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Dentistry Section

# Evaluation of Postoperative Pain in Periodontal Flap Surgery with and without Photobiomodulation using Diode LASER: A Split-mouth Randomised Controlled Study

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## ABSTRACT

**Introduction:** Flap surgery is used to treat deep periodontal pockets and recent innovations like Low-level LASER Therapy (LLLT), or Photobiomodulation (PBM), help reduce postsurgical pain. LLLT works by emitting red or infrared light at wavelengths between 660 and 940 nm, which penetrates tissues and interacts with cytochrome c oxidase to modulate immune responses, reduce inflammation and ease pain, promoting faster healing.

**Aim:** To evaluate and compare postoperative pain in periodontal flap surgery with and without PBM using a diode laser.

**Materials and Methods:** A split-mouth randomised controlled study was carried out in the Department of Periodontology at KM Shah Dental College and Hospital, Vadodara, Gujarat, India. The study took place from August 2023 to January 2024. Based on the inclusion and exclusion criteria, 14 participants (28 sites) with bilateral pocket probing depths of 5-7 mm diagnosed with generalised periodontitis stage II grade A were treated with open flap debridement. After open flap debridement, the test group (Group A) received PBM using a diode LASER (940 nm in a continuous mode with 0.5 W for 112 seconds) applied with a whitening handpiece at a 3 mm distance to the flap surfaces, whereas the contralateral arch, or control group (Group B), received no LASER treatment. The parameters assessed for postoperative pain following flap surgery included the Visual Analogue Scale (VAS) to track the patients' pain levels and the amount of analgesics they took throughout the first week following surgery. For inter group comparison of the amount of analgesics taken and assessing the VAS score, the Mann-Whitney U test was used. Data analysis was done using IBM Statistical Package for Social Sciences (SPSS) Statistics 20.0 (IBM Corporation, Armonk, NY, USA), with the level of significance set at p=0.05.

**Results:** The mean age of the participants was 41.14±2.95 years. Patients in the test group had statistically significant differences in their VAS scores from the day of surgery (day 0) to day 7 compared to the control group. The number of analgesics taken on day 1 postsurgery did not show statistically significant results, as the number of analgesics taken was similar in both the control group as well as LASER group (p-value 0.063). However, patients receiving LASER treatment used fewer analgesics on days 2, 3, 4, 5 and 6 than the control group, with a p-value of less than 0.05, indicating statistically significant findings in this regard.

**Conclusion:** Based on the present study's findings, it can be concluded that the 940 nm diode LASER has the potential to greatly minimise postoperative discomfort and reduce the quantity of analgesics that patients require following flap surgery.

**Keywords:** Light amplification by stimulated emission of radiation, Pain management, Photobiomodulation therapy, Semiconductor

## INTRODUCTION

The outcome of a periodontal flap surgery depends on a number of factors, including the incision design, the degree of tissue invasion, the instruments used, the length of time the patient experiences discomfort and the recovery time following the procedure. These factors can turn it into a stressful treatment stressful, resulting in varying degrees of pain and disabling responses depending on the level of discomfort [1].

Various techniques have been employed to reduce postoperative pain, including the surgical blocking of pain-transmitting neurons, non opioid medications, Non Steroidal Anti-inflammatory Medicines (NSAIDs), opioid analgesics, Patient-controlled Analgesia (PCA) and epidural analgesia. Recently, novel strategies for lessening postoperative pain have emerged, among which Low-level Light Amplification by Stimulated Emission of Radiation (LASER) Therapy (LLLT), also known as Photobiomodulation (PBM) therapy, has garnered significant interest and is increasingly being used in dentistry and medicine [2].

According to previous research, 30 percent of patients who underwent periodontal surgery reported pain in the first week post-treatment [3]. Numerous strategies have been employed to regulate the release of inflammatory mediators. NSAIDs are the most frequently used medications to prevent and treat postsurgical pain; however, these medications can potentially cause gastric issues and abnormal platelet function [4].

The PBM uses low-power LASER light with wavelengths between 632 and 1064 nm and a power range of 1 to 1000 mW to induce a biological response [5]. There is no vibration, sound, or heat. generated by these LASERS. LLLT causes a photochemical reaction in the cell known as biostimulation or PBM. The absorption and scattering of light within the tissue depend on tissue chromophores and wavelength. Proteins such as flavins, cytochromes, porphyrins and nuclear chromatin excessively absorb wavelengths less than 600 nm excessively, whereas water in the tissue absorbs wavelengths longer than 1150 nm excessively. The range between 600 and 1150 nm is referred to as the "optical window" for PBM,

which is the range of practical and useable wavelengths for this application [6].

The PBM is the process of using light, usually from a low-power LASER or Light Emitting Diode (LED) light source, to promote analgesia, lessen inflammation and aid in tissue repair.

It transfers energy to intracellular mitochondrial chromophores, which comprise molecules that absorb light, including endogenous porphyrins and enzymes like Cytochrome-C Oxidase (CCO). Near-infrared light can be absorbed by CCO due to its two heme-iron and two copper cores. Cellular photodissociation of Nitric Oxide (NO) from CCO can be induced by Low-level LASER Therapy (LLLT). When cells are under stress, oxygen in CCO is replaced by NO generated by mitochondrial NO synthase. This replacement lowers cellular respiration and, as a result, lowers the synthesis of molecules that store energy, such as ATP. LLLT inhibits the displacement of oxygen by dissociating NO from CCO, allowing for continuous cellular respiration [7].

Furthermore, it causes the mitochondria to release Reactive Oxygen Species (ROS), which activate Nuclear Factor Kappa B (NF-κB), a transcription factor that serves as a redox sensor [8]. Enhanced redox processes and increased production of Adenosine Triphosphate (ATP) causes neuronal membranes to repair and the transmission of pain [7].

The efficiency of these LASERS is probably influenced by several parameters, including the stability of the neural cell membrane, enhancement of the cellular resuscitation system, enhanced ATP synthesis and decreased levels of prostaglandin E2. Reduced nociceptor signal transduction [8].

The rationale for using Photobiomodulation (PBM) in periodontal flap surgery is based on its ability to enhance healing, reduce pain and inflammation and improve tissue regeneration. Although the reported results of some studies have generated controversy, they have demonstrated a significant impact of PBM on improving wound healing and reducing postoperative discomfort following periodontal procedures [9,10]. There is convincing evidence that LASERS with wavelengths of 820 nm, 940 nm and 660 nm can induce mast cell degranulation [9].

Nonetheless, there are not many case studies [11,12] discussing how PBM affects pain after periodontal flap surgery. Therefore, the aim of the present study was to evaluate and compare postoperative pain in periodontal flap surgery with and without PBM using a diode LASER to determine the efficacy of PBM.

## MATERIALS AND METHODS

A split-mouth randomised controlled study was carried out between August 2023 and January 2024 in the Periodontology Department of KM Shah Dental College and Hospital in Vadodara, Gujarat, India. The Institutional Ethics Committee approved the study (SVIEC/ON/DENT/SRP/22077).

**Sample size calculation:** The following assumptions were used to determine the sample size: The readings in Groups A and B were 0.857 and 1.306, respectively [10], with an alpha error of 5% and a beta error of 20%. The Standard Deviation (SD) considered was 0.42 [10]. Thus, the minimal sample size needed for each category was determined to be 14 (http://powerandsamplesize.com).

**Inclusion criteria:** Patients with age group between 18 and 65 years with bilateral periodontal pockets with depths of 5 to 7 mm and similar affected teeth on both sides of the maxilla and mandible were included in the study.

**Exclusion criteria:** Pregnant and lactating women, patients with a history of long-term use of antibiotics and corticosteroids, smokers, tobacco chewers and patients who are not willing to undergo treatment were excluded from the study.

### Study Procedure

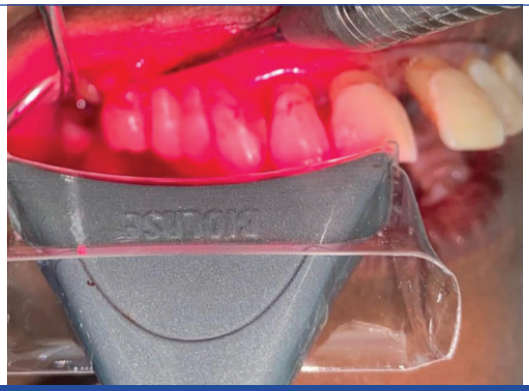
The study involved 14 patients (28 sites), with ages ranging from 18 to 65. The patients were diagnosed with generalised periodontitis stage II grade A [13], and had bilateral pocket probing depths of 5-7 mm. While performing quadrant-wise flap surgery, a coin toss approach was used; one side of the quadrant was treated with Photobiomodulation (PBM) utilising a 940 nm diode laser following flap debridement, while no laser was applied (Sham Laser) to the contralateral quadrant after flap debridement. The number of teeth included for flap surgery was the same in both the test and control groups.

**Presurgical procedure:** During the first visit, medical records and patient data were collected and oral hygiene recommendations were reinforced. Hand and ultrasonic scalers were used for both root planing and scaling. Patients were observed two times a week for the first month and after verifying their cooperation and plaque management, they were added to the research.

**Surgical procedure:** Using a double-blind method, neither the patient nor the primary investigator knew which side of the quadrant received the diode LASER PBM. After procuring written consent from the patient, the guide/secondary investigator used the coin toss method for randomisation, allotted one side of the quadrant to Group A (PBM with flap surgery) and the other side to Group B (flap surgery alone).

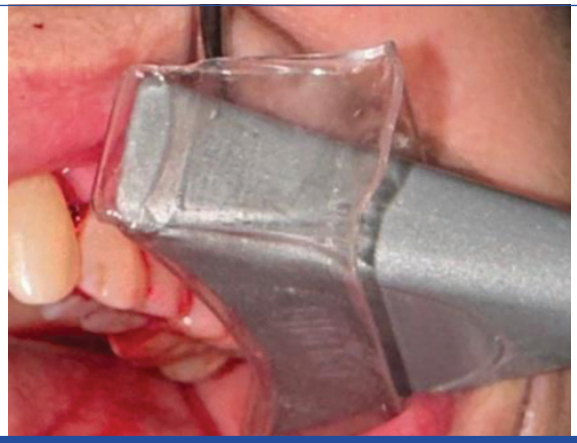
Following the administration of local anaesthesia (2% lidocaine; 1/100,000 epinephrine), the UNC-15 Probe was used to measure the depths of the pockets. Next, a full-thickness Kirkland flap procedure was performed. A crevicular incision was given using a No. 12 blade and the flap was reflected using periosteal elevators, exposing the underlying bone. The root surface was then scaled and polished and a thorough debridement was carried out. Both flap surfaces were treated with a 940 nm diode LASER (Biolase, USA) [Table/Fig-1,2] in continuous mode with 0.5 W power for 112 seconds, using a whitening hand-piece at a distance of 3 mm. The flap surgery was finished by positioning the flap borders where the bone and root surface met and it was sutured using 3-0 silk suture.


**[Table/Fig-1]:** Diode LASER with whitening handpiece displaying the LASER settings used for the study.



**[Table/Fig-2]:** Application of LASER for Photobiomodulation (PBM).

In the control group (Group B), all the steps of flap surgery were followed and the LASER was applied in an off mode to comply with the double-blinded protocol. One surgeon performed all the surgeries and a one-month time interval was kept between the two surgeries [Table/Fig-3].

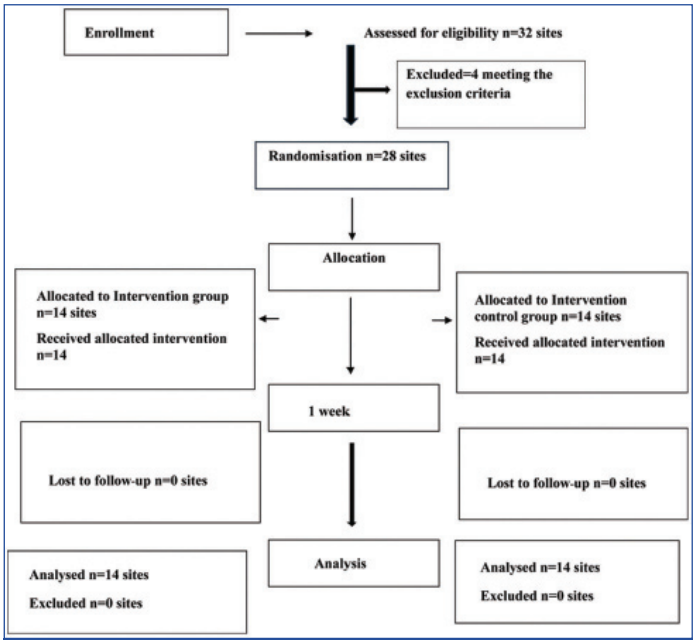


**[Table/Fig-3]:** Sham LASER application Group B.

**Postsurgery instructions:** All patients were advised to take analgesics after surgery (Ibuprofen 400 mg) and whenever they felt pain until one week post-surgery (up to 3 tablets in 24 hours). Furthermore, a 0.2% chlorhexidine rinse and 500 mg of amoxicillin were recommended (every eight hours) for five days.

The two techniques utilised to record the degree of pain were the visual analogue scale [9] {no pain (0) to severe pain (10)} and the amount of analgesics the patient took from the day of the operation to one week later. To gauge their level of pain during the day and to keep track of how many analgesics they had taken, patients were asked to log their level of pain prior to going to bed each night.

[Table/Fig-4] shows the Consolidated Standards of Reporting Trials (CONSORT) flow diagram is shown in [Table/Fig-4].




**[Table/Fig-4]:** CONSORT flow diagram.

## STATISTICAL ANALYSIS

The data were analysed using IBM SPSS Statistics 20.0 (IBM Corporation, Armonk, NY, USA) and the results were presented in graphs and tables. The significance of the research parameters between the two groups was evaluated using the Mann-Whitney U test, as part of the data did not follow a normal distribution; hence non parametric Mann-Whitney U test was used. A p-value of 0.05 or less was considered statistically significant, with p=0.05 acting as the threshold of significance.

## RESULTS

A total of 14 patients (28 sites), with a mean age of 41.14±12.95 years (ranging from 28 to 54 years), completed the procedures and follow-up sessions in this split-mouth randomised controlled clinical trial. The VAS scores for the LASER group and the control group were compared using the Mann-Whitney U test. From day 0 to day 7, the VAS score findings showed statistically significant differences between the LASER and control groups, with the LASER group experiencing significantly less severe pain ($p<0.05$). The pain experiences during the first week after surgery for both the control and LASER groups are presented in detail in [Table/Fig-5].

| VAS score | Group | N | Mean±SD | Z value | p-value |
|---|---|---|---|---|---|
| Day 0 | Control | 14 | 8.43±0.852 | **4.297** | **<0.001**** |
| | LASER | 14 | 5.86±1.231 | | |
| Day 1 | Control | 14 | 7.29±0.994 | **4.166** | **<0.001**** |
| | LASER | 14 | 4.71±0.994 | | |
| Day 2 | Control | 14 | 6.43±1.158 | **3.558** | **<0.001**** |
| | LASER | 14 | 4.43±1.158 | | |
| Day 3 | Control | 14 | 5.71±0.726 | **4.117** | **<0.001**** |
| | LASER | 14 | 3.29±1.267 | | |
| Day 4 | Control | 14 | 4.71±1.267 | **3.883** | **<0.001**** |
| | LASER | 14 | 2.29±1.069 | | |
| Day 5 | Control | 14 | 3.57±0.852 | **4.287** | **<0.001**** |
| | LASER | 14 | 1.00±1.038 | | |
| Day 6 | Control | 14 | 2.14±1.231 | **3.717** | **<0.001**** |
| | LASER | 14 | 0.29±0.726 | | |
| Day 7 | Control | 14 | 0.86±1.027 | **2.714** | **0.007*** |
| | LASER | 14 | 0 | | |
| | LASER | 14 | 0 | | |

**[Table/Fig-5]:** Comparison of the VAS score in terms of mean±SD among both the groups using Mann-Whitney U test.
(p<0.05-Significant*, p<0.001- Highly significant**)

Day 0 refers to the day of surgery. The amount of analgesics taken by the patients on Days 0, 2, 3, 4, 5 and 6 showed statistically significant results, indicating that patients treated with LASER consumed less number of analgesics compared to the control group ($p<0.05$). However, the number of analgesics taken on Day 1 did not show statistically significant results, as the amount of analgesics taken was similar in both the control group as well as LASER groups ($p=0.063$). Also, at Day 7 postoperatively, no statistically significant results were seen when comparing the two groups.

The patients' analgesic intake during the first week following surgery for both the control and LASER groups is presented in detailed [Table/Fig-6].

## DISCUSSION

The purpose of the study was to evaluate the effect of PBM using 940 nm diode LASER on pain after Kirkland flap surgery. This split-mouth randomised controlled trial's primary goal was to assess how PBM affected postoperative pain following traditional flap surgery. PBM LASERS have the ability to reduce pain by modulating inflammation in a dose-dependent way. Compared to LASERS with visible spectrum wavelengths, the LASER employed in this investigation had a deeper penetration depth because of its 940 nm infrared wavelength [14].

The VAS score and the quantity of analgesics consumed by the patient consumed were employed to assess the patient's pain perception because they are simple to use, yield results quickly and make it easier to comparisons of the patient's experience with those of other studies that have been done in a comparable fields [11,12].

In the current study, the outcomes showed that the PBM LASER may considerably reduce pain from the day of surgery to the sixth day

| Number of analgesics | Group | N | Mean±SD | Z value | p-value |
|---|---|---|---|---|---|
| Day 0 | Control | 14 | 3.29±0.611 | 2.659 | 0.008* |
| | LASER | 14 | 2.64±0.497 | | |
| Day 1 | Control | 14 | 2.71±0.469 | 1.861 | 0.063 |
| | LASER | 14 | 2.36±0.497 | | |
| Day 2 | Control | 14 | 2.57±0.514 | 3.324 | <0.001** |
| | LASER | 14 | 1.93±0.267 | | |
| Day 3 | Control | 14 | 2.50±0.650 | 3.141 | 0.002* |
| | LASER | 14 | 1.57±0.756 | | |
| Day 4 | Control | 14 | 2.00±0.555 | 4.075 | <0.001** |
| | LASER | 14 | 0.64±0.633 | | |
| Day 5 | Control | 14 | 1.57±0.646 | 4.266 | <0.001** |
| | LASER | 14 | 0.14±0.363 | | |
| Day 6 | Control | 14 | 0.50±0.855 | 2.117 | 0.034* |
| | LASER | 14 | 0 | | |
| Day 7 | Control | 14 | 0 | 0.000 | 1.000 |
| | LASER | 14 | 0 | | |

**[Table/Fig-6]:** Comparison of the number of analgesics in terms of mean±SD among both the groups using Mann-Whitney U test.
(p<0.05-Significant*, p<0.001- Highly significant**)

following surgery, with little to no change observed on the seventh day. Additionally, compared to the control group, the LASER group required less analgesics on days 0, 2, 3, 4, 5 and 6 of the procedure.

Similar results were obtained by Sanz-Moliner JD et al., using an 810-nm diode LASER and repeating the emission with a power of 0.1 W to reduce pain following Modified Widman Flap (MWF) surgery [12]. Compared to a 940 nm LASER, an 810 nm LASER has a deeper penetration. The VAS score and the quantity of analgesics used were used to determine the patients' level of pain. They conclusion that PBM LASERS can help reduce pain following surgery [12].

The PBM lasers lower biochemical markers, oxidative stress, inflammation and swelling. Bjordal JM et al., conducted a systematic review to study the effects of PBM and their key parameters, revealed that these effects are dose-dependent, with the highest effective doses occurring between 0.3 and 19 J/cm$^2$ and the lowest effective dose occurring at 7.5 J/cm$^2$ [15]. Higher doses of PBM LASERS should be applied within 72 hours of surgery and should then be gradually followed by lower doses to speed up the healing process.

The positive outcomes in the VAS score in the LASER group on the day of surgery can be related to the action of PBM, as it stimulates the production of endorphins, which are natural pain-relieving compounds in the body. It also lessens the transmission of pain signals by modulating nerve conduction. The outcomes also show that patients in the LASER group took fewer analgesics overall than those in the control group [16,17].

There are three overlapping phases in the complex and dynamic process of wound healing. Tissue damage triggers the inflammatory phase, which is the initial stage. The second phase, also known as the fibroblastic phase, involves fibroblasts that produce collagen and tropocollagen [18,19].

In relation to the several phases of wound healing, PBM appears to be more successful during the fibroblastic phase, which includes increased angiogenesis, fibroblast activity and epithelial proliferation. Previous literature has noted the effects of PBM on fibroblasts, such as enhanced growth factor release, increased proliferation and conversion into myofibroblasts [20].

Merigo E et al., assessed the influence of impacted wisdom teeth surgery on pain, oedema and trismus using a 940-nm diode LASER applied extraorally and intraorally, similar to the one utilised in this investigation [21]. The parameters were set at a total dose of 50 J, a spot size of 2.8 cm$^2$ and a power density of 0.5 W/cm$^2$. Furthermore, a bleaching handpiece was used for beam emission every 12 hours for three days. In contrast to the current study, the VAS questionnaire score, which was collected on days 2 and 7 following surgery, revealed no statistically significant difference between the LASER-treated and sham groups. Clinically, however, fewer cases of trismus, oedema and discomfort were recorded.

In a meta-analysis and comprehensive review, Zhao H et al., sought to determine how well LLLT worked as an adjunct to periodontal surgery for treating wound healing and postoperative pain [14]. At day three after surgery, there was a substantial difference in pain reduction between the groups, but at day seven, there was no difference. Additionally, the mean analgesic intake of the LLLT group during the first week was much lower than average: MD -0.60 (95% CI -0.97 to -0.22); (p=0.002). Day 14 results from free gingival graft operations demonstrated markedly faster re-epithelialisation and improved wound healing in palatal donor sites when LLLT was used as an adjuvant. The findings showed that LLLT improved postoperative pain management when used in conjunction with periodontal surgery.

The application of diode LASERS for early healing as PBM has a positive effect on fibroblast proliferation and migration. This can be repeated in future studies using similar LASER settings as those used in the current study across various periodontal surgeries to determine the efficacy of PBM.

### Limitation(s)

Further well-conducted research with larger samples and in various settings seems necessary to draw comprehensive conclusions regarding the effect of PBM LASERS on postsurgery symptoms. Also, to find out how PBM affects different cellular levels and to better comprehend the mechanisms of PBM on pain, more histological research is needed.

## CONCLUSION(S)

The present study shows that the 940 nm diode LASER settings utilised in this study could greatly minimise the amount of analgesics the patient needs to take after surgery, as well as reduce the level of postoperative pain. The future perspectives are that more patient-centered clinical investigations are required to evaluate the effects of PBM utilised in various periodontal surgical procedures from a histological perspective and to gain a deeper understanding of the mechanisms by which PBM reduces pain.

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