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SYSTEMATIC REVIEW

Effectiveness of control strategies for injection pain in local anesthesia in pediatric dentistry: a network meta-analysis

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Abstract

Background: Pain associated with anesthesia in pediatric dentistry poses significant challenges, often leading to poor treatment compliance and dental anxiety. The effectiveness of various pre-emptive analgesic interventions remains uncertain. Therefore, this network meta-analysis aimed to systematically compare the relative effectiveness of interventions for reducing injection pain during local anesthesia in pediatric dentistry and to rank their efficacy. The findings are expected to guide the selection of optimal clinical strategies. **Methods**: We searched PubMed, Cochrane, Embase, and Web of Science from database inception up to 12 August 2025, for English-language studies. The risk of bias was assessed using the Cochrane Risk of Bias Assessment Tool 2.0. The GeMTC package in R version 4.4.2 was utilized to perform the network meta-analysis. **Results**: Forty-five studies involving 3124 patients were included. The effects of interventions on subjective and objective pain, heart rate, and oxygen saturation were statistically analyzed. The network meta-analysis revealed that acupressure was most effective in controlling objective pain (SMD (standardized mean difference) −3.01, 95% CrI (credible interval) −5.66, −0.35), whereas the combination of cold stimulation, vibration, and benzocaine gel was most effective in controlling subjective pain (SMD −3.71, 95% CrI −6.87, −0.63), and Cold stimulation was most effective in reducing HR (Heart Rate) (MD (Mean Difference) −12.59, 95% CrI −20.74, −4.45). No statistically significant differences were observed concerning oxygen saturation. **Conclusion**: Acupressure, the combination of cold stimulation, vibration, and benzocaine gel, and cold stimulation were the optimal strategies for reducing objective pain, subjective pain, and HR in local anesthesia in pediatric dentistry, respectively. Further international, multicenter, prospective randomized controlled trials using standardized objective/subjective pain assessment scales are required to more comprehensively evaluate the efficacy of different interventions. **The PROSPERO Registration**: The study protocol was registered with PROSPERO (International Prospective Register of Systematic Reviews) (CRD420251126987).

Keywords

Pediatric dentistry; Local anesthesia; Network meta-analysis; Injection pain

1. Introduction

Pain control is crucial for successful procedures in pediatric dentistry. Dental anxiety and fear are significant barriers to treatment compliance and tolerance and are among the primary causes of difficulties in behavior guidance [1]. Dental anxiety in children can further lead to reduced treatment compliance and tolerance, and extended duration and cycles of treatment. Additionally, it may affect long-term cooperation with oral treatments. Effective pain control helps establish doctor-patient trust and alleviates fear and anxiety during current and subsequent visits, thereby enhancing compliance [2]. Therefore, local anesthesia and pain management are essential for providing comfortable dental treatment to children [3]. However, pain associated with local anesthetic injections is also a major contributor to dental fear and anxiety in children [4]. Therefore, pain control before local anesthetic injection is crucial in pediatric dentistry.

Many methods have been proposed to relieve injection pain, including topical anesthesia, cold stimulation, vibration, sweetening agents, and laser techniques. Topical anesthesia has been widely advocated as an effective method for relieving injection pain [5]. With recent advances in clinical techniques and devices, multiple studies and reviews have investigated the efficacy of interventions (*e.g.*, cold stimulation, vibration therapy, sweetening agents, and laser techniques) for relieving injection pain during local anesthesia in pediatric dentistry [6, 7]. Some studies have reported interventions that are more effective than topical anesthesia [8, 9]. Ninawe *et al*. [8] reported that cold stimulation was more effective than topical anesthesia for reducing injection pain in children. Bollepalli *et al*. [9] compared laser and local anesthetic spray pretreatment and found the former to be more effective in reducing injection pain. Furthermore, the efficacy of local anesthesia in reducing injection pain has been compared across various pain control interventions except for topical anesthesia. Vafaei *et al*. [10] compared cold stimulation and vibration for pain relief at the injection site. Goyal *et al*. [11] compared electrical stimulation with cold stimulation at the injection site. Overall, various pain control strategies are available for reducing injection pain during local anesthesia in pediatric dentistry; however, their relative efficacy remains uncertain.

To date, the efficacy of these pain control strategies in pediatric dentistry has not been comprehensively evaluated using a network meta-analysis (NMA). Although some interventions have been recognized as effective, the optimal intervention remains controversial, leading to uncertainty regarding their clinical application. Therefore, high-quality evidence is urgently needed to establish the relative ranking of various analgesic methods and provide a scientific basis for clinical decision-making. In this way, pediatric patients' experience can be improved, and the standardized development of pediatric analgesia can be advanced. Moreover, a systematic review of available evidence will deepen our understanding of current techniques, help identify the optimal clinical strategy, and determine areas requiring further research. By integrating evidence-based data, we conducted this network meta-analysis to compare the efficacy of different interventions for reducing injection pain during local anesthesia. The findings will not only optimize pain management in pediatric dentistry but also provide an important foundation for future research.

Notably, the effects of pharmacological interventions have been extensively reviewed in previous meta-analyses. Their routine use in children is often limited due to potential systemic side effects, safety concerns, and regulatory restrictions. Therefore, pharmacological interventions (*e.g.*, sedatives and general anesthesia) were not included in this NMA. In contrast, physical interventions are non-invasive, easy to administer, and generally more acceptable to both children and their parents as adjunctive strategies.

2. Methods

This study was conducted in accordance with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) extension for Network Meta-Analyses (PRISMA-NMA) guidelines [12]. The study protocol was registered with PROSPERO (CRD420251126987). The checklist was completed and is provided in **Supplementary material 1**.

2.1 Search strategy

We searched PubMed, Cochrane, Embase, and Web of Science from database inception through 12 August 2025. The search strategy combined Medical Subject Headings (MeSH) terms (Pediatrics, Child, Dental care, Dental procedure, Anaesthesia, and Randomized controlled trial) and free-text keywords. In addition, the reference lists of relevant articles and grey literature were manually searched to identify other eligible studies (**Supplementary material 2**).

2.2 Eligibility criteria

Inclusion criteria: (1) Population: pediatric patients (<18 years) requiring local anesthesia for dental treatment; (2) Intervention: interventions for reducing injection pain during local anesthesia. Comparison: placebo; (3) Study design: RCTs (Randomized Controlled Trials); and (4) Outcome: Subjective pain scales (Wong-Baker FACES Pain Rating Scale, and Visual Analog Scale (VAS)), objective pain scales (Sound-Eye-Motor Scale (SEM), and Face, Legs, Activity, Cry, and Consolability Scale (FLACC)), heart rate (HR), and oxygen saturation.

Exclusion criteria: (1) Animal or cell experiments, study protocols, case reports, letters, editorials, reviews, and conference papers; (2) studies with missing data or major data errors; (3) duplicate publications; (4) unavailable full text; and (5) studies involving overlapping participants.

2.3 Screening and data extraction

All retrieved studies were imported into EndNote. After duplicate publications were removed, titles and abstracts were screened independently by two investigators (Jiarong He and Pengfei Wang). Potentially eligible studies were subsequently assessed through full-text review. Disagreements were resolved by discussion or consultation with a third investigator (Ruomei Li). A spreadsheet was developed to extract data, including first author, country, year of publication, interventions and comparators, participant characteristics, and outcome metrics.

Notably, this study focused exclusively on physical interventions for alleviating injection pain during local anesthesia in pediatric dentistry and did not involve pharmacological sedation methods, such as inhalation, oral administration, intranasal, or intravenous sedation.

2.4 Quality assessment

Two investigators (Jiarong He and Pengfei Wang) independently assessed the included studies for risk of bias (RoB) using the Cochrane Risk of Bias Assessment Tool 2.0 (RoB2) from random sequence generation, allocation concealment, blinding, incomplete data, and selective reporting. Each domain was assessed as "high risk", "some concern", or "low risk". A study was considered to have a low RoB if all domains were assessed as low risk or if only one domain was assessed as having some concern; it was considered to have a high RoB if all four or more domains were assessed as having some concern or if any domain was assessed as high risk; it was considered to have moderate RoB in other cases. Disagreements were resolved by consultation with a third investigator (Ruomei Li).

2.5 Statistical analysis

All outcome metrics were continuous variables and were analyzed using mean difference (MD) and standardized mean difference (SMD), with 95% credible intervals (CrI) calculated. We created a Bayesian NMA model using the Markov Chain Monte Carlo (MCMC) method, followed by iterative simulations to estimate the relative efficacy of different interventions. To obtain the posterior distribution, the test had a model chain value of 4, an annealing value of 10,000, an iteration value of 50,000, and a step size of 10 with an initial value of 2.5. Three fundamental assumptions (transitivity, homogeneity, and consistency) should be satisfied for NMA. We conducted heterogeneity tests using the mtc:anohe function in the GeMTC package. An overall I^2 value of $< 50\%$ was considered to indicate acceptable heterogeneity among the included studies, thereby satisfying the homogeneity assumption. The node splitting method was used to assess consistency (using the mtc.nodesplit function in the GeMTC package). A p-value > 0.05 indicated consistency between direct and indirect comparisons, satisfying the consistency assumption. Convergence of results was assessed by calculating the potential scale reduction factor (PSRF), and a value of $1 \leq \text{PSRF} < 1.05$ indicated successful convergence. We constructed a network diagram, with nodes representing different interventions and lines representing direct head-to-head comparisons between interventions. The surface under the cumulative ranking curve (SUCRA) was generated to rank all interventions. Potential publication bias was assessed using funnel plots. R version 4.5.2 and STATA version 18.0 (StataCorp LLC, College Station, TX, USA) were used for statistical analyses.

For pain outcomes, subjective and objective pain scales were analyzed separately and were not pooled. Subjective pain was assessed using self-reported instruments, such as the Wong-Baker FACES Pain Rating Scale and VAS, whereas objective pain was assessed using observer-rated behavioral measures such as the SEM and FLACC. Since each pain outcome was measured using different validated instruments, SMDs were calculated for subjective and objective pain outcomes [13]. Before data pooling, the direction of all scales was checked and standardized so that higher scores consistently indicated greater pain intensity. Therefore, a negative SMD value indicated a greater reduction in pain intensity. Given the expected clinical and methodological variations across trials, random-effects NMA models were used for both subjective and objective pain outcomes. The transitivity assumption was evaluated conceptually by comparing the distribution of potential effect modifiers across treatment comparisons, including age range, type of dental procedure and local anesthetics, intervention characteristics, comparator type, pain assessment instrument, study design, and RoB [14].

3. Results

3.1 Search results

We initially searched 3990 records from databases, of which 1877 duplicate records were removed. Subsequently, 2039 studies were excluded after reading titles and abstracts. The full texts of the remaining studies were reviewed, and six studies were excluded because their full texts were unavailable. Finally, 45 eligible studies were included in the network meta-analysis (Fig. 1).

3.2 Basic characteristics and quality assessment of the included studies

The included studies originated from nine countries (one from the United States, one from Egypt, 26 from India, seven from Iran, one from Italy, one from Jordan, two from Saudi Arabia, one from Syria, and five from Turkey), and involved 3124 patients. Male participants accounted for 52.58%, and female participants accounted for 47.42%. The age of participants ranged from 4 to 16 years (**Supplementary Table 1**, Ref. [8–11, 15–55]).

Most studies were assessed as having an overall low RoB. However, 13 studies were classified as having some moderate concern regarding RoB due to the absence of blinding. Although blinding of personnel was challenging due to the nature of interventions, the absence of blinding could compromise the objectivity of some outcome measurements, potentially introducing measurement bias. Additionally, four studies were classified as having moderate RoB due to the absence of intention-to-treat analysis. These studies failed to include all randomized participants or did not follow the initial allocation, which may have underestimated the impact of missing data on the results, thereby affecting the reliability of the conclusions (Fig. 2).

3.3 NMA results

In the network diagram, each node indicated an intervention, and its size was positively correlated with the number of studies on this intervention. A larger size indicated a greater number of included studies.The lines indicated studies comparing interventions, and their thickness reflected the number of studies. A thicker line indicated a greater number of comparative studies (Fig. 3). The difference in deviance information criterion (ΔDIC) was $<$5 across all outcomes, indicating good overall model fitness (Table 1). The node splitting method was used to assess consistency within closed loops. The p values for all outcome measures were > 0.05, indicating no evidence of local inconsistency. Successful convergence of results was confirmed (PSRF = 1) (**Supplementary Fig. 1**).

3.4 Primary outcomes

3.4.1 Subjective pain scale

Forty-five studies reported subjective pain outcomes. The NMA revealed that laser and the combination of cold stimulation,vibration, and benzocaine gel significantly relieved subjective injection pain in local anesthesia in children (combination of cold stimulation/vibration/benzocaine gel *vs.* placebo: SMD −3.71, 95% CrI −6.87, −0.63; laser *vs.* placebo: SMD −2.96, 95% CrI −5.67, −0.27) (**Supplementary Table 2**).

The combination of cold stimulation,vibration, and benzocaine gel had the highest SUCRA value (90.04%), followed by laser (83.86%), and peppermint oil (78.07%). Therefore, the combination of cold stimulation,vibration, and benzocaine gel

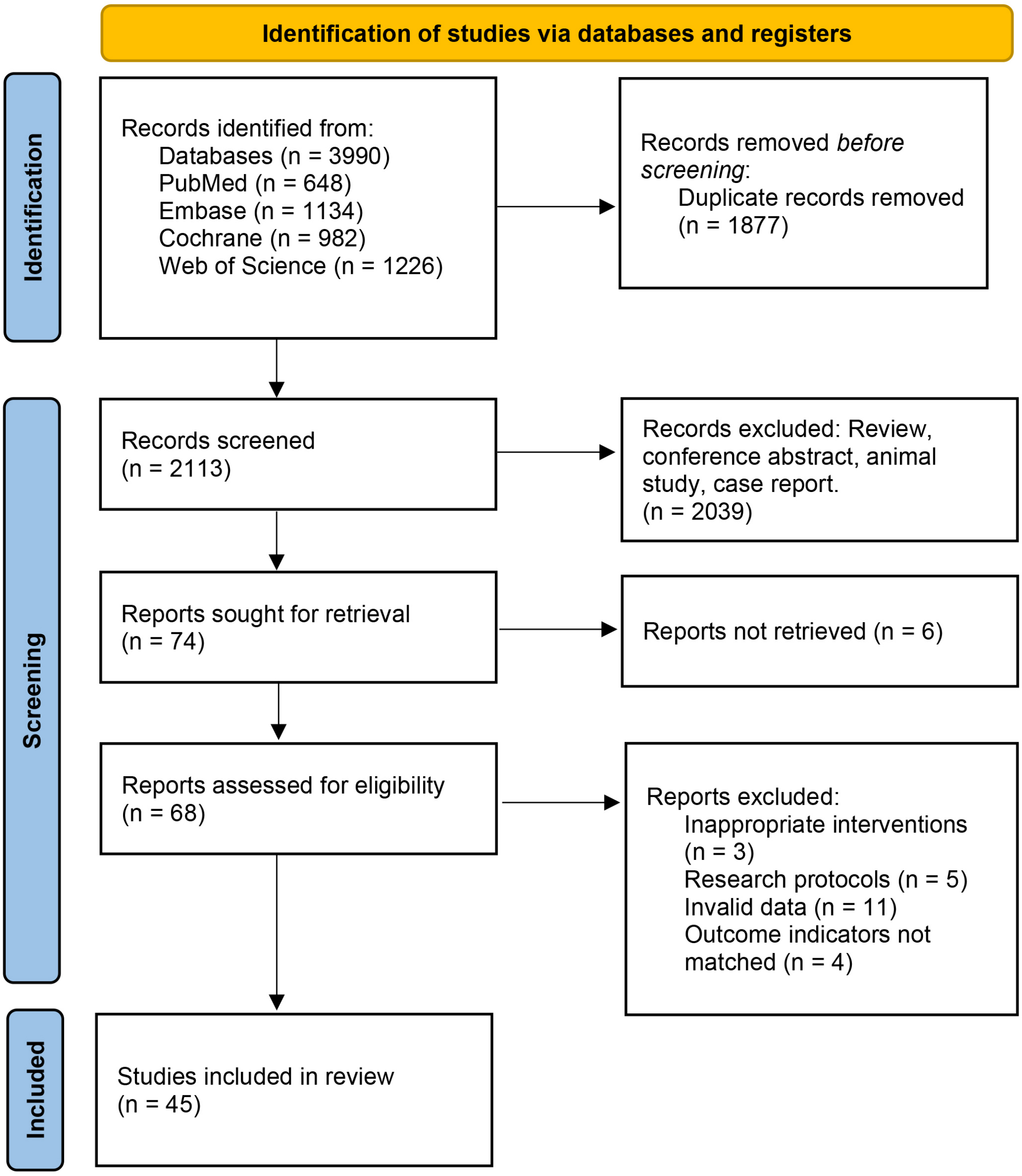

FIGURE 1. PRISMA flowchart of search and screening.

was most effective in reducing subjective injection pain during local anesthesia in children (Fig. 4A).

3.4.2 Objective pain scale

Forty-five studies reported objective pain outcomes. The NMA revealed that acupressure significantly reduced objective injection pain during local anesthesia in children (acupressure *vs.* placebo: SMD −3.01, 95% CrI −5.66, −0.35) (**Supplementary Table 3**).

Acupressure had the highest SUCRA value (87.14%), followed by the combination of lignocaine/prilocaine (82.23%), and the combination of cold stimulation,vibration, and benzocaine gel (78.84%). Therefore, acupressure was ranked as the most effective intervention for reducing objective injection pain during local anesthesia in children (Fig. 4B).

3.5 Secondary outcomes

3.5.1 HR

HR was reported in sixteen studies. The NMA revealed that cold stimulation, vibration, laser, and acupressure all significantly reduced HR during local anaesthesia injection in children (cold stimulation *vs.* placebo: MD −12.59, 95% CrI −20.74, −4.45; vibration *vs.* placebo: MD −7.74, 95% CrI −11.28, −4.2; laser *vs.* placebo: MD −7.5, 95% CrI −14.59, −0.43; acupressure *vs.* placebo: MD −9.5, 95% CrI −15.03, −3.98). However, procaine gel significantly increased HR during local anesthetic injection in children (procaine gel *vs.* placebo: MD 5.22, 95% CrI 0.91, 9.56) (**Supplementary Table 4**).

Cold stimulation had the highest SUCRA value (96.58%), followed by acupressure (86.65%) and laser (81.21%). Therefore, cold stimulation was most effective in reducing HR during local anaesthetic injection in children (Fig. 4C).

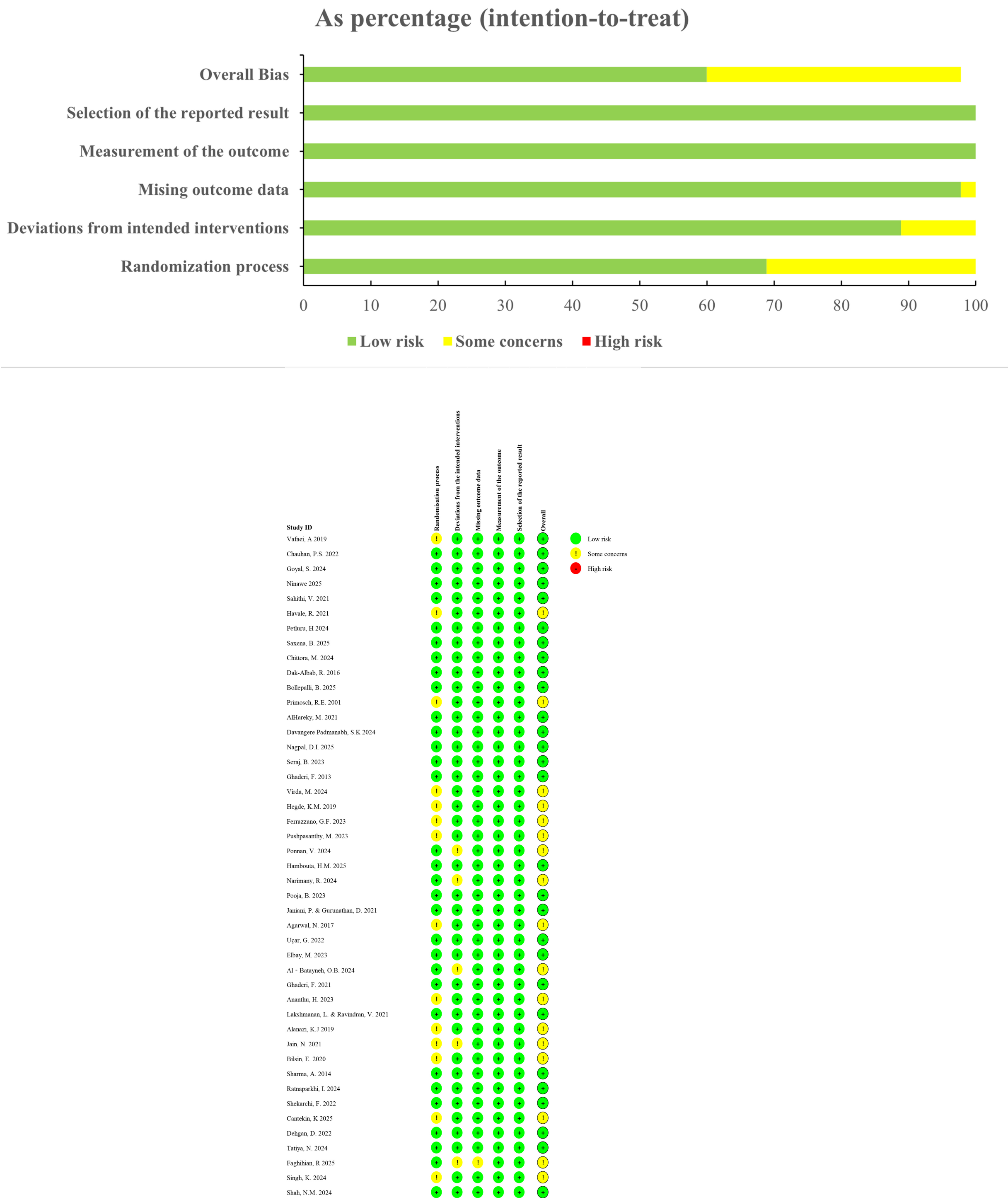

FIGURE 2. Quality assessment results.

3.5.2 Oxygen saturation

Oxygen saturation was reported in four studies. The NMA revealed no significant differences among interventions in oxygen saturation (Table 2).

We observed substantial overlap in the SUCRA plot for oxygen saturation (Fig. 4D), confirming a lack of statistical significance.

3.6 Publication bias

The comparison-adjusted funnel plots were symmetric, indicating no publication bias (Fig. 5).

4. Discussion

This NMA revealed that acupressure, the combination of cold stimulation,vibration, and benzocaine gel, and cold stimulation may be the optimal strategies for reducing objective pain, subjective pain, and HR dring local anesthesia in pediatric dentistry, respectively. Moreover, the combination of cold stimulation, vibration, and benzocaine gel demonstrated a greater reduction in objective and subjective pain compared with any individual interventions. No statistically significant improvements were observed in oxygen saturation with any of the evaluated interventions.

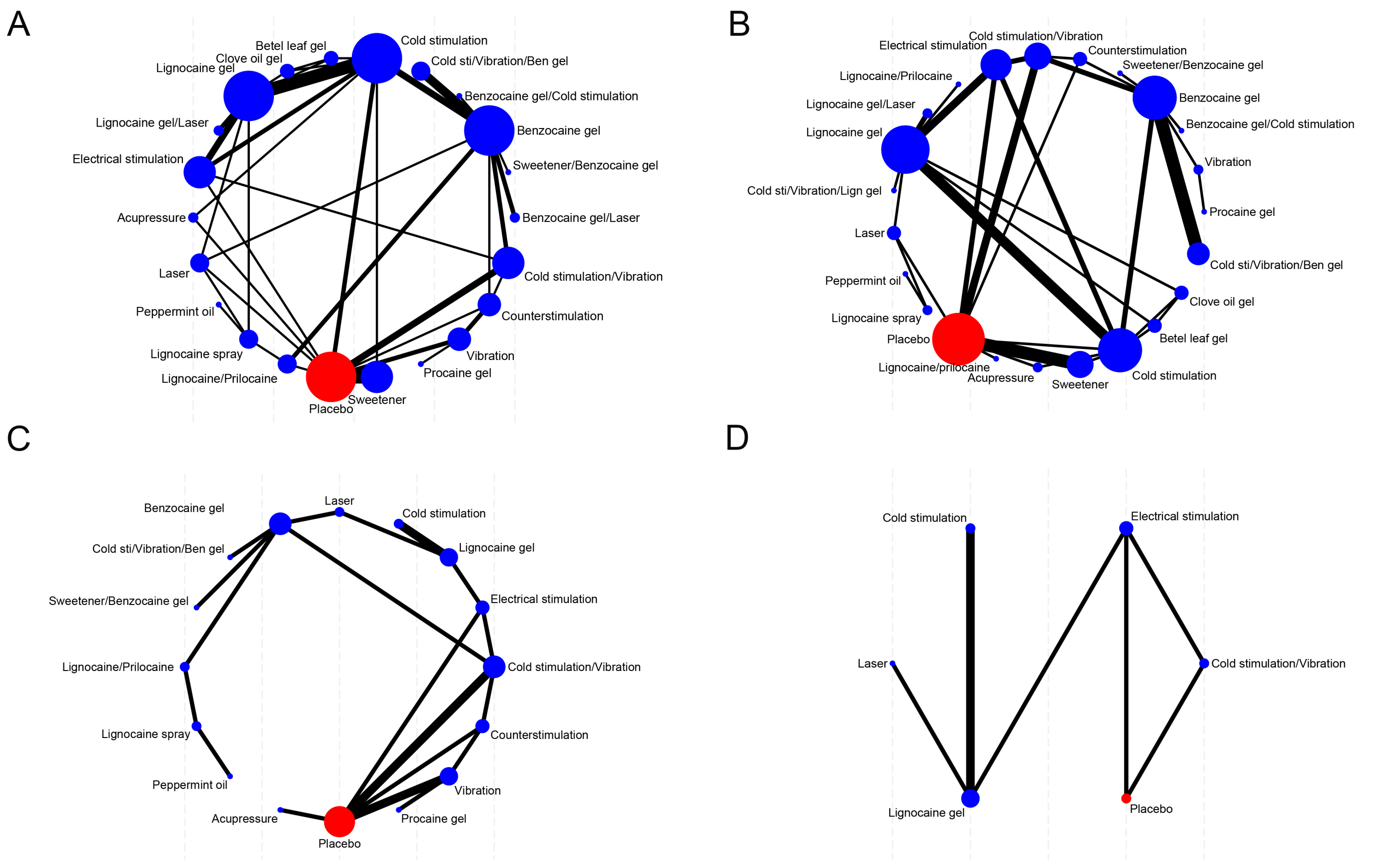

FIGURE 3. Network diagram. (A) Pain (subjective scale); (B) Pain (objective scale); (C) HR; (D) Oxygen saturation. Note: The abbreviation "Cold sti/Vibration/Ben gel" stands for "the combination of cold stimulation/vibration/benzocaine gel".

TABLE 1. Convergence of Bayesian NMA model and overall heterogeneity.

	Dbar	pD	DIC		ΔDIC	I^2	
			Consistency	Ume		Consistency	Ume
Subjective pain	58.67807	56.52378	115.31214	115.20185	0.11029	5%	5%
Objective pain	46.41668	44.96574	91.38242	91.59986	0.21744	3%	3%
Heart Rate	50.92943	32.95283	83.88226	80.17074	3.71152	27%	18%
Blood Oxygen	11.13005	11.03370	22.16375	22.09801	0.06574	10%	10%

Dbar: posterior mean of the residual deviance; pD: effective number of parameters; DIC: deviance information criterion.

TABLE 2. League table for oxygen saturation.

	Placebo	Lignocaine gel	Electrical stimulation	Cold stimulation	Laser
Lignocaine gel	0.39 (−3.75, 4.53)				
Electrical stimulation	0.73 (−2.63, 4.05)	0.34 (−2.12, 2.8)			
Cold stimulation	1.35 (−3.07, 5.83)	0.96 (−0.63, 2.61)	0.62 (−2.31, 3.6)		
Laser	0.61 (−4.18, 5.45)	0.23 (−2.25, 2.7)	−0.11 (−3.6, 3.38)	−0.73 (−3.72, 2.21)	
Cold stimulation/Vibration	0.44 (−2.94, 3.81)	0.05 (−4.06, 4.16)	−0.29 (−3.59, 3.04)	−0.91 (−5.34, 3.49)	−0.17 (−4.95, 4.63)

The data in the table are the MD (95% CrI) of the intervention in the row compared to that in the column. A larger positive MD represents higher oxygen saturation, and 0 represents no difference between the two interventions.

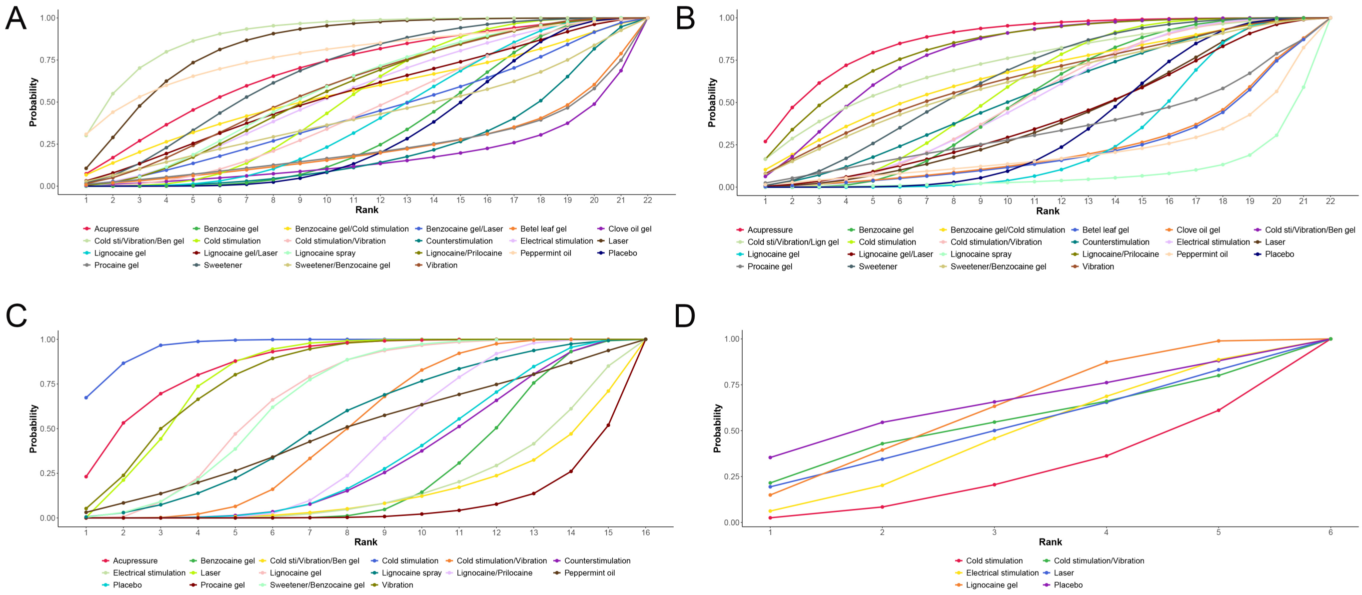

FIGURE 4. SUCRA values. (A) Pain (subjective scale); (B) Pain (objective scale); (C) HR; (D) Oxygen saturation. Note: The abbreviation “Cold sti/Vibration/Ben gel” stands for “the combination of cold stimulation/vibration/benzocaine gel”.

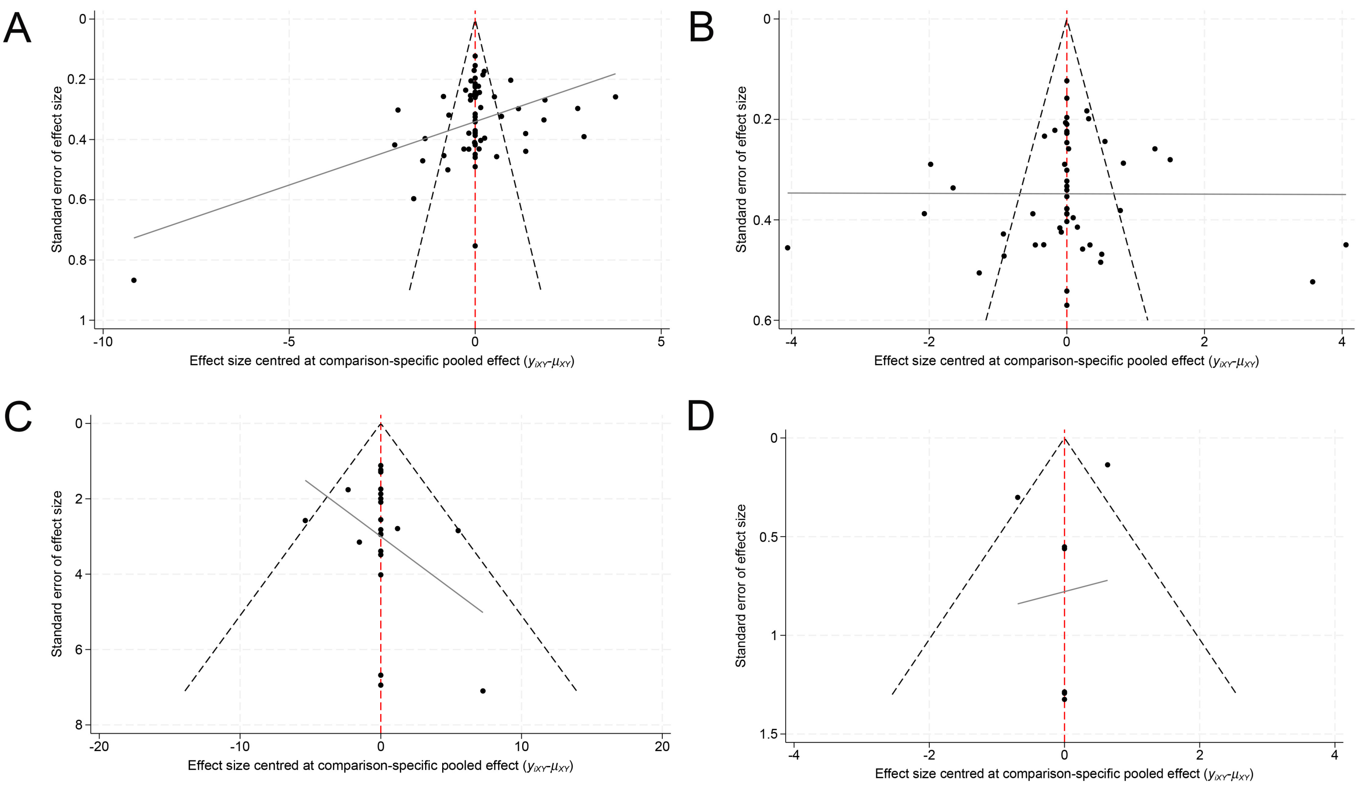

FIGURE 5. Comparison-adjusted funnel plots for publication bias. (A) Pain (subjective scale); (B) Pain (objective scale); (C) HR; (D) Oxygen saturation.

Objective pain scales are often used by healthcare providers or observers to indirectly quantify pain intensity by assessing observable physiological indicators and behaviors, without relying on the patient’s subjective description. The objective pain scales included in this study were SEM and FLACC. The SEM is based on verbal/vocal responses to sound stimuli, ocular responses, and limb movements. The FLACC scale is a standardized behavioral pain assessment tool used by healthcare providers. It quantifies pain intensity during local anesthesia by fully observing facial expression, leg movement, activity, crying, and consolability.

Our analysis revealed that acupressure was superior in reducing objective pain during local anesthetic injection, and the combination of lignocaine/prilocaine and the combination of cold stimulation, vibration, and benzocaine gel were also effective. Acupressure has been applied in dental analgesia for many years. Usichenko *et al*. [56] reported in 2016 that bilateral acupuncture at Hegu (LI4) acupoint maintained HR at a lower level during dental treatment compared with no acupuncture. The mechanism of acupuncture in pain relief involves blocking pain signaling to the spinal cord or brain (based on the gate control theory), and promoting the generation of analgesic substances (*e.g.*, endorphins and enkephalins) [57]. Acupuncture may reduce the need for analgesic medications, thereby avoiding associated side effects. However, it may also trigger adverse events, including poor hygiene-induced infections, headaches, hypotension, vertigo, palpitations, muscle spasms, soreness, and fatigue. Additionally, acupuncture is invasive, which may exacerbate anxiety in children [58]. Therefore, laser acupuncture has been explored. Laser acupuncture uses a low-level laser to stimulate traditional acupoints. This technique is not only painless but also non-invasive, atraumatic, and easy to perform, with no risk of cross-infection [59]. Sandhyarani *et al*. [60] (2021) reported that low-level laser at the Hegu point (LI4) before local anesthetic injection significantly relieves pain sensations. However, clinical studies on laser acupuncture remain limited, with only two included in this review [31, 35]. These studies used various assessment scales (FLACC, FPS, SEM, and Wong-Baker) and different outcome metrics, and they originated mostly from the Asia-Pacific region. Therefore, additional high-quality, large-sample, multicenter RCTs should be conducted in the future to determine the statistical and clinical significance of laser acupuncture compared with other interventions for alleviating pain in local anesthesia. Accordingly, these findings should be interpreted with caution.

Subjective pain scales are designed to quantify the nature and intensity of pain based on patients' subjective perceptions, experiences, and descriptions. They are grounded in a core medical principle: Pain is a subjective experience, and the patient is the most authoritative in reporting pain sensations. The subjective pain scales included in this study were the Wong-Baker FACES Pain Rating Scale and VAS. In the Wong-Baker scale, pediatric patients select corresponding facial expressions for scoring. In the VAS, patients mark a point on a fixed-length line to convert their internal, abstract pain sensations into a measurable linear distance value, thereby quantifying pain intensity.

The combination of cold stimulation, vibration, and benzocaine gel was ranked as the most effective intervention for reducing subjective pain during local anesthesia, whereas laser and peppermint oil were also effective. Cold stimulation and vibration are thought to reduce pain through the gate control theory of pain. Specifically, pain signals transmitted from the peripheral nervous system to the central nervous system are regulated by a "gate" in the spinal dorsal horn. The afferent A-δ fibers conveying acute pain and the slower C fibers are blocked by the motor nerves (A-β fibers) that rapidly transmit non-noxious stimuli. Therefore, vibration as a counter-stimulus during anesthetic injection can prioritize perception of the vibration in the brain over the injection pain [61]. Furthermore, sustained cold stimulation can activate C fibers, potentially further blocking pain signaling via A-δ fibers [62].

Cold stimulation, vibration, and topical anesthesia are widely used to alleviate pain during local anesthesia in pediatric dentistry. Numerous studies have investigated cold stimulation, vibration, benzocaine gel, and combination of these interventions; however, their conclusions remain inconsistent. Sahithi *et al*. [16] argued that the combination of cold stimulation and vibration was more effective than counterstimulation in relieving pain. In contrast, Ponnan *et al*. [32] concluded that counterstimulation outperformed the combination of cold stimulation and vibration. Meanwhile, the combination of cold stimulation and vibration has also been compared with topical anesthesia, but no statistically significant result was found [53]. These studies used different pain assessment scales and study methods, which may account for the inconsistent conclusions.

Self-reporting is considered the gold standard for pain assessment in children [63, 64]. Among all available self-report methods, pictures are preferred by children [65, 66]. Therefore, the Wong-Baker Scale is utilized to assess pain in children in numerous studies. It has been reported that children with anxiety tend to select faces expressing discomfort to reflect pain even when experiencing no pain. However, the Wong-Baker Scale often overestimates the pain level [63]. Pain is a highly individualized, multidimensional experience involving sensory, cognitive, emotional, and sociocultural factors. Although pain is the primary concern reported by patients, no standard value of pain intensity can be obtained by an objective "pain meter". Different scales have their limitations. The Pieces of Hurt tool [67] demonstrates only modest reliability and validity in preschool children aged 3–4 years. The Faces Pain Scale has demonstrated good psychometric properties and feasibility, however, evidence regarding its interpretability remainslimited, and the evidence regarding acceptability to children is mixed [68]. The VAS demonstrates good acceptability, responsivity, and validity for most children aged 8 years and older [69]. However, interpretation of VAS pain score may be challenging [70]. In conclusion, no single scale is optimal for evaluating all types of pain, as each instrument captures only specific dimensions of pain. The assessment results may be substantially influenced by the patient's age, cognitive level, cultural background, language ability, and emotional state [66]. Moreover, they cannot directly compare pain between different individuals. Therefore, objective and subjective scales should be combined to assess pain.

Changes in heart rate (HR) during local anesthetic injection in pediatric dentistry primarily reflect psychological fear and physiological stress, and may indirectly reflect the effects of different interventions in relieving pain during local anesthesia [18]. However, HR is also affected by the psychology and anxiety of children. Therefore, HR was used as a secondary outcome in this study. Consistent with the findings from objective and subjective pain scales, our results indicated that cold stimulation effectively reduced HR during local anesthetic injection in children, and acupressure and laser interventions also demonstratedstatistically significant effects.

Although SMDs may allow us to pool pain outcomes measured with different scales, their interpretation is less intuitive than MDs derived from a single measurement scale, and the results may be influenced by between-participant heterogeneity across studies. Therefore, the relative rankings of pain control strategies should be interpreted cautiously.

The included studies originated from nine countries, however, only one study was conducted in Africa, one in Europe, and one in the North America. Almost all other studies were from Asia, which may have introduced geographical limitations and potential regional bias. Therefore, the results should be interpreted carefully, and more international, multicenter, large-sample prospective RCTs using standardized objective and subjective pain assessments are required to further evaluate the efficacy of different interventions.

Although all included studies involved pediatric populations, participant ages varied considerably, ranging from 6 to 18 years, which may have contributed to heterogeneity. However, due to limitations in the available data, subgroup analyses according to age groups could not be performed. Future studies are expected to conduct more detailed analyses across different age groups to better address this concern.

This NMA is the first study to comprehensively compare the clinical efficacy of multiple physical interventions for relieving injection pain during local anesthesia in pediatric dentistry.

This NMA suggested that acupressure was the most effective intervention for reducing objective pain. However, this finding should be interpreted with caution because the number of high-quality related studies evaluating acupressure was limited.

The effect of acupressure, despite its top ranking in this analysis, should be interpreted with caution and is not readily generalizable to routine practice. Clinicians should have appropriateknowledge and training regarding acupuncture techniques before considering its applicationin pediatric patients.

The combination of cold stimulation,vibration, and benzocaine gel demonstrated a definite and robust effect on reducing both objective and subjective pain, as well as improving HR. This intervention offers a more readily applicable and evidence-supported strategy in the management of fear and anxiety in children during local anesthesia.

In this NMA, 45 studies were included, with diverse interventions and assessment scales, which may still influence the interpretability of results. Most included studies originated from the Asia-Pacific region, possibly introducing a geographic bias. In the future, more international, multicenter, large-sample prospective RCTs using standardized objective/subjective pain assessment scales are required to assess the efficacy of different interventions.

5. Conclusion

This study investigated physical interventions for reducing injection pain, including objective and subjective pain, HR, and oxygen saturation during local anesthetic injection in pediatric dentistry. Acupressure, the combination of cold stimulation, vibration, and benzocaine gel, and cold stimulation ranked highest for reducing objective pain, subjective pain, and HR, respectively. However, these findings should be interpreted with caution because the efficacy of several interventions was supported by limited evidence, and the included studies varied in pain assessment scales and geographic distribution. Therefore, additional multicenter, large-sample prospective RCTs are required to validate these findings and establish their clinical applicability.

AVAILABILITY OF DATA AND MATERIALS

All data generated or analysed during this study are included in this published article and its **Supplementary materials**.

AUTHOR CONTRIBUTIONS

JRH—conceptualization, methodology, software, validation, formal analysis, investigation, resources, data curation, writing–original draft, writing–review and editing. PFW—formal analysis, investigation, resources, data curation, writing–original draft, writing–review & editing. RML—writing–review & editing, visualization, supervision, project administration. All authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Not applicable.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

SUPPLEMENTARY MATERIAL

Supplementary material associated with this article can be found, in the online version, at https://oss.jocpd.com/files/article/2095383316746125312/attachment/Supplementary%20material.zip.

REFERENCES

[1] Shim YS, Kim AH, Jeon EY, An SY. Dental fear & anxiety and dental pain in children and adolescents; a systemic review. Journal of Dental Anesthesia and Pain Medicine. 2015; 15: 53–61.

[2] Remi RV, Anantharaj A, Praveen P, Prathibha RS, Sudhir R. Advances in pediatric dentistry: new approaches to pain control and anxiety reduction in children—a narrative review. Journal of Dental Anesthesia and Pain Medicine. 2023; 23: 303–315.

[3] Taneja S, Singh A, Jain A. Anesthetic effectiveness of articaine and lidocaine in pediatric patients during dental procedures: a systematic review and meta-analysis. Pediatric Dentistry. 2020; 42: 273–281.

[4] Alameeri AA, AlShamsi HA, Murad A, Alhammadi MM, Alketbi MH, AlHamwi A, *et al*. The feasibility of needleless jet injection versus conventional needle local anesthesia during dental procedures: a systematic review. Journal of the Korean Association of Oral and Maxillofacial Surgeons. 2022; 48: 331–341.

[5] Patel D, Lahiri B, El-Patal MA, Alazmah A, Patel P, Abokhlifa YH. To compare and analyze the potency of two topical anesthetic gels in reducing inferior alveolar injection pain in children of 8–12 years: a double-blinded clinical trial. Journal of Pharmacy and Bioallied Sciences. 2021; 13: S646–S650.

[6] Chen J, Deng K, Yu D, Fan C, Liu L, Gu H, *et al*. Recent developments in the non-pharmacological management of children's behavior based on distraction techniques: a concise review. Healthcare. 2024; 12: 1940.

[7] Garret-Bernardin A, Cantile T, D'Antò V, Galanakis A, Fauxpoint G, Ferrazzano GF, *et al*. Pain experience and behavior management in pediatric dentistry: a comparison between traditional local anesthesia and the wand computerized delivery system. Pain Research & Management. 2017; 2017: 7941238.

[8] Ninawe N, Anija CK. Comparative evaluation of effectiveness of benzocaine gel and ice for pain management in children during local anesthetic administration by CCLAD: a randomized controlled trial. International Journal of Clinical Pediatric Dentistry. 2025; 18: 19–23.

[9] Bollepalli B, Penmetsa A, Peddi R, Mannam H, Koruprolu R, Penmetsa GS. Comparison of efficacy of photobiomodulation and topical anesthetic spray in reducing the injection pain in children aged 6–12 years—a randomized clinical trial. Journal of Indian Society of Pedodontics and Preventive Dentistry. 2025; 43: 269–275.

[10] Vafaei A, Rahbar M, Dadkhah R, Ranjkesh B, Erfanparast L. Children's pain perception and behavioral feedback during local anesthetic injection with four injection site preparation methods. Maedica. 2019; 14: 343–349.

[11] Goyal S, Patel M, Bhatt R, Vaghela L, Vadher R, Choksi K. Comparative evaluation of different pain-alleviating methods on child's dental anxiety and pain perception during local anesthesia administration: a clinical study. International Journal of Clinical Pediatric Dentistry. 2024; 17: 1265–1271.

[12] Hutton B, Salanti G, Caldwell DM, Chaimani A, Schmid CH, Cameron C, *et al*. The PRISMA extension statement for reporting of systematic reviews incorporating network meta-analyses of health care interventions: checklist and explanations. Annals of Internal Medicine. 2015; 162: 777–784.

[13] Murad MH, Wang Z, Chu H, Lin L. When continuous outcomes are measured using different scales: guide for meta-analysis and interpretation. The BMJ. 2019; 364: k4817.

[14] Salanti G. Indirect and mixed-treatment comparison, network, or multiple-treatments meta-analysis: many names, many benefits, many concerns for the next generation evidence synthesis tool. Research Synthesis Methods. 2012; 3: 80–97.

[15] Chauhan PS, Farheen S, Ganti S, Nasyam FA, Tekam DA, Shah P. Comparative analysis of two different topical anesthetic gels on pain perception during local anesthetic solution administration in pediatric dental patients. NeuroQuantology. 2022; 20: 10437–10441.

[16] Sahithi V, Saikiran KV, Nunna M, Elicherla SR, Challa RR, Nuvvula S. Comparative evaluation of efficacy of external vibrating device and counterstimulation on child's dental anxiety and pain perception during local anesthetic administration: a clinical trial. Journal of Dental Anesthesia and Pain Medicine. 2021; 21: 345–355. Erratum in: Journal of Dental Anesthesia and Pain Medicine. 2023; 23: 121.

[17] Havale R, Rao DG, S P S, M Tuppadmath K, Tharay N, Mathew I, *et al*. Comparative evaluation of pain perception following topical application of clove oil, betel leaf extract, lignocaine gel, and ice prior to intraoral injection in children aged 6–10 years: a randomized control study. Journal of Dental Anesthesia and Pain Medicine. 2021; 21: 329–336.

[18] Petluru H, Nirmala S, Nuvvula S. A comparative evaluation of peppermint oil and lignocaine spray as topical anesthetic agents prior to local anesthesia in children: a randomized clinical trial. Journal of Dental Anesthesia and Pain Medicine. 2024; 24: 119–128.

[19] Saxena B, Goswami M, Singh S, Saxena A. Comparative evaluation of the effectiveness of transcutaneous electric nerve stimulation and photo-biostimulation using diode laser prior to local anesthesia administration in children undergoing bilateral orthodontic extraction—a randomized controlled clinical trial. Lasers in Medical Science. 2025; 40: 177.

[20] Chittora M, Rao D, Panwar S, Samaddar K, Remi RV. A comparative evaluation of the efficiency of warm local anesthetic solution delivered on precooled injection sites with the conventional local anesthetic technique in 7–9-year-old children: a randomized split-mouth cross-over trial. Journal of Indian Society of Pedodontics and Preventive Dentistry. 2024; 42: 126–133.

[21] Dak-Albab R, Al-Monaqel MB, Koshha R, Shakhashero H, Soudan R. A comparison between the effectiveness of vibration with Dentalvibe and benzocaine gel in relieving pain associated with mandibular injection: a randomized clinical trial. Anaesthesia, Pain and Intensive Care. 2016; 20: 43–49.

[22] Primosch RE, Rolland-Asensi G. Comparison of topical EMLA 5% oral adhesive to benzocaine 20% on the pain experienced during palatal anesthetic infiltration in children. Pediatric Dentistry. 2001; 23: 11–14.

[23] AlHareky M, AlHumaid J, Bedi S, El Tantawi M, AlGahtani M, AlYousef Y. Effect of a vibration system on pain reduction during injection of dental anesthesia in children: a randomized clinical trial. International Journal of Dentistry. 2021; 2021: 8896408.

[24] Davangere Padmanabh SK, Gangurde VB, Jhamb V, Gori N. Effect of cryoanesthesia and sweet tasting solution in reducing injection pain in pediatric patients aged 7–10 years: a randomized controlled trial. Journal of Dental Anesthesia and Pain Medicine. 2024; 24: 37–45.

[25] Nagpal DI, Dharampuria SR, Singh P, Chaudhari P, Rathi P, Gurharikar A. Effect of lidocaine ice button topical anesthesia on pain during maxillary buccal infiltration in 6–10-year children—a randomized control trial. Journal of Indian Society of Pedodontics and Preventive Dentistry. 2025; 43: 261–268.

[26] Seraj B, Bavaghar A, Hakimiha N, Hosseini Z, Kharazifard MJ, Ghadimi S. Effect of photobiomodulation therapy with an 810-nm diode laser on pain perception associated with dental injections in children: a double-blind randomized controlled clinical trial. Journal of Lasers in Medical Sciences. 2023; 14: e19.

[27] Ghaderi F, Banakar S, Rostami S. Effect of pre-cooling injection site on pain perception in pediatric dentistry: "a randomized clinical trial". Dental Research Journal. 2013; 10: 790–794.

[28] Virda M, Panda A, Kataria K. Effect of preemptive analgesia on pain perception in children: a randomized controlled trial. International Journal of Clinical Pediatric Dentistry. 2024; 17: 913–917.

[29] Hegde KM, R N, Srinivasan I, D R MK, Melwani A, Radhakrishna S. Effect of vibration during local anesthesia administration on pain, anxiety, and behavior of pediatric patients aged 6–11 years: a crossover split-mouth study. Journal of Dental Anesthesia and Pain Medicine. 2019; 19: 143–149.

[30] Ferrazzano GF, Di Fabio G, Gatto R, Caruso S, Botticelli G, Caruso S. Effectiveness and tolerability of a new formulation of a topical anesthetic in reduction of pain and parents' satisfaction in pediatric dentistry. Children. 2023; 10: 444.

[31] Pushpasanthy M, Ephraim R, Ayilliath A, Dhanya KB. Effectiveness of Aculief acupressure device on pain perception during local anesthesia in children: a double-blinded study. Journal of Indian Society of Pedodontics and Preventive Dentistry. 2023; 41: 309–315.

[32] Ponnan V, Santhakumar M, Thekke Veetil AK. Effectiveness of an external cooling and vibrating device *vs* counterstimulation in reducing discomfort of inferior alveolar nerve block in pediatric dental patients: a single-blinded randomized controlled trial. International Journal of Clinical Pediatric Dentistry. 2024; 17: 1335–1339.

[33] Hambouta HM, Sharaf DA, Wahba NA. Effectiveness of cold vibratory stimuli on pain perception governing infiltration anesthesia in the maxillary arch in children: a randomized controlled clinical trial. BMC Oral Health. 2025; 25: 900.

[34] Narimany R, Faghihian R, Jafarzadeh Samani M. Effectiveness of external precooling and vibration induced by BUZZY on pain and anxiety during inferior alveolar nerve block injection in children. International Journal of Dentistry. 2024; 2024: 5515522.

[35] Pooja B, Kamatham R, Anchala K, Avisa P. Effectiveness of low-level laser therapy in reducing pain perception of children during dental local anesthetic administration using laser acupuncture pen on the LI4 point: a randomized clinical trial. European Archives of Paediatric Dentistry.

2023; 24: 219–227.
[36] Janiani P, Gurunathan D. Effectiveness of pre-administered natural sweet-tasting solution for decreasing pain associated with dental injections in children: a split-mouth randomized controlled trial. The Journal of Contemporary Dental Practice. 2021; 22: 1434–1437.
[37] Agarwal N, Dhawan J, Kumar D, Anand A, Tangri K. Effectiveness of two topical anaesthetic agents used along with audio visual aids in paediatric dental patients. Journal of Clinical and Diagnostic Research. 2017; 11: ZC80–ZC83.
[38] Uçar G, Şermet Elbay Ü, Elbay M. Effects of low level laser therapy on injection pain and anesthesia efficacy during local anesthesia in children: a randomized clinical trial. International Journal of Paediatric Dentistry. 2022; 32: 576–584.
[39] Elbay M, Elbay ÜŞ, Kaya E, Kalkan ÖP. Effects of photobiomodulation with different application parameters on injection pain in children: a randomized clinical trial. Journal of Clinical Pediatric Dentistry. 2023; 47: 54–62.
[40] Al-Batayneh OB, Abu-Abbas R, Al-Saleh M. Efficacy of administering a sugar-free flavor before dental injections on pain perception in children: a split-mouth randomized crossover clinical trial. International Journal of Paediatric Dentistry. 2024; 34: 915–924.
[41] Ghaderi F, Ahmadbeigi M, Vossoughi M, Sardarian A. The efficacy of administrating a sweet-tasting solution for reducing the pain related to dental injections in children: a randomized controlled trial. International Journal of Paediatric Dentistry. 2021; 31: 184–190.
[42] H A, Rao A, Natarajan S, Yarmunja Mahabala K, Nayak A. Efficacy of an external cold and vibrating device in reducing discomfort during the administration of an inferior alveolar nerve block in children: a split-mouth randomised crossover study. F1000Research. 2023; 12: 984.
[43] Lakshmanan L, Ravindran V. Efficacy of cryotherapy application on the pain perception during intraoral injection: a randomized controlled trial. International Journal of Clinical Pediatric Dentistry. 2021; 14: 616–620.
[44] Alanazi KJ, Pani S, AlGhanim N. Efficacy of external cold and a vibrating device in reducing discomfort of dental injections in children: a split mouth randomised crossover study. European Archives of Paediatric Dentistry. 2019; 20: 79–84.
[45] Jain N, Juneja P, Masih U, Bhushan AKB, Bhaduaria US, Badjatya K. Efficacy of external cold and a vibrating device in reducing pain and anxiety during local anaesthesia. Journal of Family Medicine and Primary Care. 2021; 10: 4017–4022.
[46] Bilsin E, Güngörmüş Z, Güngörmüş M. The efficacy of external cooling and vibration on decreasing the pain of local anesthesia injections during dental treatment in children: a randomized controlled study. Journal of Perianesthesia Nursing. 2020; 35: 44–47.
[47] Sharma A, Suprabha BS, Shenoy R, Rao A. Efficacy of lignocaine in gel and spray form during buccal infiltration anesthesia in children: a randomized clinical trial. The Journal of Contemporary Dental Practice. 2014; 15: 750–754.
[48] Ratnaparkhi I, Winnier J, Shetty D, Kodical SR, Manoj R, Naik SS. Efficacy of sucrose application in minimizing pain perception related to dental injection in children aged 3 to 9 years: a randomized control trial. Journal of Dental Anesthesia and Pain Medicine. 2024; 24: 109–117.
[49] Shekarchi F, Nokhbatolfoghahaei H, Chiniforush N, Mohaghegh S, Haeri Boroojeni HS, Amini S, *et al*. Evaluating the preemptive analgesic effect of photo-biomodulation therapy on pain perception during local anesthesia injection in children: a split-mouth triple-blind randomized controlled clinical trial. Photochemistry and Photobiology. 2022; 98: 1195–1200.
[50] Cantekin K. Evaluation of different forms of topical anesthesia agents in dental practice. Children. 2025; 12: 610.
[51] Dehgan D, Şermet Elbay Ü, Elbay M. Evaluation of the effects of photobiomodulation with different laser application doses on injection pain in children: a randomized clinical trial. Lasers in Medical Science. 2022; 38: 6.
[52] Tatiya N, Singh C, Surana P, Ukey A, Gupta PR, Blesson A. Evaluation of the efficacy of a customized mucosal vibrator in alleviating pain perception associated with local anesthesia administration in children aged 6–10 years. International Journal of Clinical Pediatric Dentistry. 2024; 17: 404–409.
[53] Faghihian R, Tofighi MM, Ziaei S, Afzali SL. External cold and vibration with BUZZY versus topical anesthetic gel for pain and anxiety associated with infiltrative anesthesia in pediatric dentistry: a double-blinded, split-mouth, randomized, controlled trial. European Oral Research. 2025; 59: 7–11.
[54] Singh K, Jhingan P, Mathur S, Malik M, Kashyap K. Intercomparison of efficacy of transcutaneous electrical nerve stimulation and precooling vibration device on pain and anxiety management during administration of local anesthesia injection in 6–12-year-olds. International Journal of Clinical Pediatric Dentistry. 2024; 17: 297–302.
[55] Shah NM, Gulati R, Rasalkar T, Nasha D, Arya A, Tekam D. Pain perception during local anesthesia administration in pediatric dental patients and the impact of pre-cooling the injection site: an *in-vivo* study. Journal of Pharmacy and Bioallied Sciences. 2024; 16: S2119–S2121.
[56] Usichenko TI, Wolters P, Anders EF, Splieth C. Acupuncture reduces pain and autonomic distress during injection of local anesthetic in children: a pragmatic crossover investigation. The Clinical Journal of Pain. 2016; 32: 82–86.
[57] Zhou W, Benharash P. Effects and mechanisms of acupuncture based on the principle of meridians. Journal of Acupuncture and Meridian Studies. 2014; 7: 190–193.
[58] Gold JI, Nicolaou CD, Belmont KA, Katz AR, Benaron DM, Yu W. Pediatric acupuncture: a review of clinical research. Evidence-Based Complementary and Alternative Medicine. 2009; 6: 429–439.
[59] Ferreira LA, de Oliveira RG, Guimarães JP, Carvalho AC, De Paula MV. Laser acupuncture in patients with temporomandibular dysfunction: a randomized controlled trial. Lasers in Medical Science. 2013; 28: 1549–1558.
[60] Sandhyarani B, Pawar RR, Patil AT, Kevadia MV. Effect of low-level laser on LI4 acupoint in pain reduction during local anesthesia in children. International Journal of Clinical Pediatric Dentistry. 2021; 14: 462–466.
[61] Kakigi R, Shibasaki H. Mechanisms of pain relief by vibration and movement. Journal of Neurology, Neurosurgery, and Psychiatry. 1992; 55: 282–286.
[62] Nahra H, Plaghki L. Innocuous skin cooling modulates perception and neurophysiological correlates of brief CO_2 laser stimuli in humans. European Journal of Pain. 2005; 9: 521–530.
[63] Stinson JN, Kavanagh T, Yamada J, Gill N, Stevens B. Systematic review of the psychometric properties, interpretability and feasibility of self-report pain intensity measures for use in clinical trials in children and adolescents. Pain. 2006; 125: 143–157.
[64] Hadjistavropoulos T, Craig KD. A theoretical framework for understanding self-report and observational measures of pain: a communications model. Behaviour Research and Therapy. 2002; 40: 551–570.
[65] Wong DL, Baker CM. Pain in children: comparison of assessment scales. Pediatric Nursing. 1988; 14: 9–17.
[66] Nilsson S, Finnström B, Kokinsky E. The FLACC behavioral scale for procedural pain assessment in children aged 5–16 years. Paediatric Anaesthesia. 2008; 18: 767–774.
[67] Hester N, Foster R, Kristensen K. Measurement of pain in children: generalizability and validity of the pain ladder and pieces of hurt tool. In Tyler D, Krane E (eds.) Pediatric pain. vol 15, advances in pain research and therapy (pp. 79–84). Raven Press: New York. 1990.
[68] Chambers CT, Hardial J, Craig KD, Court C, Montgomery C. Faces scales for the measurement of postoperative pain intensity in children following minor surgery. The Clinical Journal of Pain. 2005; 21: 277–285.
[69] Champion GD, Goodenough B, von Baeyer CL, Thomas W. Measurement of pain by self-report. In Finley GA, McGrath PJ (eds.) Measurement of pain in infants and children (pp. 123–160). IASP Press: Seattle. 1998.
[70] Berntson L, Svensson E. Pain assessment in children with juvenile chronic arthritis: a matter of scaling and rater. Acta Paediatrica. 2001; 90: 1131–1136.

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