Review Article

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Advances in pediatric dentistry: new approaches to pain control and anxiety reduction in children - a narrative review

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Painless treatment determines the quality of pediatric dental care. Although local anesthesia has been used to manage pain in dentistry, children often cite traditional aspirating syringes as a symbol of fear and pain. Adequate pain control during dental procedures may help alleviate fear and anxiety and instill positive oral health attitudes in children. Newer approaches such as intranasal spray, centbucridine, jet injectors, buzzy devices, and acupressure have been developed to help dentists provide near-painless injections while reducing dental anxiety. This review aims to summarize newer approaches to alleviate pain and anxiety in children.

Keywords: Children; Local Anesthesia; Pain Control.

INTRODUCTION

Dental pain due to caries, pulpal involvement, and trauma is one of the chief complaints of pediatric patients visiting the dentist [1]. The interrelation of dental anxiety, fear, and pain may hinder the delivery of quality dental treatment [2]. Pain experienced during childhood may shape future pain perceptions and experiences [3]. Therefore, pediatric dentists face challenges in administering anesthesia with minimal pain and discomfort.

Local anesthetics are still administered through a traditional aspiration syringe to alleviate dental pain in children. The visual and painful nature of the injection evokes apprehension and anxiety, which are barriers to a positive dental attitude in pediatric patients [4]. Numerous advanced agents and approaches have been introduced to achieve minimal distress and pain during anesthesia administration in pediatric dentistry. This article reviews newer local anesthetics and techniques to diminish the pain and discomfort related to injections, therefore inculcating a positive attitude toward dentistry.

ANESTHETICS AGENTS (Table 1)

1. Topical anesthetic agents

Nerve conduction in the free nerve endings of the dermis or mucosa is reversibly blocked at the administration site of topical anesthetics, thus minimizing the painful sensation of needle penetration. A contact time of at least 1 min in the dried mucosa is generally required

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Table 1. Newer agents and techniques to alleviate pain and anxiety in children

Agents / methods	Details	Advantages	Disadvantages
Cetacine Topical anesthetic liquid	Dispensed into periodontal pocket; up to 60 minutes of topical anesthesia achieved	Increased depth of surface anesthesia; less sensitive to moisture	Safety data on pediatric patients not available
Oraqix Subgingival Anesthetic gel	Inserted into gingival sulcus; anesthesia lasts for 20 minutes	Rapid onset (30 sec)	Safety data on pediatric patients not available
DentiPatch® system	Lidocaine in DentiPatch diffuses into mucosa	Bioadhesiveness; better diffusion; earlier onset and longer duration of anesthesia	Poor adherence in mandible due to higher salivary flow
Intranasal spray	Diffuses through nasal mucous walls and anesthetizes maxillary anteriors	Needleless	Incidence of rhinorrhea and nasal stuffiness
Centbucridine	Natural vasoconstrictive effect	Longer duration of anesthesia than lignocaine	No safety and efficacy data available on children under 12 years
Oraverse	Nonselective alpha-adrenergic receptor antagonist; vasodilator	Accelerated reversal of oral soft-tissue sensation	Postoperative intraoral pain and swelling [29]
pH buffering of local anesthesia	Addition of sodium bicarbonate to local anesthetic solution	Reduction of injection pain and onset time in inflamed tissues	Solution needs to be freshly prepared each time as it loses stability within 3-7 days [92]
CCLAD	Computerized device controls the injection speed	Diverse injection speed control	Expensive; time consuming to set up and disinfect
Jet injector	Anesthetic solution delivered using high pressure and velocity penetrate through oral mucosa	Faster onset of anesthesia; patient acceptability	Expensive; bulky; abrupt noise and pressure sensations can induce anxiety; risk of residual hematomas at the injection site
Vibrotactile devices	Based on Gate control theory of pain	Painless injection	Discomfort associated with the sensation of vibration
Intra-Osseous anesthesia	Local anesthetic solution injected directly into cancellous bone adjacent to tooth to be anesthetized	Lesser volume of anesthetic solution	Difficult to locate perforation site; pain at injection site
Insulin syringe	30-gauge short needle	Visually appealing; cost-effective	Needle length not sufficient for nerve blocks [63]
LLLT	Based on biostimulation	Minimally invasive; anti-inflammatory and analgesic effect	Contraindicated in patients with epilepsy and pacemakers [93]
Buzzy® device	Based on Gate control theory of pain and distraction	Effective behavior guidance modality; well accepted by children	Appearance like a bee (an insect) may potentially draw a negative reaction from some children.
Cryoanesthesia	Based on Gate control theory of pain	Instantaneous anesthesia [94]; safe; inexpensive	Short duration of action
VR Analgesia	Uses sensory shielding (brain flooded with sensory inputs from VR, thus less attention available for pain stimulus)	Effective behavior guidance technique; well tolerated by children	VR induced nausea; discomfort due to larger head-mounted displays [95]
EDA	Analgesic effect based on Gate control theory of pain and endogenous opioid theory	No postoperative anesthesia	Contraindicated in apprehensive patients, those with cardiac pacemakers, cerebrovascular problems and epilepsy

CCLAD, Computer-Controlled Local Anesthesia Delivery; EDA, Electronic Dental Anesthesia; LLLT, Low-level Laser Therapy; VR, Virtual Reality.

to anesthetize surface tissues (up to 23 mm depth) [5,6].

1) HurriPAK periodontal anesthetic kit

A plastic syringe (3 ml) containing a 20% benzocaine solution is inserted deep into the gingival sulcus using disposable plastic tips. The onset of action is 30 s and the duration of action is approximately 15 min. Lengthy surgical procedures in adults may require re-administration, infiltration, or periodontal ligament anesthesia [7].

2) Cetacaine topical anesthetic liquid (Fig. 1)

Local pain control across mucous membranes, except in the eyes, can be achieved using this formula [8]. Dasarraju et al. found better topical anesthetic effects with cetacaine compared to EMLA cream and 20% benzocaine gel in children aged 7–11 years during palatal needle prick. Cetacaine showed better efficacy due to its increased depth of surface anesthesia and reduced moisture sensitivity. Although it is available as spray and liquid, it cannot be administered as an injection [9].

3) Oraqix subgingival anesthetic gel

A noninjectable gel anesthetic containing 2.5% lidocaine and 2.5% prilocaine is inserted into the gingival

Fig. 1. Cetacaine topical anesthetic liquid with single-use delivery syringe and tip.

sulcus to achieve anesthetic effects for deep scaling and root planning [10]. Oraqix can be used to relieve discomfort or pain experienced after the placement of orthodontic elastomeric separators [11]. A significant reduction in needle prick pain in the palatal mucosa has been reported following the application of Oraqix [12]. Currently, there is no information on the pharmacokinetics and safe dose of Oraqix in children aged < 18 years.

4) Clove-papaya-based topical anesthetic gel (eco pain care)

It contains clove oil (analgesic effect), chloramine (gelling agent), and papaya extract (vehicle). Clove oil activates calcium and chloride channels in ganglion cells, resulting in an analgesic effect. Anantharaj et al. reported no statistically significant differences between the topical anesthetic efficiency of clove–papaya-based topical gel, pre-cooling with ice, and benzocaine gel in pediatric patients [13].

5) DentiPatch® system (Fig. 2)

A transmucosal delivery system releases lidocaine for preinjection numbness [14]. Most of the children reported less injection pain and preferred the patch over the benzocaine gel [15,16]. Mucoadhesive patch (46.1 mg of 20% lidocaine) applied for 5 min in children aged 27 years resulted in a mean peak plasma concentration of 82 ng/mL (well below toxic levels, but 45 times higher than that found in adult patients); therefore, it must be

Fig. 2. Oraverse (Phentolamine mesylate) injection for reversal of anesthetic effect.

included in the calculation of the maximum total lidocaine dose for pediatric patients [17]. Shehab et al. reported a better efficacy of the DentiPatch® system than that of lidocaine gel in reducing pain during injection in children, thus improving patient behavior in subsequent visits [18].

6) Intranasal spray

In 2016, the Food and Drug Administration approved intranasal administration of 3% tetracaine hydrochloride/0.05% oxymetazoline (Kovanaze®) (Fig. 3) to achieve local anesthesia to perform routine restorative procedures in the maxillary anteriors in patients weighing > 88 lb (40 kg) [19,20]. The maximum recommended dose of 18 mg tetracaine/0.3 mg oxymetazoline (three 0.2 ml sprays) showed significantly higher anesthetic success with no serious adverse effects [21,22]. Future research should focus on its efficacy and safety in children under 40 kg, medically compromised patients, and those undergoing invasive dental procedures.

2. Injectable anesthetic agents

1) Centbucridine

This quinolone derivative produced a local anesthetic effect at a concentration of 0.5%. Goyal et al. reported that centbucridine and lignocaine showed similar time of onset, depth of anesthesia, and cardiovascular effects following IANB administration. The inherent vasoconstrictive nature of centbucridine results in a significantly

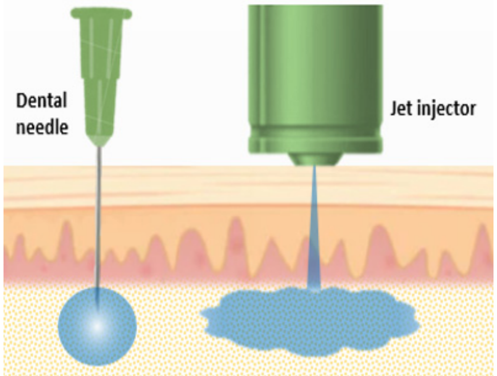

Fig. 3. Deposition of local anesthetic solution using conventional dental needle and jet injector.

longer duration of anesthesia (2.5 h) with no toxic reactions compared to lignocaine (< 2 h) [23]. Gune et al. recommended centbucridine as a substitute in 12-14 years old medically compromised patients for whom lignocaine or adrenaline was contraindicated [24]. However, its efficacy and safety should be assessed in children younger than 12 years.

2) Oraverse™ (Fig. 2)

In children, persistent anesthesia beyond the procedure is usually associated with self-inflicted soft tissue injury, impaired speech, and difficulty eating [25]. Phentolamine mesylate (local anesthesia reversal agent) is a nonselective alpha-adrenergic receptor antagonist that competitively inhibits the vasoconstrictive ability of adrenaline, resulting in increased absorption of local anesthetic and shortening the duration of anesthesia. The dose and location of administration of this drug are the same as those used to administer local anesthesia during the appointment [26]. Tavares et al. reported that the administration of phentolamine mesylate accelerated the safe recovery of oral soft tissue sensation from 135 to 60 min in children aged 4-11 years [27]. Hersh et al. observed a significantly accelerated reversal of lip sensation with phentolamine compared to sham injections and concluded that it was safe in children aged 3–5 years [28]. Vinnakota and Kamatham observed a lower incidence of phentolamine-associated adverse events (postoperative swelling, increased blood pressure, and paresthesia) in children and adolescents than in adults [29].

3) pH buffering of local anesthesia

The acidic nature of local anesthetic solutions can cause a burning sensation during administration and post-injection tissue injury. Alkalinization of dental anesthetic cartridges using an 8.4% sterile solution of sodium bicarbonate ($NaHCO_3$) at the chairside immediately before injection accelerates analgesia and reducesinjection pain [30,31]. Afsal et al. found that buffered lignocaine is the least painful and most effective anesthetic agent during inferior alveolar nerve block injections in 5–10-year-old patients [32]. Buffered lidocaine has shown an accelerated onset time for IAN blocks (−1.26 min) and inflamed tissues (−1.37 min) compared to normal tissues [33].

LOCAL ANESTHESIA DELIVERY DEVICES (Table 1)

1. Computer-controlled local anesthesia delivery (CCLAD)

Computer technology delivers local anesthetic solutions at fixed flow rates, regardless of variations in tissue resistance. The syringe of the Wand is contained within the main unit, while the Quicksleeper and Comfort Control Syringe have a base unit and a syringe [34]. The Wand is a computerized-controlled Single Tooth Anesthesia (STA) system used to anesthetize the tooth being treated by intraligamentary "injection." The STA technique prevents anticipatory anxiety and physical pain, the absence of perioral tissue anesthesia, and the delivery of a controllable, lower dose of anesthetic liquid [35,36]. Garret-Bernardin et al. stated that the Wand computerized delivery system provided less painful injections and was better tolerated among pediatric patients than traditional syringes [37]. Mittal et al. reported significantly lower pain perception with palatal infiltration using a Wand than during traditional palatal infiltration injection in 8-12-year-old children [38].

A QuickSleeper delivers a computer-assisted intraosseous (IO) injection, in which the volume and speed of diffusion of the anesthetic agent into the cortical bone are monitored by a Bluetooth pedal [39]. Less pain and soft-tissue anesthetic effects, along with the nonthreatening needle design of the Quicksleeper, can be beneficial for anxious young patients [40].

Children preferred computer-controlled delivery systems (Wand STA® and QuickSleeper® for intraligamentary and IO techniques, respectively) over conventional techniques because they experienced less pain during injection and less postoperative morbidity [41].

2. Jet injection

The liquid medication is pushed through a small orifice under the pressure created by a mechanical energy source to penetrate the subcutaneous tissue without a needle (Fig. 3). The jet injector shows a faster onset of soft tissue anesthesia with less pain and tissue damage, making it ideal for nasopalatine and greater palatine injections [4,25]. Arapostathis et al. reported inadequate anesthesia due to difficulty correctly positioning the jet injector (INJEX) on the gingival tissue area in children, resulting in greater acceptance and preference for traditional infiltration [42]. For pulpotomy and filling treatment, administration of 0.3 ml of 2% lidocaine and 1/80000 epinephrine with the Comfort-In™ injection system resulted in a shorter onset time of anesthesia and less pain, while the dental needle method showed a longer duration of anesthesia in children aged 4-11 years [43]. Mohamed et al. reported similar results in 6-8-year-old children when 4% articaine with 1:100,000 epinephrine was administered using a jet injector for pulpotomy [44]. However, conventional needle anesthesia is preferred for complicated surgical procedures or extractions due to its long duration of action and better pain control [45].

3. Vibrotactile Devices

According to the gate control theory, vibration applied concurrently to an anesthetic injection will reach the brain before pain sensation and reduce pain [46]. Ungor et al. reported pain reduction without anxiety when applying vibration concurrent with local anesthetic injection [47]. Vibrajet is a battery-operated device mounted on a conventional syringe that delivers high-frequency vibrations to the needle that the patient feels [48]. Children perceived less pain with Vibrajet than with the conventional technique when administering local anesthetic injections [49,50].

Percussive soothing micro-oscillations were delivered at the site of administration by DentalVibe. Shilpapriya et al. [51] and Tung et al. [52] reported significant decreases in pain and discomfort with the use of DentalVibe. In contrast, Felemban et al. [53] and Elbay et al. [54] concluded that pediatric patients experienced similar pain and discomfort during anesthesia administration with DentalVibe and traditional syringes. The children preferred the traditional method over DentalVibe due to the discomfort associated with the vibration and noise of the device.

Accupal uses vibration coupled with pressure at the administration site to shut the "pain gate" [48].

4. IO anesthesia

The local anesthetic solution is injected directly into the cancellous bone adjacent to the tooth to be anesthetized, resulting in effective, localized pulpal and periodontal anesthesia without extensive collateral soft tissue anesthesia or other injections [55]. In irreversible pulpitis, pulpal anesthesia can be achieved using supplemental IO injections [56]. In contrast to a higher concentration of epinephrine used in conventional injection techniques, computer-assisted IO anesthesia for a duration of 30 min can be achieved in primary and permanent teeth using 4% articaine and epinephrine diluted 1:400,000 [57].

The Stabident® system drills a small hole into the alveolar bone distal to the tooth to be anesthetized using the perforator, and an injection needle is inserted into the hole to administer anesthesia. Locating the penetration site within the alveolar mucosa can be extremely difficult once the perforator is withdrawn [58].

The guide sleeve of X-Tip® is placed into the

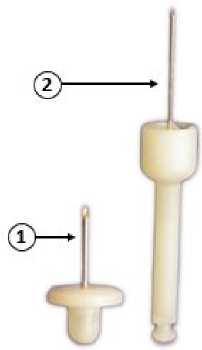

Fig. 4. Components of an Intraosseous Injection System: 1. the drill (a special hollow needle), 2. the guide sleeve accept a 27-gauge needle to inject the anesthetic solution.

cancellous bone using the perforator drill and a 27-G needle is inserted through it to inject the anesthetic solution (Fig. 4). After injection, a hemostatic agent was used to detach the guide sleeve. In MIH-affected teeth with severe hypersensitivity related to chronic pulpal inflammation, the X-tip® IO system can achieve profound anesthesia safely and effectively [59].

The IntraFlow anesthesia system allows penetration, injection, and withdrawal using a simple one-step technique without the need to relocate the perforation site. Remmers et al. observed more reliable and rapid anesthesia of the posterior mandibular teeth with IntraFlow than with the traditional inferior alveolar block technique [60].

5. Insulin syringe (Fig. 5)

The miniature needle, slim design, and bright color of the insulin syringe appear as a toy for the child patient; thus, gaining confidence and convincing children to inject takes less time and helps in the curtailment of dental appointments [61]. An insulin syringe allows almost near-painless injection due to controlled and fractionated administration of the anesthetic solution [62]. Tirupathi et al. reported similar efficacy of insulin syringes and auto-control syringes (ACS) during the administration of palatal anesthesia. Children (96.5%) preferred visually appealing insulin syringes, which can be an economical alternative to expensive ACS for palatal injections [63].

Fig. 5. Insulin syringe (1 mL) with 30-gauge short needle.

NONPHARMACOLOGICAL LOCAL ANALGESIA (Table 1)

1. Low-level laser therapy (LLLT)

LLLT suppresses painful sensations by temporarily disrupting the Na^+-K^+ pump system and biomodulating the dental pulp. Profound anesthesia is not achieved due to the inability to suppress all sensations [64]. Children show good acceptance and tolerance of erbium lasers for dental and soft tissue treatments [65]. Chan et al. reported the effective induction of pulpal analgesia using pulsed Nd: YAG laser and suggested it as a noninvasive alternative for needle-phobic children [66]. Topical anesthesia + LLLT with an 810 nm diode laser reduced injection pain in children aged 6-9 years who underwent pulpotomy treatment [67].

2. Acupressure

Direct application of pressure to acupoints with the finger in circular motion or constant and consistent pressure through a bead or pellet modulates pain perception [68]. Naik et al. recommended acupressure for various dental disorders, including dental pain, dental anxiety, gag reflex, TMJ pain, atypical facial pain, and xerostomia [69]. Avisa et al. suggested acupressure as a viable option to reduce dental pain and anxiety in pediatric dentistry without side effects [70]. Soares et al. found significantly lower heart rates in children aged 7-10 years after acupressure [71].

3. Buzzy® device (Fig. 6)

A plastic bee-shaped vibrating device with detachable

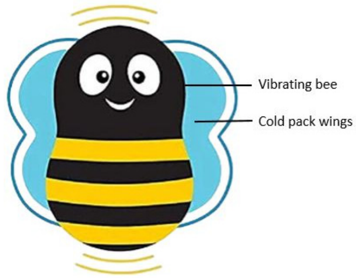

Fig. 6. Buzzy device with vibrating plastic bee and cold pack wings.

Fig. 7. Extraoral application of TENS electrodes over coronoid notch and posterior mandibular area for administration of IANB injection.

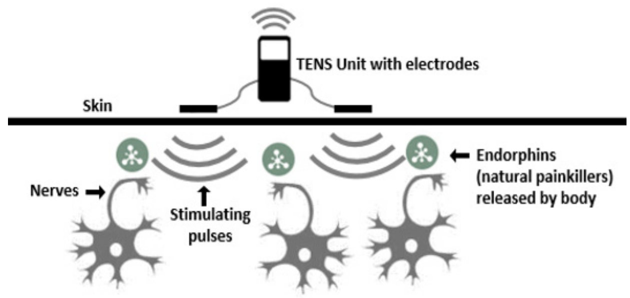

Fig. 8. Mechanism of action of TENS. Electrical stimulation of large myelinated A fibers blocks / modulates pain transmission in C fibres and promotes release of endogenous opioids (natural painkillers).

ice wings was developed based on the gate control theory principle and distraction. Vibration excites the A-beta fibers and cold excites the C fibers, which eventually blocks the A-delta and reduces pain [72]. Throughout the dental procedure, the device was attached to the arm or held manually as close as possible to the needle insertion site (approximately 5 cm above the insertion site) [73]. Children experience significantly lower pain and anxiety with dizziness than vapocoolants and analgesic creams [74,75]. Bilsin et al. reported that children experienced less pain during extraction of mandibular primary teeth when cold and vibration were administered at the site of local anesthesia [76]. Children aged 4-8 years reported significantly less pain and discomfort during local anesthesia administration with the extraoral application of a vibrating device [77]. Faghihian et al. found a better efficacy of the Buzzy device in reducing pain associated with dental injection in children than DentalVibe [78]. Alleviation of needle-associated pain and anxiety in children aged 4-11 years requiring extraction and pulpectomy is better achieved with a buzzy device than with counterstimulation [79].

4. Cryoanesthesia

The application of cold (refrigerant spray or ice) to a localized body blocks the conduction of painful nerve impulses. Although cooling produces immediate anesthesia by acting on all cells of the part, it has a very short duration (2–5 s), sufficient to reduce the discomfort caused by needle insertion [80]. Hindocha et al. reported that applying ice to the oral mucosa before injection and 5% lidocaine gel had identical effects on pain relief during needle insertion [81]. Hameed et al. suggested that tetrafluorethane refrigerant spray can be used to precool the injection site to eliminate pain in children compared to lidocaine topical spray [82]. Tirupathi and Rajasekhar stated that subjective and objective pain during local anesthesia administration could be reduced in children by pre-cooling the injection site [83]. Ice cones have shown a significantly higher efficacy in reducing injection pain than benzocaine and refrigerants [80].

5. Virtual reality (VR) analgesia

VR distracts patients by flooding the brain with processing information; therefore, no room is available to process incoming pain signals at the same time simultaneously. The VR headset blocks the sight and sound of dental instruments. VR helps reduce pain and anxiety and increases the fun of children during dental procedures [84,85]. Zaidman et al. reported that VR goggles decreased pain perception during rubber dam placement in children aged 4-12 years [86].

6. Electronic dental anesthesia (EDA)

According to the principle of transcutaneous electrical nerve stimulation (TENS), superficial nerves are stimulated by pulsed electrical current delivered across the intact skin surface via electrodes for localized pain relief. The gate control theory of pain and the endogenous opioid theory can explain the analgesic effect of TENS (Fig. 7, 8) [87,88]. It has been used to control trigeminal neuralgia or atypical facial pain and to relieve muscle spasms in myofascial pain dysfunction [48]. Choudhari SR et al. found that IANB injection administration with TENS significantly reduced pain and discomfort compared to 20% topical benzocaine application in children aged 8-12 years [89]. Siddiqui et al. reported that TENS effectively reduces pain intensity during local anesthetic injections in pediatric dental patients [90]. TENS can be a useful adjunct in pediatric patients undergoing various minor dental procedures, except for pacemakers, cochlear implants, heart diseases, neuro-logical disorders, and epilepsy [91].

CONCLUSION

Pain and anxiety induced by traditional syringes can be a barrier to the quality of dental care in pediatric patients. Several advanced agents and methods have been developed in the field of dental anesthesia to alleviate pain and anxiety in children. Effective and pain-free local anesthetic administration is crucial for developing a positive dental attitude and maintaining a proper child–dentist relationship.

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