# Is Low-Level Laser Therapy Effective for Treatment of Neurosensory Deficits Arising From Sagittal Split Ramus Osteotomy?

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**Purpose:** This study investigated the effectiveness of low-level laser therapy (LLLT) for treating neurosensory impairment after bilateral sagittal split osteotomy (BSSO).

**Materials and Methods:** This randomized, double-blinded, split-mouth trial included patients requiring BSSO. After surgery, 1 side of each patient was randomly assigned to laser therapy and the other side served as the control. At 24, 48, and 72 hours after surgery, LLLT was accomplished by intraoral application of a 660-nm laser around the surgical site (200 mW, 10 seconds, 2 J, 1.5 J/cm$^2$) followed by extraoral irradiation by an 810-nm laser (200 mW, 10 seconds, 2 J, 7 J/cm$^2$) along the distribution of the inferior alveolar nerve. Subsequently, extraoral irradiation was repeated 2 times per week for 3 weeks along the path of the inferior alveolar nerve, lower lip, and chin. On the control side, the treatment was similar to the laser side but with laser simulation. The main outcome was assessing nerve damage by a "2-point discrimination test" before and up to 60 days after surgery.

**Results:** The sample consisted of 16 patients. No significant difference was found between the laser and control sides before and after surgery and on postoperative days 15 and 30 ($P > .05$). The 2-point discrimination distance was significantly shorter on the laser side than on the control side on postoperative days 45 and 60 ($P < .05$).

**Conclusion:** LLLT was effective in the treatment of neurosensory disturbances arising from BSSO. Therefore, LLLT can be recommended to accelerate the recovery of sensory aberrations in patients undergoing BSSO.



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Since its introduction in 1957 by Trauner and Obwegeser, bilateral sagittal split osteotomy (BSSO) has been commonly used as a surgical technique for correction of skeletal disproportions in lower face.[1] Good stability, shorter period of intermaxillary fixation, and patient comfort are among the advantages of BSSO.[2] Despite its benefits, BSSO is associated with some complications, the most important of

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which is neurosensory disorder of the inferior alveolar nerve, which usually occurs from nerve strain or compression during advancement or retrusion of the lower jaw.[3] The incidence of neurosensory deficit after BSSO is clinically remarkable, ranging from 9 to 85% in the literature.[4] In most cases, altered sensation resolves within the first year after surgery; but in 1 to 2% of cases, it can persist for longer periods, leading to high morbidity and negative effects on quality of life and patient satisfaction from orthognathic treatment.[5,6] The neurosensory impairment from BSSO can appear as paresthesia (abnormal sensation such as tingling, tickling, or burning of the skin), dysesthesia (unpleasant or abnormal sense of touch, often presenting as pain), and hypoesthesia (a weaker sense of touch or sensation or partial loss of sensitivity to sensory stimuli) in the lower lip, chin, teeth, and gingiva after surgery.[7,8]

Currently, there is no consensus on the ideal approach for management of patients affected by neurosensory disturbances. Although neurosensory recovery usually occurs spontaneously at some point after nerve damage, supplementary methods can be used to enhance and accelerate the healing process. Some treatment options include physiotherapy, local electrical stimulation, acupuncture, and recently low-level laser therapy (LLLT).[9] It has been reported that LLLT induces bio-modulatory effects on cells and tissues through non-thermal or non-ablative mechanisms.[10-13] Clinically, low-power lasers are generally applied to decrease pain, accelerate the inflammatory process, and enhance the healing rate of affected tissues.[14-16] Some studies have verified the beneficial effects of LLLT on decreasing postoperative pain, swelling, and trismus after surgical removal of impacted lower third molars.[17,18] However, there are few studies on the effectiveness of LLLT in restoring normal neurosensory function of the mandibular nerve after BSSO. The results of animal studies on the effects of laser bio-stimulation on injured nerve fibers are controversial. Some studies have found that postoperative laser therapy promotes peripheral nerve regeneration in rats.[19,20] In contrast, Bagis et al[21] reported that laser irradiation had no effects on recovery of the injured sciatic nerve in rats.

This study investigated the effect of LLLT on augmenting recovery of neurosensory impairment of the inferior alveolar nerve in patients after BSSO surgery.

## Materials and Methods

### STUDY DESIGN AND PARTICIPANTS

To address the research aim, the authors designed and conducted a prospective, randomized, double-blinded, split-mouth, clinical trial.

The participants were selected from patients referred to the Department of Oral and Maxillofacial Surgery at the School of Dentistry of Mashhad University of Medical Sciences (Mashhad, Iran) from March 2014 through October 2014. The inclusion criteria dictated that the patients should be 18 to 35 years old and require BSSO for correction of mandibular prognathism. All participants underwent presurgical orthodontic treatment and their third molars were extracted at least 6 months before the surgical procedure.

The exclusion criteria were the occurrence of a bad split during surgery, patients with a history of recent surgery or tumors or trauma in the head and neck area, patients with neurosensory disturbance before surgery, and the presence of postoperative infection. Furthermore, patients who had partial or complete nerve section as observed by surgeons during surgery or those who received concomitant genioplasty were excluded from the sample. The study protocol was reviewed and approved by the ethics committee of Mashhad University of Medical Sciences, and an informed consent document was obtained from each patient after complete explanation of the treatment process.

### INTERVENTIONS

#### *Surgical Procedure*

The standard medications were prescribed for patients before, during, and after surgery according to patients' weight. The BSSO procedure was performed under local anesthesia (2% lidocaine with 1:100,000 epinephrine to provide hemostasis at the surgical site) and general anesthesia by 1 skilled surgeon according to the principles of Trauner and Obwegeser[1] as modified by Epker.[22] The horizontal and vertical bone cuts were performed with a saw and splitting was accomplished using a chisel sequence. Then, the segments were fixed by 2 bicortical screws on either side.

#### *Low-Level Laser Therapy*

After surgery, 1 side of each patient was randomly assigned to laser therapy and the other side served as the control. Two laser wavelengths were used in this study: 660 nm for intraoral irradiation and 810 nm for extraoral irradiation. On the laser side at 24, 48, and 72 hours after surgery, a low-power indium-gallium-aluminum-phosphide diode laser (wavelength, 660 nm; Thor DD2 Control Unit, Thor, London, UK) was used to irradiate 4 points located around the surgical site for 10 seconds per point. The laser operated at a power of 200 mW in continuous wave mode at an approximate distance of 1 cm from the target area (spot size at 1-cm distance, 1.3 cm$^2$), giving 2 J of energy with an energy density of 1.5 J/cm$^2$ per area. At the same appointment, extraoral irradiation was accomplished by a gallium-aluminum-arsenide diode laser (wavelength, 810 nm; Thor DD2 Control unit) to 8 points located on the ramus and body of the mandible along the distribution of the inferior alveolar nerve. The laser was applied in contact mode with the target tissue and the laser parameters were similar to those described for intraoral irradiation (200 mW; continuous wave mode; 10 seconds; 2 J per point; spot size at surface of the probe, 0.28 cm$^2$; energy density, 7 J/cm$^2$).

Subsequently, LLLT was continued 2 times per week for a period of 3 weeks. During these appointments, LLLT was performed by infrared wavelength to 8 points on the path of the inferior alveolar nerve parallel to the mandibular ridge using the same parameters described earlier (200 mW, 10 seconds, 7 J/cm$^2$). During the same appointments, 4 points on the lower labial mucosa, 2 points on the lower lip, and 9 points on the chin were exposed to infrared wavelength (200 mW, 10 seconds, 7 J/cm$^2$). The patient and the laser therapist wore safety goggles during irradiation. On the control (placebo) side, the treatment was the same as that for the laser side but the device was turned off. The laser therapist was aware of laser versus placebo treatment, but the patient was blinded to group assignment.

### VARIABLES

The predictor variable was the use of laser therapy versus placebo treatment after BSSO. The primary outcome variable was the neurosensory evaluation using the "2-point discrimination test" before and for 60 days after surgery on the laser and control sides. Baseline characteristics (age, gender, etc) and intraoperative events were similar between groups because of the split-mouth design of the study.

### DATA COLLECTION METHODS

For assessing nerve damage in this study, the 2-point discrimination test was used. The assessment was performed in a dark and quiet room with patients keeping their eyes closed. The test was explained to the patient and performed on hands on the same side as the control site. The 2-point discrimination test was applied before and immediately after the surgical procedure and 15, 30, 45, and 60 days later. For this purpose, 2 sharp needles were used to determine the smallest distance in millimeters that the patient could discern between the 2 sites. The 2-point test was applied symmetrically to 6 points marked on the lower lip and chin on the laser and control sides and the mean value was calculated separately for each side (Fig 1). One trained examiner blinded to group assignment performed the assessments. To have a double-blinded design, the patient and the outcome assessor were kept blind to the treatment groups.

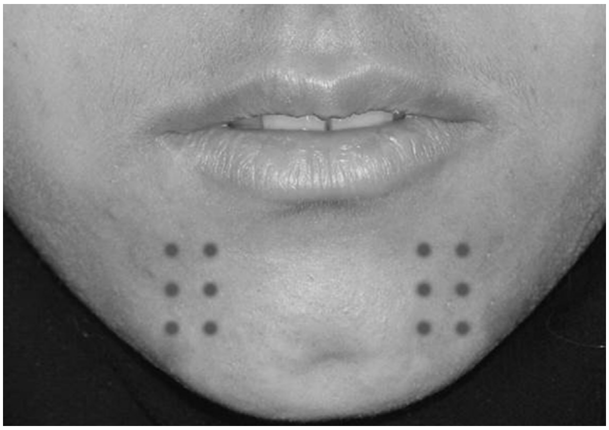

**FIGURE 1.** Symmetrical points on the lower lip and chin for assessing labiomental sensation.

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### STATISTICAL ANALYSIS

The normal distribution of the data was confirmed by the Kolmogorov-Smirnov test ($P > .05$). An independent-sample $t$ test was applied to detect any relevant difference in the 2-point discrimination distance between the 2 groups at each time point. The data were analyzed using SPSS 16.0 (SPSS, Inc, Chicago, IL), and a $P$ value less than .05 was considered statistically significant.

## Results

Sixteen patients (11 women, 5 men) with mean age of 23.1 ± 4.4 years participated in this clinical trial. The right and left sides of each patient were randomized to the laser or placebo treatment after BSSO. All selected patients completed the study and none withdrew from the study. Table 1 presents a summary of the study variables.

Table 2 presents the results of the 2-point discrimination test (outcome variable) in the laser and control

**Table 1. SUMMARY OF STUDY VARIABLES**

| Variable | |
|---|---|
| Sample size, N | 16 |
| Men, n (%) | 5 (31.25) |
| Age (yr), mean ± SD | 23.1 ± 4.4 |

Abbreviation: SD, standard deviation.

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**Table 2. DESCRIPTIVE STATISTICS AND RESULTS OF STATISTICAL ANALYSIS REGARDING THE 2-POINT DISCRIMINATION DISTANCE IN THE LASER AND PLACEBO GROUPS DURING THE STUDY PERIOD**

| | Laser Side (mm) | | Placebo Side (mm) | | |
|---|---|---|---|---|---|
| | Mean | SD | Mean | SD | *P* Value |
| Before surgery | 0.99 | 0.32 | 0.98 | 0.28 | .913 |
| Immediately after surgery | 5.99 | 0.48 | 6.03 | 0.43 | .787 |
| Postoperative day 15 | 6.04 | 0.53 | 6.09 | 0.42 | .798 |
| Postoperative day 30 | 5.87 | 0.52 | 6.14 | 0.39 | .107 |
| Postoperative day 45 | 5.49 | 0.56 | 6.08 | 0.42 | .006 |
| Postoperative day 60 | 5.12 | 0.59 | 5.97 | 0.45 | <.001 |

Abbreviation: SD, standard deviation.

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groups (predictor variable) during the study period. The 2-point discrimination distance increased after surgery compared with the presurgical assessment in the 2 groups. Afterwards, the test result gradually decreased in the laser group, but remained almost constant in the placebo group. Comparison of the 2-point discrimination distance by independent-sample *t* test showed no relevant difference between the laser and control sides before and immediately after surgery and on postoperative days 15 and 30 ($P > .05$; Table 2). However, the sensation of the lower lip and chin was significantly better on the laser than on the control side on postoperative days 45 and 60 ($P < .05$; Table 2).

## Discussion

The present study investigated the efficacy of LLLT on improving neurosensory deficits of the inferior alveolar nerve in patients who underwent BSSO. In BSSO, the osteotomy is performed in close proximity to the nerve; therefore, mechanical damage to sensory fibers of the inferior alveolar nerve frequently occurs.[23,24] Nerve injury can occur at the mandibular foramen, along the mandibular canal, or at the mental foramen. However, the lower lip and chin (distribution area of the mental nerve) are major sites of neurosensory aberration.[25] Nerve damage can be classified as neurapraxia (blockage of nerve conduction with axons and the nerve sheath intact), axonotmesis (axons divided with the nerve sheath intact), and in more severe cases neurotmesis (axons and nerve sheath are disrupted).[24] The occurrence of neurosensory deficit after BSSO is usually a combination of neurapraxia and axonotmesis, because nerve laceration rarely occurs during surgery.[3,26] In this study, sensory disturbances were found on the lower lip and chin of all patients, but complete loss of sensitivity did not occur in any patient. Therefore, the nerve damage observed in all patients was a combination of neurapraxia and axonotmesis. The patients in this study had their third molars removed at least 6 months previously to avoid the risk of a bad split, which increases the severity of nerve damage during surgery.

Nerve function can be evaluated by subjective or objective tests. Subjective tests usually consist of tactile discrimination (including 2-point discrimination), sharp versus blunt testing, and thermal stimuli. The most common objective tests are the trigeminal somatosensory-evoked potential, electromyography, electronic thermography, and mental nerve blink reflex.[27] Currently, there is no consensus as to whether subjective or objective evaluation is better for testing sensory aberrations.[4] In this study, the 2-point discrimination test was applied because it is a simple and commonly used technique that provides satisfactory results. Westermark et al[28] reported a good positive correlation between subjective and objective test results for assessing sensitivity of the lower lip and chin after BSSO. Agbaje et al[4] concluded that the use of subjective tests was the more popular method for evaluating neurosensory deficits in the literature. However, Colella et al[27] in a systematic review found that the frequency of nerve impairment as indicated by subjective measurements was greater than that of objective tests.

In the present study, the 2-point discrimination distance increased remarkably after BSSO compared with the presurgical assessment in the 2 groups. The 2-point discrimination distance gradually shortened after surgery at the laser side, but it was variable at the control side, showing almost no improvement until 60 days after surgery. There was no relevant difference between the treated and nontreated sides from before surgery to 30 days after BSSO. However, on postoperative days 45 and 60, the 2-point discrimination distance was considerably shorter on the laser than on the control side. These findings indicate the efficacy of LLLT in healing neurovascular damage and accelerating the recovery of neurosensory function. The present study suggests that laser therapy can be considered a simple and effective modality to decrease surgical complications in patients undergoing mandibular ramus osteotomy. Based on the present findings, it is expected that patients who receive LLLT after BSSO would recover sooner from sensory aberration of the mandibular nerve and would experience fewer detrimental effects on quality of life and satisfaction.

There is no ideal laser protocol for enhancing nerve regeneration after injury. The present study benefitted from red and infrared wavelengths in patients who underwent BSSO. The red laser was applied intraorally and close to the osteotomy site to improve wound healing. It is believed that low-power red laser has a shallow penetration depth (<1 cm) and thus is suitable for increasing bio-stimulation in superficial tissues. The extraoral irradiation was accomplished by an infrared laser, which provides greater penetration depth (about 2 to 3 cm) to affect deep tissues. The path of the inferior alveolar nerve and the distribution area of the mental nerve in the lower lip and chin were irradiated by the 810-nm laser. The energy delivered by the 2 wavelengths was 2 J per point, but the energy density was different because of the different surface areas of the probes. Actually, the red laser probe had a smaller surface area than the infrared probe, but it was held at a 1-cm distance from the surgical wound and the beam was divergent, thus creating a relatively large spot and less energy density at the target tissue. Previous investigators have used different laser parameters and irradiation protocols for peripheral nerve damage. Most studies have applied infrared low-level lasers for approximately 8 sessions to irradiate the distribution area of the inferior alveolar nerve, with daily application in the first few days after surgery and then 2 to 3 times per week. The irradiation protocol used in this study was somewhat similar to that of Gasperini et al[25] with some modifications. Khullar et al[23] and Miloro and Repasky[26] applied low-level laser along the distribution of the inferior alveolar nerve intra- and extraorally. The intraoral treatment sites were the mandibular foramen, the osteotomy site, and the mental foramen, whereas the extraoral treatment sites were the lower lip and chin.

The outcomes of this study are in agreement with several previous studies. Fuhrer-Valdivia et al[29] evaluated the efficacy of LLLT in patients with neurosensory impairment of the mandibular nerve after sagittal split osteotomy. The outcomes of their study showed clinical improvement in time and in magnitude of neurosensory return in the experimental group compared with the control group. Miloro and Repasky[26] assessed the potential benefit of perioperative and short-term postoperative low-level laser treatment after BSSO and found a marked acceleration in the magnitude and time course of neurosensory return of function. Gasperini et al[25] evaluated 10 patients who underwent BSSO with a Le Fort I osteotomy and were treated with low-level laser on 1 side of the jaw. The data up to 60 days after surgery showed that on the treated side sensitivity recovered faster and was almost complete at the time of the last evaluation. Khullar et al[23] indicated that LLLT resulted in subjective improvement in sensitivity of the lower lip and chin and a marked decrease in the area of neurosensory deficit in patients with paresthesia subsequent to BSSO, whereas the control group did not show any improvement.

The exact mechanism of low-power lasers in enhancing nerve regeneration after injuries is unclear. It has been suggested that laser therapy affects cellular metabolic levels and results in stimulation of light-sensitive fibers or enzymes in damaged axons and Schwann cells, thus leading to the production of certain proteins that aid in neuronal healing.[30,31] Laser application also can decrease the production of inflammatory mediators, such as arachidonic acid and its derivatives, in damaged nerve tissues, thus increasing regeneration after damage.[32] Another theory has suggested that uninjured axons and Schwann cells in the vicinity of nerve injury become upregulated and produce certain neurotropic factors that augment neuronal regeneration. These uninjured axons contribute to collateral innervation of denervated target tissues.[10,32,33]

It has been suggested that age and gender have important effects on the severity of neurosensory disturbances after BSSO.[34-36] The present study benefited from a split-mouth design. Variables such as age, gender, and systematic condition of the patients were ignored as confounding variables in this study, because each patient served as that patient's own control. In addition, intraoperative events were the same in the 2 groups. The assignment of a placebo control group allowed the authors to neutralize the psychological impact of treatment by a high-technology laser apparatus, which could attenuate patients' symptoms.[37,38] The limitations of this study were the small sample, the short follow-up period, and the extraoral irradiation of the infrared wavelength, which was somewhat due to the difficulty of applying the laser in the mouth during the first few days after surgery. The 2-point discrimination test also has been criticized by some researchers for its low sensitivity,[39] which results in failing to detect or underestimating sensory deficits and for its highly variable performance.[40] Further studies with larger samples, longer follow-ups, and various neurologic assessments are suggested to elucidate the effect of LLLT on improving neurosensory dysfunction after BSSO. Different irradiation protocols also should be compared to define the optimum lighting conditions for accelerating the recovery of neurosensory aberrations.

Under the conditions used in this study, LLLT was effective for accelerating the restoration of neurosensory function after BSSO and can be recommended as a safe and noninvasive modality to attenuate postoperative complications in patients undergoing BSSO.

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