REVIEW ARTICLE

Local Anesthesia in Pediatric Dentistry: A Literature Review on Current Alternative Techniques and Approaches

Sainath R Elicherla[1], Varada Sahithi[2], Kanamarlapudi V Saikiran[3], Mahesh Nunna[4], Ramasubba R Challa[5], Sivakumar Nuvvula[6]

Abstract

Prevalence of pain and dental anxiety plays a crucial part in pediatric dentistry. These factors cause a delay in pursuing dental treatment, which in turn increases early childhood caries. Anxiety and fear that arise before and during local anesthesia administration persist as barriers for children experiencing dental treatment. Although local anesthesia plays a significant role in managing pain for children, researchers continue to search for various comfortable methods to alleviate the pain during local anesthetic administration. Thus, the present overview aims to educate pediatric dentists concerning newer local anesthetic delivery devices and several approaches in alleviating dental anxiety and pain in children.

Keywords: Children, Dental anxiety, Local anesthesia, Recent trends.

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Introduction

The International Association for the Study of Pain defines pain as "an unpleasant sensory and emotional experience associated with actual or potential tissue damage or described in terms of such damage".[1] Odontogenic pain related to dental caries, pulpal involvement, and dental trauma was reported favorably among children.[2] It is one of the prime motives for pediatric patients to attend dental care, especially emergency services.[3] Management of pain in pediatric dental care is a critical aspect of anxiety, often related to the induction of pain and exacerbates the pain perception. Consequently, these individuals experience higher pain, which persists for a longer duration with exaggerated pain memory.[4]

Thus, inadequate pain management helps stimulate negative responses and fear in children, which constitutes an obstacle for dentists to instill a positive attitude in pediatric patients. Hence, treating pediatric patients with minimal distress and pain has become a predominant objective for every pediatric dentist.[5] The anesthetic administration in children helps eradicate the pain during dental treatment procedures. The word "Anesthesia" is an aggregate of words that includes (Greek) *an*-("without") and *esthesis* ("sensation"). Malamed described local anesthesia as a reversible loss of sensation in the encircled portion of the body caused by a depression of excitation in nerve endings or inhibition of the conduction process in peripheral nerves.[6]

The administration of a local anesthetic solution through injection is the traditional method employed in alleviating dental pain in children. Though this process successfully eliminates pain during the procedure, anxiety and antagonistic behavior remain an issue for many children before and during anesthesia administration.[7,8] However, the pain encountered while receiving dental injections may hinder coping abilities during dental treatment in subsequent visits.[9]

Thus, to overcome these shortcomings exploring new alternative and minimally invasive methods in local anesthetic administration came into the limelight with better pain control, decreased injection pain, and enhanced quality of care for pediatric dentistry children. This review intends to update and educate the pediatric dentist on recent advances and several approaches to the effective administration of local anesthesia and pain management.

[1,2,4–6]Department of Pediatric and Preventive Dentistry, Narayana Dental College and Hospital, Nellore, Andhra Pradesh, India

[3]Department of Pediatric and Preventive Dentistry, SVS Institute of Dental Sciences, Mahabubnagar, Telangana, India

Corresponding Author: Sainath R Elicherla, Department of Pediatric and Preventive Dentistry, Narayana Dental College and Hospital, Nellore, Andhra Pradesh, India, Phone: +91 9440395427, e-mail: elicherlasai@gmail.com

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Aim and Objective

The current literature review intends to compile substantial evidence for pediatric dentists concerning the utilization of recent local anesthetics, alternative methods, and techniques to diminish pain while administering anesthesia, thereby enhancing patient comfort.

Anesthetic Drugs/Agents

Topical Anesthetics Drugs/Agents

Topical anesthetic application benefits overcoming discomfort generated during the local anesthetic administration. It is active on soft tissue surface of 2–3 mm in-depth and is accessible in various forms such as liquid, gel, aerosol, ointment, and patch.[10,11] Topical anesthetics reversibly block nerve conduction by acting on the dermis or mucosa's free nerve endings at the administration site. The conduction of nerve impulse gets hindered by reducing the permeability of the nerve cell membrane to sodium ions, increasing the excitability threshold.[12]

Periodontal Anesthetic Kit

It comprises a 20% benzocaine solution, marketed as a needle-free anesthetic kit. It constitutes a disposable plastic tip and syringe (3 mL), inserted deep within the gingival sulcus. It has an onset of action in 30 seconds, with nearly 15 minutes duration of action. Generally, re-administration, infiltration, or periodontal ligament anesthesia may be necessary for performing specific, more lengthy surgical procedures in adults.[13]

Controlled Heat-aided Drug Delivery Patch

It comprises drug reservoir for a 1:1 eutectic mixture of tetracaine base and 70 mg lignocaine, heat-generating medium, and medical tape cover. The relevance of warm technology is that it eases transcutaneous delivery and analgesic effect of anesthetics.[14] Once administered to the skin, heat passes from the patch to the area, thereby increasing the skin temperature. The mixture of activated carbon, iron powder, wood flour, and sodium chloride generates this heat. The water is placed in a pouch made of filter paper sandwiched between two polymer films; one film comprises pre-calculated size holes and another film with tiny holes covering the heat-generating chemical components. Air flows through the gaps in the cover membrane at a constant pace into the heating mixture, thus generating heat when exposed to the environment by initiating a chemical reaction. This heating element can cause a rise in temperature from 39 to 41°C temperature for 2 hours, which hastens the transcutaneous drug distribution and its analgesic effect.[15]

Cetacaine

It is a topical anesthetic solution comprising a unique triple action formula that blocks nerve impulse conduction and calcium ion binding and reduces potassium and sodium ion permeability. It is designated for topical pain management across the mucous membranes, except the eyes.[16] Dasarraju et al. stated that cetacaine effectively achieves topical local anesthetic effect compared to EMLA cream and 20% benzocaine gel in children. The advantages of this agent are no need to dry the mucosal surface before applying cetacaine. Therefore, it is superior to benzocaine gel and EMLA cream. Hence, its usage is more beneficial in children, mainly where the isolation is difficult to achieve a desirable topical effect. The disadvantage of this agent is that even though it is available in liquid form, it cannot be administrated as an infiltrative anesthetic agent.[17]

Nasal Route of Anesthesia

It is a novel method to accomplish local anesthesia for maxillary teeth by deposition of an anesthetic agent from a metered device's nostrils.[18] The hypothesis is that the anesthetic solution disperses through the nose's mucous walls and affects the maxillary innervating teeth structures.[19] It constitutes a mixture of 3% tetracaine hydrochloride and 0.05% oxymetazoline. In addition to its anesthetic properties, it furthermore deteriorates bleeding risk, which occurs due to vasoconstriction of local blood vessels' without a significant cardiovascular disturbance. This method enables dental clinicians to manipulate in a conservative way necessitating pulpal anesthesia for maxillary incisors, canines, premolars with >40 kg weight.[20] Further research considering the efficiency and safety in administering this method for pediatric patients is necessary. Hersh et al. suggested that K_30_5 (3% tetracaine plus 0.05% oxymetazoline) was competent and well-tolerated during restorative procedures in adults.[21] In contrast, Capetillo et al. reported that nasal spray afforded less pulpal anesthesia than infiltration with lidocaine, and undesirable effects are elicited like nasal drainage, burning, pressure, severe respiratory depression, seizures, convulsion, and disorientation.[19,22]

According to Ciancio et al., a more significant amount of nasal discomfort is seen in the combination of 3% tetracaine plus 0.05% oxymetazoline group (25 vs 11%) than the tetracaine alone group when it is administrated for restorative procedures for vital maxillary teeth in adults. In contrast, the tetracaine alone group displayed toothache, procedural pain, and congestion. These outcomes supported that oxymetazoline's addition to tetracaine can enhance the local anesthetic effect than administering tetracaine alone.[23]

Injectable Local Anesthesia

Buffering the Local Anesthesia

Malamed described an approach where sodium bicarbonate's addition immediately before anesthetic administration enhanced the solution's pH value.[24] Local anesthetics are weak bases to create a stable injectable anesthetic solution. Therefore, blending with acid produces hydrochloride salt. Consequently, all local anesthetic solutions are acidic before injection, which may provoke a stinging or burning sensation during administration and post-injection tissue injury. Hence, to bypass these, alkalinization of dental anesthetic cartridges is beneficial before injection, which hastens analgesia and lowers injection pain.[25] For buffering the local anesthesia, 8.4% sterile solution of sodium bicarbonate ($NaHCO_3$) is added to lidocaine with epinephrine as a neutralizing agent immediately before administration of local anesthetic injection.[25]

Advantages

- Rapid onset aid in starting the procedure faster, which in turn reduces treatment time.
- Provides less painful injections.
- Produce profound, consistent anesthesia.
- Easy to use.
- Advantageous in the cases with abscess to get anesthetic action.

Interestingly, the disadvantages of buffering of local anesthesia were not reported in the literature to date. Goodchild and Donaldson suggested clinical implications of buffering the local anesthetics before injection, which is beneficial for patients who have hassle in achieving profound anesthesia in clinical dentistry.[26] Guo et al. from a meta-analysis stated that buffered lidocaine had decreased onset time and injection pain (visual analog scale) in comparison with non-buffered lidocaine during inferior alveolar nerve block.[27] Afsal et al. reported that buffered lignocaine was the most productive anesthetic agent during the administration of inferior alveolar nerve block injection in 5- to 10-year-old children.[28] Aulestia-Viera et al. also reported another systematic review and meta-analysis and stated that reduction in onset time was not appreciated when alkalinized lidocaine was administered with terminal infiltration techniques in normal tissues; in contrast, the accelerated onset of time was illustrated for IAN blocks (–1.26 minutes) and inflamed tissues (–1.37 minutes).[29]

Phentolamine Mesylate (Local Anesthesia Reversal Agent)

The long span of soft-tissue anesthesia is often an unwanted outcome of local anesthesia in children. Self-inflicted soft-tissue trauma, altered facial appearance perception, impaired speech, and difficulty in chewing are some of the postoperative consequences of local analgesia. Phentolamine mesylate is an alpha-adrenergic antagonist, which enhances the clearance of local anesthetic solution from the site of injection, diminishing the duration of action.[30] It is a vasodilator and an adversary to the vasoconstrictor, but not an anesthetic agent.[31] It produces faster diffusion of the anesthetic agent into the vascular system away from the injection site. It is available as a cartridge with a concentration of 0.4 mg/1.7 mL. Dosage of this drug depends upon the number of cartridges of local anesthetic with vasoconstrictor administered. Usually, it requires one cartridge of a reversal agent for every cartridge of the local anesthetic administered.[32] Phentolamine appears to be safe in 3- to 5-year-old children with significantly enhanced lip sensation reversal than sham injections.[33] Disadvantage of this agent is that it requires the second prick to deliver the drug to the respected site, which will hurt the child.

Grover et al. suggested that phentolamine mesylate administration improves patient care by offering significant advantages like the accelerated safe return of normal functioning of oral soft tissues from 460 to 230 minutes and shortened the post-treatment duration.[34] In a recent systematic review and meta-analysis performed by Vinnakota and Kamatham, the occurrence of adverse events like facial swelling, increased blood pressure, and reactions at the site of administration and paresthesia were more significant. Phentolamine mesylate was administered as a reversing agent compared to controls. On segregating age-based studies, there was a lower incidence of adverse events in children and adolescents than in adults (odds ratio for children 0.68 and adults 1.58).[35] Al-Khafaji et al. stated that phentolamine mesylate usage is safe and efficient in reversing soft tissue anesthesia, with 1.8 mL of 3% mepivacaine hydrochloride (without any vasoconstrictor).[36]

Centbucridine

It is a quinolone derivative with a local anesthetic effect. The 0.5% concentration of centbucridine can be used for adequate infiltration anesthesia and also for nerve blocks.[37] However, the clinical trial results are not statistically significant, but descriptively, they are superior over lignocaine, having excellent anti-allergic properties and antihistaminic properties.[37] Gune and Katre stated that centbucridine was in line with lignocaine which is the gold standard and can be considered as a substitute for 12- to 14-year-old hypersensitivity patients to lignocaine or with another amide based anesthetics and for individuals with cardiac and thyroid disorders where these vasoconstrictors are contraindicated.[37]

Local Anesthesia Delivery Devices

Jet-injection (Medjet-III)

The jet technology is a needleless injection that utilizes a mechanical energy source to deliver pressure, enabling a thin flow of anesthesia to infiltrate the soft tissues. It is presumed to have benefits over traditional infiltration methods by displaying a quick onset of soft tissue anesthesia, controlled distribution of the anesthetic dose, and high acceptance in instances of needle-phobia patients. The lack of a needle for administration advocates a positive psychological outcome.[38] This device can direct the anesthetic solution with a small orifice seven times less than the world's smallest available needle. It can administer intradermal, subcutaneous, and intramuscular volumes of 0.01–1 cm^3 at 2,000 psi with this device. It can contribute to painless anesthesia and is ideal for nasopalatine and greater palatine injections. Furthermore, mechanical adjustments can be possible for the depth of penetration.[39] Even though it has several advantages, Arapostathis et al. stated that children preferred traditional infiltration over the jet-injector due to difficulty placing the device on gingival tissue area children experienced inadequate anesthesia.[40]

Single Tooth Anesthesia

This system employs an extra-short 30-G needle placed in the gingival sulcus parallel to the tooth's long axis. The number of points for administering anesthesia differs for single- and multi-rooted teeth, i.e., one point (distal) and two (distal and mesial)/three points, respectively. The needle has to be placed into the tissue till it approaches the periodontal ligament to achieve adequate anesthesia. Advantages of single tooth anesthesia (STA) include lack of anticipatory anxiety (due to its pen-like design), lack of pain, no perioral tissue anesthetic effects (lips, tongue, and cheeks), and no damages to the crown of permanent teeth.[41] Garret-Bernardin et al. stated that STA is an effective alternative to traditional techniques due to less significant pain and discomfort in children.[42] Al-Obaida et al. stated that STA increases the patients' satisfaction and compliance due to its profound anesthetic effect in restorative procedures among adolescence.[43]

QuickSleeper [Computer-controlled Intraosseous Anesthesia System]

In this technique, anesthesia is delivered with constant velocity and pressure to reduce the anesthetic effect's injection pain.[18,44] It comprises a handpiece and a control box; signals are sent to the main control box through Bluetooth by pressing the pedal. Once the circuit is completed, the handpiece drills and administers an anesthetic solution into the intra-bony space or cancellous bone to produce maximized anesthesia efficiency.[45] Smaïl-Faugeron et al. stated that the QuickSleeper® system eases dental practitioners while dealing with children and adolescent patients as it is associated with less pain and anxiety.[46]

Smaïl-Faugeron et al. stated that QuickSleeper reduces pain compared to conventional infiltration in children as it is delivered near the teeth in the cancellous bone; thereby, it has a limited soft-tissue anesthetic effect. The authors also stated that QuickSleeper is useful in the treatment of MIH or severe pulpal inflammation.[47] Sixou et al. summarized that 58.9% of children with past dental anesthesia experience reported that this technique was more pleasant than the infiltration method as it delivers the drop by drop anesthetic solution in the first 30 seconds.[48] Carugo et al., in a systematic review, stated that computerized devices had been demonstrated to reduce pain during anesthesia compared to conventional techniques in children.[49]

Vibrotactile Devices

Vibratory stimulation is the prospective technique used in pain reduction. Many devices have been designed based on the "Gate-control" theory, which states that the neural gate can be closed while applying pressure and vibration, reducing itch and pain perception. The brain can only recognize one sensation from one area at a given time; thus, vibrating the cheek has been followed to distract the brain from the discomfort of the anesthetic shot.[50] Ungor et al. stated that vibrations were useful in reducing the pain without causing anxiety upon injection.[51]

Indications

- It is indicated in children as distraction and pain reduction created by vibrating massages.
- Indicated in cases where topical anesthesia is undesirable (due to taste or allergy) or simply insufficient for relieving pain.

Contraindications

- Contraindicated in epileptic patients.
- In severe neurological disorder patient.
- In the areas we need profound anesthesia, it can be used as an adjunct with an anesthetic method.

VibraJet

It was introduced by Miltex Inc., York, PA, in 2002.[31] It is a battery-operated device that can easily fit the standard dental syringe.[52] It produces higher-frequency vibration to the needle and for the patient to feel when the knob is turned clockwise. Chaudhry et al.[53] and Nanitsos et al.[54] concluded that children perceived less pain with VibraJect while administering local anesthetic injections than the conventional techniques in both maxillary and mandibular teeth, which requires local anesthesia procedures. In contrast, Yoshikawa et al.[55] and Saijo et al.[56] reported that pain reduction is not significant while VibraJect was attached with a traditional dental syringe.

Dental Vibe

This device comprises a rechargeable, cordless handheld vibrotactile device. Dr Steven Goldberg designed this device in 2008.[57] It delivers injections with soothing percussive micro-oscillations at the site of administration. It contains a U-shaped vibrating tip connected to a microprocessor-controlled Vibra-Pulse motor which quietly stimulates the injection site's sensory receptors, thereby closing the pain gate and blocks the painful sensation of injection prick. Tung et al.[58] in 2018 and Sermet Elbay et al.[59] in 2016 concluded that the dental vibe reduces pain in pediatric patients receiving dental injections.

Accupal

It is a cordless device that employs vibration coupled with pressure to condition the oral mucosa. Michael Zweifler invented this device. Accupal delivers pressure, and it vibrates the injection site at 360° proximal to the needle infiltration that shuts the "pain gate". After placement of the device at the injection site, the unit vibrates by applying moderate pressure. The needle is positioned in a hole with the disposable tip head, and it is attached to the battery based motor.[52]

Intra-osseous Anesthesia

The first modern intra-osseous (IO) anesthesia technique requires a motor-driven perforator to penetrate the bone and buccal gingiva. It allows the delivery of a local anesthetic agent directly into the cancellous bone next to the anesthetized tooth.[60] Idris et al. concluded that supplemental IO injection significantly influences pulpal anesthesia in irreversible pulpitis conditions.[61] Numerous systems are developed to attain IO anesthesia; commonly used devices are X tip and IntraFlow.

X-tip

The X-tip anesthesia delivery system consists of an X-tip that separates the device into two parts: the drill (a special hollow needle) and the guide sleeve component. The drill leads the guide sleeve over the cortical plate, then separated and withdrawn. The remaining guide sleeve is designed to admit a 27-G needle to inject the anesthetic solution. The guide sleeve is detached after the IO injection is complete.[52] The minimum onset time duration for anesthesia was 5 minutes, the maximum time was 9 minutes.

The primary modifications in the application of the X-tip device are:[62]

- The penetration need not be done through the attached gingiva.
- Care should be taken to detach the guide sleeve with a hemostatic agent after administering the injection.

Dixit and Joshi reported a study to compare the IO anesthetic technique using X-tip with conventional infiltration technique for anesthetizing first permanent molars afflicted by molar incisor hypomineralization in children. The authors stated that X-tip IO local anesthesia is a safe and effective technique in achieving profound anesthesia for severe hypersensitivity MIH teeth in children with chronic pulpal inflammation.[63]

IntraFlow

It contains a handpiece with a 24-G hollow perforator and disposable transfuser. This device allows the operator to pierce the bone and deposit the entire solution in one step near the attached gingiva. It delivers the local anesthesia with a low speed, high torque, and steady pressure into the bone. Once the bone penetrates, the transfuser directs the cartridge's solution for infusion.[62] Remmers et al. stated that anesthesia was rapid and secure when administered by the IntraFlow system than the traditional technique.[64]

Iontophoresis

It has a broad range of dentistry applications; one of its applications is a non-invasive procedure of anesthesia. This method can be used for delivering local anesthesia to deeper oral tissues following topical application. This procedure assists in penetrating positively charged lignocaine and adrenaline agents to deeper tissues with an electrical influence.[65] Due to the lack of needles, this technique can enhance the dentist–patient relationship. Thongkukiatkun et al. elicited that topical application of 20% lignocaine and 0.1% epinephrine, through an iontophoretic current of 120 mA for the 90 seconds, is required to anesthetize exposed, normal dentine.[66] Cubayachi et al. stated that a combination of the drugs prilocaine hydrochloride and lidocaine hydrochloride appeared to increase the mucosal accumulation after iontophoresis by 86- and 12-fold, respectively (pH 7.0). Hence, applying iontophoresis to a combination of drugs at pH 7.0 can assist in a needle-free approach to promote the onset and extends buccal anesthesia duration.[67]

Nonpharmacological Local Pain Management

Laser Analgesia

It is a noninvasive, nonthermogenic biomodulation of the dental pulp, which utilizes low-level laser therapy (LLLT). This LLLT does not achieve profound anesthesia (a complete lack of sensation), similar to infiltrative local anesthesia. It works on the principle by modifying a neuronal cell membrane's behavior, thereby causing a temporary disruption in the Na-K pump, which results in loss of impulse transmission and in achieving the analgesic effect.[68] Hence, accepting laser dental treatment reduces anxiety in children and adolescents.[69] Chan et al. validated that Nd:YAG laser effectively induced pulpal analgesia similar to that of 5% EMLA anesthetic cream and suggested that laser can be an innovative, non-invasive alternative for treating children with needle-phobic.[70] Efthymiou et al. stated that photobiomodulation therapy using laser produces adequate pulpal anesthesia in decayed permanent teeth during cavity preparation.[71] Poli et al. suggested laser-induced analgesia as a feasibly effective modality that affects pain perception and alters patients' responses with minor anxiety levels due to its limited invasiveness.[72]

Virtual Anesthesia

The distraction techniques are the most extensively practiced behavioral techniques for alleviating dental anxiety. Currently, virtual reality (VR) devices are more engaging forms of distraction. Although it has certain limitations, several authors have stated that it decreases pain and increases patient satisfaction during medical procedures.[73] Clinical trials on VR reported both subjective and objective reduction of pain and anxiety during dental procedures in children.[74] These observations recommend that VR can be used as an adjunctive tool in non-pharmacologic analgesia. Due to this analgesic potential in VR, this is termed "virtual anesthesia". Atzori et al. and Nunna et al. suggested that VR is a useful technique that helps children cope with dental fillings and extractions in a non-stressful manner with higher fun levels than its counterpart.[75,76]

Buzzy® Device

It is a bee-shaped device comprising two components: the bee's body vibration and the detachable ice wings. It works on the gate control theory principle and the descending inhibitory controls. More precisely, the vibration produced by the buzzy body will block the afferent pain-receptive fibers (A-delta and C fibers), resulting in the reduction of the pain.[77] On the other hand, due to persistent application of cold (30–60 seconds), it stimulates the C nociceptive fibers and blocks the A-delta signals when administrated in the vicinity of the nociception area.[78] Suohu et al. suggested that the external application of cold and vibration close to the local anesthesia administration site using Buzzy® device can reduce pain and anxiety in children during local anesthesia delivery adjacent to the tooth in maxillary and mandibular teeth, which are indicated for invasive procedures.[79] Bilsin et al. reported that external cooling and vibration at the local anesthetic administration site adjacent to the tooth had a significant outcome on children's pain during the extraction of mandibular primary teeth.[80]

Cryoanesthesia

This is a process of applying cold using refrigerant sprays or ice to a confined body part to hinder pain impulses' conduction by nerves.[81] Thus, the topical application of cold would excite myelinated A-fibers and stimulates inhibitory pain pathways.[81] Cooling causes neuropraxia by lowering the tissue nociceptors threshold and the conduction nerve signals, which carries pain.[82,83] Hindocha et al., in a randomized crossover study, stated that the application of ice on oral mucosa as topical anesthesia before injection has an impact identical to 5% lidocaine gel during needle insertion. This topical anesthetic effect persists for a minute after its application.[84] Hameed et al. suggested that precooling at the injection site with tetrafluorethane refrigerant spray has elicited significantly higher efficacy in eliminating pain than lidocaine topical spray in pediatric dental patients. This refrigerant tetrafluorethane spray had other benefits such as good patient acceptance due to its pleasing taste, shortened waiting time due to quicker and deeper cooling of action, and reduced children's pain perception during needle insertion and deposition of solution.[85] Bose et al. stated that precooling the soft tissue area reduces the pain perception for infiltrations and block anesthesia in children during regular dental procedures.[86] It is an easy, reliable, and cost-effective method.[87] Tirupathi and Rajasekhar, in a systematic review, stated that precooling with ice reduces pain than refrigerant spray before the local anesthetic administration.[88]

Conclusion

Current techniques discussed in the present article to deliver local anesthesia play a vital role and appear to be a practical alternative to traditional methods. These newer techniques are being projected for their advantages and have a broad scope for their usage in pediatric dentistry. Usage of current techniques for effective and pain-free local anesthetic administration produces a more pleasant experience for the dentist and children, resulting in more positive outcomes in maintaining a proper child–dentist relationship.

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