



Effect of Photobiomodulation Therapy With an 810-nm Diode Laser on Pain Perception Associated With Dental Injections in Children: A Double-Blind Randomized Controlled Clinical Trial

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Abstract

Introduction: This study investigated the photobiomodulation effect of an 810-nm diode laser in adjunction with topical anesthesia on pain perception during infiltration anesthesia of primary maxillary molars in children.

Methods: This double-blind randomized controlled clinical trial was conducted on 64 children (aged 5-9 years) requiring extraction or stainless steel crown for their primary maxillary molars. The patients were randomly allocated into two groups (n=32) of laser and control. In the laser group, the injection site (buccal and palatal mucosa) was irradiated with an 810-nm laser (200 mW, 5.2 J/cm²) after 20% benzocaine topical anesthetic application, while the control group received a placebo laser following topical anesthesia. The pain intensity experienced by children during needle insertion into the buccal and palatal mucosa was determined using a visual analog scale (VAS) and modified behavioral pain scale (MBPS).

Results: According to the results of the VAS and MBPS, no significant difference was detected in pain scores between the laser and control groups neither in the buccal nor in the palatal mucosa ($P>0.05$).

Conclusions: Photobiomodulation therapy with an 810-nm laser with the current setting adjunct to topical anesthesia did not promote significant additional effects on the pain intensity.

Keywords: Child; Low-level light therapy; Photobiomodulation therapy; Local anesthesia; Pain.



Introduction

Local anesthesia administration is a major cause of dental fear and anxiety in pediatric patients,¹ so the effective reduction of pain perception during needle insertion is an important approach to reinforcing the trust and cooperation of pediatric patients and their compliance with the treatment.²

Pain perception during injection may be associated with the mechanical trauma following needle insertion into the mucosa, the volume of injected anesthetic agent, and more importantly, the injection speed.³ Adequate knowledge about the composition of anesthetic agents, neuroanatomy of the target area, and appropriate injection technique is the key factor for successful local anesthesia.⁴ Several strategies can be used to reduce pain perception

in dental anesthetic injection, including the use of a higher-gauge needle,⁵ slow speed of anesthetic injection,⁶ optimization of the pH of the injection site,⁷ and selection of a proper type of anesthetic agent.⁸ Moreover, evidence shows that the application of topical anesthetics before injection can decrease the level of pain associated with subcutaneous and intramuscular injections.⁹ It has been reported that the topical application of 20% benzocaine and 5% lidocaine gel can significantly reduce the pain level during anesthetic injection.⁸

Infiltration anesthesia is a commonly adopted technique for pulpal anesthesia of the maxillary teeth with a high success rate in children and adults.¹⁰ In this approach, the anesthetic solution is absorbed by the cancellous bone through the thin, porous cortical plate and can result in

successful anesthesia of the pulp in teeth with intact pulp tissue in 72% to 100% of the cases.^{11,12}

The International Association for the Study of Pain (IASP) has offered the most comprehensive definition for pain as “an unpleasant sensory and emotional experience associated with actual or potential tissue damage”.¹³ The pain experience of patients usually depends on previous experiences of pain, their feelings towards pain, anxiety and stress level, and other sensory experiences.^{13,14}

The use of laser technology in dental treatments has extensively advanced in the past decades.^{15,16} Lasers have several applications in pediatric dentistry, including minimal invasive cavity preparation,^{17,18} successful direct and indirect pulp capping,¹⁹ soft tissue surgery with bactericidal and hemostatic effects,^{20,21} and reversal of soft tissue local anesthesia.¹⁶

Low-level light therapy (LLLT), recently named photobiomodulation therapy (PBMT), is a form of non-thermal light therapy with several clinical outcomes in favor of pain and inflammation reduction, immunomodulation, and tissue regeneration.²² Following the absorption of light by the cellular photo-acceptors, cell reactions can be affected in terms of an increase in cell proliferation and protein synthesis, vasodilation, and activation of several signaling pathways.²³ The optimal laser wavelengths for the therapeutic effects are usually in the red to near infra-red spectrum (600 to 1000 nm) with an energy density up to 10 J/cm² on the target site, which has been confirmed to stimulate biological processes.^{23,24}

Today, there is a growing body of evidence regarding the use of PBMT to decrease the level of pain perception during injection²⁵⁻²⁸ with controversial results regarding the effectiveness of PBMT.^{25,29,30} The use of different wavelengths, light parameters, and pain assessment methods may be the reasons for these contradictory results.³¹

The review of the currently available pieces of evidence found no previous study on the adjunctive use of PBMT with an 810-nm diode laser in combination with topical anesthesia for the reduction of pain perception associated with needle insertion in buccal and palatal mucosa during the infiltration anesthesia of the primary maxillary molars in children. Considering the significance of pain reduction in behavioral control of children, this study aimed to evaluate the photobiomodulation effect of the 810-nm laser on the pain level during the infiltration anesthesia of primary maxillary molars in 5 to 9-year-old children.

Materials and Methods

Trial Design

This double-blind (patient and examiner) randomized controlled clinical trial was conducted on 64 children aged 5-9 years (mean age of 7 years) at the Pediatric Dentistry Department of the School of Dentistry, Tehran

University of Medical Sciences.

Screening Process

Patients were enrolled in the study according to the following criteria: (I) age range of 5 to 9 years, (II) Frankl Behavior Rating Scale³² of 3 or 4 (positive or definitely positive), which was determined according to the patients' dental records (since it was mandatory to record the Frankl Behavior Rating Scale of patients in their records upon admission), (III) requiring extraction or stainless steel crown treatment of primary maxillary molars (Ds or Es) with infiltration anesthesia administration in the buccal and palatal mucosa, (IV) no history of systemic diseases such as cardiac diseases, diabetes mellitus, or cancer, (V) absence of mental disorders, (VI) absence of periapical lesions in the respective tooth, (VII) no history of pain or infection in the respective tooth, and (VIII) no intake of analgesics for a minimum of 24 hours prior to the treatment.

Randomization

The patients were randomly assigned into the control and laser groups (n=32) by a third person who was not involved in the study by the use of balanced block randomization. For this purpose, the patients were assigned to random blocks of four, and within each block, two patients received the active intervention and two others were assigned to the control group. Random allocation within the blocks was performed by Excel software.

Blinding and allocation concealment

The patients and the examiner who evaluated the pain scores and analyzed the data were blinded to the group allocation and use of laser in on or off mode. The pain scale checklist was completed by a researcher blinded to the use of laser whether in on or off mode. Also, the statistician received the data in the form of group A, and group B data had no information about the type of intervention in each group.

Intervention

In the first treatment session, a complete medical and dental history was obtained from the patients. The parents or legal guardians of the children were thoroughly informed about the study and willingly signed informed consent forms. The parents were requested to fill out a demographic questionnaire regarding the child's age, level of education of the parents, and order of birth of the child. Their socioeconomic status was also determined by asking about their level of income.

Prior to anesthetic injection, the buccal and palatal mucosa of the respective primary maxillary molar was dried with a cotton roll for 30 seconds, and then 20% benzocaine topical anesthetic agent (MASTER-DENT[®],

Dentonics, Inc, North Carolina, USA) was applied over the injection site by a cotton applicator for 1 minute.^{29,30} Next, the patients in the laser group were subjected to laser irradiation prior to needle insertion. Each buccal and palatal side was subjected to diode laser irradiation (Fox; A.R.C Laser, GmbH, Nuremberg, Germany) with an 810-nm wavelength, 200 mW power in continuous wave, 400 mW/cm² and 5.2 J/cm² power density and energy density, respectively. The irradiation was done by using a hand-piece with 0.5 cm² spot size at a 1-mm distance for 13 seconds. In the control group, after topical anesthetic application, laser irradiation was applied for 13 seconds while the laser was in off mode. For safety purposes, both the child and the operator wore protective glasses during laser irradiation. Also, it should be noted that we checked the output power of the laser with a power-meter (Laser point. s.r.l, Milano, Italy) at each session prior to use. Next, 2% lidocaine plus 1:100 000 epinephrine (Persocaine, Darou Pakhsh, and Tehran, Iran) was injected with a 20-mm 27-gauge needle at a speed of 1 mL/min^{29,30} by the use of a standard aspirable dental syringe by one person (a senior post-graduate student of pediatric dentistry). The same procedure was then performed for the palatal mucosa.

Outcome Variables and Clinical Measurement

The primary outcome of this study was the level of pain experienced during the infiltration anesthesia of primary maxillary molars in 5 to 9-year-old children by two different subjective and objective pain scales.

The visual analog scale (VAS) and the modified behavioral pain scale (MBPS) were used as subjective and

objective pain scales, respectively, to assess the pain level experienced by children during the anesthetic injection. The VAS facial expressions were shown to children prior to anesthetic injection for the purpose of acquaintance.³³ The MBPS as a behavioral scale assesses three behaviors of facial expression, cry, and body movements.³⁴

Immediately after the injection of the anesthetic agent, the children were requested to pick one of the VAS facial expressions that best described the level of pain they experienced during the anesthetic injection (Figure 1). The researcher also observed the patients during the procedure and filled out the MBPS checklist accordingly. The sum of the scores of all three domains was then calculated³⁵ (Table 1).

It should be noted that the VAS and MBPS scores were recorded immediately after injection in the buccal and palatal mucosa. All injections were performed by a senior post-graduate student of pediatric dentistry. To standardize the anesthetic solution temperature, we placed the cartridges at room temperature for 30 minutes prior to use.

Sample Size Calculation

The minimum sample size was calculated to be 32 children in each group according to a study by Ghaderi et al,²⁹ assuming $\alpha = 0.05$, $\beta = 0.2$, and the mean ($\pm$ standard deviation) pain VAS score of 21 ± 2.9 in the control and 19 ± 2.7 in the laser group by the use of the two-sample *t* test power analysis feature of PASS software.

Statistical Analysis

The pain score, birth order in the family, parents' level of

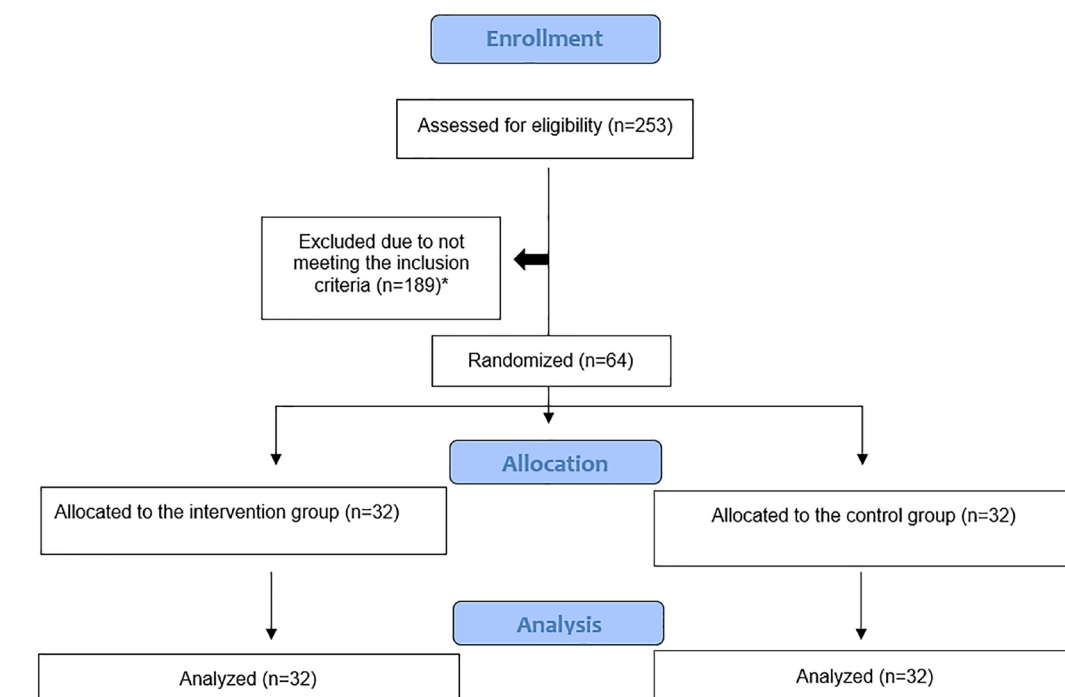


Figure 1. Flow Diagram of the Study

education, socioeconomic status, and age of the children (in months) were analyzed by the Mann-Whitney test, while the gender of children was compared by the chi-square test at $P < 0.05$.

Results

Participant Flow

The flow diagram of patient selection in this study is shown in Figure 1.

Harms

No patients were harmed during this study.

Subgroup Analysis

Table 1 presents the demographic information of the patients in the laser and control groups. Accordingly, no significant difference was detected in terms of confounding and demographic factors between the groups. Moreover, we found no significant difference between the two groups regarding age, socioeconomic status, level of parent education, and order of birth. In addition, the chi-square test showed that the two groups

were not significantly different regarding gender (Mann-Whitney U test; $P > 0.05$).

Regarding the number of treated teeth according to the FDI numbering system, tooth #54 followed by tooth #64 was the most commonly treated tooth in the laser group, and tooth #64 followed by tooth #65 was the most commonly treated tooth in the control group.

The mean VAS pain scores were 3.00 ± 2.21 and 4.66 ± 2.44 in the laser group and in the buccal and palatal mucosa, respectively. These scores were 3.66 ± 2.83 and 5.03 ± 2.94 in the buccal and palatal mucosa, respectively in the control group. Table 2 presents the frequency of VAS scores in the laser and control groups during anesthetic injection into the buccal and palatal mucosa. Although VAS pain scores were lower in the laser group compared to the control one, this difference was not significant in the buccal ($P = 0.44$) and in the palatal ($P = 0.53$) mucosa.

The mean MBPS scores in laser group were 2.28 ± 1.52 and 3.09 ± 1.61 in the buccal and palatal mucosa, respectively. In the control group, MBPS scores were 2.94 ± 2.61 and 3.75 ± 2.35 in the buccal and palatal mucosa, respectively. Table 3 presents the frequency of MBPS scores in the laser and control groups during anesthetic injection into the buccal and palatal mucosa. According to the Mann-Whitney U test, the difference in MBPS scores was not significant between the laser and control groups neither in the buccal ($P = 0.541$) nor in the palatal ($P = 0.474$) mucosa.

The mean pain scores according to the VAS and MBPS were not significantly different between the two groups ($P > 0.05$).

Discussion

This double-blind, randomized, controlled clinical trial assessed the effect of PBMT with an 810-nm diode laser on pain perception associated with anesthetic injection

Table 1. Demographic Information of Patients in the Laser and Control Groups

Variable	Category	Laser group		Control group		p Value
		No.	%	No.	%	
Gender	Female	18	56.2	22	68.8	0.302
	Male	14	43.8	10	31.2	
Birth order	1	11	34.4	15	46.9	0.386
	2	18	56.3	14	43.8	
	3	3	9.4	3	9.4	
Father's level of education	Below high-school diploma	8	25	9	21.8	0.978
	High-school diploma	8	25	8	25	
	Bachelor's degree	4	12.5	3	9.4	

Table 2. Frequency of MBPS Scores in the Laser and Control Groups During Anesthetic Injection Into the Buccal and Palatal Mucosa

VAS Score	Control Group Buccal Mucosa		Laser Group Buccal Mucosa		Control Group Palatal Mucosa		Laser Group Palatal Mucosa	
	No.	%	No.	%	No.	%	No.	%
0	4	12.5	4	12.5	2	6.3	0	0
1	4	12.5	6	18.8	4	12.5	4	12.5
2	4	12.5	4	12.5	1	3.1	2	6.3
3	4	12.5	7	21.9	5	15.6	6	18.8
4	7	21.9	2	6.3	1	3.1	4	12.5
5	4	12.5	5	15.6	2	6.3	4	12.5
6	0	0	1	3.1	6	18.8	4	12.5
7	0	0	2	6.3	3	9.4	4	12.5
8	2	6.3	1	3.1	3	9.4	2	6.3
9	1	3.1	0	0	5	15.6	1	3.1
10	2	6.3	0	0	0	0	1	3.1
P value	0.440				0.538			

Table 3. Frequency of MBPS Scores in the Laser and Control Groups During Anesthetic Injection Into the Buccal and Palatal Mucosa

MBPS Score	Control Group Buccal Mucosa		Laser Group Buccal Mucosa		Control Group Palatal Mucosa		Laser Group Palatal Mucosa	
	No.	%	No.	%	No.	%	No.	%
0	6	18.8	4	12.5	0	0	2	6.3
1	3	9.4	5	15.6	6	18.8	1	3.1
2	9	28.1	12	37.5	8	25.0	10	31.3
3	5	15.6	4	12.5	2	6.3	8	25.0
4	2	6.3	4	12.5	4	12.5	4	12.5
5	1	3.1	2	6.3	4	12.5	5	15.6
6	2	6.3	1	3.1	4	12.5	1	3.1
7	1	3.1	0	0	1	3.1	1	3.1
8	1	3.1	0	0	2	6.3	0	0
9	2	6.3	0	0	1	3.1	0	0
P value	0.541				0.474			

during the infiltration anesthesia of primary maxillary molars in 5 to 9-year-old children.

There are several theories regarding the analgesic effect of PBMT, including increasing production of serotonin, increased synthesis of beta-endorphin, and improved synaptic activity of acetylcholine esterase.³⁶ Additionally, the suppression of nerve conduction in myelinated A δ and unmyelinated C fibers was reported in a rat model following PBMT.³⁷ The use of PBMT to decrease pain perception during the application of local anesthesia is an interesting topic, which has been discussed in a few studies.^{25,26,29,30,38-40} However, there is no agreement on the clinical efficacy of this pre-treatment or standard irradiation protocols. This may be related to several variations in PBMT protocols (wavelength, power, mode of irradiation, and energy density), sites of injection, pain assessment methods, and studied populations (adults or children) among these studies.

Our results revealed no significant difference in pain scores during local anesthesia injection between the PBMT and control groups neither in the buccal nor in the palatal mucosa ($P > 0.05$). Similar to our finding, Ghaderi et al assessed the efficacy of the simultaneous application of PBMT (960 nm, 100 mW, 4 J/cm²) with benzocaine anaesthetic gel on pain perception during injection into buccal mucosa in an adult population. They found no clinically significant difference between the PBMT and control groups regarding pain perception by the use of the VAS score.²⁹ In addition, Sattayut reported no significant beneficial effects of PBMT (790 nm, 27.69 J/cm²) on the pain score compared with 20% benzocaine topical anesthesia, pressure, and light touch after injection the palatal gingiva of the upper left first molar in adult patients.³⁰ Consistent with our data, PBMT with 980 nm at the energy density of 15.62 J/cm²,⁴⁰ and 940 nm with energy density of 15.28 J/cm²³⁹ also failed to exert an analgesic effect during the local infiltration of the buccal site of the anterior maxillary region in adult

patients by means of the VAS pain score.

The selection of the 810-nm diode laser as a source of light in our study was due to the confirmed effects of this laser wavelength in a variety of soft tissue procedures carried out in dental treatments, the availability of the device,⁴¹ and its adequate penetration depth.⁴²

We found three articles with a similar wavelength to our study on this topic.^{25,38,43} In comparison with 810-nm PBMT, ice and local anesthesia showed a superior effect on pain reduction during local anesthesia injection of primary maxillary posterior teeth in children aged 9-12 years by the use of the Wong-Baker Faces Pain Rating Scale and the Sound Eyes Motor scale. In this study, the 810-nm laser was applied with 0.3 W power and in pulse mode, with no other reported details on the dose of irradiation.⁴³ In our study, we assessed the combination effects of PBMT with local anesthetic, as local anesthetic gel is routinely used in pediatric dental procedures and we wanted to evaluate the additional effect of PBMT. In a recent study, the efficacy of PBMT with an 810-nm (0.3 W; 20 s; 69 J/cm²) laser plus 10% lidocaine topical anesthesia in the pain score during the injection of the buccal mucosa of primary first mandibular molars in children aged 6-9 years was investigated. The results showed that topical anesthesia + PBMT reduced injection pain by the modified Wong-Baker Faces Pain Rating Scale and the "Face, Legs, Activity, Cry, Consolability (FLACC)" Behavioral Pain Assessment Scale with no significant effect on anesthesia efficacy and duration.²⁵ These contrary results may be related to the use of different topical anesthesia, site of injection, and higher energy density compared with ours. On the contrary, a similar newly published study with an 808-nm laser reported the beneficial effects of PBMT on pain reduction during the local infiltration anesthesia of maxillary secondary primary molars in children.³⁸ The possible reason for these different results may be related to higher energy density (32.5 J/cm²) in that study. In addition, they compared the effects of laser irradiation

with topical anesthesia, but we evaluated the combination of laser and topical anesthesia.

We also found contrary results with other wavelengths and PBMT settings. Dehghan et al assessed the different powers and energy densities of 940-nm mediated PBMT (0.3 W, 0.4 W, and 0.5 W with 20-second irradiation corresponding to 69 J/cm², 92 J/cm², and 115 J/cm², respectively) on pain experiences during local anesthesia injection on the buccal surface of maxillary and mandibular primary first molars. They found that PBMT+10% lidocaine topical anesthetic reduced pain regardless of laser dosimetry by means of the Wong-Baker Faces Pain Rating Scale and the FLACC scale as a subjective and objective score, respectively.²⁷ This mentioned study used higher energy densities and different local anesthesia compared to ours. Moreover, the utilization of PBMT with a 915-nm diode laser on pain reduction during the local infiltration of maxillary incisors was assessed in Kermanshah and colleagues' study. They reported the beneficial effect of PBMT in pulse mode with a duty cycle of 60% and energy density of 72 J/cm² compared with the sham laser on pain reduction by means of the numerical rating scale for pain.²⁶ Different study populations, sites of injection, and PBMT protocols were observed compared with our study.

We also found one report of dual wavelength PBMT by an 810+980 nm (4 J/cm²) laser that showed positive effects on pain experienced during infiltration anesthesia injection in the anterior maxilla.⁴⁴

In an interesting study, the effect of PBMT as an alternative to injection for the traditional injection of local anesthesia was evaluated.⁴⁵ They applied an 810-nm laser (200 mW, 6 J, 85 J/cm²) in a punctual mode at the buccal cervical area of the tooth and on the gingiva. The results showed that PBMT-induced anesthesia pain score values were lower than those of the traditional injection of local anesthesia, so it may be considered an acceptable alternative to local injection in restorative procedures. Nevertheless, further well-designed studies are required to confirm this claim.

In addition to different PBMT protocols, variations in the needle gauge, cartridge temperature, speed and pressure of injection can also explain the difference in the results.⁸ However, the needle gauge seems to have a lower significance compared to the sharpness of the needle bevel on pain reduction.⁴⁶ Furthermore, it should be noted that a precise comparison of our results with previous studies is not possible considering the differences in the study design, methodology, age range of patients, and type of procedures performed. Among the similar studies, just one study³⁰ evaluated the pain score in the palatal region, so further studies are required to validate our data in this respect.

Finally, it should be noted that the low level of pain scores reported in both laser and control groups may be

due to the fact that pediatric patients with Frankl Behavior Scales of 3 and 4 were enrolled in this study.

The small sample size was a limitation of this study. Moreover, it should be noted that our study was conducted on children, and their feedback may be influenced by emotional and psychological factors, including their level of fear and anxiety and other sensory experiences.^{13,14}

Future studies with a larger sample size, using other laser types, and different exposure settings are required to reach a definite conclusion. Also, the effect of PBMT on the pain level associated with other local anesthesia administration techniques should be evaluated in future studies. Clinical trials with split-mouth design are also recommended to eliminate the effect of possible confounders on the results.

Conclusion

PBMT mediated by an 810-nm diode laser with the current settings adopted in this study prior to maxillary infiltration anesthesia had no additional significant effect compared to topical anesthesia on the pain intensity reduction during needle insertion into the maxillary buccal and palatal region.

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Competing Interests

The authors declare that they have no conflict of interest.

Ethical Approval

The study was approved by the Committee of Medical Ethics of Tehran University of Medical Sciences (IR.TUMS.DENTISTRY.REC.1397.048) and registered in the Iranian Registry of Clinical Trials (available at www.irct.ir) (IRCT20171106037264N2).

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