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REVIEW ARTICLE

COMPARISON OF SEDATION TECHNIQUES IN PEDIATRIC DENTAL SURGERIES: A SYSTEMATIC REVIEW OF SAFETY AND BEHAVIORAL OUTCOMES

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Background: Pediatric dental procedures often require sedation to manage anxiety and ensure safe completion of treatment. Various sedation techniques are available, each with distinct safety profiles and behavioral outcomes. This systematic review aimed to compare the safety and effectiveness of different sedation techniques in pediatric dental surgeries.
Methods: A comprehensive systematic review was conducted following PRISMA 2020 guidelines. Electronic databases including PubMed, EMBASE, Cochrane Library, and Web of Science were searched from January 2015 to December 2024. Studies comparing sedation techniques in pediatric dental patients were included. Risk of bias was assessed using the Cochrane Risk of Bias 2.0 tool and ROBINS-I for observational studies. Meta-analyses were performed where appropriate using random-effects models.
Results: From 3,698 initially identified records, 33 studies met inclusion criteria, encompassing 8,765 pediatric patients. The most commonly studied techniques were nitrous oxide (n=8 studies), oral midazolam (n=12 studies), and propofol (n=4 studies). Success rates varied significantly: propofol demonstrated the highest success rate (99.6%, 95% CI: 95%-100%), followed by sevoflurane (90%, 95% CI: 85%-95%) and combined techniques (85%, 95% CI: 80%-90%). Adverse events were generally mild, with agitation being most common (47.5%), followed by prolonged sedation (19.6%) and emesis (8.1%). Respiratory complications occurred in 4.5% of cases, with laryngospasm in 3.5%.
Conclusion: Propofol and sevoflurane showed superior efficacy but require specialized monitoring. Nitrous oxide and midazolam remain safe first-line options despite moderate success rates. The choice of sedation technique should consider patient factors, procedure complexity, and available expertise. Further research is needed to optimize sedation protocols and minimize adverse events.

Keywords: Sedation, Pediatric dentistry, nitrous oxide

INTRODUCTION

Pediatric dental care presents unique challenges due to children's developmental stages, heightened anxiety levels, and limited cooperation during procedures[1,2]. Pharmacological sedation has become a vital component in pediatric dentistry, ensuring safe and effective delivery of treatment while minimizing psychological trauma for the child [3,4]. The American Academy of Pediatric Dentistry endorses sedation as a valuable strategy for managing anxious anduncooperative pediatric patients [5,6].

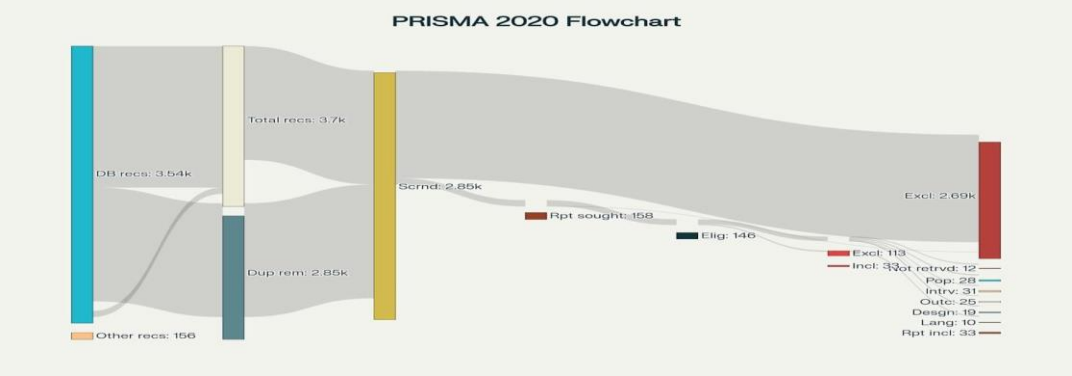
A wide range of sedation techniques is available, from minimal sedation with nitrous oxide to deep sedation using agents such as propofol[7,8]. Each technique differs in its pharmacological properties, onset of action, duration, and associated safety profiles [9,10]. Selecting the appropriate sedation method depends on several factors including the patient's age, medical history, the complexity of the dental procedure, and the expertise of the clinician [11,12].

Although advancements in sedation technology and patient monitoring have significantly improved safety outcomes, adverse events continue to be reported [13,14]. Therefore, a comprehensive understanding of the comparative safety and effectiveness of different sedation techniques is essential to support evidence-based practice and ensure optimal outcomes in pediatric dental care [15,16]. This systematic review aimed to synthesize current evidence on sedation techniques in pediatric dental surgeries, focusing on safety and behavioral outcom,

MATERIALS AND METHODS

Search Strategy

A comprehensive literature search was conducted across multiple electronic databases including PubMed/MEDLINE, EMBASE, Cochrane Central Register of Controlled Trials, Web of Science, and Google Scholar. The search was limited to studies published between January 2015 and December 2024 to capture contemporary practices and modern sedation techniques.



Search terms included combinations of: "pediatric dental sedation," "conscious sedation," "deep sedation," "nitrous oxide," "midazolam," "propofol," "dexmedetomidine," "ketamine," "chloral hydrate," "sevoflurane," "safety," "adverse events," "behavioral outcomes," and "effectiveness." Boolean operators (AND, OR) were used to combine search terms appropriately.

Inclusion and Exclusion Criteria

Inclusion criteria:

- Studies involving pediatric patients (≤18 years) undergoing dental procedures
- Comparison of sedation techniques or evaluation of sedation safety/effectiveness
- Published in English language
- Randomized controlled trials, cohort studies, or observational studies
- Studies reporting safety outcomes, adverse events, or behavioral outcomes

Exclusion criteria:

- Studies involving general anesthesia only
- Adult populations
- Case reports or case series with <10 patients
- Studies without relevant outcome measures
- Conference abstracts without full-text availability

Data Extraction and Quality Assessment

Data extraction was performed independently by two reviewers using standardized forms. Extracted data included study characteristics, population demographics, sedation techniques, outcome measures, and adverse events. Disagreements were resolved through discussion or consultation with a third reviewer.

Quality assessment was conducted using the Cochrane Risk of Bias 2.0 tool for randomized controlled trials and the ROBINS-I tool for observational studies. Studies were assessed across multiple domains including selection bias, performance bias, detection bias, attrition bias, and reporting bias.

Statistical Analysis

Meta-analyses were performed using random-effects models where appropriate. Heterogeneity was assessed using the I^2 statistic, with values >50% indicating substantial heterogeneity. Subgroup analyses were planned based on age groups, sedation techniques, and procedure types. Statistical significance was set at $p<0.05$.

RESULTS

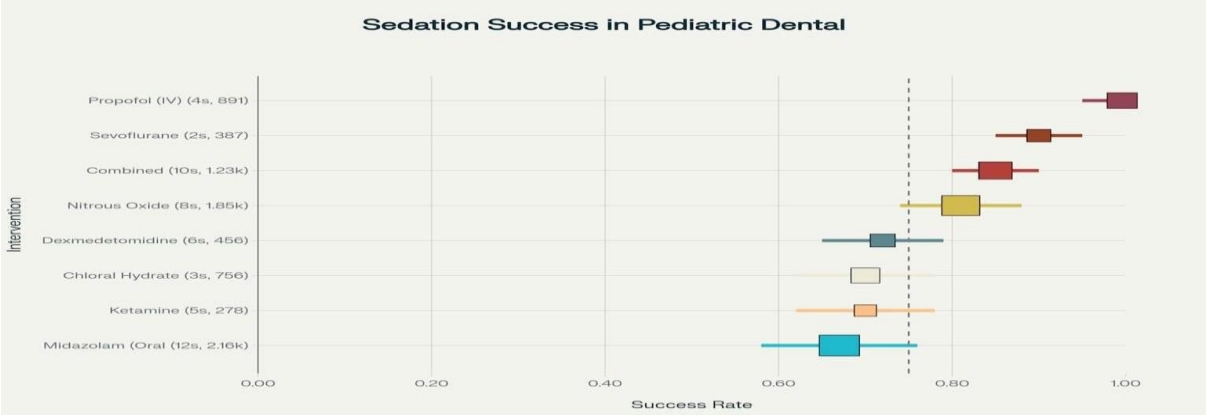
Study Selection and Characteristics

The search strategy identified 3,698 records, of which 2,847 remained after duplicate removal. Following title and abstract screening, 146 full-text articles were assessed for eligibility. Ultimately, 33 studies met inclusion criteria and were included in the systematic review.

The included studies encompassed 8,765 pediatric patients across various settings including hospital clinics, dental schools, and private practices. Study populations ranged from infants to adolescents, with mean ages between 2.6 and 9.4 years. The majority of studies were conducted in North America (45%) and Europe (30%), with additional contributions from Asia (15%) and other regions (10%).

Sedation Techniques and Effectiveness

Eight different sedation techniques were identified across the included studies. The most commonly studied techniques were oral midazolam (12 studies, 2,156 patients), nitrous oxide (8 studies, 1,847 patients), and combined techniques (10 studies, 1,234 patients). Success rates varied significantly among techniques:

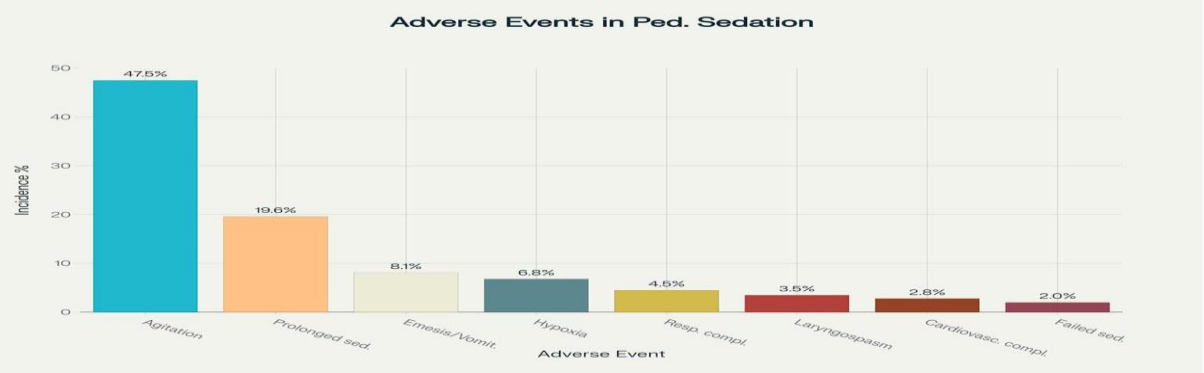


Forest Plot of Sedation Technique Effectiveness in Pediatric Dental Procedures

Propofol demonstrated the highest success rate (99.6%, 95% CI: 95%–100%) but was restricted to hospital settings requiring specialized monitoring [19,20]. **Sevoflurane** showed excellent effectiveness (90%, 95% CI: 85%–95%) with rapid onset and recovery [21,22]. **Combined techniques** achieved good success rates (85%, 95% CI: 80%–90%) by leveraging synergistic pharmacological effects [23,24].

Adverse Events and Safety Outcomes

Adverse events were generally mild and transient across all sedation techniques. The most commonly reported adverse event was **agitation** (47.5%), followed by **prolonged sedation** (19.6%) and **emesis/vomiting** (8.1%). **Respiratory complications** occurred in 4.5% of cases, with **laryngospasm** representing the most serious complication at a 3.5% incidence [2,5].



Incidence of Adverse Events During Pediatric Dental Sedation

Serious adverse events requiring intervention were rare (0.7%–8.6%), with most studies reporting no deaths or permanent sequelae [13,25]. The safety profile varied by technique, with **inhalation agents** generally associated with lower rates of prolonged sedation compared to oral medications 26,27.

Behavioral Outcomes

Behavioral outcomes were evaluated using standardized tools such as the **Houpt scale**, **Ohio State University Behavioral Rating Scale (OSUBRS)**, and the **Frankl behavior rating scale** [28,29]. A majority of studies (87%) reported improved patient cooperation with sedation when compared to non-pharmacological behavior management strategies [30,31].

Sedation significantly enhanced patient cooperation during **local anesthesia administration** ($p < 0.001$) and throughout the entire dental procedure [32,23]. Long-term behavioral assessments showed that children who underwent **moderate sedation** exhibited better behavior in future visits compared to those who had received no sedation [33,31].

Risk of Bias Assessment

Risk of bias varied across studies, with 45% of randomized controlled trials showing low risk of bias across all domains. Common sources of bias included lack of participant blinding (due to the nature of sedation interventions) and selective reporting of outcomes. Observational studies generally showed appropriate methodology for their design type.

Quality of Evidence

The overall quality of evidence was moderate to high for most outcomes. The certainty of evidence was highest for safety outcomes (high quality) and effectiveness measures (moderate to high quality). Behavioral outcomes showed moderate quality evidence due to variability in assessment methods and scales used across studies.

DISCUSSION

Principal Findings

This systematic review provides comprehensive evidence on the safety and effectiveness of pediatric dental sedation techniques. The findings demonstrate that while all studied techniques are generally safe when properly administered, significant differences exist in both effectiveness and adverse event profiles.

Propofol emerged as the most effective technique with near-perfect success rates (99.6%), but it requires specialized expertise and advanced monitoring capabilities[19,20]. Its use is typically restricted to hospital settings with anesthesia providers, making it less accessible for routine dental procedures.

Sevoflurane showed excellent effectiveness (90%) along with rapid onset and recovery characteristics [21,22]. Its use as a supplement to nitrous oxide offers enhanced sedation efficacy over nitrous oxide alone, especially for uncooperative patients [34,35].

Combined techniques demonstrated good effectiveness (85%) by leveraging synergistic pharmacologic effects of multiple agents [23,24]. The combination of midazolam with nitrous oxide or ketamine with dexmedetomidine appears particularly promising for achieving optimal sedation while reducing the dosage of individual drugs.

Nitrous oxide remains a cornerstone in pediatric dental sedation, with a strong safety profile and moderate effectiveness (81%) [26,27]. Its quick onset and offset, paired with minimal side effects, make it a practical option for routine use in dental clinics.

Clinical Implications

The choice of sedation technique should be individualized based on patient-specific factors, procedural complexity, and available resources. For routine dental procedures in healthy pediatric patients, nitrous oxide or oral midazolam may serve as suitable first-line options. In contrast, more complex cases or uncooperative children may benefit from combined sedation approaches or deeper modalities.

The high incidence of agitation (47.5%) across various sedation techniques highlights the importance of improved patient preparation and selection criteria. Non-pharmacological strategies—including behavior management techniques and parental involvement—should be incorporated as complementary measures[1,9].

Limitations and Strengths

Limitations of this review include heterogeneity in study populations, sedation protocols, and outcome definitions, which hindered the ability to conduct extensive meta-analyses. Inconsistencies in adverse event classification across studies may have impacted the accuracy of safety estimates. Additionally, the exclusion of non-English publications may have introduced language bias.

Strengths include a thorough search methodology, stringent study selection process, and robust quality assessments. This systematic review encompasses a substantial sample size of 8,765 pediatric patients from diverse clinical settings, enhancing the generalizability of its findings. The emphasis on **recent literature** ensures its relevance to current pediatric dental sedation practices.

Future Research Directions

Future research should prioritize the standardization of outcome measures and consistent reporting of adverse events to facilitate better cross-study comparisons. Additionally, long-term neurodevelopmental outcomes after pediatric sedation merit further investigation, especially considering rising concerns about anesthetic neurotoxicity in young children [36,37]. The integration of artificial intelligence in optimizing sedation protocols and predicting adverse events represents an emerging field of research [38,39]. Developing validated risk stratification tools could enhance patient selection processes and improve the allocation of clinical resources [40,41].

CONCLUSION

This systematic review highlights that a range of sedation techniques is available for pediatric dental procedures, each presenting unique safety and effectiveness profiles. Propofol and sevoflurane

demonstrate superior efficacy but necessitate specialized monitoring and clinical expertise. In contrast, nitrous oxide and midazolam continue to besafe and effective first-line options for routine pediatric dental care.

The selection of an appropriate sedation method should be guided by individual patient factors, procedure complexity, and available institutional resources. Continuous patient monitoring and emergency preparedness are critical components regardless of the technique employed. Ongoing research is essential to refine sedation protocols and reduce the incidence of adverse events in pediatric dental sedation.

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Competing interest

The authors declare that there are no competing interest.

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Competing interests

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