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# Longitudinal evaluation of the effects of low-power laser phototherapy on mandibular movements, pain, and edema after orthognathic surgery



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## ABSTRACT

The aim of this study was to longitudinally evaluate mandibular movements, pain, and edema in patients who underwent low-power laser (LPL) phototherapy after bimaxillary orthognathic surgery.

A double-blind, randomized, controlled clinical trial was conducted using 30 patients, who were divided into a study group ( $n = 15$ ) and control group ( $n = 15$ ). The former group received postoperative LPL ( $3 \text{ J/cm}^2$ , 808 nm, and 100 mW) and the latter group received placebo LPL phototherapy.

Over a period of 60 days, these groups were evaluated for: mandibular movements — opening, laterality, and protrusion; pain — visual analogue scale; and edema — measured between cephalometric points. The study group showed significantly better jaw opening ( $p = 0.009$ ), laterality ( $p = 0.036$ ), and protrusion ( $p = 0.029$ ) after 2 weeks in most comparisons.

The study group showed significantly less postoperative pain ( $p < 0.001$ ) in most comparisons, and they recovered from pain earlier than the control group. There was a reduction in edema, with no statistically significant difference for most measurements.

As observed in most analyses, there were increases in values for all mandibular movements, no significant differences in the occurrence of edema, and decreases in the occurrence of pain.

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## 1. Introduction

Orthognathic surgery is a procedure that is widely used for the correction of dentofacial skeletal deformities; in general, the procedure is performed in a bimaxillary manner via Le Fort I type osteotomy and bilateral sagittal split osteotomy. Several benefits are expected, such as improvements in masticatory function, respiratory function, phonetics, and facial aesthetics. However, there are some complications that can occur during the postoperative period, such as nausea, vomiting, pain, edema, trismus or decreased mandibular movements, haematomas, and neurosensory disorders (Silva et al.,

2006; Yamashita et al., 2007; Oncül et al., 2011). These can be minimized by the use of good surgical techniques, ice physiotherapy, and drug therapy with corticosteroids, analgesics, and opioids (Oncül et al., 2011; Widar et al., 2015; Zandi et al., 2016).

Lately, the use of low-power laser (LPL) phototherapy has drawn attention to the complications associated with oral and maxillofacial surgeries (Markovic and Todorovic, 2007). Therapeutic effects have been attributed to LPL phototherapy, such as the acceleration of wound healing, relief of pain, restoration of neural function, remodelling and repair of bone, normalization of abnormal hormonal function, stimulation of endorphin release, and modulation of the immune system (Ozen et al., 2006). It has also been shown that even a single dose of laser therapy after impacted third molar surgery can reduce edema, trismus, and pain, although without significant differences (Markovic and Todorovic, 2007; Amarillas-Escobar et al., 2010; Alan et al., 2016; Landucci et al., 2016; Sierra

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et al., 2016). In this type of surgery, the extraoral use of LPL phototherapy is more effective than its intraoral use in reducing trismus and edema (Aras and Güngörmüş, 2010).

Additionally, the use of LPL phototherapy can positively affect the recovery of sensitivity after orthognathic or oral surgeries, such as inferior alveolar nerve lateralization, third molar extractions, and dental implant placement (Ozen et al., 2006; de Oliveira et al., 2015). Laser therapy has been shown to be able to accelerate and enhance the regeneration of the affected nerve tissue (de Oliveira et al., 2015). This would be due to the ability of LPL phototherapy to reduce the production of inflammatory mediators of the arachidonic acid family from injured nerves (Ozen et al., 2006). However, few studies have demonstrated the therapeutic effects of LPL phototherapy during the postoperative period following orthognathic surgery. It has been reported that neurosensory recovery after orthognathic surgery of the mandible can be significantly improved with the use of laser therapy (Miloro et al., 2000; Gasperini et al., 2014a). Additionally, it has been reported that LPL can reduce pain and edema after orthognathic surgery (Gasperini et al., 2014b).

The objective of this study was to perform a longitudinal evaluation of mandibular movements, pain, and edema in patients treated with LPL phototherapy following orthognathic surgery.

## 2. Materials and methods

### 2.1. Study design and patients

Two hundred patients with dentofacial deformities, who needed bimaxillary orthognathic surgery (Le Fort I osteotomy, bilateral sagittal split, and genioplasty), were referred to the department of oral and maxillofacial surgery in 2015 and 2016 and asked to participate in this clinical trial. All surgical procedures were carried out by the same surgical team. The sample size was calculated using a formula that took into account the proportion of the occurrence of the fact observed in the population ( $p = 5\%$ ), the size of the population from which the sample was collected ( $n = 200$ , seen within two years), the risk calculated for a smaller margin of error ( $t = 1.96$ ), and the maximum margin of error adopted ( $d = 5\%$ ). A sample size of 27 elements was obtained. This study received approval from the local human research ethics committees (protocols 1.380.120 HSC and 1.402.224 FO), and was registered as a clinical trial (protocol RBR-5mv4y9-ReBEC). Written informed consent was obtained from all participants.

The patient selection criteria were as follows: healthy individuals; 18–40 years old; male or female; had previously extracted third molars; had received preoperative orthodontic treatment. The exclusion criteria included: those with systemic illness; individuals subjected to monomaxillary surgery or surgery without genioplasty; those who experienced rupture of the inferior alveolar nerve during surgery; those with a poor sagittal split, unstable mandibular fixation, allergies to standardized anti-inflammatories and analgesics, and postoperative infections; and those with contraindications or those who did not cooperate with laser therapy.

Patients received sequential numbers in order of enrolment, and were divided randomly into two groups using Research Randomizer software (version 4.0; ©1997–2014 by Geoffrey C. Urbaniak and Scott Plous; Middletown, CT, USA). The last author generated the random allocation sequence, the first author enrolled participants, and the second author assigned participants to interventions.

### 2.2. Surgical procedure

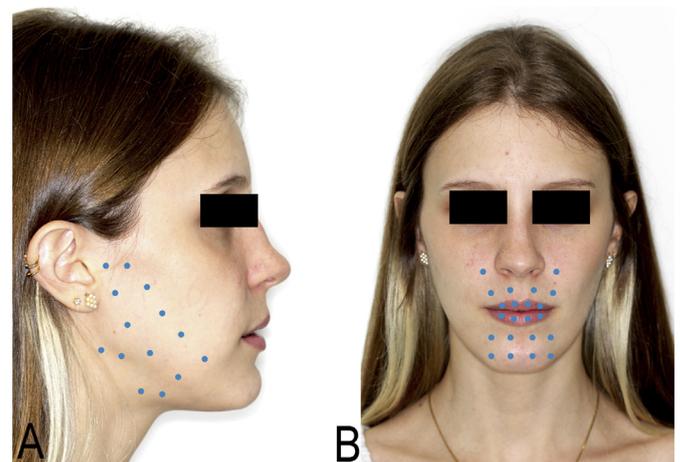
The surgical procedure consisted of conventional Le Fort I osteotomy, bilateral sagittal split ramus osteotomy, and

genioplasty, performed under general anesthesia. The surgery was initiated by the mandible, and horizontal and vertical cuts were performed with a drill. The sagittal cut was performed with a reciprocating saw and finished with a chisel. The Le Fort I type osteotomy was performed with a reciprocating saw and finished using a chisel. Finally, the genioplasty was performed with a reciprocating saw. All patients underwent rigid internal fixation of the maxilla and the mandible with miniplates and miniscrews. Medications administered pre-, trans- and postoperatively were standardized and dosed according to the body weight of patients. Patients received 2 g of cefazolin preoperatively; 500 mg of hydrocortisone trans-operatively; 1 g of cefazolin every 8 h, 10 mg of dexamethasone every 12 h, and 100 mg of ketoprofen every 12 h during admission. Home medication comprised 500 mg of amoxicillin every 8 h for 7 days; 100 mg of ketoprofen every 12 h for 5 days; and 750 mg of acetaminophen every 6 h for 3 days. All patients received cooling treatments immediately after the operation during the period of hospitalization.

### 2.3. Laser protocol

A therapeutic laser with an 808 nm wavelength gallium-aluminium-arsenide diode (Duo, MMOptics, São Paulo, Brazil) and a power output of 100 mW that administered 3 J/cm<sup>2</sup> was applied at each point every 30 s in the study group ( $n = 15$ ). A point application method was used, making contact with the skin or mucosa.

The protocol for the immediate postoperative period — 24–48 h — was all performed extraorally due to the difficulty in mouth opening. Subsequently, both intra- and extraoral protocols were implemented twice a week for 60 days. The extraoral points were arranged on each side: eight points in the mandibular ramus and body regions, two points in the preauricular region as well as the digastric and submandibular lymph node regions, nine points in the chin region, four points in the upper and lower lip regions, and three points in the paranasal region (Fig. 1). The intraoral points were located bilaterally: eight points in the region of the maxillary incision and 12 points in the region of the mandible (Fig. 2). The control group ( $n = 15$ ) received placebo applications from an apparatus similar to that used in the study group, but which did not emit energy.



**Fig. 1.** (A) Profile view and application points in the preauricular region, mandibular body/branch, submandibular lymph node, and digastric–jugular lymph node regions. (B) Frontal view and application points in the chin, upper and lower lip, bilateral paranasal, and mandibular ramus and body regions.

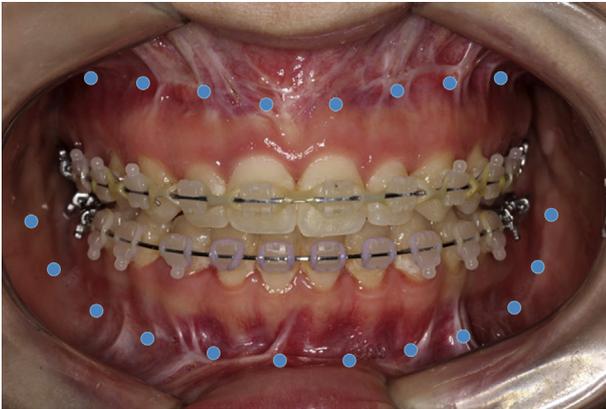


Fig. 2. Intraoral view and application points in the maxilla and mandible.

#### 2.4. Assessment

The second author was blinded after assignment to interventions in order to perform the assessments. Maximum mandibular movements were measured in millimetres during passive opening, passive right and left laterality, and active protrusion. For maximum opening, the distance in millimetres between the upper and lower left central incisors was measured, and a final, corrected value was obtained by taking into account the overbite measurement. For laterality movement, the distance between the upper midline and a vertical line marked on the lower incisor was measured. The patient was asked to move the jaw to the right and left, keeping the teeth in contact at all times. Maximum opening and laterality were performed with the help of the examiner who, with the non-dominant hand, used the thumb and forefinger between the incisors of the maxilla and the mandible. Protrusion was measured by requesting the patient to protrude the mandible as far as possible, always maintaining dental contact; the horizontal distance between the vestibular portion of the left upper central incisor and the incisal portion of the lower left central incisor was noted, and a final, corrected value was obtained by taking into account the overjet measurement (Luz et al., 1995). These measurements were performed, using a digital caliper, in the preoperative period and again in the postoperative period at 7, 14, 30, and 60 days.

Prior to each laser therapy session, a visual analogue scale (VAS) of 10 units was used to measure the intensity of pain during the immediate postoperative period, as well as at 24 h and 48 h, and then twice a week until the completion of the nineteenth session (Shirani et al., 2009; Oncül et al., 2011).

Measurements of postoperative facial edema were obtained in millimetres using a soft ruler during the immediate postoperative period, as well as at 7, 14, 30, and 60 days postoperatively. These were based on cephalometric points, including the distances between the lateral corner of the eye and angle of the mandible, between the tragus and labial commissure, and between the tragus and soft tissue pogonion (Markovic and Todorovic, 2007; van der Vlis et al., 2014; Widar et al., 2015). The right and left sides were evaluated in both groups, and the sum of the two sides was considered in the comparison between groups.

#### 2.5. Statistical analyses

The likelihood ratio test was applied to verify the difference between the two groups for the variables of age, sex, and type of deformity. The Friedman test was used to verify the possible differences between the moments of observation, when compared

concomitantly, within each group studied for the variables of mandibular movement, pain, and edema. Subsequently, the Wilcoxon post-hoc test, adjusted using Bonferroni correction, was used to verify which moments of observation differed in comparison with the others. Regarding the variable of pain, it was not possible to make comparisons between the pairs of observation moments because the sample was not large enough; however, decreases in the values between the moments of observation were evident. Finally, for the variables of mandibular movement, pain, and edema, the Mann-Whitney test was applied to verify possible differences between the two groups. The level of significance was set at 5% ( $p < 0.05$ ). The Statistical Package for Social Sciences (SPSS), version 23.0 (IBM Software Group, Chicago, IL, USA) was used to conduct the analyses.

### 3. Results

Thirty patients with dentofacial deformities who needed bimaxillary orthognathic surgery (Le Fort I osteotomy, bilateral sagittal split, and genioplasty), were enrolled in this double-blind, randomized, controlled clinical trial. The trial ended when a total of 30 participants was obtained. The individuals included in this study had a mean age of 25.1 years, with a predominance of females and a similar distribution between class II and III deformities. The demographic characteristics of the two treatment groups in the sample were similar in terms of age, sex, and type of deformity, and there were no significant differences (Table 1).

Regarding mandibular movements, there was a progressive increase in the movements evaluated in both groups. There was a more than two-fold increase between the initial and final evaluations for all movements in both groups (Figs. 3–5). There was a highly significant difference in the laser group in terms of the corrected maximum opening ( $p < 0.001$ ), sum of laterality ( $p < 0.001$ ), and corrected maximal protrusion ( $p < 0.001$ ), as well as in the control group for the corrected maximum opening ( $p < 0.001$ ), sum of laterality ( $p < 0.001$ ), and corrected maximal protrusion ( $p < 0.001$ ).

When comparing the laser and control groups, a significant difference was found in the corrected maximum opening at 14 days ( $p = 0.009$ ), 30 days ( $p = 0.019$ ), and 60 days ( $p = 0.036$ ); the sum of laterality at 14 days ( $p = 0.036$ ), 30 days ( $p = 0.024$ ), and 60 days ( $p = 0.018$ ); and the corrected maximal protrusion at 14 days ( $p = 0.029$ ), 30 days ( $p = 0.001$ ), and 60 days ( $p = 0.002$ ).

In terms of postoperative pain, there was a progressive decrease in the values evaluated in the laser group, and this decrease was highly significant ( $p < 0.001$ ); the values zero in the fourth week. In the control group, there was an increase in the scores at 24 h and then a progressive decrease; these changes were significantly different ( $p < 0.001$ ), but the values did not reach zero until the sixth week (Fig. 6).

Table 1

Distribution of patients according to age, sex, and type of deformity for both laser and control groups, as well as the significance of the likelihood ratio test.

Variable	Category	Group				p-value
		Laser		Control		
		Freq.	%	Freq.	%	
Age	11–20 years	4	26.7	4	26.7	>0.999
	21–30 years	8	53.3	8	53.3	
	31–40 years	3	20.0	3	20.0	
Gender	Female	10	66.7	9	60.0	0.705
	Male	5	33.3	6	40.0	
Deformity type	Class II	7	46.7	8	53.3	0.715
	Class III	8	53.3	7	46.7	

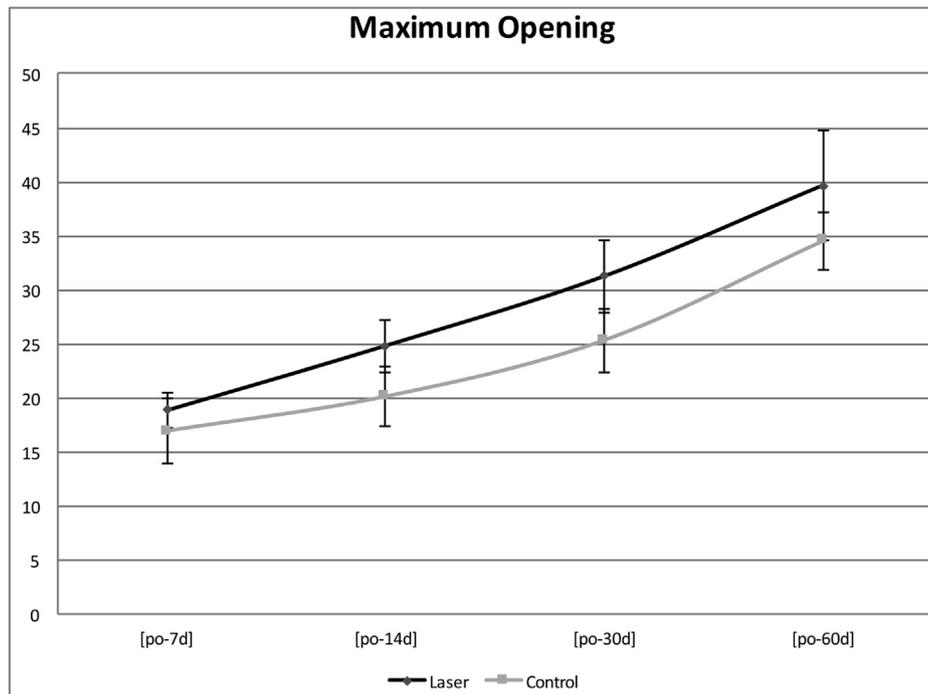


Fig. 3. Mean values and standard deviations for corrected maximum opening, according to time intervals and groups. The values are in mm.

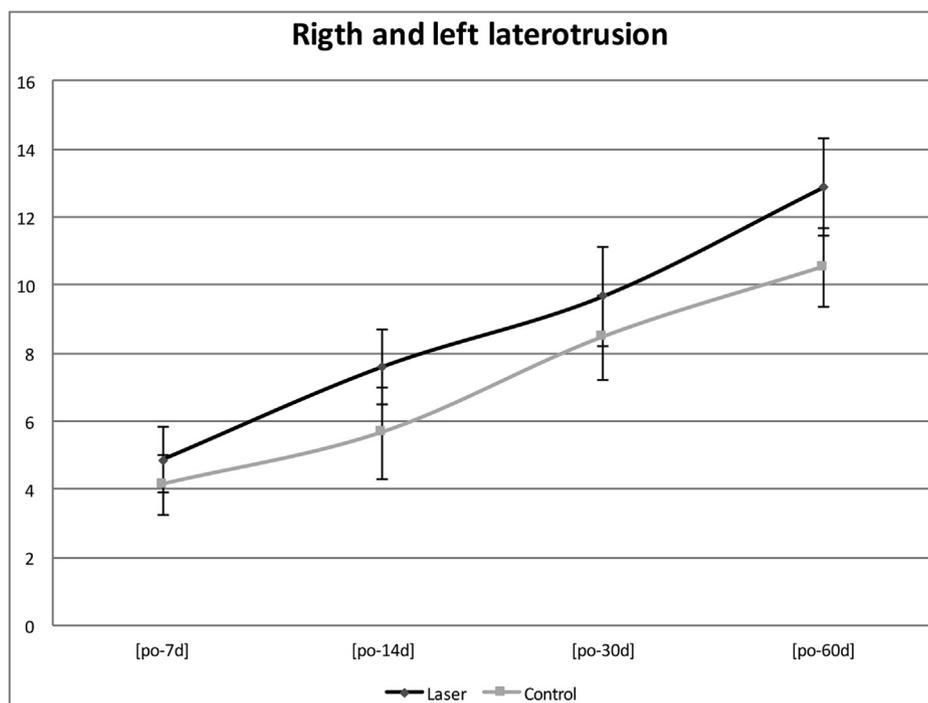


Fig. 4. Mean values and standard deviations for sum of laterality movements, according to time intervals and groups. The values are in mm.

Postoperative pain intensity was lower in the study group than in the control group. There was no significant difference for the immediate postoperative period ( $p = 0.078$ ) or in the first week ( $p = 0.113$ ), but there was a significant difference in the postoperative period for most of the comparisons (24 h,  $p = 0.008$ ; 48 h,  $p < 0.001$ ; 2 wk,  $p < 0.001$ ; 3 wk,  $p < 0.001$ ; 4 wk,  $p < 0.001$ ; and 5 wk,  $p = 0.003$ ).

Regarding postoperative edema, there was a progressive decrease in the values found in both groups. There was a highly

significant difference in the laser group for the sum of the tragus–commissure ( $p < 0.001$ ), tragus–pogonium ( $p < 0.001$ ), and corner of the eye–gonion ( $p < 0.001$ ) distances. For the control group, there were also highly significant differences for the sum of the tragus–commissure ( $p < 0.001$ ), tragus–pogonium ( $p < 0.001$ ) and corner of the eye–gonion ( $p < 0.001$ ) distances (Fig. 7).

For most of the comparisons between the groups, there were no significant differences. Those that were significant included the sum of the corner of the eye–gonion distances for the postoperative periods of

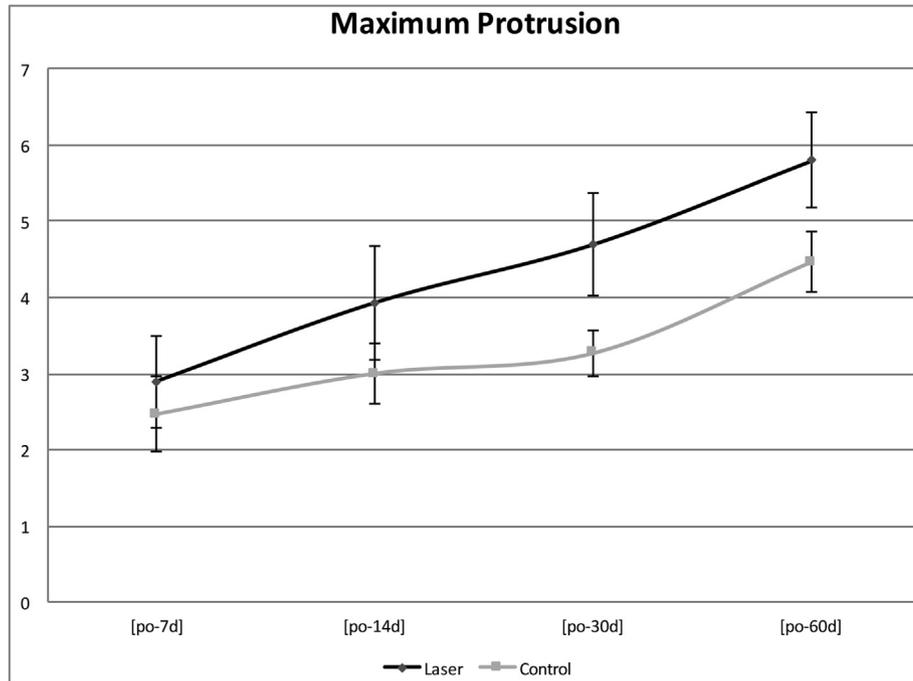


Fig. 5. Mean values and standard deviations for corrected maximal protrusion, according to time intervals and groups. The values are in mm.

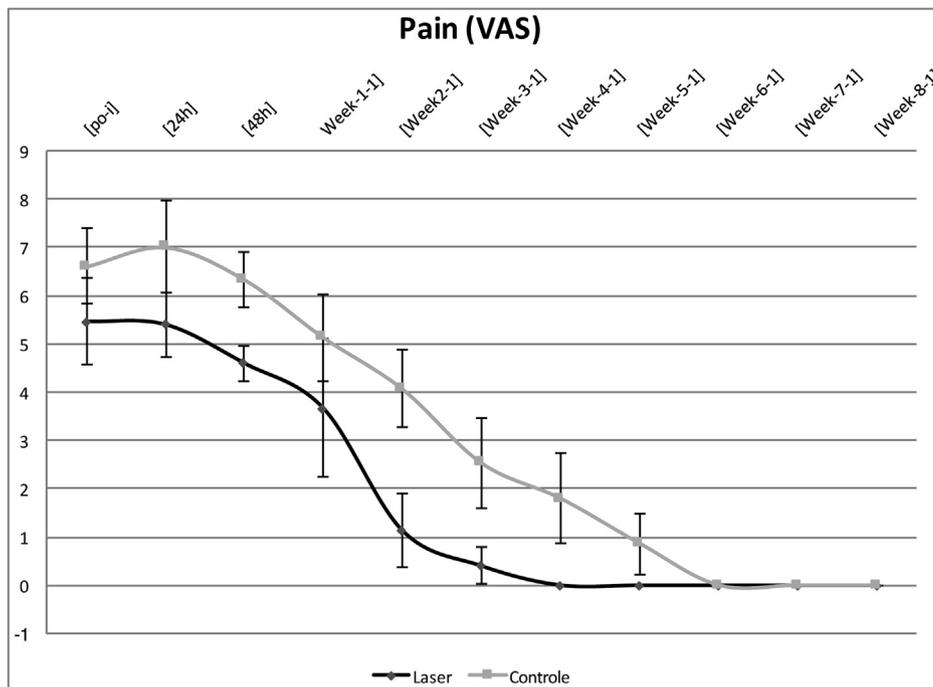


Fig. 6. Mean values and standard deviations for the visual analogue scale, according to time intervals and groups. A score of 0 was reached in the fourth week for the laser group and in the sixth week for the control group.

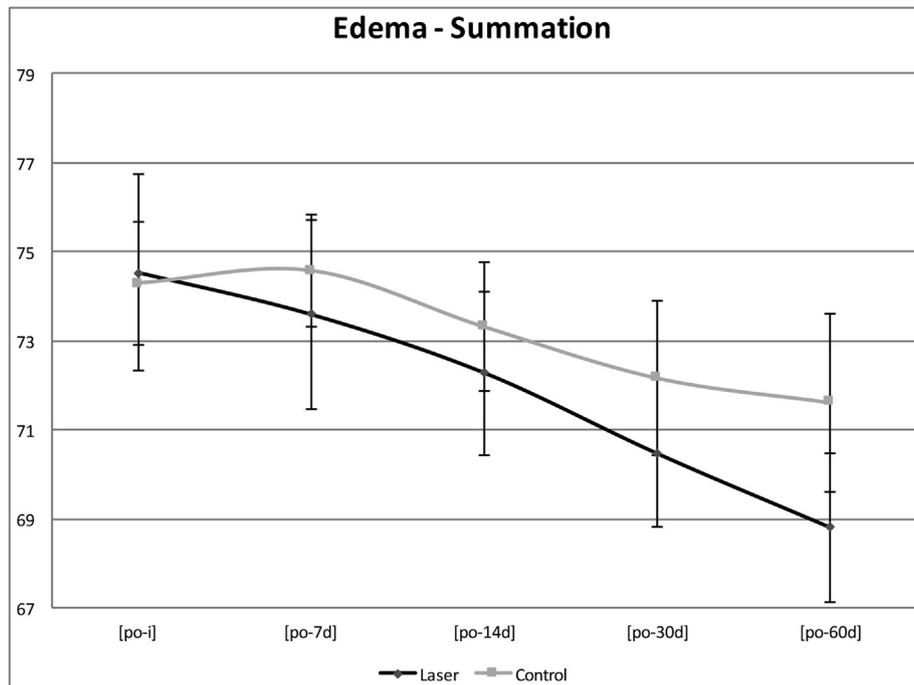
7 days ( $p = 0.027$ ), 30 days ( $p = 0.031$ ), and 60 days ( $p = 0.038$ ). Even with the addition of three bilateral measures (tragus–commissure + tragus–pogonium + corner of the eye–gonion distances), there were no significant differences in the comparisons.

**4. Discussion**

In this study, a longitudinal evaluation of mandibular movements, pain, and edema was performed in patients subjected to

orthognathic surgery following LPL phototherapy. Compared with the control group, there was an increase in mandibular movement values and a decrease in the occurrence of pain, but there was no significant difference in the occurrence of edema. Thus, the efficacy of LPL phototherapy in the postoperative period following orthognathic surgery was demonstrated.

The use of corticosteroids, such as dexamethasone, and centrally acting analgesics, such as morphine or tramadol, is recommended until hospital discharge in order to assist in controlling the



**Fig. 7.** Mean values and standard deviations for edema analysis, according to time intervals and groups, using summation of the tragus–commissure, tragus–pogonium, and corner of the eye–gonion distances. The values are in mm.

postoperative effects of orthognathic surgery (Dan et al., 2010; Raschke et al., 2018). Then the use of non-steroidal, anti-inflammatory drugs, such as ketoprofen, and paracetamol-like analgesics plus codeine phosphate may be implemented for 5 days. This approach was adopted in this study, which showed great efficacy in the LPL phototherapy group compared with the control group.

Randomization was implemented through software that is used for a variety of purposes, including experiments in clinical trials, psychology, and opinion research. Therefore, a homogeneous distribution was sought between the groups studied. The ages of the groups were similar, predominantly 21–30 years old, and not significantly different, which was similar to the demographics found in other studies (Wen-Ching Ko et al., 2012; Al-Belasy et al., 2013; Shetty et al., 2013; Widar et al., 2015). There was a female predominance, with an average of 60%, but there was no significant gender difference between the groups, as seen in other studies (Silva et al., 2006; Wen-Ching Ko et al., 2012).

Regarding the type of deformity, there was a similar distribution of angle classes II and III between the study groups, with no significant difference, contributing once again to the standardization of the studied groups. This form of distribution was an extra precaution, considering that other studies did not specify the type of deformity that was treated surgically. It is worth mentioning that the type of deformity can influence the final result of orthognathic surgery, and have a significant effect on masticatory efficiency (Yang et al., 2005; Abrahamsson et al., 2015). All surgeries were bimaxillary, as were those in other studies (Oncül et al., 2011; Shetty et al., 2013; Gasperini et al., 2014a; van der Vlis et al., 2014).

The following parameters were used with the laser (Ga Al As) protocol: a wavelength of 808 nm (infrared); power of 100 mW; energy of 3.0 J/point of irradiation; irradiation time of 30 s per point; energy density of 100 J/cm<sup>2</sup>; beam area of 0.03 cm<sup>2</sup>. A point application method was used, such that contact was made with the skin or mucosa. This protocol was an effective treatment during the postoperative period following orthognathic surgery, although the ideal protocol for LPL phototherapy has not yet been established.

One study of minor oral surgery and orthognathic surgery reported that laser therapy with the beam emission band in the infrared spectrum and the same protocol used in our study can positively affect the recovery of sensitivity after such surgical procedures (de Oliveira et al., 2015).

The application points used in our study were distributed across 50 extraoral points and 20 intraoral points. A similar distribution, but with less extent, was reported in another study using LPL phototherapy in the postoperative period following orthognathic surgery with the comparison between irradiated with non-irradiated sides (Gasperini et al., 2014a). This study, which used a similar protocol, reported improvements in pain, edema, and neurosensory disorders. Although positive results were obtained, laser therapy was performed unilaterally; thus the patients may have received a non-measurable amount of laser therapy on the control side, which could have affected the results (Gasperini et al., 2014a, 2014b).

Mandibular hypomobility after orthognathic surgery is a major concern that has been discussed in many articles (Al-Belasy et al., 2013). The most common short- and medium-term complication during functional recovery after orthognathic surgery is reduced maximum mouth opening (Ugolini et al., 2017). In our study, there were progressive and significant increases in mandibular movements, such as maximum opening, laterality, and maximum protrusion. When comparing the laser and control groups during the periods of observation, we found higher values for mandibular movements in the former group, with significant differences for all movements during the period from 2 weeks to 2 months; therefore, our study showed better results for the laser procedure compared with the conventional procedure.

In a longitudinal study following orthognathic surgery, a decrease (to one-third of its original range) in mouth opening was observed after 1 month, reaching normal levels by 6 months (Wen-Ching Ko et al., 2012). It is noteworthy that there are no studies in the literature that comment on the use of LPL phototherapy for restoring mandibular movements (maximum opening, laterality, and maximum protrusion) during the postoperative period

following orthognathic surgery. In our study, all mandibular movements were evaluated, in addition to pain and edema. Some studies that evaluated trismus with the use of laser therapy during the postoperative period were carried out following lower third molar surgeries (Aras and Güngörmüş, 2010; Amarillas-Escobar et al., 2010; Alan et al., 2016; Landucci et al., 2016; Sierra et al., 2016).

Orthognathic surgery can produce intense nociceptive stimulation, and patients may report a high degree of pain during the postoperative period (Nagatsuka et al., 2000; Oncül et al., 2011). Even when compared with other procedures involving the maxillofacial complex, orthognathic surgery is associated with high pain indexes (Tuzuner et al., 2007). The treatment of postoperative pain alleviates suffering and results in early mobilization, short hospital stays, and reduced hospital costs, as well as increased patient satisfaction (Widar et al., 2015). It is known that LPL phototherapy can modulate inflammatory processes in a dose-dependent manner, and is indicated in the reduction of acute inflammatory pain (Bjoldal et al., 2006). Our study demonstrated that the use of LPL phototherapy improves pain in patients subjected to orthognathic surgery, justifying its use. No significant difference is expected immediately after surgery because there is no time for biomodulation (Gasperini et al., 2014b). A progressive and significant decrease in pain values was observed in our study. When comparing the laser and control groups, lower values of postoperative pain intensity in the former group were found for most comparisons from 1 day to 5 weeks postoperatively. In the laser group, the decrease was progressive, whereas in the control group there were oscillations during the decrease. In the laser group, a score of 0, indicating the absence of pain, was reached in the fourth week postoperatively, whereas in the control group this score was reached in only in the sixth week.

Postoperative facial edema following orthognathic surgery can be prolonged, and is a cause of great concern in some patients (Yamamoto et al., 2016). Quantifying the extent and duration of edema is important for surgeons treating patients who are eager to achieve an aesthetic final result (van der Vlis et al., 2014). The routine use of corticosteroids in orthognathic surgery is aimed at reducing edema as well as controlling nausea, vomiting, and pain. After surgery, patients commonly require multiple analgesic drugs, so the ability of corticosteroids to reduce the need for these drugs is clinically relevant (Chegini and Dhariwal, 2012). In a study of orthognathic surgery performed only on the mandible, it was shown that, on average, 66% of the initial postoperative edema had disappeared after 1 month, and only 5% remained after 3 months (Yamamoto et al., 2016). In another study of bimaxillary orthognathic surgery, an average of 50% of the initial edema had disappeared after the third postoperative week, and only 20% remained after 3 months (van der Vlis et al., 2014). In our study, postoperative edema values progressively decreased in both groups. However, with the application of LPL phototherapy, there was no significant difference in its occurrence, which was verified in most measurements of the distances between cephalometric points. Only a few significant differences were found in the summation of the corner of the eye and angle of the mandible at most of the postoperative times. Even with the addition of three bilateral measures, there was no significant difference in the comparisons. However, another study, using split-face measurements, showed a statistically significant reduction in edema with LPL application (Gasperini et al., 2014b). These authors stated that the effect of biomodulation of the laser occurred primarily during the early stages of inflammation and decreased as mediators of inflammation decreased (Gasperini et al., 2014a). It is possible that the method employed in that study, which used a mathematical formula to calculate edema, may have influenced the results. Several

methods have been used to measure facial edema. Most authors measure the distance between two or three predetermined anatomical points on the face, such as the distances between the corner of the eye the angle of the mandible, between the tragus and commissure, and between the tragus and pogonium (Ustün et al., 2003; López-Ramírez et al., 2012). The use of cephalometric points to measure edema in the postoperative period is a non-invasive, fast, low-cost method that provides numerical data for the determination of soft tissue contour changes (Ustün et al., 2003).

## 5. Conclusion

This study confirms that LPL phototherapy improves not only pain, but also mandibular movements, thus supporting its use in the postoperative period following orthognathic surgery. In our experience, no specific problems occurred in the postoperative period with the patients in this study. However, it should be considered that, by improving functional parameters earlier in the healing process, the stability of the results could be compromised, which could increase the recurrence rate.

## Funding

There was no funding.

## Conflicts of interest

None.

## Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.jcms.2019.01.038>.

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