ηp2 = 0.01); moderate effect (approximately d = 0.5 and ηp2 = 0.06); and large effect (greater than d = 0.8 and ηp2 = 0.14) [24].

Results

Pain intensity

In the analysis of the primary outcome (pain intensity measured using the VAS), significant differences among evaluation times were found in all groups (Table 2). However, in the multiple comparisons, was observed significant reductions in pain immediately after treatment (Group 1: Median difference = 2.40 [95% CI = 1.41–3.39]; Group 2: Median difference = 1.90 [95% CI = 0.38–3.42]; Group 3: Median difference = 2.00 [95% CI = 0.01–3.99]), post 24 h (Group 1: Median difference = 2.60 [95% CI = 1.31–3.89]; Group 2: Median difference = 1.90 [95% CI = 0.35–3.45]; Group 3: Median difference = 2.70 [CI: 0.76–4.64]), and post 48 h (Group 1: Median difference = 2.60 [95% CI = 1.35 to 3.85]; Group 2: Median difference = 2.2 [95% CI = 0.98–3.42]; Group 3: Median difference = 2.50 [95% CI = 0.56–4.44]) in comparison to the pretreatment evaluations. In Group placebo, the reduction in pain in comparison to the pretreatment VAS score was only statistically significant at the 24-h evaluation. A moderate effect size was found in Groups 1, 2, and 3 (Table 2).

Table 2. Median and interquartile range (25–75%) of VAS scores at the different evaluation times before and after phototherapy.

	Pre	Immediate post	24-h post	48-h post	Effect size	*p* Value
Group 1	3.4 (3.1–4.5)	1.0 (0.4–2.0)*	0.8 (0.1–2.5)*	0.8 (0.3–2.6)*	0.62	<0.0001
Group 2	3.2 (3.0–6.6)	1.3 (0.4–2.5)*	1.3 (0.3–2.5)*	1.0 (0.5–1.3)*	0.60	<0.0001
Group 3	3.5 (3.0–6.6)	1.5 (0.6–2.9)*	0.8 (0.3–2.4)*	1.0 (0.4–2.5)*	0.59	<0.0001
Group placebo	3.5 (3.0–4.0)	3.0 (0.5–3.5)	2.0 (1.3–3.0)*	2.5 (1.8–3.5)	0.33	0.001
p Value[a]	0.75	0.33	0.34	0.06		

*Significant difference in comparison to pretreatment evaluation (Dunn's *post hoc* test).
[a]ANOVA + Kruskal–Wallis test.

Table 3. Means (SD) of pressure pain threshold (in kgf) of masticatory muscles and right and left lateral poles at different evaluation times before and after phototherapy.

	Interentions				Differences between baseline and interventions Adjusted mean difference (95% CI)		
	Baseline	Immediate post	24-h post	48-h post	Immediate post	24-h post	48-h post
Group 1							
RT	2.46 ± 0.63	2.63 ± 0.64	2.58 ± 0.62	2.75 ± 0.68	−0.17 (−0.64 to 0.3)	−0.12 (−0.59 to0.35)	−0.29 (−0.78 to 0.20)
RM	1.52 ± 0.39	1.65 ± 0.36	1.57 ± 0.36	1.60 ± 0.39	−0.13 (−0.41 to 0.15)	−0.05 (−0.33 to 0.23)	−0.08 (−0.37 to 0.21)
RLP	1.56 ± 0.39	1.70 ± 0.53	1.62 ± 0.36	1.68 ± 0.34	−0.18 (−0.53 to 0.17)	−0.1 (−0.38 to 0.18)	−0.16 (−0.43 to 0.11)
LT	2.39 ± 0.63	2.51 ± 0.77	2.64 ± 0.60	2.86 ± 0.77	−0.12 (−0.65 to 0.41)	−0.25 (−0.71 to 0.21)	−0.47 (−1.00 to 0.06)
LM	1.51 ± 0.37	1.57 ± 0.46	1.49 ± 0.35	1.44 ± 0.36	−0.06 (−0.37 to 0.25)	0.02 (−0.25 to 0.29)	0.07 (−0.20 to 0.34)
LLP	1.48 ± 0.41	1.67 ± 0.52	1.42 ± 0.38	1.46 ± 0.34	−0.19 (−0.54 to 0.16)	0.06 (−0.29 to 0.41)	0.02 (−0.26 to 0.30)
Group 2							
RT	2.41 ± 1.14	2.29 ± 0.48	2.39 ± 0.54	2.5 ± 0.67	0.12 (−0.53 to 0.77)	0.02 (−0.65 to 0.69)	−0.09 (−0.79 to 0.61)
RM	1.4 ± 0.50	1.53 ± 0.37	1.52 ± 0.39	1.58 ± 0.41	−0.13 (−0.46 to 0.20)	−0.12 (−0.46 to 0.22)	−0.18 (−0.52 to 0.16)
RLP	1.27 ± 0.56	1.61 ± 0.49	1.51 ± 0.37	1.53 ± 0.64	−0.34 (−0.73 to 0.05)	−0.24 (−0.63 to 0.15)	−0.26 (−0.61 to 0.09)
LT	2.18 ± 0.56	2.37 ± 0.49	2.67 ± 0.62	2.58 ± 0.64	−0.19 (−0.58 to 0.20)	−0.49 (−0.93 to −0.05)	−0.4 (−0.84 to 0.04)
LM	1.32 ± 0.32	1.45 ± 0.44	1.58 ± 0.40	1.7 ± 0.46	−0.13 (−0.42 to 0.16)	−0.26 (−0.55 to 0.03)	−0.38 (−0.65 to −0.11)
LLP	1.47 ± 0.60	1.52 ± 0.44	1.63 ± 0.45	1.57 ± 0.50	−0.05 (−0.45 to 0.35)	−0.16 (−0.55 to 0.23)	−0.1 (−0.51 to 0.31)
Group 3							
RT	2.26 ± 0.76	2.37 ± 0.80	2.47 ± 0.77	2.30 ± 0.86	−0.11 (−0.69 to 0.47)	−0.21 (−0.79 to 0.37)	−0.04 (−0.65 to 0.57)
RM	1.47 ± 0.65	1.56 ± 0.59	1.66 ± 0.48	1.35 ± 0.54	−0.09 (−0.54 to 0.36)	−0.19 (−0.62 to 0.24)	0.12 (−0.31 to 0.55)
RLP	1.50 ± 0.63	1.67 ± 0.70	1.58 ± 0.52	1.62 ± 0.68	−0.17 (−0.67 to 0.33)	−0.08 (−0.58 to 0.42)	−0.12 (−0.61 to 0.37)
LT	2.26 ± 0.76	2.37 ± 0.80	2.47 ± 0.77	2.30 ± 0.86	−0.11 (−0.65 to 0.43)	−0.21 (−0.78 to 0.36)	−0.04 (−0.65 to 0.57)
LM	1.47 ± 0.67	1.56 ± 0.59	1.66 ± 0.48	1.35 ± 0.54	−0.09 (−0.56 to 0.38)	−0.19 (−0.66 to 0.28)	0.12 (−0.32 to 0.56)
LLP	1.60 ± 0.69	1.77 ± 0.72	1.55 ± 0.45	1.56 ± 0.55	−0.17 (−0.73 to 0.39)	0.05 (−0.48 to 0.58)	0.04 (−0.43 to 0.51)
Group placebo							
RT	2.71 ± 0.61	2.75 ± 0.67	2.73 ± 0.62	2.90 ± 0.89	−0.04 (−0.47 to 0.39)	−0.02 (−0.50 to 0.46)	−0.19 (−0.65 to 0.27)
RM	1.85 ± 0.68	2.03 ± 0.81	1.70 ± 0.50	1.65 ± 0.58	−0.18 (−0.77 to 0.41)	0.15 (−0.41 to 0.71)	0.20 (−0.27 to 0.67)
RLP	1.75 ± 0.75	1.63 ± 0.70	1.8 ± 0.45	1.69 ± 0.51	0.12 (−0.42 to 0.66)	0.67 (0.21 to 1.13)	0.06 (−0.40 to 0.52)
LT	2.76 ± 0.65	2.78 ± 0.64	2.58 ± 0.62	2.74 ± 0.65	−0.02 (−0.50 to 0.46)	0.18 (−0.30 to 0.66)	0.02 (−0.47 to 0.51)
LM	1.55 ± 0.34	1.60 ± 0.44	1.72 ± 0.49	1.55 ± 0.52	−0.05 (−0.34 to 0.24)	−0.17 (−0.49 to 0.15)	0.00 (−0.33 to 0.33)
LLP	1.79 ± 0.67	1.66 ± 0.71	1.71 ± 0.69	1.65 ± 0.81	0.13 (−0.39 to 0.65)	0.08 (−0.43 to 0.59)	0.14 (−0.42 to 0.70)

RT: right temporal; RM: right masseter; LT: left temporal; LM: left masseter; RLP: right lateral pole; LLP: left lateral pol.

Pressure pain threshold

In the analysis of the algometric data, no phototherapy treatment effect was found regarding the PPT among the patients studied. Moreover, no significant interaction between group and treatment ($F = 0.10$; $p = 0.39$, $\eta p2 = 0.01$) was found for the right and left masseter and temporal muscles or for the right and left lateral poles (Table 3).

Electromyography

No effects of phototherapy were found regarding myoelectrical activity during MHI ($F = 0.48$; $p = 0.48$, $\eta p2 = 0.002$) or at rest ($F = 0.56$; $p = 0.63$, $\eta p2 = 0.003$).

Range of movement

In the analysis of maximum vertical mandibular movement, no significant effects of phototherapy were found in post-treatment evaluations considering group and treatment as factors ($F = 0.99$; $p = 0.44$, $\eta p2 = 0.05$) (Table 4).

Discussion

In the present study, statistically significant reductions in intensity of pain (as demonstrated by the VAS scores) were found in the post-treatment evaluations of the Groups 1, 2, and 3, which were submitted to different doses of phototherapy. Groups 1, 2, and 3 demonstrated that the dose employed (2.62 J/point, 5.24 J/point, and 7.86 J/point, respectively) had a moderate effect. The reduction in pain may be explained by a decrease in inflammatory cytokines as well as an increase in microcirculation around the irradiated area [10]. de Almeida et al. [14] discovered that the combination of multiple wavelengths enhances the transference of electrons, increases the level of ATP and neutralizes reactive oxygen species, thereby accelerating the replacement of damaged cells.

While the present investigation involved patients with TMD, the authors of a previous study found that the combination of lasers and LEDs led to a significant reduction in nonspecific knee pain in comparison to a placebo group, with a consequent improvement in quality of life [15]. There is no evidence in the literature to support the use of a specific dose of LLLT or LEDT that

Table 4. Inter-group and intra-group comparisons of maximum vertical mandibular movement (in mm), maximal mouth opening without and with pain at different evaluation times before and after phototherapy.

		Interentions				Differences between baseline and interventions Adjusted mean difference (95% CI)		
Groups	Condition	Baseline	Immediate post	24-h post	48-h post	Immediate post	24-h post	48-h post
Group 1	No pain	36.04 ± 10.03	38.98 ± 9.53	39.02 ± 9.11	37.07 ± 8.31	−2.94 (−10 to 4.39)	−2.97 (−10.14 to 4.20)	−1.02 (−7.91 to 5.87)
	Pain	45.86 ± 7.15	47.50 ± 7.23	46.84 ± 9.09	45.43 ± 8.09	−1.64 (−7.02 to 3.74)	−0.98 (−6.36 to 4.40)	0.43 (−5.28 to 6.14)
Group 2	No pain	37.26 ± 8.06	40.44 ± 8.00	41.46 ± 8.41	42.46 ± 6.85	−3.18 (−9.22 to 2.86)	−4.2 (−10.63 to 2.23)	−5.2 (−10.79 to 0.39)
	Pain	45.92 ± 7.02	47.93 ± 7.6	48.47 ± 6.37	47.98 ± 6.67	−2.01 (−7.48 to 3.46)	−2.55 (−7.56 to 2.46)	−2.06 (−7.18 to 3.06)
Group 3	No pain	36.62 ± 8.34	39.28 ± 8.97	39.65 ± 8.37	39.97 ± 6.22	−2.66 (−9.14 to 3.82)	−3.03 (−9.28 to 3.22)	−3.35 (−8.85 to 2.15)
	Pain	45.29 ± 8.23	47.35 ± 7.75	45.84 ± 6.58	46.04 ± 6.05	−2.06 (−8.04 to 3.92)	−0.55 (−6.12 to 5.02)	−0.75 (−6.15 to 4.65)
Group placebo	No pain	39.79 ± 9.77	39.68 ± 9.68	40.89 ± 9.56	39.58 ± 7.15	0.11 (−6.12 to 6.34)	−1.1 (−8.33 to 6.13)	0.21 (−7.02 to 7.44)
	Pain	46.10 ± 6.59	45.63 ± 9.71	46.34 ± 9.50	46.09 ± 6.28	0.47 (−5.74 to 6.68)	−0.24 (−6.36 to 5.88)	0.01 (−4.80 to 4.82)

is effective against myogenous TMD, due mainly to the diversity of protocols and variables employed. However, the doses employed in the present investigation are similar to those reported in a number of studies analyzed in the systematic review by Chen et al. [12]. Moreover, the device employed combines different light sources and densities, leading to different effects [14] and energy absorption rates [25], which favors the use of this phototherapeutic model.

With placebo phototherapy, a significant reduction in pain in comparison to baseline was only found at the 24-h evaluation, which can occur in a wide variety of medical conditions [26]. Jensen et al. [27] report that the therapist–patient relationship contributes to the placebo effect due to a reduction in stress and an increase in the expectation of an improvement. Such psychological changes can enhance the immune function through a reduction in stress-related hormones and the perception of pain due to the increased release of endogenous opioids, which may have occurred in the placebo group, when one considers the association between stress and different symptoms of TMD.

Unlike what occurred with pain intensity, no significant differences were found among the groups with regard to the PPT, myoelectric activity and range of movement. This may be explained by several factors. Pain intensity is related to a chronic condition and the PPT is considered a new nociceptive stimulus on painful tissue related to a very restricted area, whereas pain intensity is perceived over a large anatomic area and both involve different degrees of central sensitivity. These findings are reported in studies employing similar methods to those used herein for the assessment of pain [28].

The results of the EMG analysis are in agreement with data described by Manfredini et al. [29], who found no change in EMG signals with the change in pain, which may be related to a central adaptation mechanism. The lack of significant differences in the EMG signals of the muscles analyzed may also be related to the type of contraction, as muscle performance during sustained contractions, such as MHI, is susceptible to influences from the blood supply and reserves of metabolic substrates. The drop in blood supply can initially lead to a reduced oxygen supply, with consequent impairment regarding the production of ATP by mitochondria [30], which can also affect gains in the mandibular range of motion in comparison to baseline data.

Phototherapy is a promising resource for the treatment of skeletal muscles in cases of TMD, as it generates a significant, immediate improvement in pain, which is important to this population of patients. However, further studies are needed with a greater number of sessions and longer follow up to determine the long-term influence and accumulative effect of this phototherapeutic model.

Conclusions

Phototherapy involving a combination of super-pulsed laser (905 nm) and diodes emitting red (640 nm) and infrared (875 nm) light led to a significant reduction in pain intensity at doses of 2.62 J/point, 5.24 J/point, and 7.86 J/point. However, no significant differences were found in the analyses regarding the pressure pain point, maximum vertical mandibular movement, or myoelectrical activity of the masseter and temporal muscles in women with TMD.

Limitations

The present study has limitations that should be addressed. The patients were recruited from only one physical therapy center for TMD, which may not represent all patients with this condition. Moreover, no untreated group was included to serve at the basis for patient follow up and none of the groups was submitted to the total dose that the phototherapy device is capable of delivering.

Acknowledgements

The authors are grateful to the research team and all participants as well as University Nove de Julho, and the Brazilian fostering agencies, the State of São Paulo Research Assistance Foundation, and Coordination for the Improvement of Higher Education Personnel.

Disclosure statement

The authors report no conflicts of interest.

Funding

Funding for this study was provided by the State of São Paulo Research Foundation.

References

[1] American Society of Temporomandibular Joint Surgeons. Guidelines for diagnosis and management of disorders involving the temporomandibular joint and related musculoskeletal structures. Cranio J Craniomandib Pract. 2003;21:68–76.

[2] Orlando B, Manfredini D, Bosco M. Efficacy of physical therapy in the treatment of masticatory myofascial pain: a literature review. Minerva Stomatol. 2006;55:355–366.

[3] Gonçalves DA, Dal Fabbro AL, Campos JA, et al. Symptoms of temporomandibular disorders in the population: an epidemiological study. J Orofac Pain. 2010;24:270–278.
[4] Ferreira CL, Silva MA, Felício CM. Signs and symptoms of temporomandibular disorders in women and men. Codas. 2016;28:17–21.
[5] Wieckiewicz M, Boening K, Wiland P, et al. Reported concepts for the treatment modalities and pain management of temporomandibular disorders. J Headache Pain. 2015; 16:106.
[6] Rodrigues JH, Marques MM, Biasotto-Gonzalez DA, et al. Evaluation of pain, jaw movements, and psychosocial factors in elderly individuals with temporomandibular disorder under laser phototherapy. Lasers Med Sci. 2015;30:953–959.
[7] Gomes CAF, Politti F, Andrade DV, et al. Effects of massage therapy and occlusal splint therapy on mandibular range of motion in individuals with temporomandibular disorder: a randomized clinical trial. J Manipulative Physiol Ther. 2014; 37:164–169.
[8] Hode T, Jenkins P, Jordison S, et al. To what extent is coherence lost in tissue? 2011 [cited 2016 Aug 15]. p. 788703–788703–10. Available from: http://dx.doi.org/10.1117/12.878827
[9] Bjordal JM, Johnson MI, Iversen V, et al. Low-level laser therapy in acute pain: a systematic review of possible mechanisms of action and clinical effects in randomized placebo-controlled trials. Photomed Laser Surg. 2006; 24:158–168.
[10] Kelencz CA, Muñoz ISS, Amorim CF, et al. Effect of low-power gallium–aluminum–arsenium noncoherent light (640 nm) on muscle activity: a clinical study. Photomed Laser Surg. 2010;28:647–652.
[11] Bastos JLN, Lizarelli RFZ, Parizotto NA. Comparative study of laser and LED systems of low intensity applied to tendon healing. Laser Phys. 2009;19:1925–1931.
[12] Chen J, Huang Z, Ge M, et al. Efficacy of low-level laser therapy in the treatment of TMDs: a meta-analysis of 14 randomised controlled trials. J Oral Rehabil. 2015;42: 291–299.
[13] Santos LA, Marcos RL, Tomazoni SS, et al. Effects of pre-irradiation of low-level laser therapy with different doses and wavelengths in skeletal muscle performance, fatigue, and skeletal muscle damage induced by tetanic contractions in rats. Lasers Med Sci. 2014;29:1617–1626.
[14] de Almeida P, Tomazoni SS, Frigo L, et al. What is the best treatment to decrease pro-inflammatory cytokine release in acute skeletal muscle injury induced by trauma in rats: low-level laser therapy, diclofenac, or cryotherapy? Lasers Med Sci. 2014;29:653–658.
[15] Leal-Junior ECP, Johnson DS, Saltmarche A, et al. Adjunctive use of combination of super-pulsed laser and light-emitting diodes phototherapy on nonspecific knee pain: double-blinded randomized placebo-controlled trial. Lasers Med Sci. 2014;29:1839–1847.
[16] Coelho C, Leal-Junior ECP, Biasotto-Gonzalez DA, et al. Effectiveness of phototherapy incorporated into an exercise program for osteoarthritis of the knee: study protocol for a randomized controlled trial. Trials. 2014;15:221.
[17] Herpich CM, Leal-Junior ECP, Amaral AP, et al. Effects of phototherapy on muscle activity and pain in individuals with temporomandibular disorder: a study protocol for a randomized controlled trial. Trials. 2014;15:491.
[18] Dworkin SF, LeResche L. Research diagnostic criteria for temporomandibular disorders: review, criteria, examinations and specifications, critique. J Craniomandib Disord Facial Oral Pain. 1992;6:301–355.
[19] Manfredini D, Cocilovo F, Favero L, et al. Surface electromyography of jaw muscles and kinesiographic recordings: diagnostic accuracy for myofascial pain. J Oral Rehabil. 2011;38:791–799.
[20] Pereira TS, Flecha OD, Guimarães RC, et al. Efficacy of red and infrared lasers in treatment of temporomandibular disorders – a double-blind, randomized, parallel clinical trial. Cranio J Craniomandib Pract. 2014;32:51–56.
[21] Burckhardt CS, Jones KD. Adult measures of pain: the McGill Pain Questionnaire (MPQ), Rheumatoid Arthritis Pain Scale (RAPS), Short-Form McGill Pain Questionnaire (SF-MPQ), Verbal Descriptive Scale (VDS), Visual Analog Scale (VAS), and West Haven-Yale Multidisciplinary Pain Inventory (WHYMPI). Arthritis Care Res. 2003;49:S96–S104.
[22] Ylinen J, Nykänen M, Kautiainen H, et al. Evaluation of repeatability of pressure algometry on the neck muscles for clinical use. Man Ther. 2007;12:192–197.
[23] De Luca CJ. The use of surface electromyography in biomechanics. J Appl Biomech. 1997;13:135–163.
[24] Cohen J. Statistical power analysis for the behavioral sciences. 2nd ed. Hillsdale (NJ): Routledge; 1988. 400 p.
[25] Joensen J, Ovsthus K, Reed RK, et al. Skin penetration time-profiles for continuous 810 nm and Superpulsed 904 nm lasers in a rat model. Photomed Laser Surg. 2012;30: 688–694.
[26] Greene CS, Goddard G, Macaluso GM, et al. Topical review: placebo responses and therapeutic responses. How are they related? J Orofac Pain. 2009;23:93–107.
[27] Jensen KB, Petrovic P, Kerr CE, et al. Sharing pain and relief: neural correlates of physicians during treatment of patients. Mol Psychiatry. 2014;19:392–398.
[28] Sanches ML, Juliano Y, Novo NF, et al. Correlation between pressure pain threshold and pain intensity in patients with temporomandibular disorders who are compliant or non-compliant with conservative treatment. Oral Surg Oral Med Oral Pathol Oral Radiol. 2015;120:459–468.
[29] Manfredini D, Cocilovo F, Stellini E, et al. Surface electromyography findings in unilateral myofascial pain patients: comparison of painful vs non painful sides. Pain Med. 2013;14:1848–1853.
[30] Boyas S, Guével A. Neuromuscular fatigue in healthy muscle: underlying factors and adaptation mechanisms. Ann Phys Rehabil Med. 2011;54:88–108.