Effectiveness of phentolamine mesylate, vibration and photobiomodulation in reducing pain and the reversal of local anesthesia: A systematic review

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Abstract

Background. Dental anesthesia administration often triggers unpleasant sensations, particularly needle injection-related pain, which can evoke fear among patients, especially in the pediatric population. Vibration and low-level laser therapy (LLLT) have been extensively studied as potential methods for alleviating pain. Additionally, phentolamine mesylate (PM) has shown promise in reducing the duration of anesthesia. From a clinical perspective, inadequate control over the persistence of the anesthetic effect may lead to complications associated with its prolonged duration, such as self-injuries or functional impairments.

Objectives. This review aimed to systematically summarize and compare methods of alleviating pain during local anesthesia and reducing its duration.

Materials and methods. In November 2023, an electronic search was systematically conducted across PubMed, Web of Science, and Scopus databases using keywords (pain) AND (anesthesia) AND ((phentolamine) or (vibration) or (LLLT) OR (PBM)). The initial pool consisted of 495 records, from which 241 duplicates were eliminated. After careful examination of the remaining articles, 40 were included. The study adhered to the PRISMA guidelines.

Results. Most studies reported beneficial effects of LLLT and vibration; however, some did not corroborate these findings. Four studies had inconclusive results. Regarding anesthesia duration involving PM and LLLT, the majority of studies exhibited notable reductions, although no significant differences were revealed in 1 study.

Conclusions. Vibration and LLLT appear to be advantageous methods in alleviating pain associated with local anesthesia administration. Phentolamine mesylate and LLLT are efficient in reversing local anesthesia.

Key words: LLLT, anesthesia, vibration, PBM, phentolamine

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Background

Local anesthesia (LA) is a routine and essential aspect of dental treatment, and it plays a crucial role in ensuring a patient's comfort during various procedures.[1,2] Patients may often experience fear and anxiety during dental appointments, primarily due to the discomfort or pain associated with the procedure or the needle administering LA before dental treatments.[3–5] There is also an aspect of temporary numbness, which some patients find unpleasant,[2,6–10] and because of its presence, dentists need to provide post-procedure guidelines and advise patients to avoid activities that could lead to oral injury due to the impaired sensation.[10]

In recent years, researchers have introduced several methods designed to alleviate the pain and discomfort commonly linked to the application of LA. Concurrently, the duration and management of numbness after oral injections are also an area of interest for the researchers. There are various methods to administer LA, but the most common techniques used in research of the aforementioned subjects are; topical anesthesia, which when applied to the mucous membranes helps numb the surface before an injection[1,3,11,12]; infiltration anesthesia, which is commonly used for procedures in the maxilla or treatments involving a single tooth or a small area of the mouth[1,13]; and nerve block anesthesia, which is deposited in proximity to a major nerve plexus and usually used in treatment of the mandibular region.[1,10]

Considering the pain that may be associated with the previously mentioned injection techniques, 2 notable methods that have gained attention for their potential to minimize pain and improve the overall dental anesthesia experience include vibratory stimuli and photobiomodulation (PBM). Applying vibration during the injection was investigated considering Gate Control Theory, which states that vibratory stimuli may activate large-diameter nerve fibers, which transmit signals faster than smaller pain fibers, and their activation may inhibit the transmission of pain signals, resulting in reducing the sensation of pain.[3,4,11,14] Additionally, vibration serves as a distraction technique with the idea that the vibration sensation may reduce the perception of pain by diverting the patient's attention away from the injection.[3,11] Photobiomodulation, also known as low-level laser therapy (LLLT) or laser therapy, involves the use of specific wavelengths of light to stimulate cellular processes.[15–19] In dentistry, it has been explored for its potential to reduce inflammation and promote tissue regeneration, and for its analgesic effects which can be useful in managing pain during and after dental treatment.[20–23] It may include lower pain sensations when PBM is combined with injection of a local anesthetic agent.[15,16,24,25] As PBM induces vasodilation, it increases the microcirculation in the anesthetic region and may accelerate the elimination of LA.[2,24]

In the context of solely regulating the duration of numbness after dental anesthesia, researchers are examining the use of phentolamine mesylate (PM). It acts as a non-selective alpha-adrenergic antagonist, promoting vasodilation, which enhances regional blood flow at the site of injection,[6,7,10,26] thereby accelerating the clearance of the local anesthetic agent from the tissues and leading to a potential reduction in the duration of postoperative soft tissue numbness.[6–10]

Objectives

There is no current published literature review that comprehensively synthesizes the existing research to evaluate the use of vibration or PBM for both pain reduction and acceleration of the elimination of anesthetic agents from the oral tissues and PM for reducing the duration of numbness after LA. This review aims to provide current insights into a multifaceted approach aimed at enhancing the patient experience during and after dental anesthesia. This involves optimizing the balance between effective pain management and minimizing the undesirable postoperative effects.

Materials and methods

Focused question

This systematic review followed the PICO framework as follows. PICO question: In dental patients undergoing LA (population), do interventions such as vibration, PBM, and PM (investigated condition) reduce pain and hasten the reversal of the LA effect (outcome) compared to conventional anesthesia administration (comparison condition)? (see Fig. 1).

Protocol

The selection process for articles in the systematic review was carefully outlined following the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) flow diagram (Fig. 2). The systematic review was registered on the Open Science Framework (OSF) under the following link: https://osf.io/k9vub.

Eligibility criteria

For studies to be considered for inclusion in this review, they needed to fulfill specific criteria. These included utilizing vibrations or LLLT to alleviate pain during anesthesia administration, incorporating PM to reverse anesthesia effects, conducting in vitro studies, examining dental anesthesia applications, featuring a control group, maintaining a sample size of 10 or more

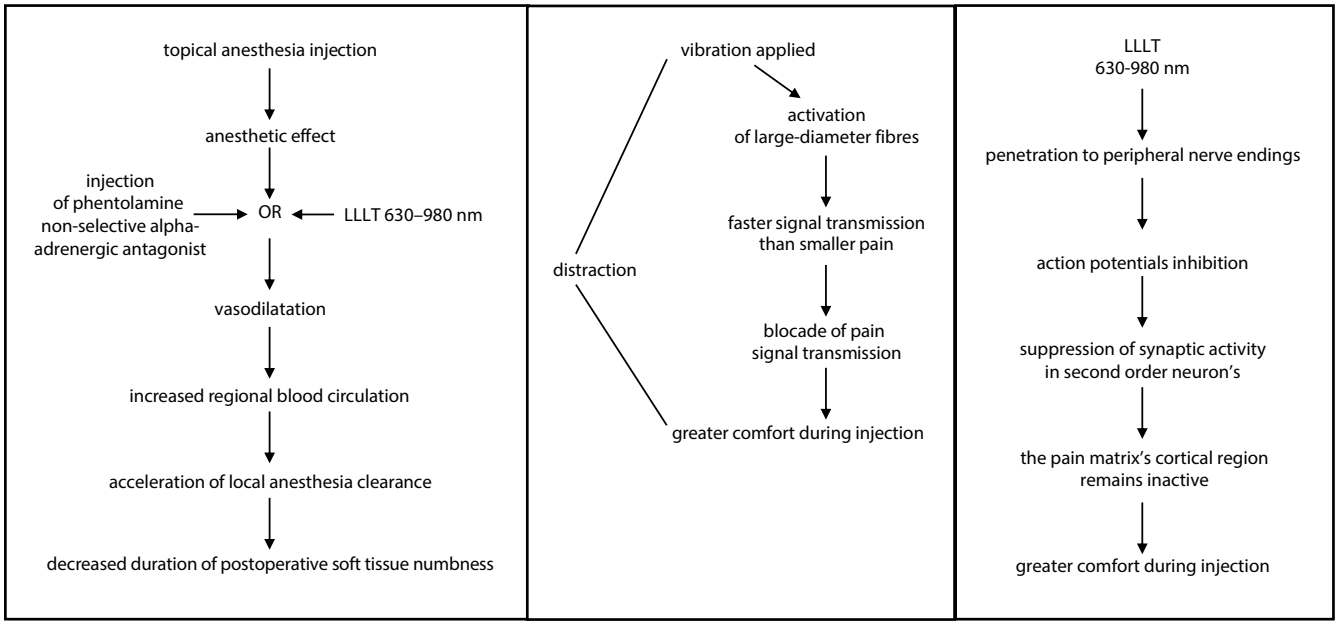

Fig. 1. The PICO framework

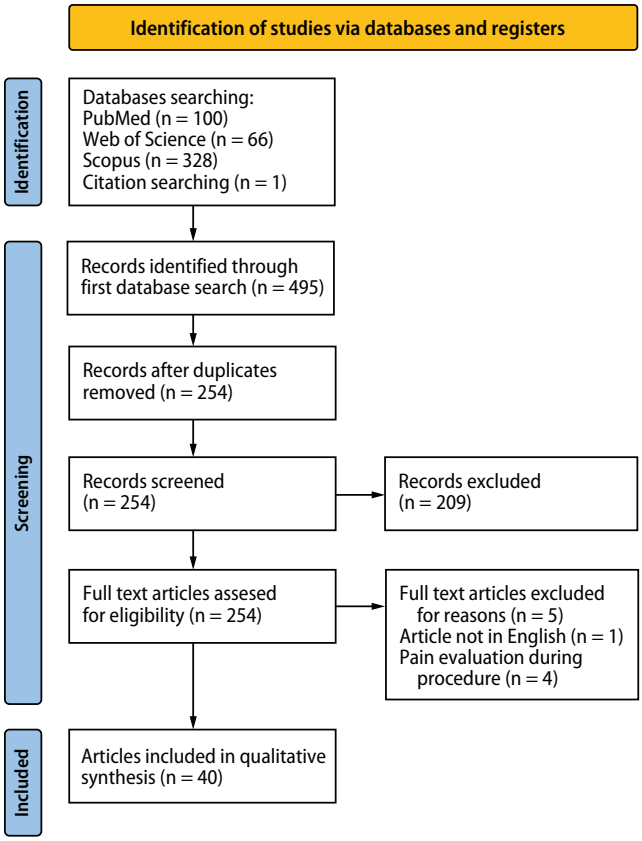

Fig. 2. The flow chart according to Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) guidelines

participants, being conducted in English, encompassing prospective case series, non-randomized controlled clinical trials (non-RCT), and randomized controlled clinical trials (RCT). On the other hand, the reviewers collectively established exclusion criteria. The included studies lacking a control group, those with a sample size of fewer than 10 participants, investigations carried out on animals, papers not in English, clinical reports, systematic reviews, opinions, editorial papers, or review articles, publications lacking full-text accessibility, and duplicates. No restrictions were applied with regard to the year of publication.

Information sources and search strategy

In November 2023, an electronic search using PubMed, Scopus, and Web of Science (WoS) medical databases was performed. Key words were used as follows: "pain"; "anesthesia"; "phentolamine"; "vibration", "LLLT"; and "PBM". In the Scopus database, the results were refined to titles, abstracts, and key words. In PubMed and WoS, the results were narrowed down to titles and abstracts. Only articles with full-text access were included.

Data collection and selection process and data items

Data, including authors, titles and abstracts of all results, were downloaded as a PDF file. The obtained information was subsequently entered into a standardized Microsoft Excel 2013 file (Microsoft Corp., Redmond, USA).

Risk of bias assessment

During the initial stages of study selection, the title and abstract of each paper were independently reviewed by 3 authors (D.F., A.S. and N.G.) to minimize the risk of reviewer bias. The level of agreement among the researchers

was assessed using Cohen's kappa test. If unanimity was not achieved, the decision on inclusion or exclusion was made by a 4th independent reviewer.

Quality assessment

Three independent reviewers (D.F., A.S. and N.G.), meticulously evaluated the procedural quality of each study encompassed in the article. Their assessment centered around crucial facets linked to the utilization of vibrations, LLLT and phentolamine in mitigating the discomfort and pain associated with LA administration, while also exploring their impact on the duration of anesthesia. The evaluation of study design, implementation and analysis hinged on several critical criteria: The adherence of all procedures to the prescribed manufacturer guidelines for the respective intervention was mandatory. Every intervention was conducted singularly by a designated operator, ensuring consistency and minimizing potential variability. The determination of the sample size was not only clearly elucidated but also justified comprehensively. Patients incorporated into the studies were exclusively those undergoing planned treatment without any emergent conditions, thereby ensuring a controlled and consistent participant profile. Moreover, the sample sizes surpassed the threshold of 10 patients/participants, thereby ensuring statistically significant power for the findings; a detailed and comprehensive depiction of the anesthesia employed was obligatory, encompassing its type, dosage and method of administration. Efforts were undertaken to blind the patients involved, mitigating potential biases in the reporting of outcomes. The scoring of studies adhered to a scale ranging from 0 to 9 points, with a higher score indicative of superior study quality. The assessment of bias risk scores was categorically classified into 3 groups: 0–3 points, signifying a high risk; 4–6 points, indicating a moderate risk; and 7–9 points, representing a low risk. Any discrepancies in scoring were meticulously resolved through extensive discussions until a consensus was collectively reached.

Results

Study selection

After conducting an initial search across three databases and eliminating duplicate entries, a total of 254 articles were initially identified as eligible for inclusion in the literature review. Following a preliminary assessment of the article titles and abstracts, 209 articles were excluded. Among the remaining 45 articles, 1 was eliminated because it was originally not in English, and 4 articles were excluded due to their incomplete relevance to the reviewed topic. Ultimately, 40 articles met the criteria for inclusion in the systematic review, all of which were clinical trials.

Effect of vibration

Investigations focused on assessing the efficacy of different vibrating devices (DentalVibe, Vibraject VAI, modified battery-powered shaver, sonic-powered toothbrush, HoMedics Atom massager, specialized Buzzy external tool) and dental instruments in alleviating patient discomfort associated with LA. In 13 of the included studies, a specialized wireless, rechargeable, handheld vibratory dental tool known as DentalVibe (DV) was employed.[3,12,13,27–36] In the research of Felemban et al.,[3] Erdogan et al.,[13] Raslan and Masri,[30] and Ramezani et al.,[35] a DV vibratory stimulus was used without the preceding desensitization of the mucosa with topical anesthesia. Hassanein et al.[29] similarly administered vibration, but the vibration-assisted injection was preceded by topical anesthesia with 20% benzocaine gel. Felemban,[3] Erdogan et al.,[13] and Raslan and Masri[30] found no statistically significant differences between the study and control groups. A significant difference in pain scores between the study and control groups, regardless of the injection method, was revealed in the study conducted by Ramezani et al.[35] With assumptions aligning with the aforementioned researchers, Joshi et al.,[31] Dak-Albab et al.,[32] Ching et al.,[33] and Salma et al.[34] evaluated the effectiveness of vibration in comparison with topical anesthetic gel and found significantly lower rates with vibration than anesthetic gel. In a comparative split-mouth clinical study by Shaefer et al.,[27] Nasehi et al.[28] and Tung et al.,[36] notable distinctions were presented, with the non-vibration group revealing higher scores for pain across all nerve blocks.

Albouni et al.[37] showed higher visual analogue scale (VAS) scores with the conventional injection (CI) method compared to the vibraject-assisted injection (VAI) method in all groups. Moreover, Hegde et al.[11] indicated significantly less pain in children using a special toy compared to conventional methods according to the Face, Leg, Activity, Cry, Consolability (FLACC) scale, Wong–Baker Pain Rating Scale and heart rate. In turn, Hutchins et al.[38] used a vibration stimulus produced by a modified battery-powered shaver compared to topical anesthetic in reducing pain during oral injections. The findings showed a notable difference in pain levels using 20% benzocaine across 2 categories: buccal anesthetic vs placebo and both buccal and palatal anesthetic vs placebo. In a study conducted by Bagherian and Sheikhfathollahi,[39] the authors investigated 48 children who received contralateral IANB or primary maxillary molar infiltration injections using cotton-roll vibration (topical anesthesia gel, cotton roll and vibration) and traditional methods as a control. The results showed significantly lower scores compared to the control method. A study by Gandhi et al.[40] found a statistically significant difference between the mucosal vibration group and the topical gel group in terms of Sound, Eye, Motor scale (SEM) and Wong–Baker FACES Pain Rating Scale (WBFPS) rates. The pain reaction assessed by Aminabadi et al.[41] in the topical anesthesia group was significantly

higher than in the other 2 groups (soft tissue vibration (C) and soft tissue vibration with a distraction exercise (C + SA), with pain being significantly less exhibited in the C + SA than in the C group.

Nanitsos et al.[42] proposed the use of a HoMedics Atom massager to apply vibration during LA. The assessment of pain using a VAS and McGill pain descriptors showed significantly lower mean rates on the vibration side during injections. The results of the study conducted by Meghana and Anjaneyulu[43] indicated that infiltration with topical anesthesia demonstrated the least pain perception, while infiltration without topical anesthesia and vibration resulted in higher pain scores, as supported by VAS assessments. Four studies[4,44–46] explored the synergistic effects of combining vibration and cold to alleviate pain during dental anesthesia using a specialized Buzzy external tool. Sahithi et al.[45] reported a significant decrease in pulse rate post-intervention and a reduction in Venham's Clinical Anxiety Rating Scale (VCARS) scores, indicating reduced anxiety, as well as a more pronounced reduction in discomfort during needle insertion, according to WBFPS and VAS scores. AlHareky et al.[4] demonstrated a significant decrease in pain post-injection compared to the control group, as indicated by VAS and FLACC scales, with no significant differences observed using the SEM scale. In the study by Marwah et al.,[44] only FLACC presented a statistically significant difference between groups, while in the study by Bilsin et al.,[46] the WBFPS demonstrated a notable contrast in favor of the vibration device.

Effect of photobiomodulation

Nowadays, researchers have been exploring PBM LLLT as a potential solution for pain reduction during anesthesia in the field of dentistry.[2,24,47–52] Part of these studies aim to not only illuminate its efficacy in pain management but also explore its potential to enhance microcirculation and accelerate the elimination of local anesthetics.[2,24]

In research by Jagtap et al.,[47] a significant statistical difference in VAS scores was found between the laser and placebo conditions in reducing pain caused by local anesthetic injections in 25 adult patients. Dehgan et al.[48] and Elbay et al.,[49] in a clinical trial involving 160 children, aimed to evaluate the impact of PBM, delivered by a 940 nm diode laser, in combination with 10% lidocaine topical anesthetic on pain experienced during LA injections. The results by Dehgan et al.[48] showed significantly lower pain scores in the groups receiving PBM compared to the placebo group. However, there was no significant difference observed among the 3 PBM groups. A study by Elbay et al.[49] showed no significant difference in injection pain among the groups.

Sharifi et al.[50] designed a triple-blind clinical trial involving 84 patients, which revealed a significant reduction in pain when LLLT was used compared to conventional injection. In a clinical trial by El Feghali et al.,[51] no significant differences in VAS pain scores between groups were found, but the results in the Verbal Rating Scale (VRS) showed significantly higher ratings of taste, undesirable numbness and overall satisfaction in the study group than in the control group. The study by Tuk et al.[52] involved 163 patients and showed significant differences in sweating rate in the extractions located in the mandibular region during maxillary or mandibular third molar anesthesia. Uçar et al.[24] revealed significantly lower PRS scores on the laser therapy side compared to the control side in a group of 60 children who required a bilateral pulpotomy in mandibular first primary molars. Annu et al.[2] demonstrated that the mean soft tissue LA reversal time duration was significantly shorter, with 660 nm wavelength therapy being more effective. Similar findings were obtained by Seraj et al.[53] in patients who received 810 nm laser irradiation 45 min after anesthesia injections.

Effect of phentolamine mesylate

Since the possibility of the use of PM in dentistry was noticed, researchers have made efforts to assess how the use of this non-selective alpha-adrenergic antagonist accelerates the disappearance of numbness and discomfort after dental anesthesia.

Tavares et al.[7] and Nourbakhsh et al.[9] researched the impact of PM on the duration of soft tissue anesthesia and the occurrence of soft tissue trauma following mandibular block injections in children aged 4–11. Tavares et al.[7] demonstrated a substantial reduction in recovery time (60 min in the PM group vs 135 min in the control group) and reported no differences in adverse events or vital signs. Nourbakhsh et al.[9] not only confirmed a significant decrease in recovery time but also introduced additional outcomes showing notable differences in the incidence of soft-tissue trauma in 43 patients divided into case and control groups.

Fowler et al.[8] and Shadmehr et al.[26] demonstrated the efficacy of PM in hastening soft-tissue recovery. Gago-Garcia[10] et al., based on data from 90 participants, claimed that the use of PM alongside 3 different substances (lidocaine, articaine and bupivacaine), compared to the average duration for each anesthetic, exhibited a strong potential to shorten the duration of anesthesia, with a particularly notable decrease observed when paired with bupivacaine. Similarly, the study by Michaud et al.,[6] which enrolled 40 adult participants, showed that PM injection significantly reduced the duration of soft tissue anesthesia in the lower lip and tongue, additionally hastening the recovery of function and reducing the time needed for smiling, drinking and speaking. General and detailed study characteristics are presented in Table 1 and Table 2, respectively.

Quality assessment

Out of the articles included in this review by 5 independent reviewers (D.F., A.S.,N.G., and A.O.),

Table 1. General characteristics of included studies

Study	Aim of the study	Materials and methods	Results	Conclusions
Annu et al., 2023[2]	Comparison of photobiomodulation (PBM) therapy at 660 and 810 nm wavelengths on the reversal of local anesthesia.	A group of 60 children (mean age: 73 months) was divided randomly into 3 equal groups. 45 min after IANB: The control group received no laser irradiation. The 2nd group underwent photobiomodulation therapy at 810 nm. The 3rd group underwent PBM at 660 nm. Reversal of local anesthesia tests: Palpation technique to check the numbness of lower lip, the pin prick test.	Reduction of the mean soft tissue local anesthesia reversal time duration by 55.5 min and 69 min with PBM at 810 nm and 610 nm wavelength, respectively. A statistically significant difference in the reversal time duration between the control group and the study group, between the 810 and the 660 nm LASER groups.	Both photobiomodulation (PBM) therapy at 660 and 810 nm wavelengths affected the mean soft tissue local anesthesia reversal time duration significantly. Photobiomodulation (PBM) therapy at 660 wavelengths was found to be more effective.
Felemban et al., 2021[3]	Assessment of vibration in reducing pain linked to LA compared to the conventional injection.	A group of 60 children was divided randomly into 2 groups. Before buccal infiltration anesthesia (BIA): The control group (31) received traditional BIA; the test group (29) received vibration with BIA. Pain assessment scales: FLACC scale by 2 external evaluators, the validated Arabic version of the Wong–Baker FACES scale, rating pain on a scale from 0 to 10 by subjects.	Regardless of age and treatment group, girls consistently maintained significantly higher average scores on both the FLACC and the Wong–Baker FACES scales than boys.	The utilization of DentalVibe did not significantly affect pain, discomfort, or time during buccal infiltration anesthesia (BIA) in pediatric patients when compared to the traditional method.
AlHareky et al., 2021[4]	Evaluation of the impact of device administering cold and vibrations during buccal infiltration injection.	A group of 51 children was divided randomly into 2 groups. Before anesthesia: Group 1: topical anesthesia of 20% benzocaine gel for 15 s. Group 2: cold + vibration, that remained active throughout the entire injection process. Pain assessment scales: visual analogue scale (VAS) by the child "behavioral/observational pain scale" by present parents, the Sounds, Eyes, and Motor (SEM) scale and FLACC scale by an external evaluator.	The VAS scale and the FLACC scale presented significant differences in post-injection pain in the study group than control. No significant difference observed using the SEM scale.	The use of external cold and vibrating devices is effective in diminishing the pain and anxiety among children undergoing infiltration dental anesthesia.
Michaud et al., 2018[6]	Evaluation of the effect of phentolamine mesylate on the duration of soft tissue anesthesia.	Forty participants were randomized into 2 groups, and in both groups, IANB was performed. Study group received phentolamine mesylate (PM) injection and the control group received an injection of sterile saline water.	Comparing to the control group, PM injection resulted in reduced duration of soft tissue anesthesia. In the lower lip: 66 min reduction In the tongue: 51 min reduction In terms of recovery of function, the reduced time was: for smiling: 55 min reduction for drinking: 66 min reduction for speaking: 68 min reduction.	Study showed that PM injection after performing IANB resulted in faster return to normal soft tissue sensation and function.
Tavares et al., 2008[7]	Assessing the safety and adverse effects (AEs) (primary objective) and effectiveness (secondary objective) of a phentolamine mesylate (PM) formulation as a local anesthesia reversal agent for pediatric patients.	A total of 152 pediatric patients randomized into 2 groups: 72 subjects receiving PM injection, 43 patients in control group with sham injection. The observation for safety and efficacy assessments was 4 h. Adverse events were categorized to severity (mild, moderate or severe). The duration of the LA measurement 6–11-year-olds group (4–5-year-olds were excluded) palpation technique.	A 60% and 55.6% reduction in the median time for the return of normal tongue and lip sensation, respectively. Thirty-seven AE reported, 36 mild or moderate, 1 severe.	Phentolamine mesylate injections exhibited no serious adverse effects. Phentolamine mesylate shortened the duration of soft tissue anesthesia in children in both the maxilla and mandible.

18 studies were considered of high quality (with a score of 7–9 points).[2,3,6,8–10,13,24,26,27,30,33,46–49,51,53] Three studies[35,36,40] were classified as low-quality (0–3 points). Additionally, 19 studies were considered to have a moderate risk of bias, scoring between 4 and 6 points[4,7,11,12,28,29,31,32,34,37–39,41–45,50,52] (Table 3).

Discussion

Pain management is a crucial element in building positive attitudes and cooperation between patients of different ages and dentists.[3,4,11,14] Although LA is commonly used

Table 1. General characteristics of included studies – cont.

Study	Aim of the study	Materials and methods	Results	Conclusions
Fowler et al., 2011[8]	Exploring the efficacy of phentolamine in reversing soft-tissue anesthesia.	Eighty-five adults with asymptomatic teeth in need of endodontic therapy were randomly assigned to receive either phentolamine or a sham treatment after the treatment with LA. Pain levels assessment at the injection site and in the tooth every half-hour during the initial 2 h, then every hour for the subsequent 3 h: VAS. Anesthesia reversal: Palpation technique at 15-min intervals for 5 h.	Phentolamine effect compared to the sham group: Maxillary, lip/cheek Disappearance of numbness: 35 min faster Return-to-normal sensation: 88 min faster Mandibular lip Numbness: 24 min faster Sensation: 47 min faster Tongue Numbness: 24 min faster Sensation: Not significantly reduced	Phentolamine presented quicker return of normal soft-tissue function and sensation following local anesthesia.
Babaei et al., 2011[9]	Evaluation of the LA duration after phentolamine mesylate (PM) distribution and the occurrence of soft-tissue trauma following this type of injections.	Split-mouth study including a group of 60 children was divided randomly into 2 equal groups. 30 min after LA: First group received PM. The 2nd group received sham injection. On the next visit the contralateral side was treated conversely. Palpation technique to check anesthesia duration. Monitoring of the safety, efficacy, and soft-tissue trauma every 15 min for 3–5 h. Vital signs were recorded 30 min after anesthesia and every 1 h.	Group 1: Sensation of soft tissue with PM injection was 29.47 min, and without – 135.52 min. Group 2: sensation of soft tissue with PM injection was 33.12 min, and without – 106.04 min. Statistically significant difference in time of return of a normal lip sensation between case and control groups. 19% of patients (8) without PM injection and 2% – 1 patient after PM injection (statistically significant) traumatized their lips a few hours after treatment. No trauma to tongue and cheek was found.	Use of PM can be beneficial to reduce the duration of LA in children needing dental procedures and can lower the incidence of soft-tissue trauma connected to dental anesthesia.
Gago-García et al., 2021[10]	Evaluation of the phentolamine mesylate (PM) distribution on anesthesia duration within 3 distinct local anesthetics, comparing it to the average duration for each individual anesthetic, and between all 3 types of anesthetics.	A group of 90 individuals was divided randomly into 3 equal groups: Group 1: lidocaine 2% 1/80000; Group 2: articaine 4% 1/200000 Group 3: bupivacaine 0.5% 1/200000. The untreated side served as the control. IANB was performed. After treatment PM was administered with a 1:1 ratio of anesthesia to reversal agent. Patients marked boxes for 15-min intervals after the reversal agent injection to note sensations: numbed, tingling or normal. Postoperative pain evaluation: The Heft–Parker visual analogue scale.	The average duration of anesthesia after injection of phentolamine mesylate: Group 1: Lip – 59.6 min, tongue – 52.5 min, normative value – 180 min. Group 2: lip – 88.5 min, tongue – 84.5 min, determined normative value – 258 min. Group 3: lip – 249 min, tongue – 214 min, normative value – 460 min.	Phentolamine mesylate has the potential to decrease the duration of anesthesia when used alongside various local anesthetics, especially bupivacaine.
Hegde et al., 2019[11]	Comparison of pain, anxiety and behavioral perception when administering local anesthesia with and without a vibrating and distracting toy.	A split-mouth study including a group of 30 children separated randomly into 2 equal groups 1: 6–8-year-olds, 2: 9–11-year-olds. Before injection of anesthesia the 1st group received vibration and at the 2nd appointment – conventional topical anesthesia. Group 2 inversely. Pain assessment scales: The Face, Legs, Activity, Cry, Consolability (FLACC) scale, pulse rate, the Wong–Baker faces pain rating scale (WBFPRS).	Statistically significant differences between conventional and device methods in pulse rate during treatment, FLACC and WBFPRS scores in both age groups.	These results suggest the device's effectiveness in decreasing pain across different age groups, leading to improved clinical outcomes.
Shilpapriya et al., 2015[12]	Comparison between the effectiveness of Dental Vibe® and topical local anesthetic in pain reduction	Split-mouth study including 30 children. Before anesthesia they were split into: Control group using topical anesthetic study group using DentalVibe during the 1st appointments. The other method was used at the 2nd appointment. Pain assessment scale: Universal pain rating scale.	Statistically lower mean pain scores were exhibited in the study group compared to the control group.	DentalVibe serves as a beneficial tool before dental injections, relieving pain and stress.

Table 1. General characteristics of included studies – cont.

Study	Aim of the study	Materials and methods	Results	Conclusions
Erdogan et al., 2018[13]	Assessing the efficacy of a Vibratory Stimulation Device for intraoral local anesthesia administration.	Thirty-one participants received local anesthesia infiltration at the right maxillary incisors' apical region. They were randomly assigned to either conventional infiltration or conventional infiltration with DentalVibe. A 2-week interval between procedures. Pain assessment scales: VAS and WBFPRS.	No significant differences between groups.	The use of the vibration did not show any significant decrease in the perceived pain level linked to the administration of local anesthetic via maxillary anterior infiltration.
Uçar et al., 2022[24]	Evaluation of LLLT on pain during anesthesia administration, anesthesia efficacy and duration time of anesthesia.	Split-mouth study including a group of 60 children (mean age 7.11 ±1.12 years). Before injection: One side with topical anesthesia application and LLLT (810 nm diode laser). Opposite, control side with topical anesthesia application and placebo laser use. A 4–7 days interval between procedures. Pain assessment scales: WBFPRS – pain during injection of a needle and deposition of anesthetic solution; FLACC scale – anesthesia efficacy.	Injection pain significantly lower on the LLLT side than on the placebo side according to the WBFPRS scale but not the FLACC scale. Anesthesia efficacy and duration time not modified by LLLT. No pain response rate in relation to anesthesia efficacy higher on the LLLT side than on the control side.	Low-level laser therapy has an impact on alleviating injection pain; however, it did not affect anesthesia efficacy and duration time.
Shadmehr et al., 2019[26]	Evaluation of the LA duration after phentolamine mesylate (PM) distribution.	A group of 100 patients diagnosed with symptomatic irreversible pulpitis in their first or second mandibular molars were assigned to receive either OraVerse or a placebo following a treatment. Pain assessment scales: The Heft–Parker visual analogue scale – before and at 6, 12, 24, 36, 48, and 72 h after treatment. Soft-tissue anesthesia was monitored every 15 min for 5 h.	PM group: Lip sensation in about 120 min and tongue sensation in about 103 min. The control group: Lip sensation after around 152 min and tongue sensation after around 174 min. Patients administered phentolamine exhibited notably increased pain scores at 6- and 12-h intervals. The use of analgesics notably higher in the OraVerse group compared to the control group.	Despite phentolamine expediting the return of regular soft tissue sensation, it heightened postoperative pain in patients with symptomatic irreversible pulpitis, potentially restricting its administration within this patient group.
Shaefer et al., 2017[27]	Evaluate DV3 device mediation of injection discomfort during LB block and IANB without topical anesthetic, compared to the routine operator manipulation. Measure DV3's impact on the time required for complete anesthesia during an IANB.	Sixty volunteers. Bilateral intraoral LB block on one side using the DV3 device, while control injections involved routine operator manipulation. Subjects randomly divided into equal groups for IANB: One group with vibration and control without. Pain assessment scale: VAS, modified symptom severity index (SSI). Complete mandibular anesthesia duration post-IANB: A cold test on specific teeth.	Subjects receiving DV3 during the injection exhibited notably lower VAS scores. The mean numb time did not significantly differ between DV3 and non-DV3 groups.	The DV3 notably decreased discomfort during dental injections. However, its usage did not impact the duration for achieving complete mandibular anesthesia.
Nasehi et al., 2015[28]	To assess the pain experienced during LA using a vibrating intra-oral device (DentalVibe).	Ninety-nine subjects (mean age 39.18 ±17.45 years) underwent local anesthetic injections on each side of the oral cavity, randomly either with or without a vibration device. Anticipated and actual pain assessment: VAS scale.	The mean VAS scores for anticipated and actual pain significantly differed between study and control group with higher scores in the non-vibration group across all nerve blocks. Control group: No significant difference between anticipated and actual pain. Study group: Significantly lower actual pain scores than for anticipated pain in specific nerve blocks, no significant difference for palatal injections.	The vibration proved to be an effective method for relieving the clinical pain experienced during local anesthetic injections.
Hassanein et al., 2020[29]	Evaluation of vibration effectiveness in minimizing pain during local anesthesia comparing it to traditional injection methods.	Split-mouth study including 60 patients randomized into 2 equal groups. Group I: Injection with vibration. Group II: Traditional injection with topical anesthetic. A 2-week interval between procedures. Pain assessment scales: FACES Pain Rating scale, FLACC scale.	FACES Pain Rating Scale, FLACC Scale: There is a significant difference between study and control groups in self-reported pain.	Vibration during local anesthetic injections is more effective in reducing pain than traditional methods (with topical gel) in pediatric dental patients.

Table 1. General characteristics of included studies – cont.

Study	Aim of the study	Materials and methods	Results	Conclusions
Raslan and Masri, 2018[30]	Comparison of perceived pain level during 3 types of anesthesia with and without vibration.	A group of 40 children (mean age 8.2 ±1.8 years) was enrolled into the study. Pain assessment during buccal and palatal infiltration on the maxilla and IANB on the mandible was performed. Each anesthesia on both sides of the arches with and without vibration. 6 injections during 4 visits. Pain assessment scales: WBFPRS, FLACC scale.	Pain scores did not differ significantly in all 3 methods according to both pain scales.	Pain perceived by children during 3 types of anesthesia did not differ regardless if vibration technique was used or not.
Joshi et al., 2021[31]	Evaluation of the effectiveness of vibration on decreasing the pain during anesthesia in comparison with topical gel.	Split-mouth study including a group of 50 adults (mean age 25.06 ±7.32 years). Before IANB: One side received a vibration. Opposite, the control side received topical anesthesia. Pain assessment scale: VAS.	Mean pain rate significantly lower on the vibration side than on the control side.	Application of vibration reduces the pain perceived by patients during local anesthesia more effectively than topical anesthesia.
Dak-Albab et al., 2016[32]	Evaluation of the effectiveness of vibration on decreasing the pain during anesthesia compared with topical gel.	Split-mouth study including a group of 30 children. Before injection: One side received a vibration. Opposite, the control side received topical anesthesia. A 1- or 2-week interval between procedures. Pain assessment scale: FLACC scale.	Mean pain rate significantly lower on the vibration side than on the control side. Significant differences in F, L and C components between vibration and topical gel sides.	Application of vibration reduces the pain perceived by patients during local anesthesia better than topical anesthesia.
Ching et al., 2014[33]	Comparison of perceived pain during anesthesia between vibration and traditional techniques.	Split-mouth study including a group of 36 children (mean age 14 years). Before injection: One side received a vibration. Opposite, the control side received just local anesthesia. Pain assessment scales: WBFPRS.	Mean pain rate significantly lower in the vibration group than in the control group.	Vibration reduces pain perceived during anesthesia more effectively than traditional method.
Salma et al., 2021[34]	Evaluation of vibration on reducing pain during anesthesia application.	Split-mouth study including a group of 166 adults (mean age 28.4 ±7.1 years). Before injection: One side received a vibration. Opposite, the control side received topical anesthesia. A 3-week interval between procedures. Pain assessment scale: VAS scale, during needle insertion (PP), midinjection pain (MIP). Heart rate: Baseline heart rate (BHR), penetration heart rate (PHR), and midinjection heart rate (IHR).	VAS scale: Median pain rates were lower in the study group than in the control: 43% less at penetration; 67% less during injection. Significantly lower pain during injection and anesthetic deposition in study group than control group. Heart rate: A. Per side Pain rates significantly higher during penetration than mid injection in both groups. Significantly higher increase in heart rate at penetration than during injection in both groups. B. Study group vs control group Significantly lower pain during injection in study group than control group. Significantly lower increase in heart rate in study group than control group. In control group pain rates at penetration and during injection were significantly different according to the: LA technique – values higher for IANB; gender – values higher in women.	Vibration has a pain-reducing effect during anesthesia administration compared to conventional methods.
Ramezani et al., 2017[35]	Effect of vibration on pain perceived during local anesthesia.	Split-mouth study including a group of 36 children (mean age 5.7 years). Before injection: One side received a vibration. Opposite, the control side received a placebo. Pain assessment scales: WBFPRS.	Significant difference in pain scores between study and control group. No difference in pain scores in terms of age, gender or injection type.	Vibration is an effective method of decreasing pain during anesthesia.

Table 1. General characteristics of included studies – cont.

Study	Aim of the study	Materials and methods	Results	Conclusions
Tung et al., 2018[36]	Comparison between the effectiveness of vibration, manual stimulation and conventional anesthesia on decreasing the pain during administration of LA.	A group of 150 children (age 5–7 years). Control group: 11.1 ±2.4. Manual stimulation group 10.7 ±2.2 vibration group 11.1 ±2.3 years) was divided randomly into 3 equal groups. Before injection: The control group received just local anesthesia, the 1st study group – manual stimulation, the 2nd study group – vibration. Pain assessment scales: WBFPRS. Heart rate	No significant differences regardless of injection type. Mean pain rate significantly lower in the vibration group than control and manual stimulation group. No significant difference in pain scores between control and manual group. Significant difference in pain scores between vibration group and manual group. No significant differences in heart rate between groups.	Vibration is significantly more effective in decreasing pain during anesthesia than manual stimulation and conventional methods.
Albouni et al., 2022[37]	Comparing the pain levels between traditional syringe injections (CI) and those assisted by Vibraject technology (VAI – vibraject assisted injections).	A group of 75 children was divided randomly into 3 equal groups. I: Upper buccal infiltrations (UBI), II: Posterior palatal infiltrations (PPI) III: IANB All received both conventional and vibration-assisted injections in separate dental visits 2 weeks apart. Pain assessment scales: The VAS and FLACC scales.	Significant differences in VAS score between conventional CI and VAI syringe in Groups I, II, and III with higher VAS scores associated with the CI. In the FLACC scale, "mild" and "moderate" pain responses were significantly higher with VAI, while "severe pain" responses were significantly higher with CI.	VibraJect-assisted injection was more effective in minimizing pain during all 3 methods of local anesthetic administration in clinical dental procedures for children.
Hutchins et al., 1997[38]	Comparison of the effectiveness of vibration and topical anesthetic in reducing the pain felt during oral injections of local anesthesia.	A double-blind study consisted of 61 patients receiving a combination of topical anesthetic or placebo with or without 1-min vibration. The location of the injection was the palatal and buccal side of both maxillary 1st premolars. Pain assessment scale: A 5-point scale where 0 described no pain, 1 – mild pain, 2 – moderate pain, 3 – distressing pain, 4 – horrible pain, 5 – unbearable pain.	The use of topical anesthesia leads to a reduction in pain values across 2 categories: Buccal anesthetic vs placebo and both buccal and palatal anesthetic vs placebo. The presence of vibration alone or in the combination with anesthetic, the placebo alone and placebo plus vibration did not exhibit a statistically significant correlation with the pain level.	The topical anesthetic demonstrates a reduction in pain values, although the clinical relevance remains uncertain. The application of vibration appears to have limited effectiveness; however, exploring its other variations, using vibration during, not before the injection process or the use of a more effective vibration transfer could enhance its efficacy.
Bagherian and Sheikhfathollahi, 2016[39]	Children's behavioral responses to local anesthetic injections with the cotton-roll vibration method in comparison to the conventional topical anesthesia.	Forty-eight children (mean age 5.94 ±1.88 years) received contralateral IANB or primary maxillary molar infiltration injections randomly using cotton-roll vibration (topical anesthesia gel, cotton roll, and vibration) and control (routine topical anesthesia) methods. Each child received the alternate method on the other side in the next session. Pain assessment scales: FHFHTC scale, producing total scores from 0 to 18.	Regardless of gender, age and area of local anesthesia, the cotton-roll method showed significantly lower mean FHFHTC pain reaction scores compared to the control method.	The cotton-roll technique proves to be more effective than standard topical anesthesia in reducing children's behavioral pain responses. Topical anesthesia may provide greater psychological impact than pharmacological effects in reducing children's behavioral pain reactions.
Gandhi et al., 2008[40]	Effectiveness of vibration in minimizing pain during local anesthetic injections comparing to lignocaine jelly.	A group of 30 children.1-visit procedure: Application of topical anesthesia, traditional injection. 2-appointment procedure after 4–5 days on the contralateral side of the arch: Application of the mucosal vibrator before, during local anesthetic administration to the injection site and continued after needle removal. Pain assessment scales: The SEM scale, WBFPRS.	WBFPRS and SME scales. There is a statistically significant difference between the mucosal vibration and the topical gel group.	Using a vibration method during local anesthetic injections is more effective in reducing pain than traditional methods (with topical lignocaine gel) in pediatric dental patients.
Aminabadi et al., 2008[41]	Evaluate the efficacy of counterstimulation and distraction on pain during intraoral injection in pediatric patients.	A group of 78 children (mean age: 4.72 years) was divided randomly into 3 equal groups. Before IANB: Soft tissue vibration (C + SA), soft tissue vibration with distraction exercise (CD + SA), topical anesthesia (SA). Pain assessment scales: SEM scale.	Pain reaction in SA group significantly higher than in C + SA and CD + SA groups. Pain significantly less exhibited in CD + SA group than in C + SA group.	Both counter stimulation and distraction may effectively reduce pain.

Table 1. General characteristics of included studies – cont.

Study	Aim of the study	Materials and methods	Results	Conclusions
Nanitsos et al., 2009[42]	Evaluation of the effectiveness of vibration on decreasing the pain during anesthesia.	Split-mouth study including a group of 62 adults (mean age 45 years). Before IANB, mandibular or buccal infiltration: One side received vibration. Opposite, the control side received no vibration. Pain assessment scales: VAS, McGill pain descriptors.	Statistically significant difference between anticipated and actual pain for block and infiltration injections. VAS: Mean pain rate significantly lower on the vibration side than on the control side during infiltration and IANB injections, as well as for each of these injections separately. McGill pain descriptors: Mean pain rate during injections significantly lower on the vibration side than on control side.	Application of vibration reduces the pain perceived by patients during local anesthesia.
Meghana Reddy, 2020[43]	Comparison between vibration and topical gel on decreasing the pain during anesthesia.	A group of 10 patients who required dental treatment in the 3 quadrants was enrolled into the study. Before infiltration: One quadrant received vibration; one quadrant received topical anesthesia with benzocaine 20% gel; the control side received just local anesthesia. Pain assessment scale: VAS.	Mild pain for topical gel application + anesthesia. Moderate pain for vibration + anesthesia. Severe pain for the anesthesia alone.	Topical anesthesia is better than vibration in decreasing pain during anesthesia.
Marwah et al., 2020[44]	Assessing patients' pain perception and comfort during the administration of local anesthesia by comparing the Buzzy system to the conventional syringe.	Fifty children were randomly separated into 2 groups: 1st group had LA administered using conventional syringe; 2nd group had Buzzy (vibration + cold) followed by administration of LA. Pain assessment scale: WBFPRS, pulse oximeter, FLACC scale.	The pulse rate, oxygen saturation levels and WBFPRS exhibited statistically insignificant results. The FLACC scale: Significantly higher score in the conventional than Buzzy group.	The combination of external cold and vibration can alleviate pain and anxiety experienced during the administration of local anesthesia.
Sahithi et al., 2021[45]	Evaluation of the external vibrating tools and counterstimulation effectiveness in reducing a child's dental anxiety and pain perception when receiving local anesthetic.	A group of 100 children was divided randomly into 2 equal groups: Group BD received vibration; Group CS received counterstimulation. Anxiety levels evaluation: Venham's Clinical Anxiety Rating Scale (VCARS), Venham Picture Test (VPT), and a Pulse oximeter. Pain assessment scales: WBFPS, VAS before, during, and after the administration of local anesthesia.	Post-intervention pulse rate measurements significantly decreased, indicating reduced anxiety, particularly notable in the BD group. The BD group exhibited a more pronounced reduction in pulse rate and subjective discomfort (WBFPS, VAS) during LA needle insertion compared to the CS group. VCARS scores showed a reduction only in the BD group.	Vibrating external stimulation demonstrated superior efficacy compared to counterstimulation in reducing needle-related anxiety among pediatric patients.
Bilsin et al., 2020[46]	Evaluation of the effectiveness of external cooling and vibration on decreasing the pain during anesthesia.	A group of 40 children (mean age 9.36 ±1.12 and 9.20 ±0.92 years for the control and study group, respectively) was divided randomly into 2 equal groups. In the study group external cold and vibrating device were used 2 min prior and during injection. In the control group anesthesia was performed without any additional application. Pain assessment scales: WBFPRS.	Mean pain score presented statistically significant difference between both groups. The mean age of the subjects negatively correlated with the mean scores of pain in both groups. A significant difference in pain rates between positive and definitely positive behaviors in control group.	Application of external cooling and vibration reduces the pain perceived by patients during anesthesia.
Jagtap et al., 2019[47]	Assessment of LLLT impact on the reduction of pain caused by local anesthetic injections.	Twenty-five patients (18–60-year-olds). Bilateral anesthesia was administered. The sites were divided into Condition A – LLLT 660-nm side and Condition B – Placebo side (without LLLT). Pain assessment scale: VAS scale.	Statistically significant difference in pain perception between the laser and placebo groups.	This study indicated a reduced perception of pain in the laser condition compared to the placebo condition.

Table 1. General characteristics of included studies – cont.

Study	Aim of the study	Materials and methods	Results	Conclusions
Dehgan et al., 2022[48]	Evaluation of photobiomodulation used with different laser doses on reducing pain during anesthesia.	A group of 160 children (mean age 7 ±1.12 years) was divided randomly into 4 equal groups. Before anesthesia: 1st, 2nd and 3rd group received photobiomodulation at wavelength of 940 nm for 20 s with a power of 0.3 W, 0.4 W and 0.5 W, respectively. The control group with placebo application of laser. Pain assessment scales: WBFPRS, FLACC scale.	WBFPRS, FLACC scale scores. Significantly lower pain scores in the all-study groups than in the placebo group. No significant difference in the pain scores according to WBFPRS scale between the study groups.	Pain perceived during injection is reduced with the application of the photobiomodulation therapy prior to the injection regardless of the used dose in comparison to traditional method.
Elbay et al., 2022[49]	Evaluation of photobiomodulation used with different laser doses on reducing pain during supraperiosteal anesthesia and comparison of pain reduction during injection with and without photobiomodulation.	A group of 160 children (mean age 8.56 ±1.68 years) was divided randomly into 4 equal groups. Before anesthesia: 1st, 2nd and 3rd group received photobiomodulation at wavelength of 940 nm and a power of 0.3 W for 20, 30 and 40 s, respectively. The 4th group (control group) received a placebo application of laser. Pain assessment scales: WBFPRS, FLACC scale.	No significant differences between groups.	Pain perceived during injection did not differ between control group and photobiomodulation groups.
Sharifi et al., 2022[50]	Evaluation of LLLT with 810–980 nm wavelengths on pain during injection.	Split-mouth study including a group of 84 adults (mean age 24.76 ±2.63 years). Prior to the injection: One side received LLLT. Opposite, the control side received a placebo. A 14-day interval between procedures. Pain assessment scale: VAS.	Mean injection pain significantly lower on the LLLT side than on the placebo side. Injection pain significantly lower on the LLLT side than on the placebo side in women. No significant differences in men in terms of laser or placebo therapy and injection pain. No significant differences between overall pain scores in women and men with or without LLLT. No significant differences between women and men in terms of pain scores with LLLT therapy. Injection pain significantly lower in men without LLLT therapy. Significant differences between pain scores in women and men without LLLT.	Low-level laser therapy successfully reduced perceived pain during infiltration in the anterior region of the maxilla.
El Feghali et al., 2022[51]	Evaluation of the effectiveness of PBM on decreasing the pain during anesthesia in comparison with topical gel.	A group of 60 adults (mean age: Topical anesthesia group 42.27 ± 14.83 years, Laser group: 45.4 ± 15.84 years) was divided randomly into 2 equal groups. Before buccal infiltration: T group received topical anesthesia; L group received PBM. Pain assessment scales: VAS, Verbal Rating Scale (VRS).	VAS scale: No significant differences in pain scores between groups. VRS scale: Significantly higher ratings of taste, undesirable numbness, and overall satisfaction in L group than T group.	Photobiomodulation has a similar effect on decreasing pain as topical anesthesia; however, it exhibits better effects in terms of undesirable effects such as unpleasant taste and numbness.
Tuk et al., 2017[52]	Evaluation of LLLT therapy on pain perceived during local anesthesia.	A group of 163 adults (mean age 25.06 ±7.32 years) was divided randomly into 2 groups. Before IANB/local infiltration: Study group received LLLT therapy, the control group received placebo irradiation. Pain assessment scale: 11-point numerical rating scale (pain and anxiety), a blood volume pulse, a sweat conductance or galvanic skin response sensor.	Mandibular region: Heart rate a bit higher in control group than in LLLT group. Sweating slightly higher in LLLT group than in control group. Pain scores presented slight differences. Statistically significant difference between LLLT and control groups only in sweating rate. Maxillary region: Heart rate a little bit higher in control than LLLT group. Pain scores were lower for the LLLT group compared with control group. No significant differences between groups.	Low-level laser therapy is not effective in decreasing pain during LA.

Table 1. General characteristics of included studies – cont.

Study	Aim of the study	Materials and methods	Results	Conclusions
Seraj et al., 2020[53]	Assessing the effect of PBM at 810 nm wavelength on the reversal of local anesthesia.	Split-mouth study including a group of 34 children. Subjects were divided into 2 groups: In the laser side patients received 810-nm laser irradiation, 45 min after anesthesia injection, and the other side received placebo. A 7–10 days interval between procedures. Reversal of local anesthesia tests: Palpation technique every 15 min after the procedure.	Significant difference in the duration of anesthesia for both laser and sham laser groups. The time of anesthesia in the study – laser group was reduced by 43 ±24.03 min.	810-nm diode laser significantly reduced the duration of anesthesia time.

in dentistry, ongoing efforts are being made to improve techniques, methods and devices to alleviate injection anxiety.[11,14] The analysis of 40 studies investigating vibration-based and PBM methods alongside LA reveals promising outcomes in reducing pain during injection procedures across pediatric and adult populations. As pain is subjective in nature, the core indicators of the clinical effect of the presented methods were based on patient-reported sensations measured by different scales. The most frequently used were the VAS, FLACC scale, WBFPS, Wong–Baker Pain Rating Scale, and others, alongside more objective methods such as pulse and heart rate at baseline and after injection, pulse oximeter, blood volume pulse, sweat conductance, or galvanic skin response sensor. The analysis of the studies indicated a high degree of certainty for evidence and quality.

The impact on the level of pain perception during LA was analyzed in 32 scientific studies, 7 included PBM,[24,47–52] and 25 focused on the use of vibration.[2,4,11–13,27–46] Overall, 21 (65.5%) studies revealed significant pain reduction during injection, 7 (22%) found no significant differences, and 4 (12.5%) presented inconsistent results. In the area of vibration-based methodology, 17 research studies focused on the pediatric population,[3,4,11,12,29,30,32,33,35–37,39–41,44–46] 7 studies on adults,[13,27,28,31,34,38,42] and in 1 case, detailed characterization of the participants was not provided.[36] In the analysis of children and adolescents, a significant reduction in the incidence of pain was observed in 12 cases (70.5%).[11,12,29,32,33,35,37,39–41,45,46] No significant differences were observed in 2 (12%) publications[3,30] and inconsistent results were reported in 3 (17.5%) other studies.[4,36,44] In the analysis of the adult groups, a significant difference in decreasing pain during anesthesia was observed in 5 (72%) studies[27,28,31,34,42] and no significant difference in 2 (28%) studies.[13,38]

As a part of the research on PBM, 4 experiments were conducted on adults[47,50–52] and 3 on children and adolescents.[24,48,49] Children and adolescents were assessed with the WBFPS and FLACC scales in 3 studies.[24,48,49] Results indicated that in both scales, significant differences between groups were found in 1 study[48] and no significant differences in 1 paper.[49] Additionally, in 1 study,[24] significant differences between groups were presented in relation to WBFPS; however, regarding the FLACC scale, no significant differences were noted. In 4 studies conducted on adults, the VAS, numerical rating scale of pain, heart rate, and sweating were used to assess pain linked with injection. Among them, PBM measured with the VAS presented a statistically significant decrease in pain during injections in 2 studies,[47,50] while no significant differences were found in the remaining paper.[51] A significant difference in sweating was reported during mandible injections in 1 study.[52] However, in the same study, the numerical rating scale of pain, heart rate and sweating during maxillary anesthesia showed no significant differences.[52]

Reversal of the LA duration was evaluated in 9 studies.[2,6–10,24,26,53] For this purpose, 6 studies used PM[6–10,26] and 3 PBM.[2,24,53] Classifying papers according to the age of the respondents, 5 studies concerned children and adolescents[2,7,9,24,53] and 4 evaluated adults.[6,8,10,26] Significant differences in the duration of anesthesia were revealed in 8 studies. Only 1 study,[24] evaluating the use of PBM, in children did not observe any significant changes in anesthesia duration. In terms of adverse effects, no significant differences between the study and control groups were noted in 5 studies.[6–10] In 1 study,[9] which concerned children as an investigated group, nausea and elevated body temperature were reported. Postoperative pain was assessed in 2 studies,[8,26] both using a VAS. In the study by Shadmehr et al.,[26] pain 6 and 12 h after the procedure was significantly higher in the study group, whereas no significant differences were found in the other group.[8]

Limitations

Although all the selected studies were clinical studies, the samples were relatively small, and study participants were of different ages, which influenced the assessment methods/scales used. More studies are needed to verify the effects of PM, PBM and vibration. Since PM use is not permitted in all countries, the effect of the medication on patients of other nationalities could not be assessed. Moreover, significant heterogeneity among the included studies does not allow us to perform a meta-analysis. However, further research should be conducted to enable proceeding with a meta-analysis.

Table 2. Detailed characteristics of included studies

Study	Method	Additional pain reducing method	Parameters of PBM/PM/vibration appliance	Exposure time	Type of anesthetic + concentration + dose	Method of LA	Procedure type	Age category	Assessment method	Significant differences between study and control group	Duration of anesthesia study group vs control group
Annu et al., 2023[2]	PBM	N/A	660 and 810 nm wavelengths 100 mW	45 min after injection, irradiation for 12 s, 6 places, continuous mode	lignocaine with adrenaline LIGNOX 2% A 1.5 mL	IANB	pulp therapy of mandibular molars	children: 4–8 years	palpation technique (anesthesia duration) the pin prick test	yes	mean soft tissue local anesthesia reversal time duration study groups: 660 nm – 130.5 min 810 nm – 144 min control group: 199.5 min
Felemban et al., 2021[3]	V	N/A	DentalVibe Injection Comfort System	5 s prior, during injection and 5 s after	mepivacaine 2% with 1:100,000 epinephrine	buccal infiltration anesthesia (BIA)	dental treatment	children: 6–12 years	FLACC scale, the validated Arabic version of the Wong–Baker FACES scale	no	N/A
AlHareky et al., 2021[4]	V	cold	The Buzzy device	just before and during injection	2% lidocaine with 1:100,000 adrenaline, 1.8 mL	BIA	dental treatment	children: 5–12 years	FLACC scale SEM scale VAS	yes no yes	N/A
Michaud et al., 2018[6]	PM	N/A	PM: 1.7 mL; 0.4 mg	after treatment	2% lidocaine with 1:100,000 adrenaline 1.8 mL	IANB	study	adults: over 18 years	anesthesia duration adverse effects	yes no	Study group lip – 120 min tongue – 105 min smiling – 96 min drinking – 104 min speaking – 72 min Control group lip – 170 min tongue – 134 min smiling – 151 min drinking – 170 min speaking – 140 min
Tavares et al., 2008[7]	PM	N/A	PM: if ½ cartridge of anesthetic = 0.2 mg; 1 cartridge = 0.4 mg	after treatment (20–49 min after injection)	2% lidocaine with 1:100,000 adrenaline 15–30 kg: ½ cartridge over 30 kg: ½ or whole cartridge	supraperiosteal injection; IANB; Gow–Gates nerve blocks	dental treatment (restorative or periodontal, crowns)	children: 4–11 years	anesthesia duration adverse reactions	yes no	75 min (55.6%) decrease in the median time for the return of normal lip sensation 67.5 min (60%) reduction in the median time for the return of normal tongue sensation.

Table 2. Detailed characteristics of included studies – cont.

Study	Method	Additional pain reducing method	Parameters of PBM/PM/vibration appliance	Exposure time	Type of anesthetic + concentration + dose	Method of LA	Procedure type	Age category	Assessment method	Significant differences between study and control group	Duration of anesthesia study group vs control group
Fowler et al., 2011[8]	PM	N/A	PM: the same amount (1.8 mL/3.6 mL) as the cartridge of anesthetics	after treatment PM group: 71 min in maxilla 84 min in mandible Control group: 67 min in maxilla, 85 min in mandible	2% lidocaine with 1:100,000 adrenaline additionally 4% articaine with 1:100,000 or 2% lidocaine with 1:100,000 adrenaline 1.8 mL/3.6 mL	IANB, long buccal nerve block additionally: buccal infiltration, an intraosseous injection or infiltration	endodontic treatment	adults: 18–81 years	anesthesia duration VAS postop pain adverse reactions	yes no no	Study vs control Maxillary Lip/Cheek: Disappearance of numbness: 99 min vs 134 min Return-to-normal sensation: 136 min vs 224 min Mandibular Lip: Numbness: 121 min vs 145 min Sensation: 170 min vs 217 min Tongue: Numbness: 106 min vs 121 min Sensation: 142 min vs 169 min
Gago-García et al., 2021[10]	PM	N/A	PM the same amount (1.8 mL,1.7 mL) as the cartridge of anesthetics	after treatment	Group I lidocaine 2% 1/80,000 Group II articaine 4% 1/200,000, Group III bupivacaine 0.5% 1/200,000	IANB	tooth filling, tooth extraction, full mouth disinfection, implant placement, and root canal treatment	adults: over 18 years	anesthesia duration adverse reaction	yes no	On average Group I lip – 59.6 min tongue – 52.5 min normative value – 180 min Group II lip – 88.5 min tongue – 84.5 min normative value – 258 min Group III lip – 249 min tongue – 214 min normative value – 460 min

Table 2. Detailed characteristics of included studies – cont.

Study	Method	Additional pain reducing method	Parameters of PBM/PM/vibration appliance	Exposure time	Type of anesthetic + concentration + dose	Method of LA	Procedure type	Age category	Assessment method	Significant differences between study and control group	Duration of anesthesia study group vs control group
Hegde et al., 2019[11]	V	N/A	Vibration device	2 min prior injection	N/A	inferior alveolar nerve block (IANB)	bilateral dental treatment	children: 6–11 years	FLACC scale	yes	N/A
									Wong–Bakers Pain Rating Scale	yes	
									pulses rate at the baseline and after injection	yes, after injection no, at the baseline	
Shilpapriya et al., 2015[12]	V	N/A	DentalVibe	1 minute before, during and 10 second after injeciton	N/A 2 mL	N/A	bilateral dental treatment	children: 6–12 years	universal pain assessment tool	yes	N/A
Erdogan et al., 2018[13]	V	N/A	DentalVibe	5 s prior, during and 5 s after injection	2% mepivacaine with 1:100,000 adrenaline 1 mL	infiltration technique at the apical region of the right maxillary incisors	study	adults: 18–26 years	Wong–Baker FACES Pain Rating Scale	no	N/A
									VAS	no	
Babaei et al., 2011[19]	PM	N/A	PM: 15–30 kg: 0.2 mg; above 30 kg: 0.4 mg	30 min after injection	lidocaine 2% 1/80,000 adrenaline max. 1 cartridge	IANB	bilateral dental treatment (except for extraction)	children: 4–11 years	anesthesia duration	yes	Group I Study vs control sensation of soft tissue 29.47 min vs 135.52 min. Group II Study vs control sensation of soft tissue 33.12 min vs 106.04 min.
Uçar et al., 2022[24]	PBM	N/A	810 nm wavelength 0.3 W 400-µm fiber	20 s continuous mode	4% articaine hydrochloride with 1/100 000 adrenaline 1 mL	local infiltration	bilateral pulpotomy in first primary molars in the mandible	children: 6–9 years	Wong–Baker FACES Pain Rating Scale	yes	Mean soft tissue anesthesia duration study group: 160.91 min control group: 161.83 min
									FLACC scale	no	
									anesthesia duration	no	
									adverse effects	no	
Shadmehr et al., 2019[26]	PM	N/A	PM: 1.7 mL; 0.4 mg	after treatment	2% lidocaine with 1:100,000 adrenaline 1.8 ml	IANB	single-session endodontic treatment	adults: over 18 years	anesthesia duration	yes	Study group lip – 120 min tongue – 105 min Control group lip – 152 min tongue – 174 min
									Heft–Parker visual analogue scale pre and postoperative	preoperative no postoperative adverse effect	

Table 2. Detailed characteristics of included studies – cont.

Study	Method	Additional pain reducing method	Parameters of PBM/PM/vibration appliance	Exposure time	Type of anesthetic + concentration + dose	Method of LA	Procedure type	Age category	Assessment method	Significant differences between study and control group	Duration of anesthesia study group vs control group
Shaefer et al., 2017[27]	V	N/A counter-stimulation in control group	DentalVibe Injection Comfort System	10 s before, during and 5 s after injection	3% mepivicaine 0.5 mL for LB; 1.8 mL for IANB	intraoral long buccal (LB), IANB	study	adults: 21–32 years	VAS symptom severity index (SSI)	yes	N/A
Nasehi et al., 2015[28]	V	N/A	DentalVibe Injection Comfort System	DentalVibe used as per manufacturer's recommendations	Lignocaine hydrochloride with 1:200,000 adrenaline	IANB Long Buccal Infraorbital Palatal	bilateral dental treatment	adults: over 18 years	VAS	yes	N/A
Hassanein et al., 2020[29]	V	N/A	DentalVibe	5 s prior and during injection	mepivacaine HCl 2%, 1:20,000 levonordefrin	IANB	bilateral mandibular pulpotomy	children: 5–7 years	Wong–Baker FACES Pain Rating Scale FLACC scale	yes yes	N/A
Raslan and Masri, 2018[30]	V	N/A	Dentalvibe	buccal infiltration + IANB: 5 s prior, 60 s of anesthesia deposition and 5 s after injection palatal infiltration: 5 s prior and during anesthesia deposition	4% articaine hydrochloride with 1/100,000 adrenaline	buccal and palatal infiltration IANB	dental treatments in maxilla and mandible on both sides of the arches	children: 6–9 years	Wong–Baker Faces Pain Rating Scale FLACC scale	no no	N/A
Joshi et al., 2021[31]	V	N/A	DentalVibe	1 min prior, during and 10 s after injection	2% lidocaine with 1:200,000 adrenaline	IANB	bilateral dental extractions in the mandible	adults: 18–50 years	VAS	yes	N/A
Dak-Albab et al., 2016[32]	V	N/A	DentalVibe	30 s before injection	N/A	IANB	bilateral dental treatment	children: 8–12 years	FLACC scale	yes	N/A
Ching et al., 2014[33]	V	N/A	DentalVibe	5 s before, during anesthesia application, immediately stopped after needle	2% lidocaine with 1:100,000 adrenaline 0.85 mL	infiltration anesthesia	bilateral dental treatment	adolescents: 10–17 years	Wong–Baker FACES Pain Rating Scale	yes	N/A

Table 2. Detailed characteristics of included studies – cont.

Study	Method	Additional pain reducing method	Parameters of PBM/PM/vibration appliance	Exposure time	Type of anesthetic + concentration + dose	Method of LA	Procedure type	Age category	Assessment method	Significant differences between study and control group	Duration of anesthesia study group vs control group
Salma et al., 2021[34]	V	N/A	DentalVibe	10 s before, during and 5 s after anesthesia	2% lidocaine with 1:100,000 adrenaline 1.8 mL	IANB, buccal, palatal infiltration	bilateral maxillary or mandibular extractions	adults: 18–55 years	VAS during needle insertion mid-injection pain	Yes	N/A
									heart rate baseline heart rate (BHR), penetration heart rate (PHR), and midinjection heart rate (IHR)	Yes	
Ramezani et al., 2017[35]	V	N/A	DentalVibe	5 s before, during and 5 s after injection	2% lidocaine with 1:80,000 adrenaline	IANB, infiltration block	bilateral maxillary or mandibular treatment	children: 5–7 years	Wong–Baker FACES Pain Rating Scale	yes	N/A
Tung et al., 2018[36]	V	manual stimulation with thumb (another group)	DentalVibe	10 s prior, during and 2 s after injection	2% lidocaine with 1:100,000 adrenaline	IANB/long buccal injections, maxillary infiltration injection	operative dental treatment	children: 7–14 years	Wong–Baker FACES Pain Rating Scale	yes	N/A
									pulse rate	no	
Albouni et al., 2022[37]	V	N/A	VibraJect	No specific data	2% lidocaine with 1:100,000 adrenaline	upper buccal infiltrations (UBI), posterior palatal infiltrations, IANB	bilateral dental treatment	children: 6–9 years	VAS	yes	N/A
									FLACC scale	yes	
Hutchins et al., 1997[38]	V	20% benzocaine	A modified battery-powered shaver	1 min before treatment	2% lidocaine with 1:100,000 adrenaline 0.2 mL	palatal and BIA of both maxillary first premolars	N/A	adults: over 18 years	5-point VAS	no, for vibration; yes, for topical anesthesia	N/A
Bagherian and Sheikhfathollahi, 2016[39]	V	verbal distraction	cotton roll	before, during and few seconds after injection	lidocaine 2% 1/80,000	IANB, maxillary infiltration	bilateral dental treatment	children	the author developed face, head, foot, hand, trunk, and cry (FHFHTC) scale	yes	N/A
Gandhi et al., 2018[40]	V	N/A	Rajasthan University of Health; Science (RUHS) mucosal vibrator	before, 1min during and 15 s after injection	N/A 1 mL	IANB	bilateral mandibular restoration, pulpotomy, pulpectomy or extraction	children: 6–11 years	SEM scale	yes	N/A
									Wong–Baker FPR scale	yes	

Table 2. Detailed characteristics of included studies – cont.

Study	Method	Additional pain reducing method	Parameters of PBM/PM/vibration appliance	Exposure time	Type of anesthetic + concentration + dose	Method of LA	Procedure type	Age category	Assessment method	Significant differences between study and control group	Duration of anesthesia study group vs control group
Aminabadi et al., 2008[41]	V	verbal distraction	thumb and forefinger	N/A	2% lidocaine with 1/100000 epinephrine, 1 mL	IANB	mandibular restoration	children: 4–5 years	SEM scale	yes	N/A
Nanitsos et al., 2009[42]	V	N/A	HoMedics Atom massager	N/A	N/A	buccal or mandibular infiltration IANB	bilateral dental treatment	adults: 18–72 years	VAS	yes	N/A
									McGill pain descriptors	yes	
Meghana et al., 2020[43]	V	N/A	Waterpik Vibrator	N/A	N/A	infiltration injection	dental treatment in 3 quadrants	N/A	VAS scale	yes, but in favor of the topical anesthesia	N/A
Marwah et al., 2020[44]	V	cold	The Buzzy device	N/A	lidocaine 2% with 0.005 mg adrenaline	N/A	dental treatment	children: 5–10 years	Wong–Baker FACES Pain Rating Scale (WBFPRS)	no	N/A
									FLACC scale	yes	
Sahithi et al., 2021[45]	V	cold; counter stimulation in control group	BuzzyR device	N/A	lidocaine 2% 1/80,000	N/A	extraction and pulp therapy treatment in mandible	children: 4–11 years	Venham's Clinical Anxiety Rating Scale (VCARS)	pre and postop Yes	N/A
									Venham Picture Test (VPT)	pre no post yes	
									pulse oximeter	yes	
									Wong–Baker FACES Pain Rating Scale (WBFPS)	yes	
									VAS	yes	
Bilsin et al., 2018[46]	V	cold	The Buzzy device	2 min prior and during injection	2% lidocaine 2 mL	local mandibular anesthesia	extraction of mandibular primary molars	children: 7–12 years	Wong–Baker Faces Pain Rating Scale	yes	N/A
Jagtap et al.[47]	PBM	N/A	660-nm wavelength; 60 wM power	3 minutes before injection	N/A	N/A	bilateral extraction	adults: 18–60 years	VAS	yes	N/A

Table 2. Detailed characteristics of included studies – cont.

Study	Method	Additional pain reducing method	Parameters of PBM/PM/vibration appliance	Exposure time	Type of anesthetic + concentration + dose	Method of LA	Procedure type	Age category	Assessment method	Significant differences between study and control group	Duration of anesthesia study group vs control group
Dehgan et al., 2022[48]	PBM	N/A	980 nm wavelength 0.3 W, 0.4 W and 0.5 W a 400-µm fiber	20 s continuous mode	4% articaine hydrochloride with 1/100,000 adrenaline 1ml	buccal LA in maxilla or mandible	primary first molar treatment	children: 6–12 years	Wong–Baker FACES Pain Rating Scale	Yes	N/A
									FLACC scale	Yes	
Elbay et al., 2022[49]	PBM	N/A	940 nm wavelength 0.3 W a 400 µm fiber	20 s, 30 s, 40 s continuous mode	4% articaine hydrochloride with 1/100,000 epinephrine 1 mL	supra-periosteal anesthesia	dental treatment	children: 6–12 years	FLACC scale	No	N/A
									Wong–Baker FACES Pain Rating Scale	No	
Sharifi et al., 2022[50]	PBM	N/A	810–980 nm wavelengths; 50 mW, 810 nm, 100 mW, 810–980 nm or +50 mW, 980 nm	90 s prior the injection, dual continuous mode	2% lidocaine hydrochloride with 1:100,000 adrenaline 1.8 mL	buccal infiltration in anterior maxilla	bilateral restoration of central incisors in the maxilla	adults: over 18 years	VAS	Yes	N/A
El Feghali et al., 2022[51]	PBM	N/A	1,064 nm wavelength; 0.5 W; 10 Hz, 100 µs pulse width	60 s before injection	4% articaine with 1:100,000 adrenaline 2.2 mL	buccal infiltration injection	dental treatment in anterior maxillary region from canine to canine	adults	VAS	No significant differences	N/A
									VRS scale (taste, undesirable numbness, overall satisfaction)	Yes	
Tuk et al., 2017[52]	PBM	N/A	810 nm wavelength; 200 mW	Two times protocol: 30 s irradiation, 30 s interval, 30 s irradiation; 2 min of irradiation in total before injection continuous mode	articaine/hydrochloride 40 mg with epinephrine 0.01 mg 1.7 mL	IANB+ buccal infiltration/palatal and buccal infiltration	maxillary or mandibular third molar extractions	adults: 18–75 years	11-point numerical rating scale (pain and anxiety)	No	N/A
									blood volume pulse	No	N/A
									sweat conductance or galvanic skin response sensor	Yes, in mandible	N/A
Seraj et al., 2020[53]	PBM	N. d.	810 nm diode laser	45 min after injection, irradiation for 12 s in 6 spots	lidocaine 2% and 1: 100,000 epinephrine	infiltration	treatment of mandibular first molars	children: 4–8 years	palpation technique	Yes	Study laser group: 145.15 ±23.27 min. Sham group: 188.82 ±12.31 min.

N/A – no data; PBM – photobiomodulation; V – vibration.

Table 3. Quality assessment of included studies

Analyzed study	All procedures followed manufacturer's guidelines	Information about the anesthetic	Single operator	Clearly explained and justified sample size	No acute situations	Minimum 10 participants	Control group (split mouth included)	Use of single method	Single- or double-blinded	Sum	Risk of bias
Annu et al., 2023[2]	1	1	0	1	1	1	1	1	0	7	low
Felemban et al., 2021[3]	1	1	0	1	1	1	1	1	0	7	low
AlHareky et al., 2021[4]	1	1	0	1	1	1	1	0	0	6	moderate
Michaud et al., 2018[6]	1	1	1	1	1	1	1	1	1	9	low
Tavares et al., 2008[7]	1	0	0	0	1	1	1	1	1	6	moderate
Fowler et al., 2011[8]	1	1	1	0	1	1	1	1	1	8	low
Babaei et al., 2011[9]	1	1	1	0	1	1	1	1	1	8	low
Gago-García et al., 2021[10]	1	1	0	1	1	1	1	1	1	8	low
Hegde et al., 2019[11]	0	0	1	1	1	1	0	1	0	5	moderate
Erdogan et al., 2018[13]	1	1	1	0	1	1	1	1	0	7	low
Shaefer et al., 2017[27]	1	1	0	1	1	1	1	1	0	7	low
Uçar et al., 2022[24]	1	1	0	1	1	1	1	0	1	7	low
Shadmehr et al., 2019[26]	1	1	1	0	1	1	1	1	1	8	low
Shilpapriya et al., 2017[27]	1	0	0	0	1	1	1	0	0	4	moderate
Nasehi et al., 2015[28]	1	1	0	0	1	1	1	1	0	6	moderate
Hassanein et al., 2020[29]	1	1	1	0	1	1	1	0	0	6	moderate
Raslan and Masri, 2018[30]	1	0	1	1	1	1	1	1	0	7	low
Joshi et al., 2021[31]	1	0	0	1	1	1	0	1	0	5	moderate
Dak-Albab et al., 2016[32]	1	0	0	1	1	1	0	1	0	5	moderate
Ching et al., 2014[33]	1	1	0	1	1	1	1	1	0	7	low
Salma et al., 2021[34]	1	1	1	0	1	1	0	1	0	6	moderate
Ramezani et al., 2017[35]	0	1	0	0	1	1	0	0	0	3	high
Tung et al., 2018[36]	0	1	0	0	1	1	0	0	0	3	high high
Albouni et al., 2022[37]	1	0	1	0	1	1	1	0	0	5	moderate
Hutchins et al., 1997[38]	1	1	0	0	1	1	1	0	0	5	moderate
Bagherian and Sheikhfathollahi, 2016[39]	0	1	0	1	1	1	1	0	0	5	moderate

Table 3. Quality assessment of included studies – cont.

Analyzed study	All procedures followed manufacturer's guidelines	Information about the anesthetic	Single operator	Clearly explained and justified sample size	No acute situations	Minimum 10 participants	Control group (split mouth included)	Use of single method	Single- or double-blinded	Sum	Risk of bias
Gandhi et al., 2018[40]	0	0	0	0	1	1	1	0	0	3	high
Aminabadi et al., 2008[41]	0	1	1	0	1	1	1	0	0	5	moderate
Nanitsos et al., 2009[42]	1	0	0	0	1	1	1	1	0	5	moderate
Meghana Reddy, 2020[43]	1	0	0	1	1	1	0	1	0	5	moderate
Marwah et al., 2020[44]	1	1	0	1	1	1	1	0	0	6	moderate
Sahithi et al., 2021[45]	1	1	0	1	1	1	0	0	0	5	moderate
Bilsin et al., 2020[46]	1	1	1	1	1	1	1	0	0	7	low
Jagtap et al., 2019[47]	1	0	0	1	1	1	1	1	1	7	low
Dehgan et al., 2022[48]	1	1	1	1	1	1	1	0	1	8	low
Elbay et al., 2022[49]	1	1	1	0	1	1	1	1	1	8	low
Sharifi et al., 2022[50]	1	0	0	1	1	1	1	0	0	5	moderate
El Feghali et al., 2022[51]	1	1	0	0	1	1	1	1	1	7	low
Tuk et al., 2017[52]	1	1	0	0	1	1	1	1	1	7	low
Seraj et al., 2020[53]	1	1	0	0	1	1	1	1	1	7	low low

Conclusions

Significant reductions in pain perception, assessed using diverse pain scales, were observed in most cases evaluating the vibration-based and PBM methods. Furthermore, notable differences in anesthesia reversal using PM or PBM were documented with minimal adverse effects, underscoring the safety of these techniques.

Further research is warranted to explore the long-term efficacy, adverse event profiles and broader applications, particularly in the case of PBM, which has the least number of clinical trials regarding the subject evaluated in this review.

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