Keywords
Pediatric Dentistry; Pain Management; Restorative Dentistry; Local Anesthesia; Analgesics; Sedation

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Pharmaceutical Approaches to Pain Management in Pediatric Restorative Dentistry A Comprehensive Review

Abstract
The goal of pain management in pediatric restorative dentistry is to achieve a successful clinical outcome, patient cooperation and good long-term oral health behavior. Dental pain in children is not only associated with biological factors such as caries and pulpal inflammation, operative procedures and administration of local anesthetic, but is also affected by psychological factors such as fear and anxiety, sensory sensitivity and past dental experiences. In this study, the local anesthetic, topical anesthetic, systemic analgesic and sedation-based techniques for the control of pain and anxiety in pediatric restorative dental care are explored in-depth. A literature survey was carried out to identify existing literature on the topic with primary emphasis on literature published between the years 2018. The evidence reviewed supports the following conclusions: Local anesthesia is the cornerstone of procedural pain control; topical anesthetics augment comfort during injection. Opioids should be used sparingly because of their safety concerns, but acetaminophen and non-steroidal anti-inflammatory drugs can be helpful for pre- and post-operative discomfort. Sedation strategies such as nitrous oxide, oral sedation, intranasal sedation and intravenous sedation can be useful when a child is anxious, very young, or uncooperative, but can only be used with careful selection of patients, accurate weight dosing, monitoring and preparedness. New technologies like needle-free systems, enhanced topical treatments and tailored pain management could further enhance dental care for children. In general, pain management should include pharmacologic interventions and child-friendly behavioral directions that will improve safety, comfort, and treatment outcomes.

1. INTRODUCTION

Childhood dental pain is a complicated sensory and emotional experience related to dental caries, pulp involvement, operative treatment, the application of local anesthesia, and restorative treatment. Pain can be pre-treatment related to carious lesion, or pre-treatment related to the preparation of the cavity, pulp therapy, the routine of rubber dams, injection, or post-treatment inflammation in pediatric restorative dentistry (Lupu et al., 2024). As children may lack the capacity to explain the severity, location, and nature of the pain, dental pain assessment in children during the clinical process should be carefully observed, with age-related communication and knowledge of behavioral reactions (Morgan, 2021; Ortiz, 2020). Pediatric dental pain is not just a biological experience, but also a psychological experience that is affected by fear, prior dental experience, parental attitude, sensory sensitivity and clinical environment (Stein Duker et al., 2022).

The issue of pain during restorative procedures is a significant concern in pediatric dentistry since untreated or inadequately treated pain may impact

cooperation, quality of treatment, and subsequent dental visits. Restorative procedures in children are commonly linked to anxiety since children will fear the noise of equipment, needles and injections, dental practices, new environment and lack of control during treatment. Dental phobia and anxiety can amplify pain perception and pose a behavior management challenge to clinicians (Shekhar et al., 2022). Children who have a negative dental experience can develop a long-term avoidance behavior that puts them at risk of untreated caries, emergency treatment, and more invasive treatment needs in the future (Morgan, 2021; Rashid, 2026). Thus, the impact of pain management is crucial to not only achieve immediate clinical success but also establish a positive attitude towards oral healthcare.

Pain management among pediatric patients poses special challenges as the cognitive, emotional, and physiological development of such patients is not like adult development. Younger children might not know the intent of treatment, and may convey their pain by crying, moving, refusing or withdrawing instead of describing. Depending on the age, temperament, anxiety, developmental status, and past dental experience, the perception of pain also varies (Miller, 2024; Stein Duker et al., 2022). Moreover, children with special health care needs or high anxiety might need altered pharmacological and behavioral interventions to provide safe and effective dental care (Coté et al., 2019). These factors render pain management in pediatrics a very personal process.

Pharmaceutical interventions are a core part of restorative dentistry in pediatrics since behavioral education may not be adequate to contain procedural pain. The reduction of pain, anxiety and distress during the process of dental treatment is usually achieved using local anesthetics, topical analgesics, systemic analgesics, nitrous oxide and sedative agents. Recent data shows that the preferences of pediatric dentists towards local and topical anesthesia are still developing, especially about the application of articaine and other anesthetic agents in children. Sedation guidelines and protocols are also significant to children who are unable to endure dental treatment using local anesthesia and behavioral management methods alone (Gao & Wu, 2023; Steiger, 2025). Nevertheless, pain management with the help of pharmacological treatment should be cautious since children are more susceptible to dosing mistakes, adverse drug reactions, airway issues, and overdose (Furstein, 2022).

Evidence-based pharmaceutical protocols are increasingly in demand since restorative dental treatment, pulp treatment, and treatment under sedation or general anesthesia are frequently necessary in children with high amounts of caries or inadequate cooperation (Yazdanbakhsh, 2024). The application of scientifically proven methods in managing caries and dental pain is supported by evidence-based guidelines as opposed to empirical and inconsistent clinical practices (Slayton et al., 2018). The bibliometric tendencies in the literature on pediatric dentistry also indicate the increasing academic interest in researching the topic of pediatric dental care, pain management, sedation, and outcomes of treatment (Perazzo et al., 2019; Pooja & Ramar, 2023).

Thus, the purpose of this study is to critically analyze pharmaceutical methods of pain management in pediatric restorative dentistry. In particular, it appraises the efficacy, safety, clues, and constraints of the popular pharmacological agents, such as local anesthetic, topical anesthetic, systemic analgesic, and sedation-based methods. It also talks about the contemporary clinical guidelines, safety issues, and the new trends in administering drugs and managing dental pain in children. This study aims to contribute to safer and more effective and child-centered pain management practice to support restorative dental care of children.

2. Methodology

An extensive review of literature was done to explore pharmaceutical methods of addressing pain in restorative dentistry in children. The research topic concerned the evidence on local anesthesia, topical anesthesia, systemic analgesics, nitrous oxide sedation, oral and intranasal sedative agents, control of postoperative pain, safety issues, and the recent pharmacological advances in dental care of children.

An electronic search of Web of Science and Google Scholar was done to identify the relevant literature. The search process was restricted mainly to publications from 2018 to 2026 to include the latest evidence. The keywords used included “pediatric dentistry,” “pain management,” “dental anesthesia,” “analgesics,” “sedation,” “restorative dentistry,” “local anesthesia,” “topical anesthesia,” “nitrous oxide,” and “pediatric dental pain.” The search was also narrowed down using the Boolean operators like AND, and used the words pediatric dentistry AND pain management, dental anesthesia AND children, analgesics AND pediatric dentistry, and sedation AND pediatric restorative dentistry.

Articles were included that focused on any of the following areas: pharmacological pain management, anesthesia, analgesia, sedation, or drug safety in dental pediatric practice. The chosen publications have been analyzed, contrasted and formulated into broad subject areas, such as local anesthetic agents, topical anesthetics, systemic analgesics, sedation-based methods, adverse effects, monitoring considerations, and upcoming trends. Recent and topic-specific sources were prioritized to guarantee relevance, scientific accuracy, and relevance to pediatric restorative.

3. Pharmacological Approaches to Pain Management

3.1 Physiology of Pain in Pediatric Dental Patients

Biological, psychological, and environmental factors combined to contribute to pain in pediatric restorative dentistry (Adnan et al., 2022). The common causes of dental pain include caries lesions, dentinal hypersensitivity, pulpal inflammation, operative dentistry, injection of local anesthetic, and the response of tissue after the procedure. The perception of dental pain in children is highly dependent on the level of development, prior dental experiences, anxiety, parental expectations, and attributing the discomfort to the appropriate understanding level and the possibility to communicate it (Ortiz, 2020). Children unlike adults do not necessarily give clear descriptions of pain but may show distress in

form of crying, body movement, refusing, withdrawal or disruptive behavior during treatment.

The neurophysiology of dental pain is characterized by the stimulation of nociceptors in the dentin, pulp, periodontal tissues and oral mucosa. Branches of the trigeminal nerve carry the pain signals and are processed centrally with emotional and cognitive variables possibly increasing or decreasing the pain experience. During restorative procedures, dentinal tubules, pulpal tissues, gingiva, and periodontal structures could be stimulated, resulting in nociceptive responses. This explains why it is necessary to have an effective anesthesia in cases of cavity preparation, pulp therapy, matrix placement, application of rubber dam, and restorative finishing procedures (Sayed et al., 2026).

Psychological modulation has a significant role to play in children perception of pain. Dental fear and anxiety may decrease the pain threshold, enhance anticipatory distress, and diminish cooperation (Chauhan et al., 2026). Even when tissue injury is minimal, children with sensory over-responsiveness or overall anxiety can find the routine dental practice very stressful (Stein Duker et al., 2022). Pain on local anesthetic injection is another primary cause of fear, and could affect future dental behavior. Research on dental care in children has indicated that anxiety and lack of cooperation can be reduced with the help of distraction, behavioral support, and pharmacological pain management during the administration of anesthesia and restorative care (Shekhar et al., 2022; Singh et al., 2023). Thus, pediatric dental pain may be viewed as a multidimensional phenomenon, which needs to be managed both pharmacologically and through supportive behavioral means. Figure 1. Categorization of significant pharmaceutical methods to be applied in the management of pain in pediatric restorative dentistry.

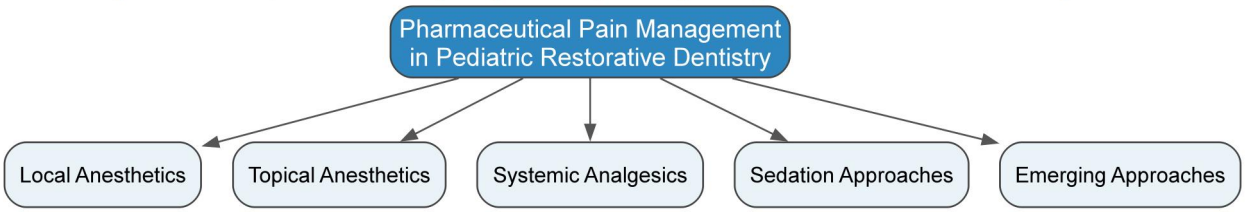

Figure 1. Classification of Pharmaceutical Pain Management Approaches in Pediatric Restorative Dentistry

3.2 Local Anesthetic Agents in Pediatric Dentistry

Pharmaceutical pain control based on local anesthesia in pediatric restorative dentistry is the background. It inhibits the conduction of nerve impulses by blocking sodium channels and thus prevents the transmission of pain impulses in the nerve to the operative site (Baghel et al., 2025). The type of local anesthetic to be used varies based on the age, weight, medical history, duration of treatment, the site of injection, whether the child requires hemostasis, and the potential for soft-tissue trauma after the injection. Pediatric dental practice surveys indicate that the preferences towards local and topical anesthetic use are still changing, especially when it comes to the use of articaine, lidocaine and other agents on children (Baumgartner et al., 2024). Table 1 provides an overview of the largest drug classes used in the management of pain and anxiety in children, their clinical applications, the main safety considerations, and references.

Table 1. Common Pharmaceutical Agents Used in Pediatric Restorative Dentistry

Agent/Class	Main Use	Key Precaution	References
Lidocaine	Routine local anesthesia for restorative procedures	Weight-based dose calculation is essential	(Baumgartner et al., 2024)
Articaine	Infiltration anesthesia and selected mandibular procedures	Use cautiously and avoid overdose	(Haidar & Raslan, 2023)
Topical anesthetics	Reduce injection discomfort	Avoid excessive mucosal application	(Pasternak & Woroń, 2024)
Acetaminophen/NSAIDs	Preoperative or postoperative pain control	Consider hepatic, renal, and gastric risks	(Miroshnychenko et al., 2023)
Sedative agents	Anxiety control and cooperation support	Require monitoring and trained personnel	(Coté & Wilson, 2025)

3.2.1 Lidocaine

One of the most used local anesthetics in pediatric dentistry is lidocaine, which is typically considered the standard agent to compare to. It is an amide-type anesthetic that functions by stabilizing neuronal membranes and inhibiting sodium ion entry, thus inhibiting depolarization and transmission of pain. Lidocaine is often combined with epinephrine to increase the duration and hemostasis. It can be used in pediatric restorative procedures in infiltration anesthesia, inferior alveolar nerve block, pulpal anesthesia, and soft-tissue anesthesia (Bani-Hani et al., 2024).

To minimize risks of systemic toxicity, dosage must be calculated based on the body weight. Lower body mass and unpredictable drug metabolism expose pediatric patients to increased risk of overdose. Lidocaine can be applied in practice as a standard restoration, pulp therapy, extractions associated with restorative planning, and carious lesions that need operative intervention (MOralSurg, 2021). But, long-term soft-tissue numbness may put young children at a higher risk of biting their lips or cheeks; hence, parental postoperative guidelines are necessary.

3.2.2 Articaine

Articaine has been of greater interest in pediatric

dentistry due to its many favorable properties, such as high tissue diffusion, effective pulpal anesthesia, and clinical performance. It is also an amide local anesthetic, but it has a thiophene ring, which increases its lipid solubility and tissue penetration. Articaine is most frequently employed as 4% articaine with epinephrine, and has been assessed for infiltration and nerve block in children (Ansharieta et al., 2020).

Based on comparative evidence, articaine might be effective in dental procedures in pediatric patients, specifically for infiltration of mandibular molars for which there is a clinical desire for success (Haidar & Raslan, 2023). However, safety is still a major issue and higher concentration formulations and the reports of paresthesias have led to cautious use in some paediatric settings. A meta-analysis of the use of articaine versus lidocaine in pediatric dentistry indicated that adverse effects should be taken into consideration; however, articaine is clinically useful when appropriate doses and indications are used (L. Li & Sun, 2023). The current practice patterns suggest that there is inter-professional variation in the level of comfort and preference for articaine by pediatric dentists, which means that it is important to use evidence-based decision-making (Baumgartner et al., 2024).

3.2.3 Mepivacaine and Prilocaine

Alternatives to local anesthetics include mepivacaine and prilocaine, which are injected in selected cases in children. When a shorter duration is desired or epinephrine should be limited, Mepivacaine may be used without a vasoconstrictor due to its relatively low vasodilatory activity. May be helpful for brief restorative interventions or for children who are at risk for postoperative soft-tissue trauma. Prilocaine is also an effective anesthetic; it must be used with care, due to the possibility of methemoglobinemia in very young children or medically susceptible patients.

These agents should be used on a case-to-case basis considering each patient's medical history, duration of procedure and dosage restrictions. While lidocaine and articaine are more frequently mentioned in recent pediatric dental publications, mepivacaine and prilocaine are still important options to consider when certain clinical situations call for a change in anesthetic selection. Safe administration to children requires knowledge of pharmacokinetics, maximum recommended dose and systemic risks (Halling et al., 2021).

3.2.4 Buffered Local Anesthesia

There is local anesthesia with buffering to minimize discomfort from the injection and speed up the onset of anesthesia. Burning can be a side effect of conventional local anesthetic solutions that are acidic, especially with the addition of vasoconstrictors. Adding sodium bicarbonate will increase the pH of the anaesthetic solution and potentially decrease the pain of injection and improve patient acceptability.

In restorative dentistry for children, minimizing the pain associated with the injection is particularly critical as it is the most feared part of dental visits. Buffered anesthesia may be used to enhance comfort, but is only routinely used if available, affordable, buffered solution is stable, and the clinician prefers it. Buffering, along with slow injection and topical anesthesia and distraction, may help to create a more positive treatment experience (Bani-Hani et al., 2024).

3.2.5 Computer-Controlled Anesthetic Delivery Systems

Computer-controlled local anesthetic delivery systems have been designed to control the pressure of the injection and speed of the flow. These systems can minimise the discomfort from speedy deposition of anaesthetic solutions and potentially increase acceptance among nervous children. They are especially helpful for the palatal injection, periodontal ligament injection and when precise delivery is required.

But effective operation of computer-controlled systems requires operator training, child cooperation and setting. These systems do not eliminate the need for proper communication, topical anesthesia, and behavioral guidance; they might however, help minimize discomfort related to the injection. Even with computerized delivery, there can still be fear of needles. So it is important to note that these technologies are not necessarily the solution to pediatric dental pain control but rather are adjunctive to it (Baumgartner et al., 2024).

3.3 Topical Anesthetics

To enhance the child's acceptance of the injection, and to decrease the pain of the surface, topical anesthetics are used widely prior to the injection of local anesthetic. They stimulate superficial mucosal nerve endings, and are best applied to dry mucosa to allow for adequate contact time. Topical agents are a part of a comprehensive pain control plan that includes explanation, distraction, slow injection and reassurance, which are all practiced by pediatric dentists (Pasternak & Woroń, 2024). Table 2 provides an overview of commonly used injectable and surface anesthetic agents, their clinical use in children, major limitations, and relevant literature supporting the use of these agents.

Table 2. Local and Topical Anesthetic Agents: Uses, Benefits, and Limitations

Agent	Category	Clinical Use	Limitation	References
Lidocaine	Local anesthetic	Restorations, pulp therapy, nerve blocks	Soft-tissue biting and toxicity risk	(Baumgartner et al., 2024)
Articaine	Local anesthetic	Effective infiltration anesthesia	Safety concerns require careful dosing	(Haidar & Raslan, 2023)
Mepivacaine	Local anesthetic	Short procedures or vasoconstrictor-limited cases	Shorter duration	(Halling et al., 2021)

Benzocaine	Topical anesthetic	Pre-injection surface anesthesia	Methemoglobinemia risk if overused	(Pasternak & Woroń, 2024)
EMLA cream	Topical anesthetic	Selected surface anesthesia cases	Longer contact time; prilocaine-related caution	(Bani-Hani et al., 2024)

3.3.1 Benzocaine

Benzocaine is a topical anesthetic that is widely used in dental practices. It serves to provide surface anesthesia and comes in gels, sprays and ointments. Quick acting and flavoursome good for paediatric patients. Benzocaine, however, should be administered with care as it has been known to be associated with methemoglobinemia when overused, especially in young children. Thus, the smallest effective dose is recommended and repeated or overuse of the drug is not recommended (Bani-Hani et al., 2024).

3.3.2 Lidocaine Gel and Spray

Another frequently used drug for mucosal anesthesia prior to injection or minor soft-tissue techniques is topical lidocaine. Gels and sprays containing lidocaine can help alleviate discomfort during insertion of the needle and are helpful for restorative dentistry when local infiltration or nerve block is needed. Systemic absorption can occur, however, particularly when applied to large mucous surfaces or in large amounts. It is therefore necessary to have an awareness of paediatric dosing.

3.3.3 EMLA Cream

Eutectic mixture of lidocaine and prilocaine (EMLA cream) has been used topically in medical and dental practice. It may be more effective at providing surface anesthesia than some conventional topical products, but may have limited use in the oral cavity because of taste, ease of application contamination with saliva and contact time. In addition, children at risk of methemoglobinemia should be cautioned about the presence of prilocaine. In general, these topical anaesthetics make your patients more comfortable, but they should be used as adjuncts and not as an alternative to deep local anaesthetic during therapeutic treatments (Coté & Wilson, 2025).

3.4 Systemic Analgesics in Pediatric Dentistry

Preoperative dental pain, postoperative discomfort and inflammation related to restorative or pulp-related procedures are important points in which systemic analgesics play an important role. The type of analgesic selected should be based on the severity of the pain, the age and weight of the child, history of medical conditions, drug allergies, hepatic and renal status and risks of adverse reactions. Evidence-based reviews of paediatric acute dental pain highlight the need to select the appropriate analgesics for dental pain and avoid unnecessary opioid exposure (Miroshnychenko et al., 2023; Ting et al., 2025).

3.4.1 Acetaminophen/Paracetamol

Acetaminophen is a common drug for children's dental pain that is used for mild to moderate pain. It has analgesic and antipyretic properties, but weak anti-inflammatory properties. Well tolerated within recommended weight-based dosing limits. Yet overdose can lead to acute liver damage; there is a need for exact dosages and parent education. Acetaminophen is indicated following caries excavation, pulp therapy, placement of stainless-steel crowns, or placement of multiple restorations when the postoperative discomfort is anticipated in pediatric restorative dentistry.

3.4.2 Non-Steroidal Anti-Inflammatory Drugs

NSAIDs work well for dental pain as many dental procedures result in inflammation mediated pain. Ibuprofen is frequently used in children and has an analgesic and anti-inflammatory effect. It is preferred in cases of pulpal inflammation, inflammatory dental conditions or postoperative tissue irritation. Ketorolac is more potent NSAID, and is more reserved in the paediatric arena, due to gastrointestinal, renal and bleeding risks (Bansal et al., 2019; Verma et al., 2025).

It is noted that evidence shows that in many cases, non-opioid analgesics are effective as first-line treatment for dental pain. There are also general recommendations for dental pain that focus on non-opioid interventions, but some of these recommendations are largely derived from adolescents and adults and may need to be carefully adapted to younger children (Carrasco-Labra et al., 2024).

3.4.3 Opioid Analgesics

Opioid analgesics are available with very limited indications in the field of restorative dentistry in the pediatric population. They are not commonly used since most children's dental pain can be treated effectively with local anesthesia, acetaminophen, NSAIDs or non-opioid combination therapy. Opioids are associated with the potential for respiratory depression, sedation, nausea, constipation, misuses, dosing errors, and drug interactions. Unless considered, such cases should be limited to exceptional cases under strict clinical supervision with following institutional and national regulations. There is a strong trend in current pain management that advocates for limiting opioid use in children and prioritizing pain management options that do not involve opioids (Ting et al., 2025).

3.5 Sedation-Based Pharmaceutical Approaches

Sedation is the use of drugs to reduce pain and anxiety when local anesthesia and behaviour management are not adequate to facilitate safe and humane delivery of dental care. It is especially relevant to children who are very young, who are anxious, who need a lot of restorative care or have special health care needs. Sedation is designed to help the patient feel less anxious and to help him or her cooperate with treatment while keeping him or her safe. Sedation, however, is not a substitute for local anesthesia – adequate local anesthetic administration is still necessary for pain control (Coté et al., 2019; Wilson et al., 2021). Figure 2. Clinical decision making pathway for choosing of Pharmaceutical Pain Management Strategies in paediatric restorative dentistry.

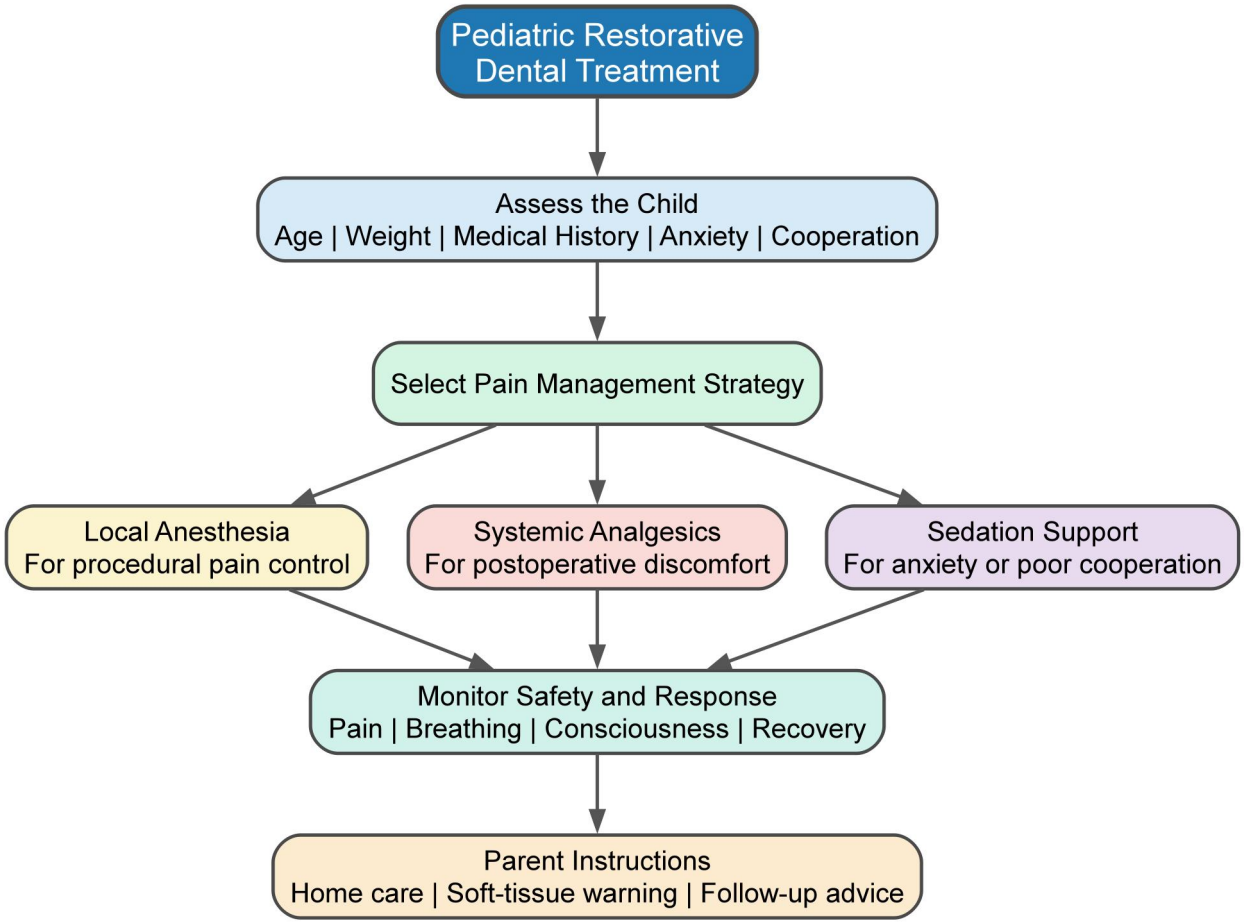

Figure 2. Clinical Decision-Making Flowchart for Pediatric Dental Pain Management

3.5.1 Nitrous Oxide-Oxygen Sedation

In pediatric dentistry, one of the most widely used and safe methods of sedation is nitrous oxide – oxygen sedation. It is anxiolytic, mildly analgesic, it has a quick onset effect and quick recovery time. It is titratable and has few residual effects and can be used for restorative procedures in mildly to moderately anxious, but instruction-following children. Useful when giving local anaesthetic, cavity preparation and for shorter restorative appointments.

The main mechanism of action of nitrous oxide is central nervous system depression and modulation of pain and anxiety pathways. Generally well tolerated, but needs proper equipment, scavenging systems, patient selection and monitoring. This recent meta-analysis confirms the continued use of N2O in paediatric dental sedation, while also highlighting the importance of considering the quality and heterogeneity of evidence when applying this to clinical practice (X. Li, 2025).

3.5.2 Oral Sedation

For children who suffer from moderate anxiety or limited cooperation, oral sedation is used. Midazolam is a very commonly used oral sedative agent, known for its anxiolytic, sedative and amnesic effects. Diazepam is longer lasting and less predictable in its recovery profile, and hydroxyzine can be used as a mild sedative with antiemetic activity. Oral sedation is easy to administer but has disadvantages, such as unpredictable recovery and degree of sedation, variable absorption and delayed onset.

A review of oral sedation agents in paediatric dentistry highlighted that factors for safety include appropriate case selection, dosage calculation, fasting status, monitoring, emergency preparedness and discharge criteria (Dowdy et al., 2023). Sedation should only be done by trained clinicians who have the facilities and rescue capability to do so.

3.5.3 Intranasal Sedation

Intranasal sedation has become a very handy technique since it does not involve the challenge of oral swallowing, and it is absorbed more quickly by the nasal mucosa. Mazazolam, ketamine and dexmedetomidine are some of the agents studied in dental practice in children. Naresal formulations have the potential to enhance the quality of sedation, but they must be closely monitored because of the possibility of respiratory depression, paradoxical reactions, over-sedation, or delayed recovery.

The crossover study on intranasal ketamine versus intranasal midazolam and dexmedetomidine combination in pediatric dental patients reveals the increasing popularity of alternative routes of sedation in the context of procedural management (Dubey et al., 2024). Nonetheless, intranasal sedation must be administered to patients of carefully selected patients and under proper monitoring standards.

3.5.4 Intravenous Sedation

Intravenous sedation is usually used when the child has to be treated with advanced behavioral control, extensive treatment, or when he cannot be safely treated with minimal or moderate sedation. It is titratable, fast acting, more dangerous, and involves more training, equipment, monitoring, and emergency preparedness. Hospital-based or specialist settings may be more suitable to intravenous sedation. It is recommended to perform constant monitoring prior to, during, and following sedation, such as airway, ventilation, oxygenation, circulation, and level of consciousness (Coté & Wilson, 2025; Wilson et al., 2021). Table 3 shows the major sedation techniques applied to fearful or uncooperative children, their popular agents, indications, safety needs and supporting.

Table 3. Sedation-Based Pharmaceutical Approaches in Pediatric Dentistry

Method	Common Agents	Main Indication	Safety Requirement	References
Nitrous oxide-oxygen sedation	Nitrous oxide with oxygen	Mild to moderate anxiety	Oxygen delivery, scavenging, monitoring	(X. Li, 2025)
Oral sedation	Midazolam, diazepam, hydroxyzine	Moderate anxiety or limited cooperation	Recovery observation and emergency readiness	(Dowdy et al., 2023)
Intranasal sedation	Midazolam, ketamine, dexmedetomidine	Faster onset or poor oral acceptance	Close respiratory monitoring	(Janiani et al., 2023)
Intravenous sedation	Specialist sedative regimens	Severe anxiety or extensive treatment	Advanced training and airway management	(Coté et al., 2019)
General anesthesia	Multiple anesthetic agents	Extensive care or inability to cooperate	Hospital/specialist setting	(Yazdanbakhsh, 2024)

3.6 Pain Management in Special Pediatric Populations

Children with special health care needs need a separate pain management planning. Pain expression, cooperation and response to pharmacological agents can be modified due to developmental disabilities, autism spectrum disorder, ADHD, sensory processing difficulties, medical compromise, and past traumatic dental experiences. Sensory over-responsive children can find dental sounds, lights, tastes, and touch unpleasant and this can contribute to pain-related behavior (Stein Duker et al., 2022). Children and youth with developmental disabilities need clinical care in a flexible manner, including the involvement of caregivers, modular behavior guidance, and attention to pharmacological support (Sarvas et al., 2024).

Children with complicated medical histories, such as pediatric cancer survivors or children with medical conditions that require the use of general anesthesia, might require further evaluation prior to the use of analgesics, anesthesia, or sedation (Sharma, 2023; Yazdanbakhsh, 2024). Before choosing any drug, drug interactions, immunosuppression, hepatic or renal impairment, airway issues and status of the systemic disease should be taken into consideration. Such patients might need to work in conjunction with pediatricians, anesthesiologists, or medical specialists.

3.7 Safety, Adverse Effects, and Toxicity

At the heart of pharmaceutical pain management in pediatric dentistry is the concept of safety. Kids are more susceptible to medication error, due to the need to calculate doses based on weight, and minor miscalculations can be severely toxic. When the maximum doses are overdosed or in case of accidental intravascular injection, local anesthetic systemic toxicity can take place. It can cause circumoral numbness, dizziness, agitation, seizures, cardiovascular depression or arrhythmias. Prevention involves aspiration, slow injection, correct dose calculation, and total anesthetic given.

The local anesthetics based on amide have a low risk of allergic reaction; however, reactions to preservatives, latex, or other substances are possible. Topical anesthetics might be toxic when used in excess especially benzocaine or prilocaine containing agents due to the risk of methemoglobinemia. Airway obstruction, hypoventilation, oxygen desaturation, aspiration, paradoxical agitation, prolonged sedation, and respiratory depression are some of the sedation-related complications. Hence, preparedness to monitor and respond to emergencies is critical (Furstein, 2022).

Another area of concern is drug interactions. Sedatives can also be used together with other central nervous system depressants, antihistamines, anticonvulsants or drugs used in behavioral and neurological disorders. The choice of analgesics should take into account the risk of hepatic, renal, gastrointestinal, and bleeding. The safety of dental anesthesia is a topic of discussion that is becoming more focused on patient safety, training of providers, and their access to relevant anesthesia care (Johnson et al., 2026). Newer sedation standards support the necessity to have organized follow-up, staff training, and discharge safety (Coté et al., 2019). Figure 3. Safety guideline to choose, administer, and monitor pharmaceutical analgesia in pediatric restorative dentistry.

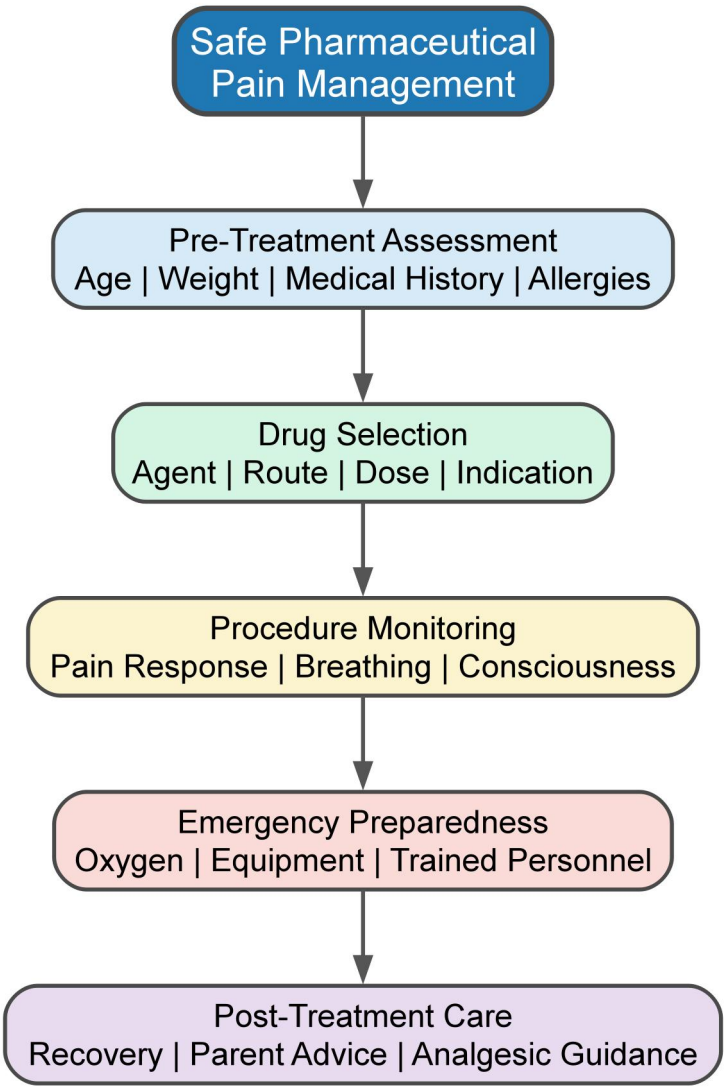

Figure 3. Safety Framework for Pharmaceutical Pain Management in Pediatric Restorative Dentistry

3.8 Clinical Guidelines and Recommendations

Evidence-based and personalized management of pain in pediatric dentistry is supported by clinical guidelines. The AAP/AAPD sedation guidelines focus on the proper assessment of the patient, informed consent, fasting where necessary, observation of the patient during the sedation process, emergency equipment, observation of recovery, and discharge preparedness (Coté et al., 2019). These guidelines are especially critical since sedation is a continuum and children can accidentally proceed to deeper levels of sedation (Hogan, 2020).

Evidence on the ADA has also played a role in the recommendations of pain management, particularly in the use of non-opioid analgesics and acute dental pain (Kör & Zortuk, 2026). A meta-analysis and systematic review of analgesics in the pediatric population with acute dental pain offers valuable information on the choice of medication in children. Evidence-based recommendations on pharmacologic treatment of acute dental pain in adolescents and adults can provide helpful context but cannot be directly applied to younger children unless pediatrically modified (Carrasco-Labra et al., 2024). Carious Lesion Management Guidelines are also used in support of minimal invasive and prevention-based strategies that can help to decrease the necessity of painful or extensive restorative practice (Slayton et al., 2018).

3.9 Emerging Trends and Innovations

The new trends in the management of dental pain in children are better drug delivery systems, anesthesia without needles, better topical formulations, distraction by virtual reality, intranasal sedation, and individualized pain management. The syringe systems that are needle-free and modified are designed to decrease the fear of injections. The latest studies on the comparison of insulin and safety syringes in pediatric dental anesthesia indicate the increasing interest in methods that minimize pain and anxiety in the administration of anesthetic drugs (Sasikumar & Ramesh, 2025).

Innovative approaches to topical anesthesia are also under investigation to enhance mucosal penetration, onset, and patient comfort (Pasternak & Woroń, 2024). Another promising field is intranasal sedative combinations, especially in children who are unable to take oral sedatives or need more reliable procedural sedation. Virtual reality is explored as a non-pharmaceutical but supportive method to decrease anxiety and enhance the treatment experience, but it is still in its infancy (de Barros Padilha, 2023).
AI and personalized dentistry can one day aid individualized pain prediction, risk prediction and treatment plan development. Nevertheless, AI is an adjunct that does not replace an actual pharmaceutical intervention in the area of pediatric restorative dentistry (Dua et al., 2025). Combining specific pharmacological regimens with child-based behavioral interventions, enhanced monitoring, safer administration of drugs, and risk-specific assessment are likely to be part of future pain management. Overall, the future of pharmaceutical pain management in pediatric restorative dentistry is shifting towards safer, evidence-based, and patient-centered methods that balance analgesic efficacy, anxiety reduction, and clinical safety.

4. Synthesis and Future Directions

4.1 Overview of Major Pharmaceutical Strategies

Some of the pharmaceutical pain management in pediatric restorative dentistry are local anesthetics, topical anesthetics, systemic analgesics and the use of sedation. Local anesthesia has been the most popular way of managing procedural pain since it directly inhibits the transmission of nociceptives during the preparation of cavities, pulp therapy and restorative treatments (Chandakavathe et al., 2023). Lidocaine remains popular due to its proven safety profile, whereas articaine has received recognition due to its diffusion property and clinical efficacy, especially in the case of chosen restorative cases. Topical anesthetics like benzocaine, lidocaine solutions, and EMLA cream can be beneficial as adjuncts to alleviate the pain of injections. Systemic analgesics, especially acetaminophen and ibuprofen, are important for managing preoperative or postoperative pain. Methods of sedation such as nitrous oxide, oral sedation, and nasal sedation, are clinically applicable in cases where anxiety or fear and lack of cooperation hinder therapy (Yilmaz et al., 2020).

4.2 Clinical Implications

Pain management in children cannot be treated in the same way but needs a tailored approach in planning the treatment. Age, body weight, medical history, anxiety level, type of procedure and expected duration of treatment are the factors that should be used to decide on the drug, dose, route, and technique. Pharmacological interventions are not effective alone but when they are combined with behavior management methods like tell-show-do, distraction, positive reinforcement, parental guidance, and child-friendly communication (Comfort et al., 2024). This combination method enhances collaboration, alleviates suffering, and contributes to a healthier dental experience.

4.3 Current Challenges

Although there have been improvements in the control of dental pain among children, a number of challenges exist. The process of drug selection, anesthetic technique, sedation protocols, and postoperative analgesic regimens are not fully standardized yet. Clinical practice can be different based on training, geographical area, equipment availability and the preference of the practitioner. The second limitation is the comparative paucity of long-term pediatric data, especially with respect to more recent anesthetic systems, intranasal sedatives and more sophisticated drug delivery systems.

4.4 Future Perspectives

The way forward in the future must be on safer anesthetic systems, better topical formulations, needle-free delivery, better drug release technology, and a personalized model of pain management. Precision pediatric dentistry can assist clinicians in making more accurate predictions regarding pain response, anxiety, and medication risk. Pharmacological innovation and child-centered care can be used to enhance the safety, comfort and treatment outcomes in pediatric restorative dentistry.

5. Conclusion

Pain management through pharmaceuticals is a vital aspect of pediatric restorative dentistry since unmanaged or improperly managed pain may influence cooperation, quality of treatment, and subsequent dental behavior. Children are not like adults in their perception of pain, their ability to communicate, emotional reaction, and tolerance to drugs; consequently, pain management should be developed in a special and unique way. Topical anesthetics are used to enhance comfort during an injection, whereas local anesthetics continue to be the mainstay of procedural pain control. Systemic analgesics like acetaminophen and NSAIDs may be used to treat preoperative and postoperative pain, but the use of opioids should be extremely limited due to safety

issues. Sedation based strategies such as nitrous oxide, oral sedation and intranasal sedation are supplementary in the case of nervous, very young, or uncooperative children, whose behavioural direction and local anesthesia are not adequate. Nonetheless, these approaches demand selection of patients, proper calculation of dose, constant observation, emergency preparedness, and professional competence. Special attention is also needed for children with developmental disabilities, medical compromise, sensory sensitivity, or previous traumatic dental experiences. In general, managing dental pain in children should be based on the combination of drug treatment and child-oriented behavioral methods. The way forward in future should be on safer anesthetic systems, better topical formulations, new drug delivery systems, and personalized pain-control regimens. An evidence-based strategy that focuses on efficacy and safety can be used to enhance clinical outcomes, lessen dental fear, and facilitate positive long-term oral healthcare experiences in children.

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