EFFECT OF PHOTOBIOMODULATION THERAPY ON NEUROSENSORY RECOVERY OF THE LOWER LIP AND CHIN AFTER BILATERAL SAGITTAL SPLIT RAMUS OSTEOTOMY COMBINED WITH GENIOPLASTY: A PILOT STUDY

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ABSTRACT
This research is a pilot study to investigate the effect of photobiomodulation on neurosensory recovery after bilateral sagittal split ramus osteotomy combined with genioplasty in 4 patients. On the randomly selected side, 660 nm laser wavelength, 100 mW power, and 8 J/cm2 energy intensity were applied to the oral cavity, lips, and chin, totaling 19 points, 6 times, 1 week apart each time. The control side was not exposed to light, but the laser head position was the same. They were evaluated using the total scores from the visual analog scale and the neurosensory test for a total of 8 time periods. The study's results found that overall, there were no differences in the 4 patients' total scores at different time periods. It was concluded that the use of photobiomodulation at these parameters was not effective in neurosensory recovery of the lower lip and chin after bilateral sagittal split ramus osteotomy combined with genioplasty.
Keywords: Bilateral Sagittal Split Ramus Osteotomy, Genioplasty, Photobiomodulation Therapy, Neurosensory Recovery

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INTRODUCTION

Orthognathic surgery is a surgical intervention to correct the dental and facial abnormalities to be near normal or normal dental occlusion and facial proportion. There are various risks of complications from the surgery. One of the most common complications is nerve injury that is estimated to occur in approximately 50% of cases (Jędrzejewski et al., 2015). The inferior alveolar nerve (IAN) is the most impacted nerve after this surgical procedure, resulting in sensory impairment in the lower lip and chin area. The second nerve that may impairment is the infraorbital nerve (McLeod et al, 2016). The occurrence of paresthesia in the lower lip and chin region has been linked to surgical techniques such as Bilateral Sagittal Split Ramus Osteotomy (BSSRO), genioplasty, and Hofer osteotomy. Nevertheless, the combination of BSSRO with genioplasty is frequently associated with the occurrence of these problems (McLeod et al, 2016; D'Agostino et al., 2010; Kim et al., 2011).

In cases where individuals encounter paresthesia in the lower lip and chin region as a result of IAN damage subsequent to orthognathic surgery, there are several techniques utilized to facilitate the recovery of the IAN such as administration of vitamin B and C supplements, the use of steroids, the implementation of localized physiotherapy, electrical stimulation, acupuncture, and more recently, the application of low-level laser therapy (LLLT) or photobiomodulation (PBM) (de Oliveira et al., 2015; José et al., 2020; Firoozi et al.,2020).

PBM involves the use of low-energy laser light within the red or infrared spectrum (600-1000 nm). When the light is administered to biological tissues, it is assimilated by cytochrome c oxidase (CCO), an enzyme located inside the mitochondria. This assimilation prompts an escalation in electron transport and a subsequent rise in electrical potential across the mitochondrial membrane. Consequently, this process culminates in the augmentation of adenosine triphosphate (ATP) synthesis. The first effects of this phenomenon elicit a range of physiological activities by activating reactive oxygen species (ROS), cyclic AMP, nitric oxide (NO), and calcium ions. These activations subsequently impact gene expression, protein synthesis, cell proliferation, and the suppression of inflammation (de Freitas et al., 2016). Hence, PBM is employed for diverse tissue types, encompassing brain tissue. The effects of this substance on neural tissue encompass various mechanisms that promote nerve regeneration. These mechanisms include an increase in cell metabolism, stimulation of Schwann cell proliferation, regulation of DNA and RNA synthesis, and alteration of enzyme activity. Collectively, these effects lead to the preservation of neural cells. PBM further promotes enhanced blood circulation and aids non-injured neighboring nerve cells (José et al., 2020; Ishiguro et al., 2010). Numerous investigations have been conducted to investigate the utilization of PBM in facilitating the recuperation of the IAN after the extraction of lower third molars and BSSRO surgery. The majority of these studies have reported PBM being a significantly effective method in IAN recovery. Nevertheless, there is no standardization regarding the laser energy parameters for IAN recovery after BSSRO. Previous studies have used vary the wavelengths of light, which range from 632 to 904 nm. Additionally, the power and energy used range from 20 to 200 milliwatts (mW) and 1.2 to 100 joules per square centimeter (J/cm2) respectively including the duration of laser light irradiation (application time) and number of light irradiations (session) also vary in each study (Firoozi et al., 2020; Hosseinpour et al., 2019). The single-mode laser with a wavelength of 660 nm has been shown to have few used for the recovery of IAN following BSSRO surgery. However, some studies have provided evidence supporting the benefits of using a 660 nm wavelength light for nerve recovery in experimental animals while there are very few clinical studies (Ishiguro et al.,2010; dos Reis et al., 2009; Belchior et al., 2009; Barbosa et al., 2010; Gigo-Benato et al., 2010). In addition, there have been no studies of the use of PBM to recover the IAN after BSSRO surgery combined with genioplasty which is a procedure most often associated with lower lip and chin numbness.

This study aims to investigate the effects of PBM with a 660 nm wavelength on the sensory recovery of the IAN following BSSRO surgery combined with genioplasty.

RESEARCH METHODOLOGY

This research is a pilot study designed as a double-blinded randomized controlled trial (RCT). The study has received ethical approval from the Human Research Ethics Committee of the Faculty of Dentistry, Prince of Songkla University, under project code EC6510-038.

The study sample consists of patients undergone orthognathic surgery to correct dental and facial deformities using the BSSRO technique in combination with genioplasty at the Oral and Maxillofacial Surgery Clinic of the Faculty of Dentistry, Prince of Songkla University. Inclusion criteria for the study are age 18 or older, no lower third molars presented or had removed at least 6 months prior to surgery, undergoing BSSRO surgery with genioplasty, with or without upper jaw surgery, experiencing numbness in the lower lip and chin on both sides following the BSSRO surgery and genioplasty. Exclusion criteria are previous jaw surgery, accidents, or lower jawbone pathology, direct damage to IAN or mental nerve during surgery, significant jawbone fractures or "bad split" during surgery, postoperative wound infections, neurological disorders or mental health conditions that would interrupt assessment, lack of willingness to participate or follow the scheduled treatment.

Informations including patient demographics, skeletal classification, type of surgery, the amount and direction of lower jaw and chin movement, and other postoperative complications were collected from the medical records.

The first researcher performed a simple randomization to select the side for laser application. Participants who underwent laser exposure were placed in a quiet, relaxing environment and instructed to sit comfortably. They were required to wear laser safety glasses before the laser exposure. The laser device used in the research was the Sirolaser (SIRO Laser, Sirona Dental System GmbH, Bensheim, Germany), as shown in Figure 1. This laser utilized a Gallium Aluminum Arsenide diode with continuous wave emissions set at a wavelength of 660 nm. with an 8 mm. diameter of laser tip. In the research, a power setting of 100 mW and an energy density of 8 J/cm2 were used, and each laser exposure took 40 seconds per point, resulting in an energy of 4 J per point. The first researcher designated a total of 10 laser exposure points intraorally, with six points located on the buccal vestibule of the lower second molars to the lower third molar. The remaining four points were on the labial mucosa. A total of 9 points were designated extraorally, with three points along the lower lip border and six points on the chin, for a total of 19 points, as shown in Figure 2. Each laser exposure point took 40 seconds, and the total time required for one round of laser exposure was approximately 13 minutes. The control side was treated in the same manner as the experimental side, with the laser device placed in the same position but no laser light was applied during this time. The total time for laser exposure on both sides was approximately 26 minutes. The laser exposure sessions began in the first week after surgery and continued weekly until six weeks were completed, totaling six sessions.

Figure 1 The Sirolaser device (SIRO Laser, Sirona Dental System GmbH, Bensheim, Germany) and the laser tip with an 8-millimeter in diameter.

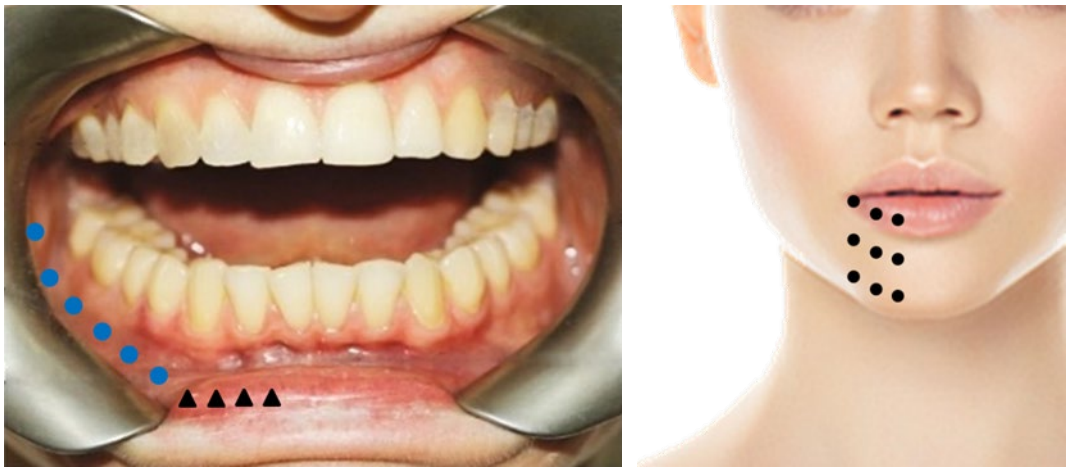

Figure 2 Laser exposure points both inside and outside the oral cavity.

In this study, the recovery of IAN was evaluated using the Visual Analog Scale (VAS) and the Scoring Neurosensory Test (SNST) in the lower lip and chin areas, following the methodology outlined by Suchatpong P and Vittayakittipong P (2021). The VAS and SNST scores were calculated separately for the lower lip and chin on both sides. Then these scores were summed to obtain a total score with a maximum value of 22, as shown in Table 1. The evaluation of nerve recovery was performed at eight time points: before surgery, 1 week post-surgery or before the first laser exposure (T0), 3 weeks post-surgery or after the third laser exposure (T1), 6 weeks post-surgery or after the last laser exposure (T2), 3 months post-surgery (T3), 4 months post-surgery (T4), 5 months post-surgery (T5), and 6 months post-surgery (T6), as depicted in Figure 3.

The VAS, SNST, and total scores for the lower lip and chin on both sides were recorded at each time point. The differences in total scores were then calculated between different time points (e.g., T0-T1, T0-T2, T0-T3, T0-T4, T0-T5, T0-T6, T1-T2, T2-T3, T3-T4, T4-T5, T5-T6). These score differences were compared and statistically analyzed to assess the sensory nerve recovery.

Table 1 Assessment of sensory nerve recovery with visual analog scale and scoring neurosensory test.

Evaluation method	Equipment	Testing method	Scoring	Maximum score
1) Visual analog scale, VAS	A straight line that is 10 cm long with marks from 0 to 10.	- mark a sign on the line for the level of numbness, where 0 indicates no numbness, and 10 indicates the most severe numbness	- In accordance with the scores received.	10
2) Scoring neurosensory test				
2.1) Light touch sensation	paintbrush, number 00	- Use the paintbrush to touch lightly a 1 cm length, and then ask the patient that they can feel it or not. Repeat this process three times.	- If the patient does not feel it, assign a score of 1. - If the patient feels it, assign a score of 0.	3
2.2) Brush directional stroke	paintbrush, number 00	- Use the paintbrush to gently stroke in different directions over a 2 cm in length and then ask the patient which way it is stroked. Repeat this process three times.	- If the patient answers incorrectly, assign a score of 1. - If the patient answers correctly, assign a score of 0.	3
2.3) Two-point discrimination	Two point discriminator	- Starting from a distance of 16 mm, then decreasing the distance by 2 mm at a time. Record the shortest distance that the patient can be discriminated between 2 points. - Subtract the distance mentioned above from the distance that recorded before the surgery in each area.	- If unable to discriminate the 2-point distance at 16 mm, assign a score of 3. - In cases of the measured distance is greater than or equal to the pre-surgery distance, subtract the mentioned distance from the pre-surgery value: If ≥6, assign a score of 3. If 4, assign a score of 2. If 2, assign a score of 1. If 0, assign a score of 0. - If the measured distance is less than the pre-surgery distance, assign a score of 0.	3
2.4) Sharp-blunt discrimination	Dental explorer	- Use the pointed side to test sharpness, press down approximately 1 mm. - Use the blunt side to test bluntness, press down approximately 1 mm. - Alternate or randomize between sharp and blunt. - Repeat this process 3 times.	- Incorrect answer: Score 1 point. - Correct answer: Score 0 points.	3
Total score				22

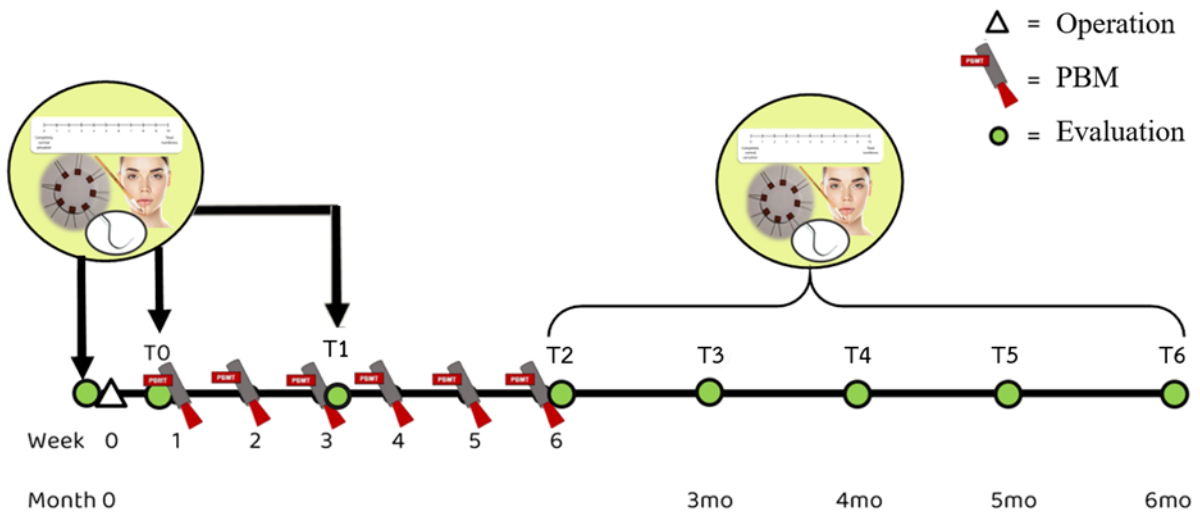

Figure 3 Number of PBM exposures and the time interval for numbness assessment.

Statistical data analysis was performed using SPSS Statistics software (SPSS® 23.0, SPSS Inc.). Non-parametric statistics were applied to VAS and SNST data. Wilcoxon Signed Rank Test and Mann-Whitney U Test were used to analyze differences in values at different time intervals, with statistical significance set at $p<0.05$.

RESEARCH RESULTS

There were 4 female patients who met the inclusion criteria. The average age was 32.25 ± 9.43 years (range 21-41). Details of the diagnosis and surgical procedures are shown in Table 2, and the graph displays the total scores for lower lip and chin numbness in the 4 patients, as in Figure 4.

Table 2 Characteristics of the patients included in this study

Case No.	Gender	Age	Diagnosis	Operation	Mandibular & chin movement
1)	Female	28	Skeletal class II Vertical maxillary excess (VME) Mandibular antero-posterior deficiency	Lefort I osteotomy Bilateral sagittal split ramus osteotomy Genioplasty Corticotomy with bone graft	- Mandible advance Rt. 12 mm. Lt. 9 mm. - Chin advance 10 mm.
2)	Female	41	Skeletal class II Maxillary antero-posterior excess Mandibular antero-posterior deficiency	Lefort I osteotomy Bilateral sagittal split ramus osteotomy Hofer osteotomy Genioplasty	- Mandible advance 7 mm. bilateral - Chin correct midline
3)	Female	39	Skeletal class II Mandibular antero-posterior deficiency	Bilateral sagittal split ramus osteotomy Genioplasty	- Mandible advance Rt. 1.5 mm. Lt. 2 mm. -Chin advance 10 mm.
4)	Female	21	Skeletal class III Maxillary antero-posterior deficiency Mandibular antero-posterior excess	Lefort I osteotomy Bilateral sagittal split ramus osteotomy Genioplasty Iliac crest block graft	- Mandible setback Rt. 7 mm. Lt. 7 mm. - Chin advance 6 mm.

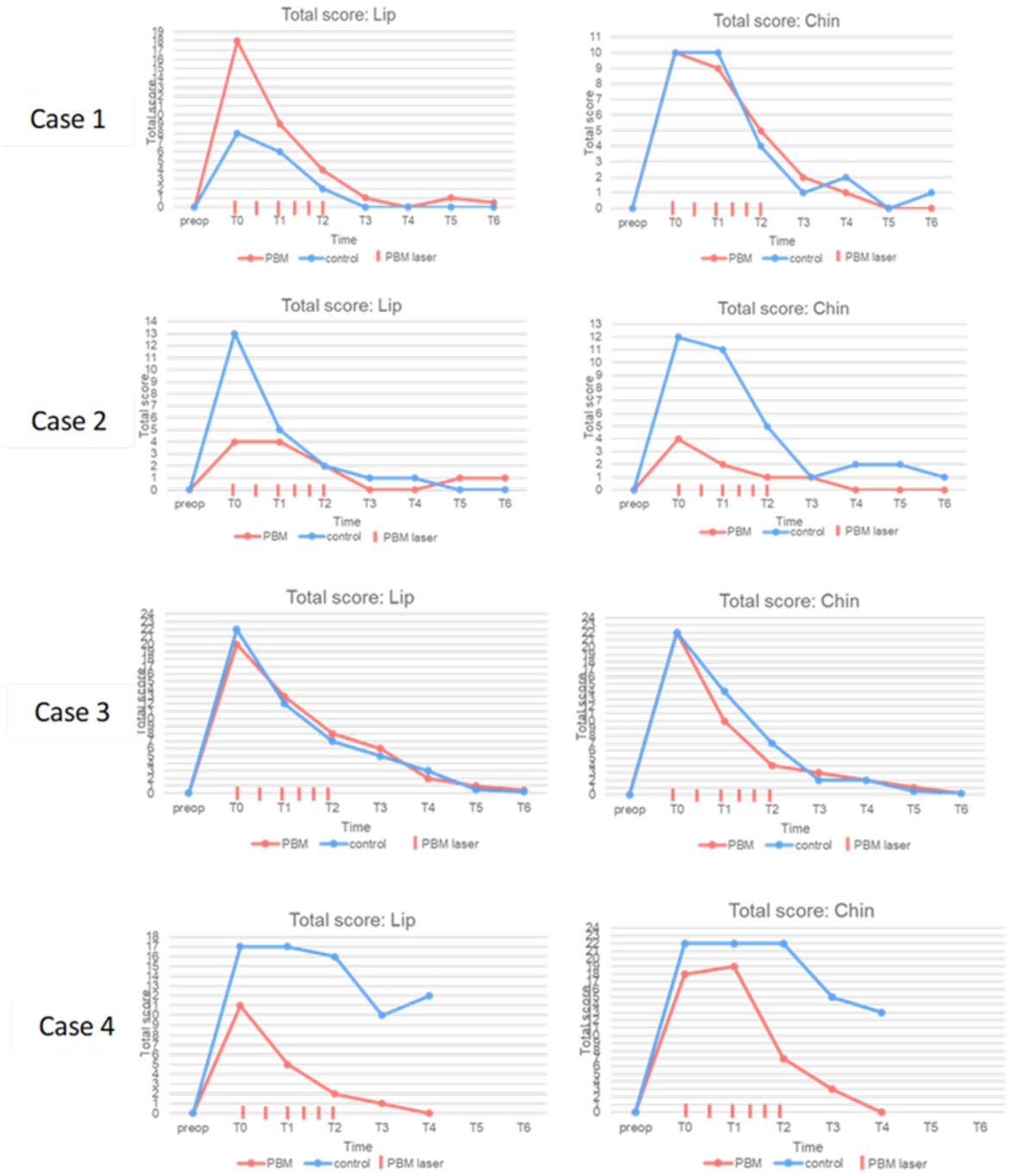

Figure 4 The total score of both the control and PBM-treated sides in the lower lip and chin area of all 4 patients.

Patient 1, one week after surgery, had more pronounced lower lip numbness on the side that received laser exposure (total score of 18) compared to the control side (total score of 8). However, numbness in both sides of the chin had the same score of 10. When analyzing the lip numbness graph after 3 weeks (T1), the side with laser exposure had a reduced score of 9, while the control side had a reduced score of 6. After 6 weeks, or upon completing the laser exposures, both sides showed a reduction in numbness, with the control side recovering faster at 3 months compared to the laser-exposed side, which recovered at 4 months. However, the numbness in the chin region after laser exposure continuously decreased without significant differences, and both sides recovered at 5 months.

Patient 2, after surgery, had more pronounced numbness in both the lower lip and chin on the control side compared to the side that received laser exposure, with total scores of 13 and 12, respectively. Meanwhile, the laser-exposed side had the same score of 4 for both the lower lip and chin. After the laser exposures, the control side reduced the lip numbness score at 6 weeks after surgery, while the chin numbness score was reduced at 3 months. However, when the laser exposures was completed, the lip numbness on the laser-exposed side had recovered by 3 months, while the control side recovered by 5 months, and both sides had minimal numbness.
Patient 3, after surgery, had similar degree of numbness in both sides of the lower lip and chin. After the laser exposures, both sides showed a gradual reduction in numbness, with minor differences. After 6 months, the patient still had minimal numbness.
Patient 4, one week after surgery, had more pronounced lower lip and chin numbness on the control side compared to laser exposure side, with total scores of 17 and 11, respectively. In the chin region, the control side had a total score of 22, while the laser-exposed side had a total score of 18. After completing of laser exposures, both sides showed a continuous reduction in numbness. The lower lip and chin in laser exposed side showing normal recovery at 4 months after surgery. The control side, however, still had minor numbness in both the lower lip and chin regions, with total scores of 12 and 13, respectively.
The median values of the total scores for the control and laser-exposed sides in both the lower lip and chin regions are shown in Figure 5. Statistical analysis using the Mann-Whitney U test did not reveal a significant difference in the median values of the score differences between the control and laser-exposed sides in the lower lip and chin regions (Table 3).

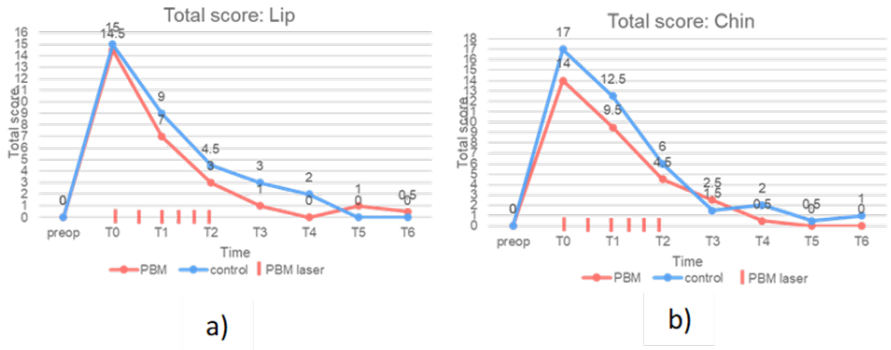

Figure 5 The median values of the total scores for the control and PBM-treated sides in the lower lip (a) and chin (b) regions.

Table 3 Median values of the differences in total score at different time intervals for the lower lip and chin regions, comparing the control side with the PBM-treated side (N=4).

Different	Lip		P*	Chin		P*
	Control	PBM		Control	PBM	
T0-T1	5.0	6.5	0.885	0.5	1.5	0.661
T0-T2	8.5	10.5	0.773	6.5	8.0	0.773
T0-T3	10.0	12.0	0.885	10.0	11.5	0.773
T0-T4	10.0	14.5	1.000	9.5	13.5	1.0
T0-T5	13.0	17.0	0.827	10.0	10.0	0.487
T0-T6	13.0	17.5	0.827	11.0	10.0	0.658
T1-T2	3.5	4.0	0.655	6.0	5.0	1.000
T2-T3	2.0	2.0	0.877	4.5	2.0	0.08
T3-T4	0.0	1.0	0.234	-0.5	1.0	0.137
T4-T5	1.0	-1.0	0.178	1.5	1.0	0.369
T5-T6	0.0	0.5	0.246	0.3	0.0	0.825

DISCUSSION & CONCLUSION

The preliminary study found that the use of PBM did not have a clear effect on the recovery of lower lip and chin numbness after BSSRO combined with genioplasty. However, among the patients who received PBM, 2 out of 4 experienced slightly faster recovery of sensation in the lower lip and chin. The main factors affecting the effectiveness of PBM appear to be related to the laser's energy for accessing the IAN and mental nerve. Several factors play a role in the energy levels used for PBM, including laser intensity, laser energy, wavelength, and tissue depth for laser light penetration (Zein et al., 2018). Currently, there are no established standard values for laser wavelength used in PBM, as well as for adjusting laser intensity, energy, exposure time, and frequency of laser irradiation. Many studies have employed PBM for the recovery of the IAN after BSSRO surgery, and they have found significant positive results (Firoozi et al., 2020; Hosseinpour et al., 2019). These studies used various combinations of laser wavelengths, different laser intensities (ranging from 1.2 to 100 J/cm2), laser power (20-200 mW.), exposure times (10-90 seconds per spot), and the number of irradiation sessions (6-10 times). The positioning of the laser heads also varied (Firoozi et al., 2020; Hosseinpour et al., 2019). This pilot study specifically used a laser intensity of 8 J/cm2, laser power of 100 mW, exposure time of 40 seconds per spot, 6 irradiation sessions, and laser tip placement to cover along both the IAN and mental nerve. In comparison to previous studies, the intensity, power, and positioning of laser tip in this study appear to be sufficient for utilizing as a PBM method in the neurosensory recovery IAN. The wavelength range for laser light used in PBM can indeed vary, and it typically falls within the range of 632 to 980 nm (Firoozi et al., 2020; Hosseinpour et al., 2019). Generally, red light lasers (600-650 nm) have less penetration power into tissues compared to deep red to near-infrared light lasers (650-950 nm) (Avci et al., 2013). This study utilizes PBM with a 660 nm. wavelength, which is in the intermediate range between red light and deep red light. While the laser's intensity and energy output used in this study are adequate, the limitation of the wavelength might restrict its ability to penetrate sufficiently for accessing the IAN located within mandible, beneath the buccal vestibule tissue, and the deeper mental nerve branches within the oral tissue. Additionally, this 660 nm. wavelength may experience energy attenuation when penetrating deeper tissues compared to longer wavelengths (Barbosa et al., 2020). Furthermore, postoperative swelling in the laser application area such as gingiva, buccal vestibule, labial mucosa, lower lip and chin may make the distance of the nerve further from the laser exposure, potentially making it less effective. Most studies investigated the use of PBM for IAN recovery following BSSRO surgery typically used a combination of various wavelengths to enhance the IAN recovery. In the study conducted by Gasperini et al. (2014), they utilized light wavelengths of 660 nm in combination with 780 and 798 nm. In the study by Eshghpour et al. (2017), they used light wavelengths of 660 nm in combination with 810 nm. However, there was a current study that support the use of a single 660 nm wavelength from the Sirolaser device to expedite nerve recovery and improve various aspects of the quality of life following oral surgery. However, it is important to note that this study based on report from only two patients (Nunes et al., 2021).

Previous studies that have used PBM to recover the IAN often started laser irradiation immediately after the patient left the operating room or sometimes one day post-surgery (Gasperini et al., 2014; Führer-Valdivia et al., 2014; Guarini et al., 2018). This contrasts with the approach of this pilot study, which began laser irradiation one week after surgery. The reason for this delay is that during the initial 3-5 days following surgery, patients often experience tissue swelling, including the lower lip, chin, and intraoral tissues around the laser application site. This swelling can make laser irradiation more challenging, and patients may experience discomfort. Additionally, the swelling can result in increased thickness of the tissues covering the nerve, potentially reducing the efficiency of laser energy transmission. Therefore, this study initiated laser irradiation at one week after surgery, when the swelling had

subsided, and patients were experiencing reduced discomfort. However, it's worth noting that even after one-week post-surgery, some improvement in lower lip and chin numbness was observed in some patients, which may have contributed to the relatively less effect of PBM in this study. This change in the timing of PBM initiation is a notable difference in the methodology of this study and may have implications for the study's outcomes and the effectiveness of PBM in the recovery of IAN function after BSSRO combined with genioplasty.

Recommendations for Future Research

The limitations of this study include its pilot nature and the inclusion of patients undergoing both BSSRO and genioplasty, potentially leading to a smaller sample size compared to cases involving BSSRO alone. This limitation is one of the factors contributing to the lack of statistical significance. Additionally, the use of a single 660 nm wavelength may not be sufficient to penetrate both the IAN and the mental nerve, as mentioned earlier. Therefore, future studies should consider using a combination of 660 nm and longer wavelengths to enhance effectiveness. Furthermore, a larger number of participants should be recruited to ensure clearer and more significant results.

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Data Availability Statement: The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

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