Evaluation of the effectiveness of photobiomodulation therapy as an alternative method to local anesthesia injection in pediatric dentistry

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Abstract

Background:

The idea of receiving local anesthesia (LA) via an injection is a major source of dental fear and anxiety. In children, dental anxiety is considered the main reason for avoiding dental treatments. Moreover, there are potential complications during/after LA administration. Thus, it is necessary to search for painless, low-risk, and nonpharmacological anesthetic approaches.

Aim:

This study was performed to evaluate the effectiveness of photobiomodulation (PBM) therapy as an alternative method to LA injection for conventional restorative treatments in pediatric patients.

Settings and Design:

This was a split-mouth randomized clinical study.

Materials and Methods:

The study included 15 children between 6 and 12 years old. Each child had 2 similar contralateral caries lesions in the first permanent molars in the same jaw, total (30) teeth. For each child, one tooth was treated under conventional LA injection and the other was treated under PBM-based anesthesia. The Wong–Baker's Faces Pain Scale was used for reporting the pain and discomfort levels at the end of the treatments.

Statistical Analysis:

Data statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS) version 20. Mann–Whitney *U*-test was used to compare between the groups.

Results:

The PBM-based anesthesia group recorded a mean pain score of 2.27 ± 1.28. The conventional LA group recorded a mean pain score of 1.73 ± 0.7. The difference between the groups was not statistically significant ($P = 0.168$).

Conclusions:

PBM-based anesthesia may be an optional alternative to LA injection for conventional restorative treatments in children with dental anxiety, needle phobia, or special needs, and it deserves further studies and improvement.

Introduction

Dental caries is the only chronic disease leading to mineral loss from teeth.[1] In children, the presence of carious teeth may have a strong negative effect on the child's quality of life as early experience of pain, decreased appetite, delayed speech development, and reduced self-confidence.[2] Thus, early dental intervention is highly recommended.

The most common method for pain prevention during caries removal and other dental interventions is local anesthesia (LA) injection which prevents discomfort during oral treatments and promotes easy treatment for the patient and the dentist.[3] Although dental LA is an essential part of dentistry, it may cause local or systemic complications such as hematoma, syncope, infection, paresthesia, toxicity, and allergy.[4]

Although LA is used for pain elimination during dental treatments, its administration itself causes pain. As a result, the idea of receiving an injection is considered a source of fear and phobia.[5] Evidence has shown that levels of dental anxiety are related to poor clinical oral health status. In children, dental anxiety is one of the main reasons for them to avoid receiving dental treatment.[6] Even though LA is still the basis of pain control in the dental field, researchers continue to look for new and improved methods to manage pain. Recently, photobiomodulation therapy (PBMT) is one of these proposed methods.[7,8]

Laser analgesia is a noninvasive, nondestructive, and nonthermal biomodulating technique with the ability to suppress or decrease painful sensations. Low-energy-level irradiation form is a characteristic of laser analgesia. The mechanisms of this effect are not completely clear, even though several theories have been proposed as direct and indirect influences of laser energy on nerves and nociceptors and modifications of the Na^+-K^+ pump systems.[9] Some researchers have reported that photobiomodulation (PBM) therapy can affect both C and Ad nerve fibers, while other studies have stated that only C fibers are affected.[10]

A literature review has introduced reliable evidence about the mechanism of nerve function blockage using PBM therapy by near-infrared (NIR) diode lasers (637–980 nm).[10] NIR lasers can penetrate soft tissues such as the gingiva, affecting the nerve endings in alveolar structures. According to “optical window,” NIR wavelengths can deeply penetrate through dental hard structures to reach the pulp tissue, causing biological effects.[11] These data are promising in the sense of offering a potential alternative to the injection of LA for procedures of dental cavity preparation. Hence, this study aims to evaluate the effectiveness of PBM therapy as an alternative method to LA injection for conventional restorative treatment in pediatric dentistry.

Materials and Methods

This study was approved by the Research Ethics Committee of the Faculty of Dental Medicine for Girls, Al-Azhar University with code (REC-PE-23-11). This study was a split-mouth randomized clinical study. All treatment details were explained to the children's parents or caregivers. Written informed consent was obtained before treatment. Thirty teeth from 15 children were involved in this clinical trial. The sample size was calculated based on the results of a previous study[12] using the G*Power software (version 3.1.9.7). It was calculated that a total sample size of 30 teeth (n = 15 in each group) was required to detect a large effect size of 1.06, with an actual power (1–b error) of 0.8 (80%) and a significance level (a error) 0.05 (5%) for the two-sided hypothesis test. The participants did not have any relevant medical history, and their ages ranged from 6 to 12 years. Each child had two similar contralateral carious permanent first molars (PFMs) in the upper or lower arch according to the International Caries Detection and Assessment System (ICDAS) with no pulpal involvement and no history of pain. ICDAS is a clearly defined criterion for clinical caries evaluation by visual detection of caries, where 0 means sound tooth and 5 or 6 means severe decay.[13] For this study, only cavities classified as ICDAS 3, 4, or 5 were included. Children who were unable to score correctly to the treatments or with large lesions at the possibility of pulpal involvement were excluded.[12] For each child, one tooth was treated under conventional pharmacological LA (control group), and the other was treated under PBM-based anesthesia (PBMT group). For each child, the two treatments were done with at least 1-week interval in a random sequence.

Randomization

The Consolidated Standards of Reporting Trials were followed.[14] Four opaque-sealed envelopes were used to determine which group (conventional LA or PBMT) should be the first treatment and at which side (right or left) the treatment would be started. The children picked up one pocket by themselves then the treatments were performed.

Conventional local anesthesia (control group)

Conventional LA for the control group was obtained by injection of mepivacaine hydrochloride 36 mg/1.8 mL with epinephrine 0.018 mg/1.8 mL (Mepadrenal 3%, Alexandria Co., Alexandria, Egypt) using needles, 30G (0.3 mm × 12 mm) for maxilla, for infiltrative technique, and 27G (0.4 × 21 mm) for mandible, for nerve block. The procedure was applied as painlessly as possible with previous application of topical anesthesia (benzocaine 20%, Iolite, Dharma Research, Inc., Miami, FL. 33166. USA) for 2 min on a clean dry tissue [Figure 1a].[12]

Figure 1:

Illustrative photographs showing (a) Conventional local anesthesia injection for caries removal of lower right permanent first molar, (b) Photobiomodulation (PBM)-based anesthesia application in the lower left permanent first molar at the buccal side, (c) PBM-based anesthesia application at the lingual side

Mandibular nerve block technique

The child was requested to open his mouth as wide as possible. The operator positioned the ball of the thumb on the coronoid notch of the anterior border of the ramus. The needle was inserted between the internal oblique ridge and the pterygomandibular raphe. The barrel of the syringe was directed between the two primary molars on the opposite side of the arch. The needle tip was advanced slightly into the mucosa. After a negative aspirate to rule out intravascular placement, a few drops of the anesthetic solution were injected to relieve the pain of the needle insertion itself. Then, the needle was advanced until bony resistance was met. The needle was withdrawn about 2 mm, and after a negative aspirate, the remaining anesthetic solution was deposited slowly.

Maxillary infiltrative technique

The patient had the mouth partly open. The cheek was pulled in a superior direction to stretch the tissues, and the needle was inserted at the height of the mucobuccal fold, 45° parallel to the long axis of the tooth. The initial needle penetration was shallow. A small amount of the anesthetic solution was injected into the superficial mucosa. After a few seconds, the needle was slowly advanced toward the bone, and after a negative aspirate, the remaining amount of anesthetic solution was injected slowly.

Photobiomodulation-based anesthesia (photobiomodulation therapy group)

A 980-nm diode laser (LX16Plus, Woodpecker, China) with a flat-top profile (FT) handpiece with an external diameter of 17 mm was used.[15] The irradiations were done in continuous wave (CW) and contact modes. The laser beam covered a tissue surface area of 2.269 cm^2. The irradiation was performed for 120 s on the buccal side, and additionally for 120 s on the lingual/palatal side of the tooth covering the crown and the root surfaces of the tooth (240 s total) with a power of 400 mW.[16] The energy dose delivered to the tooth was 48 J per side. As the area of the spot was 2.269 cm^2, the energy density was 21.15 J/cm^2 per side, and in total was 42.3 J/cm^2. The total energy delivered to the tooth was 96 J. Irradiations were performed following the biosafety rules [Figure 1b,c].

After anesthesia, caries removal and cavity preparation were done with a high-speed handpiece (W&H alegra, Austria) with a new bur for each tooth (round, diamond). This procedure was followed by using a hand excavator (Dentsply, Germany). The cavities were restored with composite resin.

Pain/discomfort analysis

The Wong–Baker Pain Scale was used to assess the possible discomfort of the children due to the restorative procedures. The pain/discomfort was rated as 0, 2, 4, 6, 8, and 10 where 0 (zero) means "no hurt" and 10 means "worst hurt," which also is shown with faces.[17] The children were well instructed to correctly answer with the numerical scale.

Statistical analysis

Data management and statistical analysis were performed using the IBM© SPSS© Statistical Package for Social Science, (SPSS Inc., Chicago, IL, USA). Data were explored for normality by checking the data distribution and using Kolmogorov–Smirnov and Shapiro–Wilk tests. Comparisons between the groups with respect to nonparametric numeric variables were performed using the Mann–Whitney *U*-test to compare between the groups, while Kruskal–Wallis was used to compare between ICDAS scores within the same group.

Results

The study included 15 patients: 6 males (40%) and 9 females (60%) with no statistically significant difference in pain level between both sexes regardless of the method of anesthesia ($P > 0.05$).

Regarding the pain scores reported by the 15 children, there was no statistically significant difference between the PBMT group (mean pain value was 2.27 ± 1.28) and the conventional LA anesthesia group (mean pain value was 1.73 ± 0.7) ($P = 0.168$) [Figure 2].

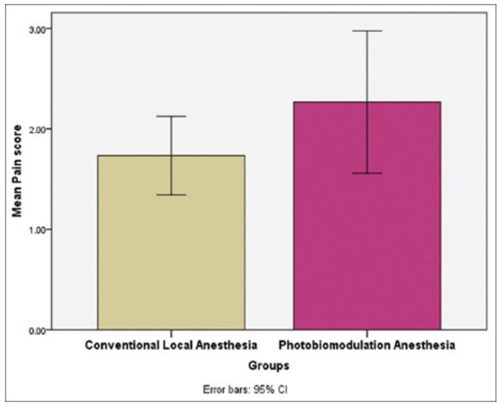

Figure 2:

Bar chart illustrating mean pain scores in photobiomodulation-based anesthesia and conventional local anesthesia groups. CI = Confidence interval

The treated PFM was in the lower jaw in 66.7% of the cases and in the upper jaw in 33.3% of the cases with no statistically significant difference in pain level between upper and lower treatments ($P > 0.05$) [Table 1]. Concerning ICDAS scores, score 3 was in 40% of the cases, score 4 was in 33.3% of the cases, and score 5 was in 26.7% of the cases, with no statistically significant difference between them regardless of the method of anesthesia ($P > 0.05$) [Table 2].

Groups	Tooth	Median	Mean±SD	*P*
Conventional local anesthesia	Upper	2	2.00±0.00	0.168 NS
	Lower	2	1.60±0.84	
PBM-based anesthesia	Upper	2	2.40±0.89	0.787 NS
	Lower	2	2.20±1.48	

*significant ($p \leq 0.05$), ns: non-significant ($p > 0.05$). Significance level $P \leq 0.05$. PBM=Photobiomodulation; SD=Standard deviation; NS=Nonsignificant

Table 1:

Descriptive statistics and comparison of pain scores between upper and lower teeth within the same group (Mann–Whitney *U*-test)

Groups	ICDAS score	Median	Mean±SD	SE	95% CI for mean		*P*
					Lower bound	Upper bound	
Conventional local anesthesia	3	2	1.67±0.82	0.33	0.81	2.52	0.581 NS
	4	2	2.00±0.00	0.00	2.00	2.00	
	5	2	1.50±1.00	0.50	−0.09	3.09	
PBM-based anesthesia	3	2	2.00±1.79	0.73	0.12	3.88	0.557 NS
	4	2	2.80±1.10	0.49	1.44	4.16	
	5	2	2.00±0.00	0.00	2.00	2.00	

*significant ($p \leq 0.05$), ns: non-significant ($p > 0.05$). Significance level $P \leq 0.05$. PBM=Photobiomodulation; SD=Standard deviation; CI=Confidence interval; SE=Standard error; ICDAS=International Caries Detection and Assessment System; NS=Nonsignificant

Table 2:

Descriptive statistics and comparison of pain score within conventional local anesthesia- and photobiomodulation-based anesthesia groups according to the International Caries Detection and Assessment System score (Kruskal–Wallis test)

The success of photobiomodulation-based anesthesia

PBM-based anesthesia was associated with the same pain scores as conventional LA in 9 cases, while higher scores were recorded using PBM-based anesthesia in 5 cases. A lower pain score was recorded using PBM-based anesthesia in one case [Figure 3].

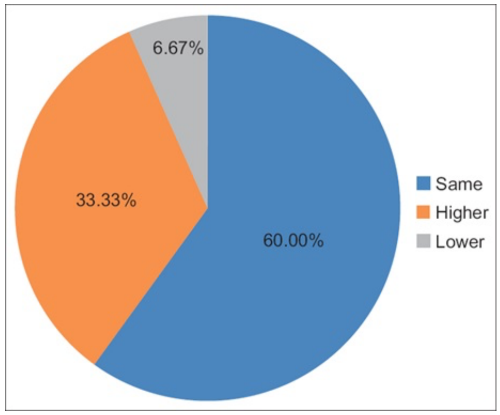

Figure 3:

Pie chart illustrating pain scores in photobiomodulation-based anesthesia compared to conventional local anesthesia. PBM = Photobiomodulation

Discussion

The most common method for pain control during invasive dental procedures is achieved by injection of a local anesthetic solution; however, this method itself causes pain. The anxiety and fear produced before and/or during the administration of anesthesia are still an issue for many children and adults.[18,19] This fear may make parents and children postpone or avoid dental treatment, exhibit weak cooperation, or develop needle phobia.[20] Self-lip, tongue, or cheek injury may also occur in children due to the effect of anesthesia posttreatment.[21] Based on these drawbacks of LA, it is necessary to continue searching for more acceptable methods for LA. Thus, this study aimed to test the effectiveness of PBMT as an alternative method to conventional LA.

The most appropriate dental anesthesia would be able to block nociceptor activity with a nonpharmacological and nontraumatic approach. Furthermore, it should last only for dental procedure time. Hence, PBMT is a suitable candidate as an anesthetic approach, because depending on the parameters used, it blocks nociceptor activity.[22] Moreover, PBMT does not need any pharmacological agent, and it is pain-free and does not cause oral soft-tissue numbness.[23]

According to the literature, there are no golden parameters for PBMT yet.[24] In the current study, a 980-nm diode laser was used for PBM in agreement with Sobouti *et al*., 2022, who investigated the effect of compound topical anesthetic application combined with PBMT on the level of pain perceived during placement of mini-screws and 24 h post the procedure in the buccal side of the maxillary bone and reported that compound topical anesthetic combined with PBMT provided adequate LA for the placement of mini-screws.[25]

There was evidence of a reduction of pain intensity for NIR diode laser (850 nm to 980 nm).[26] Furthermore, the NIR diode lasers are poorly absorbed by water, and due to the poor absorption by water, these wavelengths penetrate deeply into the tissue.[27] Moreover, the main advantage of the NIR diode laser is its safety (avoiding tissue damage) even when it is used in contact with the tissue.[28]

In the present study, the output power was 400 mW with continuous mode. This comes in line with the study conducted by Wu *et al*. which tested the effect of low-level laser therapy on tooth-related pain and somatosensory function evoked by orthodontic treatment.[16] The laser was applied on both buccal and lingual/palatal surfaces of the tooth in contact mode with a total time of application 240 s (120 s for each surface), and this is in accordance with Ebrahimi *et al*., 2021, who evaluated the effectiveness of PBMT as an alternative to LA for conventional cavity preparation in permanent teeth.[12]

The laser beam was delivered to the tooth by a 17-mm diameter FT profile handpiece. As the FT handpiece allows for homogenous laser power distribution within the target tissues, and minimizing wasted energy.[29]

The current study was a split-mouth design because the split-mouth design is a valid study design and has the advantage of removing a lot of inter-subject variability from the estimated treatment effect. It potentially requires fewer subjects than a parallel-group design with the same power.[30] This is because each patient performs as his own control. The main disadvantage of the split-mouth design is the risk of crossing over the reaction from the tested side to the control side that may happen.[31] To avoid this disadvantage, at least 1-week interval between the two interventions for each child was done.

The current study showed that there was no statistically significant difference in pain scores between the PBM-based anesthesia and conventional LA groups. This result is in agreement with a previous randomized crossover clinical study that used (810-nm diode laser, CW, and noncontact mode, with total time of application 120 s), and it reported that there was no statistically significant difference in pain score between PBMT- and conventional LA-based treatments.[23]

On the other hand, Ebrahimi *et al*., 2021, evaluated PBMT as an alternative to injection for anesthesia before conventional caries removal in permanent teeth. An 810-nm with a 3-mm external diameter tip was applied in punctual and contact modes, and it was confirmed that the pain score from the PBMT group was significantly lower than the pain score from the conventional LA group.[12]

This finding may be due to the different parameters used. Another reason may be that the PBM delivery tip in the current study had a wider diameter (17 mm), so it covered a larger surface area leading to lower power and energy density. The most important parameters in PBMT are the power density (irradiance) and the energy density (fluence).[32] Increases in power density, in general, will lead to greater penetration. More photons will traverse the tissue.[33] However, in PBMT, the power should be below 500 mW, so the treatment does not cause a significant temperature rise in the treated tissue and, therefore, no harmful effect on the tissue.[34] Thus, in the present study, a higher output power was used but within a limit.

Moreover, the difference in the results may be because the absorption of laser light at 800–980 nm is high in hemoglobin.[35] The present study was performed on newly erupted teeth in young patients which are richer in blood supply than teeth in adult patients.[36] Thus, more photons may be absorbed by hemoglobin rather than reaching pulpal nerves.

Conclusions

Within the limitations of this study, it has shown that: although there was no statistically significant difference between PBM-based anesthesia and conventional LA for conventional cavity preparation of carious PFMs, PBM-based anesthesia using the described parameters is not clinically relevant for all cases.

PBM-based anesthesia may be an optional alternative to LA injection in some situations, especially in children with dental anxiety, needle phobia, or special needs.

PBM-based anesthesia deserves further research and improvement.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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