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Comparative evaluation of photobiomodulation therapy at 660 and 810 nm wavelengths on the soft tissue local anesthesia reversal in pediatric dentistry: an in-vivo study

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Background: Local anesthesia has been reliably used to control pain during dental procedures and is important in pediatric dentistry. However, children occasionally complain of prolonged numbness after dental treatment, leading to several problems. Studies conducted to reverse the effect of local anesthesia using phentolamine mesylate and photobiomodulation therapy (PBM) are encouraging but limited. PBM is a type of light therapy that utilizes visible and near-infrared non-ionizing electromagnetic spectral light sources. Hence, this study used this modality to compare the reversal of local anesthesia at two different wavelengths. This study compared the effect of PBM at 660 and 810 nm wavelengths on the reversal of soft tissue local anesthesia using a diode LASER in pediatric dentistry.

Method: Informed consent and assent were obtained, and the participants were then divided randomly into three groups of 20 children each: control group-without LASER irradiation, LASER irradiation at 660 nm, and LASER irradiation at 810 nm. Sixty children aged 4–8 years with deciduous mandibular molars indicated for pulp therapy were administered an inferior alveolar nerve block. After 45 min of injection, a duration that was similar to the approximate duration of treatment, they were exposed to 660- and 810-nm LASER irradiation according to their groups until reversal of local anesthesia was achieved. The control group did not undergo LASER irradiation. The reversal of the soft tissue local anesthetic effect was evaluated using palpation and pin prick tests every 15 min, and the LASER irradiation cycle continued until reversal of the soft tissue local anesthesia was achieved.

Results: A significant reduction of 55.5 min (27.6%) in the mean soft tissue local anesthesia reversal time was observed after the application of 810 nm wavelength PBM and 69 min (34.7%) after 660 nm wavelength LASER irradiation.

Conclusion: PBM with a 660 nm wavelength was more effective in reducing the mean soft tissue local anesthesia reversal duration, and thus can be used as a reversal agent for soft tissue local anesthesia in pediatric dentistry.

Keywords: Comparative Study; Local Anesthesia; Photobiomodulation Therapy; Reversal.

INTRODUCTION

Since the 19th century, local anesthetic (LA) solutions have been the first-hand approach in dentistry to alleviate pain during different clinical procedures and are thus used routinely [1,2]. As the first and foremost requirement to start any type of dental procedure is to alleviate the associated pain, LA agents are extensively used in dentistry [2].

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However, the situation is different for children who find their feelings or experiences unpleasant after anesthetic injections. The prolonged effect of local anesthesia on soft tissues, even after completion of the dental treatment, has been observed as an issue in 15% of children [1]. This unintentional prolonged duration of anesthesia experienced as prolonged numbness in younger children results in various problems while chewing, swallowing, speech, etc [3,4]. The prolonged numbness in the soft tissue has been observed to be for approximately 3 to 5 h, which is actually more than required [5]. Researchers have developed several methods to overcome these problems [6].

Photobiomodulation therapy (PBM) utilizes visible (400–700 nm) and near-infrared (700–1100 nm) electromagnetic light sources that are non-ionizing in nature. These include Light Amplification by Stimulated Emission of Radiation (LASERs), light emitting diodes (LEDs), and/or broadband light. Other terms used earlier for PBM therapy include cold LASER, low-level LASER therapy, or LASER therapy [7].

In 1967, Mester discovered PBM at the Semmelweis Medical University in Hungary. In 1964, McGuff successfully used a ruby LASER to treat malignant tumors in rats in Boston, USA. Mester customized the ruby LASER to possess only a fraction of the power as it possessed in the McGuff's design, which was used for treating malignant tumors in rats. Using LASER, Mester showed improved wound healing in rats in which tumors were surgically implanted. This was the earliest indication that PBM may be beneficial in medicine [8].

Mid-1990s witnessed the introduction of diode LASERs in oral surgery [9]. Since LASER technology was introduced into dental practice, there have been various studies claiming the minimally invasive and innovative use of LASERs for various treatment modalities. The high-power mode proved to be advantageous in surgical procedures, along with restorative and preventive dentistry, while the low-power mode showed analgesic, anti-inflammatory, and bio-stimulative effects [10]. The absence of vibration and contact, painless nature, and reduction in the need for local anesthesia add to its advantages in pediatric dentistry, thus offering a more acceptable and tolerant treatment modality for children [11].

In accordance with previous studies in which diode LASERs showed an increase in microcirculation [12-14], our study used this mechanism of action to accelerate the elimination of soft tissue local anesthesia in pediatric dentistry. Pertaining to the availability of only one preliminary study on the effect of PBM on soft tissue local anesthesia reversal, our study aimed to compare soft tissue local anesthesia reversal at two different wavelengths, thus helping to reduce the consequences of prolonged numbness. The aim of this study was to compare the effects of PBM at 660 and 810 nm wavelengths on the reversal of soft tissue local anesthesia using diode LASER in pediatric dentistry. We hypothesized that PBM led to a reduction in the reversal time duration of soft tissue local anesthesia, with 660 nm wavelength being more effective than 810 nm.

METHODS

This was a prospective, parallel, single-blind, interventional study. The sample size was estimated to be 51, with 17 children in each group, based on the reference article "Assessment of photobiomodulation therapy by an 810-nm diode laser on the reversal of soft tissue local anesthesia in pediatric dentistry: a preliminary randomized clinical trial." by Seraj et al. [6], using "A priori: Compute required sample size" with an effect size of 0.46, keeping type I error as 0.05 and power as 0.80. However, this minimum sample size was considered, and to reduce the effect of other factors on statistical significance, 20 children were recruited from each group, resulting in a total sample size of 60.

Before commencement, the study was approved by the institutional ethics committee under IEC number BV(DU)MC&H/Sangli/IEC/D-76/22. The study has also been registered with the Clinical Trials Registry, India, under the registration number CTRI/2022/08/044888.

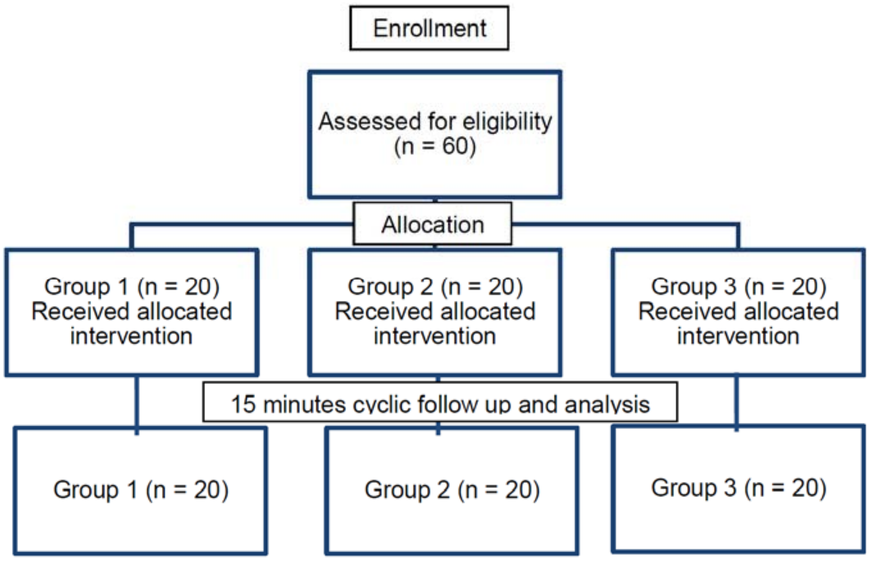

Fig. 1. CONSORT (Consolidated Standards of Reporting Trials) Flowchart of the study

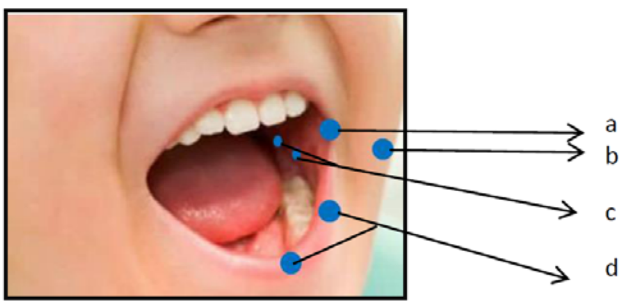

Fig. 2. Six LASER irradiation points represented by blue dots. (a) One point at the labial commissure (b) One point on the skin at the injection site below the vermilion (c) Two points at the site of injection (d) Two points on the lower lip. LASER, Light Amplification by Stimulated Emission of Radiation.

Fig. 3. Clinical photograph showing application of LASER photobiomodulation therapy for the reversal of soft tissue local anesthesia. LASER, Light Amplification by Stimulated Emission of Radiation.

The study was performed on 60 children who visited the Department of Pediatric and Preventive Dentistry (Fig. 1), Bharati Vidyapeeth Dental College & Hospital, Sangli between 28/08/2022 and 28/10/2022. Children in the age group of 4–8 years, belonging to Frankl's behavior rating scale 3 (positive), with their deciduous mandibular molars indicated for pulp therapy, were included in the study. Children with a history of systemic disorders or medication use were excluded from this study.

The demographic data were recorded for each patient. Informed consent was obtained from the parents and informed assent from the children. The selected children were then randomly allocated by the investigator into three groups of 20 children each, by selecting numbered chits concealed in envelopes.

- Group 1: Control group without LASER irradiation
- Group 2: Group to undergo PBM using 810 nm wavelength LASER

Table 1. Inter group comparison of mean soft tissue local anesthesia reversal time duration taken in minutes

Group	N	Mean	Std. deviation	Std. error	Median	Chi-square value	P-value of KruskalVallis test
1	20	199.50	22.355	4.999	210	41.457	< 0.001**
2	20	144.00	13.239	2.960	150		
3	20	130.50	18.274	4.086	127.50		
Total	60	158.00	35.093	4.530			

N, number; Std, standard.

- Group 3: Group to undergo PBM using 660 nm wavelength LASER

These children were kept unaware of the interventional group to which they belonged to.

Lignocaine hydrochloride gel (Xylocaine 2% jelly, Zydus Healthcare Limited, India.) was applied at the injection site followed by the administration of inferior alveolar nerve block with 1.5 ml of lignocaine with adrenaline (LIGNOX 2% A, Indoco Remedies Limited, India).

After 45 min of local anesthesia administration pertaining to the approximate treatment time, the children in the LASER group underwent 810 & 660-nm wavelength irradiation by diode LASER (NovoLASE, India). Six points (Fig. 2 and 3) were irradiated based on the reference article "Assessment of photobiomodulation therapy by an 810-nm diode laser on the reversal of soft tissue local anesthesia in pediatric dentistry: a preliminary randomized clinical trial." by Seraj et al., using LASER for 12 s each at 100 mW power and receiving an energy of 6.12 J/cm^2, in continuous mode with non-contact therapy hand piece:

- Two points at the "site of injection,"
- Two points on the "lower lip,"
- One point at the "labial commissure,"
- One point on the skin at the "injection site below the vermilion" [6].

Anesthesia reversal was evaluated and simultaneously recorded by a single investigator using:

- Palpation technique for subjective symptoms [15]: Children were taught to assess their lip numbness using finger palpation. The soft tissues were tapped softly using the index or middle finger, and they were asked to assess it as normal, tingling, or numb after comparing it to the non-anesthetized side of their mouth as a reference.
- The pin prick test for objective signs [16] was performed using a sterile 26-gauge × ½ inch needle. The needle was inserted into the anesthetized area, taking care not to penetrate the submucosal tissue.

Soft tissue local anesthesia reversal was assessed after each cycle of PBM at intervals of 15 min until the local anesthetic effect was reversed. The duration of anesthesia reversal was calculated by summing the treatment duration, which was 45 min, with an interval of 15 min until the soft tissue sensation was regained. The data were compiled and subjected to statistical analysis.

Statistical analysis

The data obtained were compiled in an MS Office Excel Sheet (v. 2019, Microsoft Redmond Campus, Redmond, Washington, United States) and subjected to statistical analysis using the Statistical Package for Social Sciences (SPSS v. 26.0, IBM). Descriptive statistics, such as the mean and standard deviation of the numerical data, are presented.

Inter-group comparisons for all three groups were performed using the Kruskal-Wallis test and ANOVA, followed by three pairwise comparisons using the Mann-Whitney U test. For all statistical tests, we considered P-value < 0.05, to be statistically significant, and P-value < 0.01 as statistically highly significant in this study, keeping α error at 5% and β error at 20%, thus giving power to the study at 80%.

RESULTS

This study was performed on 60 children, with 20

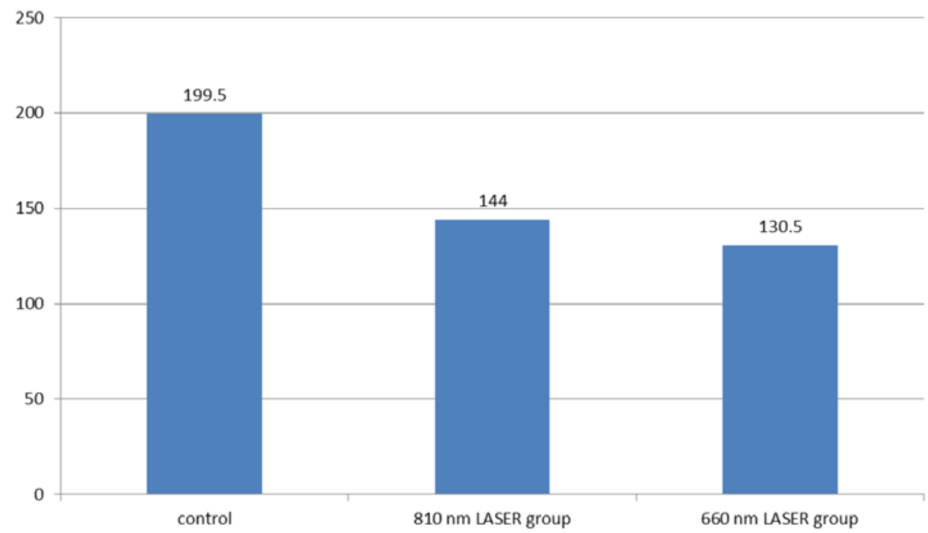

Fig. 4. Inter group comparison of mean soft tissue local anesthesia reversal time duration taken in minutes. LASER, Light Amplification by Stimulated Emission of Radiation.

Table 2. Inter group Pair wise comparison of mean soft tissue local anesthesia reversal time duration taken in minutes using Mann-Whitney U test

Inter group Comparison	Mann-Whitney U value	Z value	P Value of Mann –Whitney U Test
1 versus 2	4.500	-5.351	< 0.001**
1 versus 3	3.000	-5.373	< 0.001**
2 versus 3	110.500	-2.498	0.014*

children (10 boys and 10 girls) in each group aged 4–8 years, with a mean age of

i) Group 1 (control group): 73 months

ii) Group 2 (810 nm): 73 months

iii) Group 3 (660 nm): 73 months

Table 1 depicts various descriptive statistical values for the mean soft tissue local anesthesia reversal time in all three groups. We used the P-value of the Kruskal-Wallis Test < 0.01 as a highly significant comparison for the mean reversal time duration among all the three groups.

Fig. 4 represents intergroup comparison with a significant reduction from 199.5 min to 144 min showing a decline of 55.5 min (27.6%) in the mean soft tissue local anesthesia reversal time duration after the application of 810 nm wavelength PBM, and from 199.5 min to 130.5 min showing 69 min (34.7%) reduction after 660 nm wavelength LASER irradiation.

Table 2 reveals a statistically high significant difference between the control and LASER groups with the P-value of Mann-Whitney U Test < 0.01 for the mean soft tissue local anesthesia reversal time duration, while a significant difference was recorded for the same between the 810 and 660 nm LASER group as we used P-value of Mann-Whitney U Test < 0.05 as statistically significant. However, 660 nm showed a significant difference in the mean soft tissue local anesthesia reversal time when compared to the 810 nm wavelength.

This indicated that the application of PBM helped in the reversal of soft tissue local anesthesia in a shorter time. The wavelengths of 810 nm and 660 nm reduced the duration of soft tissue local anesthesia by 55.5 min and 69 min, respectively.

Thus, 660 nm wavelength was found to be more effective in reversing the effects of local soft tissue anesthesia than 810 nm wavelength.

DISCUSSION

The prolonged effect of soft tissue local anesthesia has always been a matter of special concern, as its effect remains in the form of tongue and lip numbness, even after the completion of dental procedures. This is one of the reasons why pediatric patients resist dental visits. In 13% of children, prolonged local soft tissue anesthesia results in soft tissue injuries [2]. These inflicted soft tissue injuries in children have a negative impact on the child's and parents' further compliance with dental practitioners. In certain cases, soft tissue injuries are misdiagnosed as infections, leading to inappropriate hospitalization or antibioticprescription [17]. Several studies have investigated the need for LA reversal agents [6,15,18].

Phentolamine mesylate is a pharmacological protagonist for local anesthesia reversal and has shown positive results in various studies conducted for the analysis [2]. Some of these studies were conducted on pediatric patients [15,18].

Tavares et al. showed that in 152 children aged 4–11 years, the mean duration of soft tissue local anesthesia reversal in patients who were administered phentolamine mesylate was 60 min, which was less than that in the control group, who recorded a recovery time of 135 min [15].

Hersh et al. showed that the mean duration of soft tissue local anesthesia reversal in children aged 2–5 years was 61 min after receiving phentolamine mesylate compared to 109 min in the control group. The reduction in the duration was highly significant [18].

PBM was another mode of reversal in a preliminary study conducted by Seraj et al. [6]. Since the discovery of PBM in 1967 [8], a myriad of effects has been scientifically proven and established using this modality.

A review of the literature has shown that this therapy causes a reduction in isometric tension of the vascular smooth muscle, which was proven in an in vivo model in which the administration of percutaneous PBM reversed histamine-induced spasm in atherosclerosis by relaxing the vascular smooth muscle [19].

Cytochrome C complex is the primary target of photobiomodulation. It is found in the inner membrane of the mitochondria and is a vital component of the electron transport chain that regulates cellular metabolism [20]. LASER stimulation produces free nitric oxide (NO). It functions as a powerful vasodilator and an important cellular signalling molecule that is helpful in various physiological processes [21].

Chromophores are molecular photoacceptors that absorb low-power visible light photons within their electronic absorption bands. Hemoglobin and melanin are the main tissue chromophores involved in PBM. They exhibit higher absorption bands at shorter wavelengths [21].

Studies by Maegawa et al. and Kubota showed that an 830-nm diode LASER photobiomodulation increased blood flow by increasing vasodilation [22,23].

With respect to this mechanism of action, Seraj et al. conducted a study including 34 children aged 4–8 years to reverse soft tissue local anesthesia using 810 nm PBM and showed a reduction of 43 min in the reversal duration of soft tissue local anesthesia in comparison to those without PBM [6]. The reduction in the reversal time of soft tissue local anesthesia at 810 nm wavelength in our study was 55 min. The variation observed in the results could have been influenced by the variation in sample size and configurations of the LASER used in both studies.

Our study showed an average reduction of approximately 62 min for both wavelengths in the reversal duration of soft tissue local anesthesia using PBM in children aged 4–8 years. However, 660 nm, a shorter wavelength, was more effective in reversing the effect of soft tissue local anesthesia, with a mean reduction of 69 min, compared to 55 min with 810 nm PBM.

In conclusion, the effective results of PBM showed a highly significant reduction in the reversal duration of soft tissue local anesthesia making it a recommended local anesthesia reversal therapy in pediatric dentistry, with 660 nm being more effective than 810 nm wavelength. The safety and non-invasiveness of PBM are sufficient to establish it as a reliable contender to provide a comfortable and satisfactory response from pediatric patients upon the completion of dental treatment and even after returning home. Additionally, PBM reduced the chances of postoperative self-inflicted soft tissue injuries in children and increased their compliance with subsequent visits to pediatric dentists.

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AUTHOR CONTRIBUTIONS

Ankita Annu: Conceptualization, Data curation, Investigation, Methodology, Project administration, Writing - original draft
Sujatha Paranna: Conceptualization, Supervision, Validation, Visualization
Anil T. Patil: Conceptualization, Project administration, Supervision, Visualization, Writing - review & editing
Sandhyarani B.: Conceptualization, Visualization, Writing - review & editing
Adhithi Prakash: Data curation, Writing - review & editing
Renuka Rajesh Bhurke: Data curation, Writing - review & editing

CONFLICT OF INTEREST: We, Dr. Ankita Annu, Dr. Sujatha Paranna, Dr. Anil T Patil, Dr. Sandhyarani B, Dr. Adhithi Prakash, and Dr. Renuka R Bhurke, hereby declare no conflict of interest for the original paper being submitted to your journal.

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