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Painless Anesthesia in Pediatric Dentistry: An Updated Review

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Abstract
Dentists have a lot on their plate already without having to worry about how to deal with their young patients' pain. There have been several advancements in local anaesthetic for dentistry in recent years that can be used in conjunction with standard methods to reduce the discomfort patients feel from the syringe and needle and put them at ease. The purpose of this review is to provide dentists with up-to-date information on painless local anesthetic techniques, such as the computer-controlled local anaesthesia delivery system, Jet injectors, Safety dental syringes, and topical anesthetics, and to summarize recent advancements in these areas.

Keywords*: painless dentistry, dental anesthesia, pediatric dentistry, local anesthesia, recent advances*

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I. INTRODUCTION

An unpleasant sensory and emotional experience linked to actual or potential tissue damage or explained in terms of such damage; this is how the International Association for the Study of Pain (IASP) defines pain. One of the medical and dental profession's most crucial pillars is effective pain management[1]. Most people put off getting dental treatment because they are afraid of the pain or the dentist. A child can be taught to have a positive dental attitude if their discomfort is managed effectively.

Anesthesia is typically used to ensure that the patient does not feel any discomfort or pain during their treatment. Loss of sensation in a localized area due to the decrease of excitation in nerve endings or suppression of the conduction process in peripheral nerves was defined by Stanley F. Malamed as Local Anesthesia in 1980[2]. The ability to effectively administer local anesthetic is crucial in the field of dentistry since it aids in pain management and patient care. The dentist's primary concern is that their patients feel as little discomfort as possible during dental procedures. "The application of local anesthetic can be uncomfortable, but most patients report feeling much better soon after.

The use of a syringe and needle to provide local anesthetic has been linked to elevated levels of fear and anxiety in patients even before dental work has begun[3]. However, the injection itself can be painful or otherwise uncomfortable. This is why kids hate going to the dentist. The most challenging component of patient management is addressing this kind of fear-related behaviour. Without an efficient pain control system, dental therapy may be compromised regardless of the dentist's clinical skills, which can be a barrier to both the dentist's ability to give a successful treatment and the patient's ability to get necessary dental care.

Modern dental anesthetic techniques have come a long way from their invasive roots, making the experience more pleasant for both the patient and the dentist. Although it is nearly impossible to inject a patient without some pain, modern techniques, needles, and anesthetic gels have greatly reduced that pain compared to older approaches[4]. These techniques along with the conventional ones can be utilized for better handling of pain.

II. ADVANCES IN LOCAL ANAESTHESIA DELIVERING SYSTEMS

Needles and syringes, initially introduced by Cook approximately 150 years ago5, are still widely used for administering local anesthetics. Penetration of the oral mucosa with a needle results in mechanical trauma. Recent developments in local anesthetics have shown promising results in alleviating patients' fear of needles. Some of them are;

- Computer-controlled local anaesthesia
- Jet injectors
- Safety dental syringes
- Topical anesthesia
- Electronic dental anesthesia
- Iontophoresis in dentistry
- Vibrotactile systems

Computer controlled local anesthesia delivery (CCLAD) system:

Pain is reduced due to the computer-controlled, gradual, and steady release of local anesthetic made possible by computer-controlled local anesthesia delivery systems[6]. Before settling on a system, the operator should consider factors like its weight, infection management, speed and form of drug injection, danger of aspiration, etc. Wand (launched in 1997)[7] was the first CCLAD used, and future versions include Wand Plus and CompuDent. Comfort Control Syringe introduced in 2001 is another option that diverges from the Wand system in that it lacks a foot control.

a.) Wand system: This system helps the operator to place the needle at the site to be anesthetized with finger-tip accuracy and better control as compared to traditional syringes. The local anesthetic is administered at a constant rate with the use of foot activated control in this system[8]. The handpiece is lightweight and can be held with a penlike grasp for better tactile sensations[8].

The Wand system is the most popular and commonly used CCLAD owing to its operator friendliness and its circumference that is half the size of the conventionally used syringes[9]. The syringe is integrated into the main system, rather than being in a separate hand piece like in the Quicksleeper. Because the operator must hold the CCLAD in the area to be anesthetized for a considerable amount of time, its weight is also a factor. Lighter devices are preferable over heavier ones to reduce the risk of needle break injuries and operator muscle fatigue. Anesthesia solution is lost at a rate of 0.3-0.4 ml every cartridge change while using the Wand system since the cartridges are stored in the main unit[10]. Aspiration time in the conventional Wand system was initially around 14 seconds which has now been reduced to 5 seconds in the advanced version of the system, WandPlus. Feda et al[11] and Mittal et at[12] reported that CCLAD proved to be of advantage while delivering the palatal anesthesia by reducing the pain as compared to buccal anesthesia.

b.) Computer Comfort Syringe (CCS) system: CCS consists of a base unit, a syringe and no foot control, unlike the Wand system[13]. The injection and aspiration can be controlled with the help of the syringe itself and the solution is deposited into the desired tissues irrespective of the resistance offered[14]. Practitioners who are used to the standard syringe and needle method will find this more comfortable. Five predetermined speeds can be selected using the device's three buttons. You can begin or end anesthetic delivery, aspirate, or speed up or slow down the injection with the start, stop, aspirate, and double buttons. Digital readouts on the main unit show the elapsed time, injection rate, and volume injected. CCS is not as "recommended as the former due to the weight of the device, but it does have higher advantage over the usual way of anesthetic delivery when compared to the Wand system.[13]

Jet injectors:

The first jet-injection devices, used for mass immunization in 1866, were adapted for use in the intramuscular and subcutaneous administration of drugs such hepatitis B vaccine and insulin.[15] Anesthesia is induced via jet-injection due to the release of pressure generated by a mechanical energy source, which is sufficient to force a liquid drug dose through a very small aperture. Without the need for a needle, a thin column of fluid can be forced deep into the subcutaneous tissue.[16]

Jet injections have an advantage of fast drug delivery and absorption, less tissue damage and lesser pain[15]. These injections are best used on patients with needle-phobia and apprehension. Commonly used brands of jet injections are SyrijetMarkll, MED H JETIII etc.

So far, dental practitioners have reported mixed results when using jet injectors. The installation of rubber dam clamps, drainage incisions for abscesses, retraction cords, and orthodontic bands or space maintainers are all potential applications despite the lack of clinical data supporting their usage[17]. Successful pain control in children with jet injectors has been reported at 96.3%, 83.5%, 100%, and 100% for extraction, pulp therapy, tooth preparation, and various clinical procedures.[18]

a.) **MED JETH III:** This system was developed in the year 2011. In this system, the medication is directed through a small orifice that is 7 times smaller than the needle with the smallest diameter.[15] Its accuracy is unquestionable and it delivers the anesthetic at a low pressure and does not compromise on environment safety, patient comfort and user compliance.

b.) SYRIJET MARK II: Syrijet has been in use since the last 40 years and has undergone some minor advancements as well.[19] The reusable, autoclavable unit employs 1.8cc syringes for administering local anesthetic in increments as little as 0.2cc. It can inject up to 0.2 mL at a time, and its nozzle possess pressures of up to 2,000 psi. This is comparable to the effect of a typical needle penetrating 1 cm deep into the tissue. William Greenfield and Joseph Karpinski et al.20 reported that using Syrijet alone was sufficient for performing minor surgical procedures such as extraction of deciduous anterior teeth and permanent central and lateral incisors, soft tissue procedures, removal of bone spicules, application and removal of arch bars and ligature wires. Extraction of permanent anterior teeth and deciduous posterior teeth may necessitate the use of additional local blocks, while extraction of permanent posterior teeth typically necessitates the use of additional local

blocks. Researchers found that patients had a positive reaction to the tool and were able to use it in needle-sensitive locations like the incisive papilla.

Although the disagreeable taste of the anesthetic can be reduced by taking extra precautions when injecting, there is also the risk of bleeding from the puncture sites, especially if stabbed twice or thrice. Pain perception was significantly reduced compared to the traditional method of giving local anaesthetic, therefore it follows that some procedures can be performed with just Syrijet, while others will require additional anesthetic measures.[21]

Safety dental syringes:

As soon as the needle is removed from the tissues, a protective coating slides over it to shield the healthcare provider from the risk of a needle stick injury. The syringes and needles now used for providing local anesthetic in the mouth provide a risk of blood-borne infections spread from one person to another due to the sharp hollow-bore steel. The Hyposafety syringe, Ultrasafety plus XL syringe, Ultrasafe syringe, SafetyWand syringe, etc. are all examples of popularly used safety needles. However, these syringes are not seen as superior to regular syringes and provide insufficient assistance in avoiding needle-stick accidents.[22].

a.) Ultra Safety Plus XL Syringe: The anesthetic carpules are put inside the sterile, disposable shield of the Ultra Safety Plus XL syringe (Septodont, Lancaster, PA, USA). Autoclaving the plunger assembly makes it suitable for reuse. Ultra Safety Plus XL syringes protect the worker cleaning the dental tray from the needle because the needle is covered both before and after injection. Additionally, the needle does not need to be disassembled before disposal. Users of this syringe type noted an increase in the amount of time needed to switch out anesthetic carpules.

b.) UltraSafe Syringe: An example of a disposable syringe and needle is the UltraSafe syringe (Safety Syringes Inc, Carlsbad, CA, USA), which consists of a clear plastic syringe barrel with a retractable needle sheath. The needle is hidden before and after injection, protecting the provider from damage, and the clear plastic barrel of the syringe allows the provider to see the contents of the carpule, which is helpful for aspiration and for observing the anesthetic content. The UltraSafe syringe differs from the Ultra Safety Plus XL syringe in that the entire assembly is disposable and cannot be sterilized in an autoclave.[23]

c.) HypoSafety Syringe: Translucent disposable plastic syringe and needle set was manufactured by Dentsply MPL Technologies in Susquehanna, Pennsylvania, USA; with brand name: HypoSafety. After administering an injection, the needle can be withdrawn into the syringe's barrel. Therefore, the needle is concealed both during and after the injection, protecting medical staff from accidental needle sticks. The problem with this syringe is that if the needle is bent, the dentist cannot re-expose the safety shield and give the patient a second injection; this can slow down the procedure and necessitate the use of a second syringe.

d.) Safety Wand: The SafetyWand is a device specifically made for the STA/CompuDent (WAND). It is a specially designed wand handpiece with a self-retracting needle. The SafetyWand provides a fully automated single-handed activation as well as the ability to reuse the device repeatedly during a single patient session.

Topical anesthesia:

Substances that can anesthetize the skin or mucosa at the surface are called "topical anaesthetics." In dentistry, these compounds are used to temporarily numb the oral mucosa's sensory nerve ends, making dental injections and other minimally invasive treatments more tolerable for patients. The agents are available in a number of tasty formulations, including gels, ointments, sprays, and solutions. When compared to injectable anesthetics, the full impact of a topical anesthetic solution takes longer to take effect but has a higher concentration. Typically, 1–5 minutes of contact time is necessary for topical anesthetics to fully take effect.

a.) Lidocaine patches: Lidocaine patches have a muco-adhesive base and deliver; the local anesthetic via the trans-oral delivery route. It is commonly used for superficial mucosal and gingival procedures and prior to needle pricking into the mucosa.[24] It is absorbed into the mucous membrane and the effect is seen within 2 minutes and lasts up to 30 minutes after the removal of the patch.[25] The disadvantages of this system involve the high cost and poor adhesion to the oral mucosa.

b) Emla cream (Eutectic Mixture of Local Anaesthetics): When a patient needs a medication that isn't commercially available, their pharmacist may use a procedure called "compounding" to manufacture it. When combined, the melting points of lidocaine and prilocaine's crystalline bases are lower than those of either drug alone, making the combo suitable for use in operations involving only mild discomfort. We refer to combinations like these as eutectic. Liquid was seen at room temperature when lidocaine and prilocaine were combined at a ratio of 1:1. This eutectic combination may be used to make an emulsion if an emusifier were to be added to it. The EMLA lineup looks like this: To make 1 gm of EMLA cream, 25 mg of lidocaine, 25 mg of prilocaine, 19 mg of arlactone 289 (emulsifier), 10 mg of carbopol 934 (thickener), 9.6 mg of sodium hydroxide, and 1 gm of distilled water are used.[26] And although it shows satisfactory results for pediatric use of the cream,

additional research is yet to be conducted in order to determine the adverse effects and prevention of overdose of the anesthetic.

c.) Oraqix: Oraqix, EMLA's dental formulation, consists of lidocaine 2.5% and prilocaine 2.5%. Within 30 seconds of applying the periodontal gel (Oraqix) to the periodontal pockets, the area becomes numb. After 30 seconds, there is no further increase in the level of anesthesia. The average time for anesthesia to take effect is 20 minutes and 40 seconds (the range is 14–27 minutes). The anesthetic may need to be reapplied periodically in order to last throughout the entire operation[27]. Adults who need local anesthesia in periodontal pockets for scaling and/or root planing may be given Oraqix. Pain relief during intra periodontal gingival retraction, palatal anesthesia prior to palatal needle penetration, and the implantation of orthodontic temporary anchorage devices are all examples of how Oraqix has been put to use in prosthodontics.

d.) Intranasal sprays: These are a mixture of 3% tetracaine hydrochloride and 0.05% oxymetazoline[28]. A metered device is used for infiltrating an anesthetic solution through the nostrils to anesthetize the maxillary anterior teeth, canines and premolars[28]. It reduces the bleeding by inducing vasoconstriction of the regional blood vessels thus making the operational field favourable to operation.

Electronic Dental Anaesthesia

Transcutaneous electrical nerve stimulation (TENS), which has been utilized for the alleviation of pain, is the premise behind electronic dental anesthesia. In 1967, Shealy pioneered the use of TENS to treat persistent pain.

The Pain Gate Mechanism and the Endogenous Opioid System[29] are the two basic pain relief processes proposed to explain how TENS works to alleviate pain.

In order to alleviate pain via the pain gate mechanism, the A sensory fibers must be excited (activated), hence decreasing the transmission of the noxious input from the c-fibres, down the spinal cord, and up to the higher centers[30].

The electrical stimulation of the endogenous opioid system results in the release of opioid peptides from the pituitary and hypothalamus into the bloodstream or cerebrospinal fluid. However, TENS's precise mechanism is still unclear; it may involve multiple mechanisms[31].

Dental anesthesia equipment is a form of TENS unit optimized for intraoral use, typically with lower current and higher frequencies. In patients receiving dental treatment, EDA has been proposed as an alternative to traditional syringe anesthesia[32]. According to one study, its pain-relieving benefits are equivalent to those of local anesthesia, but without the risks of conventional local anesthetics or the inconvenient lingering numbness that might occur after surgery. Another study found that EDA may be useful for children who are afraid of needles[33]. Researchers found that children with EDA had a higher tooth pain tolerance and less cardiovascular stress during rubber dam clamp placement[34].

Patients having a history of cerebrovascular accident (CVA) or other neurological problems (epilepsy), patients with cardiac pacemakers, and pregnant women are advised against using EDA for the same reasons as those who should not use TENS. Dentists and physiotherapists have been using transcutaneous electrical nerve stimulation (TENS) to treat temporomandibular joint pain for a long time. While EDA was not as efficient as LA in reducing discomfort during cavity preparation in children aged 6 to 12 years old.

Iontophoresis

First used to deliver a medication for the purpose of establishing surface anesthesia in 1993, iontophoresis has come a long way since its humble beginnings in the early 1990s. In order to improve the transport of ionized and unionized molecules, iontophoresis makes use of a steady low-voltage electrical potential. By extending its sensory component and distributing medications into the area-surface, it serves as a mode of active transportation[36].

Iontophoresis has several uses in dentistry, and one of them is the creation of a painless form of anesthesia. Local anesthetics, once applied topically, can be absorbed into the deeper tissues this way. It facilitates the electrically induced tissue penetration of positively charged drugs like lignocaine and adrenaline[37]. With the avoidance of needle, this technique could offer better patient management and dentist-patient relationship.

Gangarosa described the use of iontophoresis for three basic applications in dentistry[36]

a) Treatment of hypersensitive dentine (e.g. in teeth sensitive to air and cold liquids) using negatively charged fluoride ions
b) Treatment of oral ulcers ('canker sores') and herpes labialis lesions ('fever blisters') using negatively charged corticosteroids and antiviral drugs, respec- tively.
c) Topical anaesthesia
   A clinical study published in 1994 reported the use of iontophoresis for surgical extraction of deciduous teeth.

Vibrotactile devices

Vibrotactile devices are used to lessen the discomfort of needle pricks. In order to alleviate pain, it employs the gate control principle. It has been hypothesized that the brain will receive the counter stimulation of vibration before the pain feeling from an anesthetic injection". Since the brain can only process one sensory input at a time, whichever sensation reaches the brain first will be experienced. Dentalvibe, Syringe Micro Vibrator (smv), and Accupal are alternative options that operate on a similar concept. Unlike Accupal, which just employs vibration, the Dentalvibe and syringe micro vibrator applies micro-vibration to the injection site.

a.) DentalVibe: Recently released, the cordless, handheld injection device DentalVibe (BING Innovations LLC, Crystal Lake, IL, USA) uses vibration diversion based on the pain gate hypothesis. The gadget emits a rhythmically shifting pattern of pulsed, percussive vibrations with increased amplitude, softly tapping the mucosa. The purpose of the varying pattern is to maintain activity38 in the A- nerve fibers. The DentalVibe is a vibrating dental tool with a U-shaped tip and a Vibra-Pulse motor controlled by a built-in microprocessor. To administer an injection, first activate the U-shaped vibrating tip and place it on the injection site; then put the dental needle anywhere within the vibratory zone. In addition to illuminating the injection site, it also features a retractor for the lips and cheeks.

b.) Accupal: For injections into the palate region, there is the cordless Accupal. It works by first conditioning the palate mucosa with vibrations and then applying pressure. According to the manufacturer, the "pain gate" is closed when using Accupal (Accupal, Hot Springs, AR, USA), which applies pressure and vibrations to the injection site 360 degrees proximal to the needle penetration. Applying light pressure causes the device to illuminate the injection site and begin vibrating.The motor is connected to a disposable tip through which the needle is inserted. One AAA battery is required[38].

c.) Vibraject: In recent years, a vibrating dental local anesthetic attachment has been made available. This apparatus was designed on the basis of gate-control theory, which suggests that when nerve impulses are evoked by the tactile sensation that is simultaneously transmitted through a- delta fibers, pain transmission through A-delta and C- nociceptive fibers is suppressed at the level of secondary neuronal cell bodies and the dorsal horn. Yoshikawa et al. noticed no reduction in injection pain while using a typical cartridge type dental syringe with a 30-gauge needle to administer the vibraject[39].

III. CONCLUSION

Many working dentists have placed a premium on developing pain-free dental procedures. Some nervous or fearful people may find relief from their discomfort using the aforementioned techniques. Different methods of administering dental anesthetic without the use of needles have been developed in recent years. New anesthetic methods have been introduced in recent years thanks to developments in local anesthesia. With the rise of automated delivery systems, new approaches to anesthesia have emerged. Topical anaesthesia, electronic dental anaesthesia, jet-injectors, iontophoresis, and computerized control local anaesthesia administration systems are the most well-known alternate means of delivering anaesthetic in dentistry. Needle-free injectors and the CCLAD system may be less painful than traditional injection methods, with fewer research finding otherwise. Both doctors and patients benefit much from the wand, and those who are scared of needles appreciate the comfort and convenience of this device. This innovation is a huge time saver and an improvement over the syringe in terms of patient comfort. This anesthetic wand has a pen-like grip, making it simple to hold, rotate, and target its anesthetic injection. Dental medicine has benefited greatly from the development of numerous effective medications for managing pain during and after procedures. Therefore, it is crucial for today's dentists to be well-versed in the various anesthetic tools and procedures that might be used. When the aim of painless anaesthesia is reached and the patient is pleased with the enhanced quality of treatment, it is very rewarding for the dentist. These strategies will be effective in their goal of making kid dental appointments more enjoyable, and they will also help create a favorable dental attitude in patients for future procedures. These approaches have been tried and true, but depending on your needs, budget, and the tools at your disposal, they may take more time and money than you'd want. However, the newest procedures will aid in providing efficient and effective oral health care with improved patient satisfaction and reduced suffering, even though some dentists still prefer using the traditional ways.

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