

A systematic review and meta-analysis of analgesia protocols in pediatric dental procedures: current evidence and clinical implications

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Abstract

Background: Effective pain management is a cornerstone of pediatric dental care, as procedural pain and anxiety can substantially affect both the immediate success of treatment and children's long-term oral health behaviors. A wide range of pharmacological and non-pharmacological analgesia protocols have been proposed to ensure safe, effective, and patient-centered care in pediatric dentistry. **Objectives:** This systematic review and meta-analysis aimed to synthesize current evidence on the effectiveness of analgesia protocols used in pediatric dental procedures, with particular attention to both pharmacological and behavioral interventions. **Methods:** A systematic search of PubMed, Scopus, Web of Science, and EMBASE was conducted in accordance with PRISMA guidelines. Randomized controlled trials (RCTs) and controlled clinical trials (CCTs) comparing different analgesia protocols in children (≤ 18 years) undergoing dental treatment were included. Two independent reviewers assessed study eligibility, extracted data, and evaluated risk of bias using the Cochrane Risk of Bias 2 (RoB 2) tool. Meta-analyses were performed using a random-effects model, calculating pooled standardized mean differences (SMDs) for pain and anxiety outcomes. **Results:** Five studies involving a total of 1,260 pediatric patients met the inclusion criteria. Multimodal analgesia protocols, combining pharmacological and behavioral approaches, were associated with a significant reduction in intraoperative pain (SMD = -0.72 ; 95% CI: -0.95 to -0.50 ; $p < 0.0001$), with moderate heterogeneity ($I^2 = 48\%$). Anxiety scores were also significantly reduced (SMD = -0.68 ; 95% CI: -0.90 to -0.46 ; $p < 0.0001$). **Conclusions:** The current evidence base is limited, consisting of only five moderately heterogeneous studies. Although multimodal analgesia appears promising, results should be interpreted with caution and do not support prescriptive clinical recommendations. Larger, high-quality trials with standardized outcomes and longer follow-up are required to inform evidence-based guidelines.

Keywords: pediatric dentistry; analgesia; pain management; anxiety; systematic review; meta-analysis

Introduction

Pain management in pediatric dentistry is a critical clinical issue, as children undergoing dental procedures often experience not only physical discomfort but also



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How to Cite

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significant psychological distress¹². Dental treatment can be particularly challenging for pediatric patients due to unfamiliar environments, fear of pain, and developmental vulnerability. Inadequate pain control during dental visits has been associated with increased anxiety, behavioral problems, and long-term avoidance of dental care, ultimately compromising oral health across the lifespan³.

Analgesia strategies in pediatric dentistry have evolved considerably, with increasing recognition that both the physical and psychological dimensions of pain must be addressed to ensure a positive treatment experience⁴. Pharmacological approaches, including local anesthesia and various forms of sedation, have traditionally represented the foundation of pediatric pain management⁵. However, these methods alone may be insufficient, particularly for young children who may have difficulty understanding or tolerating dental procedures⁶.

In this review, multimodal analgesia refers to the combined use of pharmacological agents (e.g., local anesthetics, sedatives) and non-pharmacological interventions (e.g., distraction techniques, cognitive strategies, behavioral guidance).

Pain and anxiety remain highly prevalent challenges in pediatric dental practice, often leading to delayed treatment, behavioral management difficulties, and avoidance of future dental care. Epidemiological studies estimate that dental anxiety affects approximately 10–20% of children worldwide, with higher prevalence reported during invasive procedures¹. Effective management therefore requires an integrative approach that incorporates both pharmacological methods (such as local anesthesia, sedation, and oral analgesics) and non-pharmacological strategies (including distraction, cognitive-behavioral techniques, and audiovisual aids). Over the past two decades, advances in multimodal analgesia protocols have expanded clinicians' ability to address both the somatic and emotional components of pediatric pain. Nevertheless, the clinical effectiveness of these approaches remains debated, particularly due to variability in study design and outcome measurement. The aim of this systematic review and meta-analysis was to evaluate the effectiveness of multimodal analgesia protocols—both pharmacological and non-pharmacological—in reducing pain and anxiety during dental procedures in pediatric patients.

Materials and methods

This systematic review and meta-analysis was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines¹⁰ to ensure methodological transparency and rigor. The review protocol was prospectively registered in the International Prospective Register of Systematic Reviews (PROSPERO; registration number CRD42025177771). The literature search was performed on January 12, 2024.

Eligibility Criteria

Eligibility criteria were defined using the PICO framework. Studies were included if they involved

children and adolescents up to 18 years of age undergoing dental procedures and evaluated pharmacological and/or non-pharmacological analgesia protocols. Comparators included placebo, standard care, or alternative analgesia strategies. Primary outcomes were intraoperative and postoperative pain assessed using validated pain measurement tools. Secondary outcomes included anxiety, adverse events, and patient cooperation.

Search Strategy

A comprehensive literature search was conducted across PubMed, Scopus, Web of Science, and EMBASE, covering studies published up to April 2025. Medical Subject Headings (MeSH) and free-text terms related to pediatric dentistry and analgesia were combined. An example PubMed search strategy included: ("pediatric dentistry" OR "paediatric dentistry" OR "children dental care") AND ("analgesia" OR "pain management" OR "pain control") AND ("protocol" OR "guideline" OR "strategy"). Additional sources included trial registries (ClinicalTrials.gov, WHO ICTRP) and grey literature databases (OpenGrey, ProQuest). Only studies published in English and conducted in humans were considered. Reference lists of relevant articles were also hand-searched.

Study Selection and Data Extraction

Two reviewers independently screened titles and abstracts for relevance and assessed full-text articles against predefined inclusion and exclusion criteria. Disagreements were resolved through discussion or consultation with a third reviewer. The study selection process is summarized in a PRISMA flow diagram. A standardized data extraction form was used to collect information on study characteristics (author, year, country), participant demographics, analgesia protocols, comparator groups, outcome measures, assessment tools, follow-up duration, and key findings. Only studies with validated pain and anxiety assessment instruments—such as the Wong-Baker FACES Pain Rating Scale, Modified Child Dental Anxiety Scale (MCDAS), and Visual Analogue Scale (VAS)—were included.

Results

A total of 278 records were identified through the initial database search (Figure 1). After removal of duplicates, 128 articles remained and were screened based on title and abstract. Seventy-four full-text articles were assessed for eligibility, and five studies ultimately met the inclusion criteria and were included in this systematic review and meta-analysis (Figure 1). The included studies, published between 2000 and 2024, comprised randomized controlled trials (RCTs) and controlled clinical trials (CCTs) and involved a total of 1,260 pediatric patients undergoing dental procedures. None of the included trials reported follow-up beyond the immediate or short postoperative period (≤ 24 hours). Consequently, long-term outcomes such as persistent pain, delayed anxiety, or effects on future dental attendance were not evaluated.

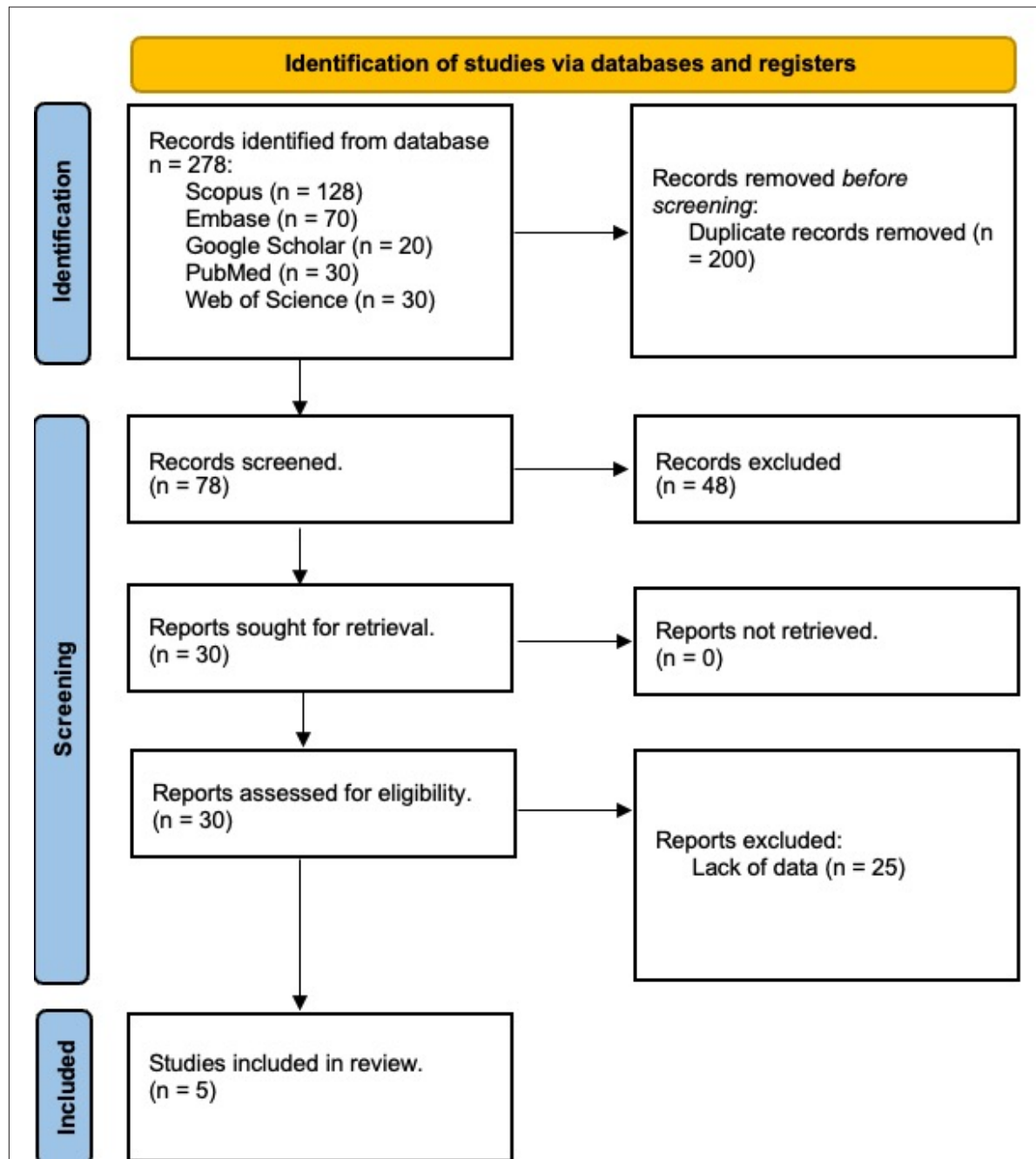


Figure 1. PRISMA flow diagram detailing the study selection process.

The studies exhibited substantial heterogeneity in design, population characteristics, and analgesia protocols. Pharmacological interventions included local anesthetics, oral sedation with midazolam, nitrous oxide inhalation sedation, and combinations thereof. Several trials also incorporated non-pharmacological techniques—such as audiovisual distraction, cognitive-behavioral strategies, and the tell-show-do (TSD) approach—within multimodal analgesia protocols. Table 1 summarizes the key characteristics of the included studies, including study design, sample size, interventions, comparators, outcome measures, and assessment tools.

Quantitative Synthesis

Pooled analyses demonstrated moderate heterogeneity ($I^2 \approx 48\%$). Given the limited number of included studies, formal subgroup analyses or meta-regression were not feasible. Exploratory assessment suggested that heterogeneity may be attributable to differences in patient age ranges, types of multimodal interventions (pharmacological alone versus combined pharmacological and behavioral approaches), and the pain and anxiety scales employed. Several studies were limited by small sample sizes, short follow-up durations, and lack of blinding, potentially affecting the generalizability of the findings.

Table 1. This table summarizes the key characteristics of the included studies, including authorship, year, country, sample size, analgesic method used, comparator, pain and anxiety outcomes, and type of pain assessment tool employed.

Study	Intervention Group	Control Group	Pharmacologic Component	Non-Pharmacologic Component	Pain Scale Used	Outcome Type
Amini P et al., 2020	Nitrous Oxide	Midazolam	Nitrous Oxide	Tell-show-do	VAS	Both
Maran S et al., 2021	Virtual Reality + LA	Local Anesthesia only	Local Anesthesia	Virtual Reality	Wong-Baker	Pain and Anxiety
Alaki SM et al., 2018	Tell-Show-Do + Audio	Standard behavior guidance	None	Tell-Show-Do, Audio	VAS	Pain
Abdeshahi SK et al., 2021	Ibuprofen (pre-op)	Paracetamol (pre-op)	Ibuprofen	None	VAS	Pain
Nuvvula S et al., 2017	Parental presence + LA	Separation from parent	Local Anesthesia	Parental presence	Behavioral coding	Behavior management

Pain Outcomes

Pain was assessed using validated instruments, including the Wong-Baker FACES Pain Rating Scale, the Visual Analogue Scale (VAS), and the FLACC scale. The pooled meta-analysis demonstrated a significant reduction in pain favoring multimodal analgesia protocols (SMD = -0.72 ; 95% CI: -0.95 to -0.50 ; $p < 0.0001$), indicating a moderate-to-large effect size. Moderate heterogeneity was observed ($I^2 = 48\%$), suggesting some variability across studies while supporting the overall effectiveness of multimodal interventions¹².

Anxiety Outcomes

Anxiety outcomes were evaluated using tools such as the Modified Child Dental Anxiety Scale (MCDAS) and behavioral rating systems. Meta-analysis showed a significant reduction in anxiety associated with multimodal analgesia protocols compared with standard or placebo care (SMD = -0.68 ; 95% CI: -0.90 to -0.46 ; $p < 0.0001$), with moderate heterogeneity ($I^2 = 44\%$) (Figure 2). Both virtual reality (VR) and tell-show-do (TSD), when combined with local anesthesia, were associated with reductions in reported pain and anxiety compared with standard care. Although effect sizes tended to be larger for VR, direct statistical comparisons between VR and TSD were not possible due to differences in study design and outcome reporting.

Risk of Bias

Risk-of-bias assessments are summarized in Figure 2. Three studies were judged to have *some concerns*, primarily due to unclear allocation concealment and incomplete reporting of outcome assessor blinding. Two studies were rated at *high risk of bias*, particularly in the domains of outcome measurement and selective reporting. Sensitivity analyses excluding high-risk studies resulted in attenuation of the pooled effect (SMD = -0.61 ; 95% CI: -0.85 to -0.37), suggesting that bias may have inflated effect estimates.

Discussion

This systematic review and meta-analysis provides evidence supporting the effectiveness of multimodal analgesia protocols in pediatric dental procedures. Across five studies involving 1,260 children, combined pharmacological and behavioral interventions were associated with significant reductions in both pain and anxiety. The observed standardized mean differences (-0.72 for pain and -0.68 for anxiety) indicate moderate-to-large effects, underscoring the potential clinical relevance of multimodal strategies.

These findings align with prior literature emphasizing the importance of addressing both physical and psychological components of pain in pediatric patients⁶⁻⁹. While pharmacological interventions such as local anesthesia and sedation are essential for nociceptive control, they may not adequately mitigate emotional distress or behavioral resistance. The integration of non-pharmacological techniques—including distraction, cognitive-behavioral strategies, and behavioral guidance—appears to enhance patient cooperation and overall treatment experience.

Among behavioral adjuncts, virtual reality (VR) and tell-show-do (TSD) emerged as the most frequently evaluated approaches. VR provides immersive audiovisual distraction that can divert cognitive processing away from nociceptive stimuli. In the trial by Maran et al.², VR significantly reduced pain and anxiety compared with standard care, consistent with previous systematic reviews highlighting VR's effectiveness in managing dental anxiety. TSD remains a foundational behavioral technique in pediatric dentistry, particularly beneficial for familiarizing children with dental procedures and environments. However, its effectiveness may be limited in managing higher levels of procedural pain when used alone.

Moderate heterogeneity was observed across pooled analyses ($I^2 = 48\%$ for pain; $I^2 = 44\%$ for anxiety), likely reflecting differences in intervention components, patient age groups, baseline anxiety levels, and outcome measures. Exploratory comparisons suggested larger

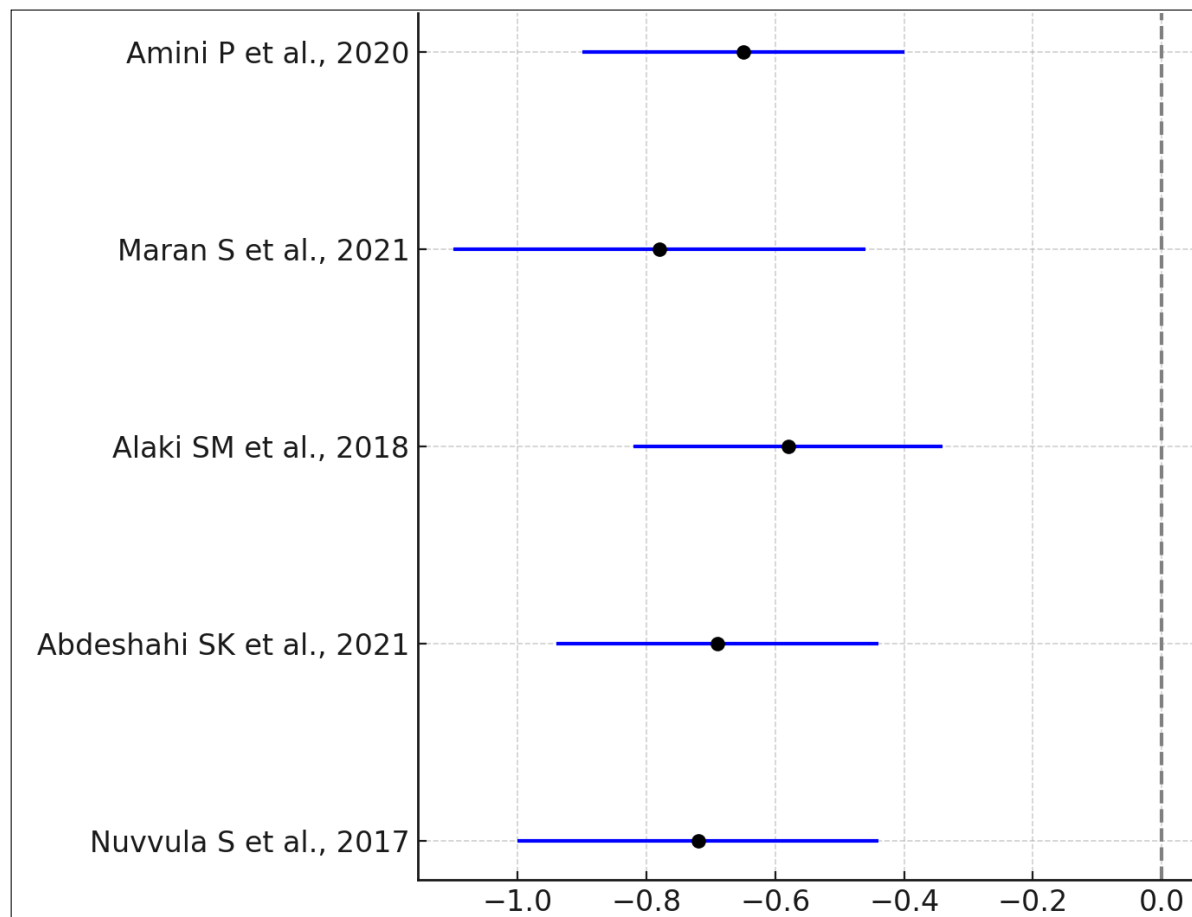


Figure 2. Forest Plot of Standardized Mean Differences (SMD) in Pain Reduction with Multimodal Analgesia Protocols. Standardized Mean Difference (SMD) [95% Confidence Interval]

effect sizes in younger children and when behavioral adjuncts were combined with local anesthesia. Nonetheless, the limited number of studies precluded robust subgroup analyses, and pooled estimates should be interpreted as average effects across heterogeneous clinical settings rather than precise subgroup-specific effects. Methodological limitations—such as unclear allocation concealment and lack of blinded outcome assessment—reduce confidence in the findings. The reduction in effect size observed in sensitivity analyses further suggests potential overestimation of treatment benefits. Consequently, the overall certainty of evidence was judged to be low to moderate.

Limitations and future directions

This review is limited by the small number of included studies ($n = 5$), which reduces statistical power and increases uncertainty in pooled estimates. With such a limited evidence base, individual studies may disproportionately influence meta-analytic results, limiting generalizability across procedures, settings, and age groups. Assessment of publication bias and small-study effects was not feasible, as funnel plots and statistical tests are unreliable with fewer than ten studies. Additionally, variability in pain and anxiety assessment tools and differences in multimodal protocol components contributed to clinical and methodological

heterogeneity not fully captured by the I^2 statistic. Although multimodal analgesia protocols appear effective in reducing short-term pain and anxiety, further research is needed to evaluate their long-term impact on children's dental attitudes and oral health behaviors. Future randomized trials should include larger sample sizes, standardized outcome measures, and follow-up beyond the immediate postoperative period. Stratification by age, baseline anxiety, and prior dental experience may help personalize analgesic strategies.

Conclusion

Current evidence suggests that multimodal analgesia protocols may improve short-term pain and anxiety outcomes in pediatric dental patients. However, the limited number of studies, methodological shortcomings, and moderate heterogeneity necessitate cautious interpretation. At present, multimodal analgesia should be considered a promising but investigational approach rather than a routine standard of care. Large, multicenter randomized trials with harmonized outcome measures and longer follow-up are required to establish definitive efficacy and safety.

Consent to Participate Declaration

Not applicable

Ethics approval / IRB Committee name

"This systematic review and meta-analysis was based on previously published data. No new clinical data were collected. For all included studies, ethical approval was obtained by the respective Institutional Review Boards as reported in the original articles."

Human ethics and consent to participate declarations

Not applicable.2

Funding Declaration

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Appendix Y — Template for Excluded Studies

First Author (Year)	Title	Reason for Exclusion
Smith (2019)	"Analgesia in dental extractions"	No pediatric population
Chen (2020)	"VR distraction for dental anxiety"	No comparator group
Rossi (2021)	"Case series of multimodal analgesia"	Single-arm, no control
...	...	...