



The effect of low-level laser radiation on improving inferior alveolar nerve damage after sagittal split osteotomy: a systematic review

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Abstract

Inferior alveolar nerve (IAN) damage is a common complication occurring after sagittal split osteotomy (SSO) and results in sensory disorders of the jaw region. In recent years, published experimental and clinical evidence suggests that low-level laser (LLL) radiation is effective in nerve recovery. Therefore, the aim of the present study was to review clinical trial studies investigating the effect of LLL radiation on improving the sensory defects of IAN after SSO. The keywords associated with SSO and LLL were searched in PubMed, Medline (via Ovid), Web of Science (WOS), Scopus, and Cochrane Library databases. Then, controlled clinical trial studies published before November 2017 regarding LLL radiation conducted on patients with IAN neuropathy due to SSO were investigated. The articles fulfilling the study criteria were further scrutinized and the necessary information was extracted from them. A total of seven papers were included in the study. The diode laser used had a wavelength range of 760–930 nm, radiation power of 20–200 mw, and radiation energy of 10.2–95 J (per point of radiation). In the mentioned studies, the patients underwent 3–20 sessions of laser irradiation and were monitored for an additional 0–23 months after completion of the laser intervention. The tests performed in the mentioned studies dealt with examining the perceptions of superficial touch and pressure, two-point discrimination, stimulus movement on skin, temperature, and pain. Furthermore, the patients' general awareness regarding sensory perception in the mandibular region was gauged. In six studies, laser irradiation caused relative improvement in the IAN sensory disorder for a subjective test as well as for one or more objective tests. In the reviewed clinical trial studies, LLL was generally found to be effective in improving the IAN sensory disturbance resulting from SSO, though there was no placebo effect.

Keywords Low-level laser · Inferior alveolar nerve · Sagittal split osteotomy

Introduction

Surgeries for correcting lower jaw deformities are common in dentistry procedures and play a significant role in improving the esthetics and function of the jaw [1, 2]. Sagittal split osteotomy (SSO) is a common surgical technique for correcting lower jaw deformities, which is either done as unilateral sagittal split osteotomy (USSO) or bilateral sagittal split osteotomy (BSSO) [1, 3]. Unfortunately, in spite of its effective clinical outcomes, this intervention causes certain

complications including the temporomandibular joint damage, unwanted fractures, impaired occlusion, infection, and inferior alveolar nerve (IAN) damage [2].

So far, a wide range in the incidence of IAN damage, resulting from this group of surgeries, is reported. The incidence of sensory neuropathies due to IAN damage can occur in all 100% of cases [4–6]. The IAN neuropathy manifests as the sensory deficit to warm and cold stimuli, mild to severe pain, and loss of tactile sensation, which are considered unpleasant and disconcerting for the patients. These conditions affect the quality of life of patients in different aspects such as physical functioning and social relations [7]. The incidence of IAN neuropathy depends on both, the surgeon's adeptness and the anatomical status of the jaw. Moreover, it seems that BSSO, by itself, is a possible risk factor in the incidence of IAN neuropathy [5].

The recovery period for IAN neuropathy, caused by SSO, varies from patient to patient. Most patients improve

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considerably or completely during the first year after surgery [6, 8]. However, some reports indicate that even 2 years after the surgery, over 50% of patients still complain of neuropathy [9].

There is no known cure for IAN neuropathy. Therefore, the introduction of therapeutic options for these patients is helpful. In recent years, through clinical trials, low-level laser (LLL) has shown suitable ability in improving nerve function [8, 10, 11]. In addition, LLL has displayed considerable success in the recovery of nerves with mild to severe damage in experimental studies [12–14]. The aim of the present study was to review the clinical effectiveness of LLL radiation to treat the IAN neuropathy after SSO.

Methods

The methodology and search strategy for this study were performed according to preferred reporting items for systematic review and meta-analysis (PRISMA) statement [15]. First, searches for the common words and phrases related to SSO and IAN were carried out based on MeSH. Thereafter, the following keywords were extracted and searched in PubMed, Medline (via Ovid), Web of Science (WOS), Scopus, and Cochrane Library databases, whereby papers published before November, 2017 were extracted. In order to increase the search sensitivity, first 100 articles related to eligible articles were screened in Google Scholar.

Keywords

“low-level laser” OR “low-level laser therapy” OR “low-power laser” OR “low-intensity laser” OR laser OR phototherapy OR “photodynamic therapy”) AND (“Inferior alveolar nerve” OR “alveolar nerve” OR “lingual nerve” OR “mandibular nerve” OR “trigeminal nerve” OR “sagittal split osteotomy” OR “bilateral sagittal split osteotomy” OR “sagittal split ramus” OR “orthognathic surgery” OR osteotomy) AND (neuropathy OR “nerve injury” OR “nerve damage” OR “nerve recovery” OR neurosensory)

The articles in each database were limited to the English language and clinical trials, respectively. Remaining articles were transferred to Mendeley desktop software (ver. 1.17.11) and duplicated titles were removed. Then, the articles were sent to the two reviewers electronically. The reviewers (F.A and S.A) evaluated the papers (title, abstract, or full text) in terms of the study criteria, quality, and risk of bias, and the papers approved by them underwent final review of a reviewer (M.A).

The inclusion criteria were

- English paper
- Original study
- Randomized controlled trial study
- IAN neuropathy resulting from USSO or BSSO
- LLL intervention

The exclusion criteria were

- Complete IAN section during surgery
- Jaw and facial tumors
- History of IAN neuropathy before SSO
- Lack of reporting on the evaluation method of IAN neuropathy
- No report on the laser irradiation conditions such as radiation wavelength and site of laser radiation
- Lack of access to full-text paper

To assess the quality of eligible studies, the revised CONSORT 2010 statement was used [16]. This checklist examines the various parts of a clinical trial report. In summary, it contains 25 items and 12 subitems (a total of 37 sentences). Two reviewers (F.A and S.A) separately examined the quality of the studies and agreed together.

To assess the risk of bias in studies, Cochrane Risk of Bias Tool was used. This checklist contains six items that include (1) selection bias (random sequence generation, allocation concealment), (2) performance bias (blinding of participants and personnel), (3) detection bias (blinding of outcome assessment), (4) attrition bias (incomplete outcome data), (5) reporting bias (selective reporting), and (6) other bias. In this checklist, the risk of bias categorized as high (H), low (L), or unclear (U) [17]. Two reviewers (F.A and S.A) examined the risk of bias separately and agreed together.

From the final papers, the following information was extracted: type of study, number of patients, laser irradiation conditions such as the radiation wavelength and energy, neuropathy measurement tests, site of radiation, number of therapeutic sessions, duration of patient monitoring, and effectiveness of LLL treatment in comparison to placebo as effective (E) or ineffective (I). Monitoring duration meant the duration of patient follow-up after completion of the laser therapy sessions.

Furthermore, in the reviewed studies, if the laser radiation conditions had not been reported individually, the author, if possible, calculated and recorded the conditions through a formula, using alternate information available in the relevant paper.

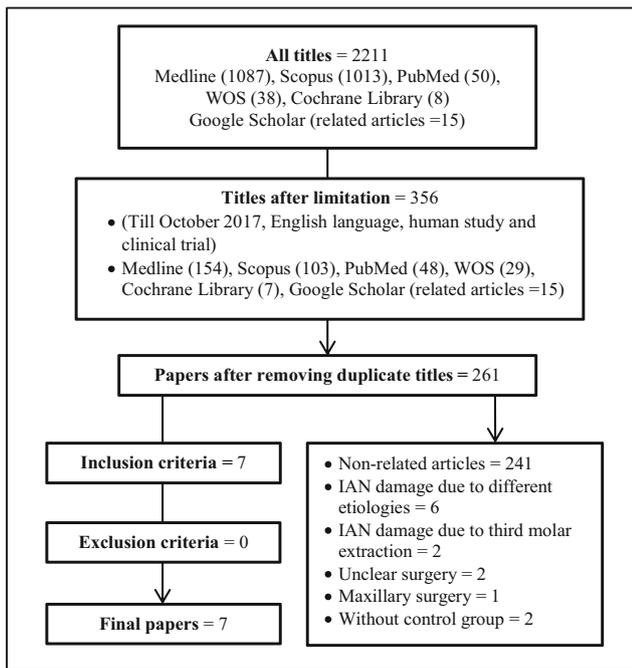


Fig. 1 The articles selection process

Results

Figure 1 displays the results of papers retrieved from the five mentioned databases. A total of 2211 paper titles were screened, but only seven met the inclusion criteria. Finally, the seven papers were inspected carefully. A summary of the final articles is reported in Table 1.

Type of study and number of patients

All the studies were randomized controlled clinical trials; six studies were double-blind, while one was single-blind [21]; three studies had a split-mouth design. In this way, a half lower jaw was radiated by laser, while the other half lower jaw was subjected to the LLL without radiation as a placebo [19, 21, 23]. In the other studies, the patients either received laser radiation or placebo [18, 20, 22, 24]. The numbers of patients undergoing LLL intervention were 105, and those receiving placebo were 76 individuals. Regarding split-mouth studies, 38 patients received both, laser radiation, and placebo, in each half of the lower jaw.

Laser and irradiation conditions

In all studies, the diode laser (GaAlAs) was used. In one study, a combination of laser and LED [18], in another study, a combination of two laser wavelengths [23], and in a third study, a combination of three laser wavelengths was used [19].

The radiation wavelengths had a range of 660–830 nm. At each point of radiation, the radiation energy of the laser had a range of 1.2–9 J and energy density of 1.5–100 J/cm². Further, at each point of radiation, LLL had a power of 20–200 mW and power density of 154–3600 mW/cm². In one study, the radiation energy and energy density were not mentioned individually and were not calculable [18]. The radiation time in each therapeutic session had a range of 2–12 min. In one study, the radiation time was not mentioned [24].

The lasers were used intra-orally or intra/extra-orally. In intra-oral approach [18–24], the labial, buccal, osteotomy site mucosa, and mandibular foramen, and in extra-oral approach [18, 19, 21, 23, 24], the skin surface along with the IAN path, and chin were the common points of laser radiation in the studies. At least, 3 [22] to 25 points [21] in the above parts were radiated. The radiation time for each point is not mentioned in two studies [20, 24]. In other studies, this time varies from 10 [19, 23] up to 90 s [18, 22].

Therapeutic sessions and follow-up

Laser radiation in six studies was done immediately or in the first 2 days after SSO (acute nerve injury) and in one study, 2 years after SSO (chronic nerve injury) [24]. There were diverse therapeutic sessions and intervals. The patients went through at least three and at most 20 sessions of LLL therapy. Mohajerani et al. [18] used laser radiation on days 1, 2, 3, 7, 14, 28 after the surgery; Guarini et al. [20] and Führer-Valdivia et al. [22] applied the laser on days 1, 2, 3, 5, 10, 14, 21, and 28 after surgery; Eshghpour et al. [19] used the laser on days 1, 2, and 3, and then, twice a week for 3 weeks after the surgery. Gasperini et al. [23] used laser immediately after surgery, and then, on days 1, 2, and 3 after surgery, and in 10 consecutive sessions with 48 h intervals; Buysse Temprano et al. [21] applied laser two times a week for 10 sessions, 48 h after surgery; Khullar et al. [24] used 20 radiation sessions on different days (between 20 and 63 days).

In two studies, after completion of the therapy sessions, the therapy outcome was investigated [21, 24]. In the other studies, the minimum and maximum follow-up period was 1–23 months after completion of the laser therapy sessions (2–24 months after the surgery).

Assessing IAN neuropathy

In six studies, the evaluation of sensory disorder was done in subjective and objective groups. In the subjective test, five studies asked the patients to grade the sensory perception of their lower jaw area with a numerical range from “I have no sensation” to “I have complete sensation” (general sensory discrimination) [18, 20, 22–24]. In four studies, the five-

Table 1 A summary of the articles

Author (s)	Type of study	Laser/ Placebo(No.)	Surgery	Wavelength (nm)	Energy (J)/energy density (J/cm^2)	Power (mw) /power density (mw/cm^2)	Radiation time (min per session/sec per point)	Sessions/ radiation points (N)	Follow-up (month)	Test	Efficacy
Mohajeri et al. [18]	DB-RCT	10/10	BSSO	810 632 (LED)	-/5 -/2	-	12/90	6/8	6	GSD, DD, 2PD, TD, PD, THD	E(GSD, 2PD, DD)
Eshghpour et al. 2017 [19]	DB-RCT (Cross over)	16/16	BSSO	660 810	2/1.5 2/7	200/154 ^a 200/714 ^a	0.7/10 1.3/10	3/12	1	2PD	E
Guarini et al. 2017 [20]	DB-RCT	33/9	BSSO	810 810 ± 20	2/7 9/31.8	200/714 ^a 100/353	3.8/10 4.5/-	6/23 8/6	23	GSD, PD, 2PD, THD, DD	E(GSD, 2PD, PD, DD)
Buyssc Temprano et al. 2017 [21]	SB-RCT (Cross over)	12/12	BSSO	808	2.8/100	100/3600	11.7/28	10/25	0	TD, PD	I
Führer-Valdivia et al. 2014 [22]	DB-RCT (Cross over)	16/14	BSSO	810 ± 20	9/ 32	100/357 ^a	4.5/90	8/3	5	GSD, 2PD, PD, THD, DD	E(GSD)
Gasperini et al. 2014 [23]	DB-RCT (Cross over)	10/10	BSSO	660 789	1.2/5 1.2/30	20/500 ^a 60 /1500 ^a	0.7/10 2.7/20	4/12	1	GSD, 2PD	E
Khullar et al. 1996 [24]	DR-RCT	8/5	SSO	780 820	2.8/70 6/46.2 ^a	70 /1750 ^a 70/550	11.3/40 -	10/18 20/4	0	GSD, TD, THD, PD	E(GSD)

DB-RCT double-blind randomized controlled trial, *BSSO* bilateral sagittal split osteotomy, *GSD* general sensory discrimination, *DD* directional discrimination, *2PD* 2-point discrimination, *TD* touch discrimination, *PD* pain discrimination, *THD* thermal discrimination, *E* effective, *SB-RCT* single-blind randomized controlled trial, *I* ineffective, *SSO* sagittal split osteotomy

^a Calculated by the author

scale level ranging from “absence of sensation” to “normal sensation” was used [18, 20, 22, 23]. In another study, the perception of general sensation was measured by the 10-point visual analog scale (VAS) [24].

The thermal perception was evaluated in four studies [18, 20, 22, 24]. To measure thermal perception, a Thermotester instrument [24] or heated pipe was used, while for perception of cold, ethyl chloride was used. Furthermore, one of the studies employed hot gutta-percha [21]. The Thermotester has a probe that gradually increases the temperature after adaptation to the skin temperature. The patient is asked to press the inverter button of the device when they sense a temperature change (cold or heat), so that the probe temperature can reach the skin temperature automatically.

In three studies, superficial touch and pressure perception were evaluated [18, 21, 24]. The stimuli contact with skin was done with monofilaments of different weights (Semmes Weinstein monofilaments). If the patient was able to perceive the stimulus of the lighter monofilaments, it suggested a better tactile sensory perception.

In three studies, the perception of stimulus movement was examined on skin (directional discrimination) [18, 20, 22]. In this test, a nylon filament, staying in contact with the skin, is moved in a certain path, the patient is required to detect this path.

In five studies, two-point discrimination was tested [18–20, 22, 23]. In this test, the patient perceives the distance between the two stimuli of contact with a relatively sharp tip on the skin surface. Shorter distance discrimination implies better sensory power.

The perception of pain was investigated in five studies [18, 20–22, 24]. In three studies, pain perception was measured through the surface pressure of a needle in terms of VAS [18, 20, 22]. In two studies, the threshold for tolerating cold or heat was measured until the pain was felt [21, 24].

Outcome

In six studies (6/7), the laser intervention was associated with improved sensory perception. This improvement developed in some or all of the sensory tests. The subjective sensory perception, two-point discrimination, and stimulus movement path showed improvement in 5/5, 4/5, and 2/3 of studies, respectively.

Among the five papers that assessed pain, variable conditions were observed. In one study, the pain threshold of heat stimulation was normal among all patients [24]. In another study, no report was found to compare the intensity of pain of heat stimulation between the laser and placebo groups [21]. Furthermore, in a study, normal sensory perception to temperature was regained on the seventh day after surgery [18]. In the two remaining studies, LLL indicated improved pain perception in one case (1/2) [20].

In addition, LLL did not have any significant effect on improving superficial touch perception (0/3) and temperature perception (0/4 of studies), as compared with the placebo.

Quality of studies

Items 3a (important changes to methods after trial commencement), 6b (any changes to trial outcomes after trial initiated), 7b (when applicable, explanation of any interim analyzes and stopping guidelines), and 14b (why the trial ended or was stopped) were unrelated to the mentioned studies. Also, the items 13b (for each group, losses and exclusions after randomization, together with reasons) and 17b (for binary outputs, the presentation of both absolute and relative effect size is recommended) were only considered in the studies with excluded patients during the trial and binary qualitative variable. Accordingly, the number of positive items in each study was divided into 31–33 and the quality of articles was expressed as percentage.

The distribution of quality of studies varied from 61.3 to 84.4% that indicates a moderate to high level of quality. Most reasons of the decline in the quality of studies were the lack of explanation of the study registration, randomization, subgroup analysis, and funding sources (Table 2).

Risk of bias

Table 2 shows the low risk of bias in studies, generally. The most biases were lack of explanation of blindness, randomization, and distribution of patients in the study groups. Also, follow-up was not performed in two studies.

A review of studies

Mohajerani et al. divided a sample of 20 patients, who had undergone BSSO with IAN neuropathy, into two 10-person groups. The patients underwent placebo radiation or

combination of diode laser and LED in four regions of the mandibular foramen, site of osteotomy, lip, and cheek bilaterally after 1, 2, 3, 7, 14, and 28 days of the surgery. They, then, monitored the patients for 6 months after the intervention. In their results, LLL was able to significantly improve the general sensory perception (21–25%), two-point discrimination (15.3–16.2%), and the perceived movement of stimulus on skin (15.1–21.5%), as compared with placebo. However, the effect of LLL on pain and superficial touch perception was no better than the placebo. Further, normal temperature sensations were regained in both groups after the seventh day of surgery [18].

Eshghpour et al. performed interventions on patients involving two types of laser after time intervals of 1, 2, and 3 days of surgery. A 660-nm diode laser was used at the site of the surgical wound, while an 810-nm diode laser was employed on the skin surface in the mandibular region. Further, laser radiation on this area continued in the IAN path using intra- and extra-oral procedures for 3 weeks (twice a week). After completion of the LLL treatment, the patients were monitored for 1 month. They used the chin area and two-point discrimination test after time-intervals of 15, 30, 45, and 60 days of surgery to evaluate sensory perception. Their findings showed a significant improvement in two-point discrimination on day 45 (9.7%) and day 60 (14.2%), only. For the other times, the two-point discrimination was better in the laser group, though the difference with the control group was not significant [19].

In Guarini et al. study, the longest LLL monitoring period was conducted over 2 years. A total of 13 patients in the laser group were compared with five placebo patients. The radiation was done for eight sessions on days 1, 2, 3, 5, 10, 14, 21, and 28 after the BSSO. The radiation sites included mucosal points of the mental and mandibular foramen, and surgical wound. In their findings, by the end of the 2 years, LLL caused improved subjective sensation (33.3%), touch perception threshold (25.3%), two-point discrimination (58.6%), and

Table 2 The quality and bias assessment of articles based on the modified CONSORT 2010 statement and Cochrane risk of bias tool

Study		Mohajerani et al. [18]	Eshghpour et al. [19]	Guarini et al. [20]	Buyse Temprano et al. [21]	Führer-Valdivia et al. [22]	Gasperini et al. [23]	Khullar et al. [24]
Quality	No. positive items	25/32	22/31	25/33	23/32	27/32	25/31	19/31
	%	71.9	64.5	75.6	71.9	84.4	80.7	61.3
Bias	Random sequence generation	H	H	L	U	U	H	H
	Allocation concealment	H	H	U	U	L	H	H
	Blinding of participants and personnel	H	U	L	L	L	H	H
	Blinding of outcome assessment	L	L	L	H	L	L	L
	Incomplete outcome data	L	L	L	H	L	L	L
	Other (follow-up)	L	L	L	H	L	L	H

pain perception (38.3%), as compared with the placebo. However, in terms of temperature perception, the difference was not significant. The sensory perception of cold improved faster than of heat for the two groups. By the end of the second year of monitoring, 33% of patients experienced improved heat sensation and all of them sensed cold very well [20].

Buysse Temprano et al. performed at least 10 sessions of laser therapy, with an 808-nm diode laser at 48–72 h intervals. They irradiated the IAN path on the skin surface as well as the buccal region in at least 25 points. Assessing the pain (through heat stimulation) and touch sensation was performed in sessions 1, 3, 6, and 10. Their findings indicated that the extent of improvement in tactile sensations was more rapid in the laser group than in the placebo group, but the difference between the two groups was not significant. In the touch sensation test of the 10th session, 76% and 57% of the half-jaw in the laser and control groups improved, respectively [21].

Führer-Valdivia et al. performed eight sessions of laser radiation on patients and evaluated them in terms of sensory perception on days 1, 30, 60, and 180 after radiation. The intra-oral laser radiation was performed bilaterally at the surgical site, mandibular, and mental foramen. In their results, the general sensation (47.4% by the end of 6 months) improved significantly. Furthermore, 62.5% of the laser group's individuals showed an improvement in the two-point discrimination; however, the difference between the laser and control group was not significant. The perception of pain, stimulus path, and temperature had no suitable trend of improvement in either group [22].

Gasparini et al. performed LLL or placebo intervention on 10 patients undergoing BSSO and LeFort I surgery with a split-mouth design. They used three diode laser wavelengths. Immediately, and 1, 2, and 3 days after the surgery, the site of the surgical wound was irradiated by a 660-nm diode laser, while the skin along the mandibular bone was irradiated by a 789-nm diode laser. Then, from the fifth day onwards with 2-day intervals, the patients received 10 sessions of intra/extra-oral 780-nm diode laser radiation. They evaluated the patients immediately after surgery, and thereafter on days 15, 30, and 60 through the two-point discrimination test in the mental region as well as in terms of general sensation. The laser radiation caused a faster rate of improvement in IAN neuropathy than the placebo. At the end of the 2 months, the patients in the laser group had better two-point discrimination (17.2%) and general subjective sensation (29.1%) than the placebo group [23].

Khullar et al. conducted a trial on patients, who continued to have sensory disorders 2 years after BSSO, in laser and placebo groups. Laser therapy was performed for 20 sessions in a period of 20–60 days. The extra-oral (extreme one-third of the lower lip) and intra-oral regions (second molar and premolar on the buccal side and mandibular foramen) were radiated. By the end of treatment, the laser improved the

subjective sensations in the lip and chin area, as compared with the placebo. It did not have a significant effect on improving the sensation of temperature and touch compared to the placebo group [24].

Discussion

The review performed on seven randomized clinical trial studies indicates that LLL is relatively effective in improving the IAN neuropathy resulting from SSO surgery. In the subjective test, the patients showed improved sensation in IAN-associated dermatome. In the objective tests, improvement in perception of two-point discrimination, stimulus path, and pain (though to a lesser extent) were observed. Nevertheless, with regard to the sensory perception of temperature and superficial touch, the effect of the laser was no better than the placebo.

The damage that occurs to the IAN during SSO surgery may be a result of the osteotomy, displacement of the bone, or use of fixator; in response to which the nerve may be, relatively or completely, compressed, stretched, penetrated, or torn [4, 25]. Furthermore, the formation of scar and fibrotic tissue during the restoration of surgical site and nerve can cause IAN neuropathy and thus affects its stability [26].

The extent of damage to the IAN during SSO may vary given the duration of recovery from neuropathy in these patients, which ranges from neuropraxia, axonotmesis, and *neurotmesis*, involving local damage to myelin, damage to axon and myelin, and some degree of neuronal rupture, respectively [27]. The more severe damage to the nerve, the more difficult is its restoration and recovery, which can leave more sequelae [27].

The function of LLL radiation in improving nerve damage is manifested through various cellular and molecular aspects. Among them, the diminished inflammation and improved restoration of the myelin sheath are very important. Experimental studies have well demonstrated the effectiveness of diode laser radiation at wavelengths similar to those of reviewed studies on re-myelination and modulation of inflammatory conditions. The possible mechanisms of LLL radiation related to nerve restoration include the reduction of prostaglandins, acute phase inflammatory factors like TNF- α , IL-1 and interstitial *metalloproteinase* [28, 29], the synthesis of growth factors [30], and the formation of myelin sheath and new neurons [11, 31–34].

Irrespective of the time that has passed after the SSO surgery, LLL can improve IAN neuropathy, though early initiation of laser therapy is ideal. In the Khullar et al. study, patients who had undergone BSSO surgery 2 years prior and had some degree of sensory disruption in the lower jaw region, after laser radiation experienced an improved sensation of the lip and jaw, two-point discrimination, and enhanced pain

perception [24]. In another spectrum, Guarini et al. reported that in early initiation of laser radiation and 2-year monitoring of patients, the laser indicated stable results in improving IAN neuropathy compared to placebo [20].

In studies that received a combination of laser wavelengths [18, 19, 23], generally, a larger number of objective items of sensory perception showed significant improvements. In other words, by combining different laser settings, their synergistic potential in nerve restoration can be greatly enhanced. However, for reasons unknown, using a combination of different laser settings can bring about variable effects, as observed in experimental studies involving nerve damage recovery [33, 35].

In the reviewed studies, a range of power and energy densities was used. Buysse Temprano et al. employed the maximum energy density (100 j/cm²) and power density (3600 mw/cm²) of an 808-nm diode laser at the expense of a very small radiation spot (0.028 cm²) [21]; from the results, it seems that the very small spot size may have been responsible for the ineffectiveness of the laser. In the Wang et al. study, an 808-nm diode laser with energy densities of 3, 8, but not 15 j/cm² caused a relative improvement in sciatic nerve damage, with a spot size of 3.8 cm² [11]. Nevertheless, as the patients were not followed up, this may have caused bias in their results [21].

Among the objective tests, the laser had ineffective results on the sensory perception, temperature, and superficial touch. In other words, in the studies examined here, the improvement of sensory perception in terms of temperature and superficial touch in the patients was time-dependent, and the laser did not show a better effect than placebo. This lack of success does not seem to be associated with the time period that has passed between IAN damage and initiation of laser radiation [20, 24]. A β and C axons are *mechanoreceptors*, and A δ and C axons are involved in transmitting the sense of pain and temperature. The A β , A δ , and C nerve fibers diminish in diameter and speed of neurotransmission, respectively, and the C fibers lack myelin [36]. Considering the above-mentioned characteristics, A β , A δ , and C, respectively, are more likely to be damaged and their function impaired [37]. Thus, with the reduction in numbers of A δ and C nerve fibers, the transmission of temperature and pain messages decline. Here, lasers with their possible mechanisms may not have the capability to restore lost neurons and temperature receptors.

Among the limitations of the reviewed papers, we can refer to the heterogeneity in laser settings, and also measurement tools for sensory impairment which can influence the comparability of the results from studies. Based on this, it is not possible to correctly propose a suitable laser setting for improving IAN neuropathy after SSO. It seems that 3–10 therapeutic sessions with 48–72 h interval as well as several intra-oral and extra-oral radiation points in the early days after SSO can provide suitable clinical results by considering effective LLL radiation parameters.

In order to obtain a clearer perception from the effect of LLL therapy on sensory impairment, we also propose to use different clinical tests for IAN neuropathy evaluation, such as brush stroke directional discrimination, warm/cool detection threshold, tactile detection threshold, two-point discrimination, and visual analog scale in the related future studies.

Conclusion

In conclusion, the findings of this systematic review study showed that LLL radiation can be of interest as an instrument for rehabilitating patients with IAN neuropathy occurring due to SSO surgery. Paying attention to the early initiation of laser irradiation and therapy sessions, using effective LLL settings, can improve the rate of sensory recovery in patients with IAN neuropathy. Performing studies with various radiation setting, in particular considering successful animal studies, can provide more comprehensive results for the LLL effects; in addition, a longer follow-up and better performing randomization by taking into account variables like age, sex, and the severity of neuropathy, can produce even better results from the LLL.

Compliance with ethical standards

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