Review Article

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Alternative practices of achieving anaesthesia for dental procedures: a review

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Managing pain and anxiety in patients has always been an essential part of dentistry. To prevent pain, dentists administer local anaesthesia (LA) via a needle injection. Unfortunately, anxiety and fear that arise prior to and/or during injection remains a barrier for many children and adults from receiving dental treatment. There is a constant search for techniques to alleviate the invasive and painful nature of the needle injection. In recent years, researchers have developed alternative methods which enable dental anaesthesia to be less invasive and more patient-friendly. The aim of this review is to highlight the procedures and devices available which may replace the conventional needle-administered local anaesthesia. The most known alternative methods in providing anaesthesia in dentistry are: topical anaesthesia, electronic dental anaesthesia, jet-injectors, iontophoresis, and computerized control local anaesthesia delivery systems. Even though these procedures are well accepted by patients to date, it is the authors' opinion that the effectiveness practicality of such techniques in general dentistry is not without limitations.

Keywords: Electronic Dental Anesthesia; Local Anesthesia; Needleless Anesthesia; Needle-Free Anesthesia.

INTRODUCTION

Treating patients with minimal discomfort and pain has always been paramount in dentistry and continues to grow in necessity with the array of contemporary techniques and devices in our armamentarium. Poorly managed pain control can instigate fear and negative response in patients, which becomes an obstacle for clinicians to create a positive overall patient experience [1,2].

The most common method for pain control is achieved by administering a local anaesthetic solution via an injection. Even when this method successfully removes pain throughout the procedure, the anxiety and negative response produced prior to and/or during the administration of the anaesthetic remains an issue for many children and adults [3,4]. According to Szmuk et all [5], 10% of the general population is affected by needle-phobia, the aetiology of which is complex and multi-factorial. The injection itself is painful and although most patients are tolerant of needles, the pain experienced during administration itself may act as a barrier for some patients from receiving dental injections and necessary dental treatment in subsequent visits [6].

For this reason, although the traditional local anaesthetic injection method is widely used, dental researchers continue to investigate and develop alternative, more patient-comfortable methods for achieving anaesthesia. In the last two decades, an array of devices have been developed to deliver anaesthesia without involving the

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standard needle [7].

This article explores the modern concepts developed in delivering alternative, patient-comfortable anaesthesia, as well as discussing the challenges for achieving an optimal pain control during dental procedures.

ALTERNATIVE DELIVERY SYSTEMS FOR DENTAL PROCEDURES

The majority of practicing dentists use the traditional aspirating syringe and needle, first introduced by Cook nearly 150 years ago [8]. Using a needle causes mechanical trauma whilst penetrating oral mucosal tissues, initiating pain in the patient before anaesthetic itself is given [9]. Newer technologies have been developed that can help the patient with reduced injection-pain and minimal adverse effect prior to infiltration of anaesthetic agent [10]. Researchers in the last decades have focused on developing alternative delivery systems or practices to provide anaesthesia [11]. These include (Table 1):

1. Topical Anaesthesia
2. Electronic Dental Anaesthesia
3. Jet-Injectors
4. Iontophoresis
5. Computer-controlled local anaesthesia

TOPICAL ANAESTHESIA

Effective administration of local anaesthetic without the use of a needle would indeed be revolutionary. It would reduce patient anxiety while at the same time lead to a decline of needle-stick injuries. Surface anaesthesia may be achieved by physical (refrigeration anaesthesia) or pharmacological means, such as topical anaesthetic agents [12]. For a local anaesthetic to be effective it must be active when applied topically. Unfortunately, some anaesthetic agents cannot achieve this, and some work better than others. Topical anaesthetics have many uses in dentistry including:

1. alleviating the discomfort produced by local anaesthetic injections,
2. reducing the pain of operative dental procedures,

Table 1. Alternative anaesthesia delivery systems: advantages and disadvantages

Method	Advantages	Disadvantages
Topical Anaesthesia	• Ease of use • Shown to relieve pain for a range of minimally invasive procedures such as scaling and removal of arch bars	• Most common method of administration of local anaesthetic agents that causes toxic reactions • Not ideal for more invasive procedures such as soft tissue biopsies and restorations.
Electronic Dental Anaesthesia	• Shown to increase acceptance in children and periodontal procedures	• Limited range of procedures where the method can be used – for example, inapplicable for surgical or endodontic procedures. • Variable degree of efficacy between patients • Technique sensitive
Jet injectors	• Fast and easy to use • Immediate uptake at the site of administration	• Noise and pressure produced from equipment may negatively affect patients • Possibly cause haematoma of soft tissues • High overhead cost
Iontophoresis	• Action on extended surface and applications on teeth and oral mucosa	• Can irritate skin and oral mucosa
Computer controlled local anaesthesia	• Provides tactile feedback • Less intrusive appearance • Variety of modes available	• Involves a needle • Cost of equipment • Slow delivery speed – can take up to four minutes per cartridge
Computer controlled intraosseous anaesthesia	• Smaller dosage of LA • Reduced soft tissue anaesthesia • Rapid onset of profound pulpal anaesthesia • Palatal/lingual and buccal anaesthesia with a single needle	• It involves a needle • Additional application time • Shortened duration of anaesthesia

3. relieving the pain of ulcers and other mucosal lesions,
4. skin anaesthesia prior to venepuncture for sedation or general anaesthetic [12].

Both amide and ester anaesthetic agents are active when applied topically and local anaesthetics can be incorporated into many different preparations to influence efficacy. These preparations include water soluble salts, dissolved in organic solvents, as oil-water emulsions, as eutectic mixtures, incorporated into patches and controlled-release devices, using iontophoresis and phonophoresis, and incorporated into liposomes. The maximum concentration of lignocaine that can be obtained in oil droplets is 20%; however, when lidocaine is combined with prilocaine they produce a euteric mixture of local anaesthetics (EMLA) which can achieve a concentration of 80% [13]. Due to its low melting point it allows it to change into a liquid form in the oral cavity which facilitates rapid transmucosal absorption of the bases [14]. According to AstraZeneca Pharmaceuticals the maximum dosage for children 1 to 6 years old and weighing more than 10kg is 20 g over 100 cm^2 for 4 hours while for children 7 to 12 years old and weighing more than 20 kg is 20 g over 200 cm^2 for 4 hours [15].

Topical anaesthetics can reduce discomfort of potentially painful dental procedures. Meechan and Thomason found that pain from periodontal ligament injections was less following a 5 min application of EMLA compared to a similar application of 5% topical lignocaine [16]. Svenson et al. [17] reported that EMLA reduced the pain and unpleasantness of scaling in both maxillary and mandibular teeth when compared to placebo, while others have suggested more comfortable periodontal probing examination [18]. Furthermore, intra-oral topical anaesthetic agent can produce significant analgesia for the removal of arch bars [19]. Taware et al. [20] reported an 81% success in undertaking dental extractions in both adults and children with topical lignocaine patches as the sole means of anaesthesia. The relief of post-extraction discomfort was also described by occluding on cotton wool rolls soaked with 7 ml of 0.25% bupivacaine with 1:200,000 adrenaline [21].

Evidence suggests that topically active anaesthetic agents cannot achieve complete analgesia for soft tissue biopsies or allow restorative treatment painlessly without any supplementary local anaesthetic injections [12]. It has been claimed that topical application is the most common administration route of local anaesthetics that would cause toxic reactions [12]. It must be stressed that EMLA is not currently available for a dedicated intra-oral used and in fact the manufacturers do not recommend the use of EMLA on mucosa [12]. Some common intra-oral topical anaesthetic formulations are Xylonor gel and Desensetin gel or liquid [22,23].

ELECTRONIC DENTAL ANAESTHESIA

Electronic Dental Anaesthesia involves the use of the principle of transcutaneous electrical nerve stimulation (TENS) which has been used for the relief of pain. TENS was introduced by Shealy in 1967 to help control chronic pain. Among several theories that explain the mechanism by which TENS causes pain relief, there are two primary pain relief mechanisms: The Pain Gate Mechanism and the Endogenous Opioid System [24].

Pain relief by means of the pain gate mechanism involves activation (excitation) of the Aβ sensory fibres, reducing the transmission of the noxious stimulus from the c-fibres, through the spinal cord and on to the higher centres [25].

In the endogenous opioid system, the electrical stimulation causes release of pituitary and hypothalamic opioid peptides into the systemic circulation or into the cerebrospinal fluid. However, the exact mechanism of TENS remains unknown and may be a combination of one or more mechanisms [26].

Devices developed for dental anaesthesia are TENS units modified for intraoral use which operate at lower current and higher frequencies. Electronic Dental Anaesthesia (EDA) devices have been used to control the pain of trigeminal neuralgia or atypical facial pain, and

to relieve muscles spasms in myofascial pain dysfunction [27]. The use of EDA has been suggested as a potential alternative to the conventional syringe anaesthesia in patients undergoing dental treatment [28]. One study has favoured its use as its efficacy in pain control has been described as comparable to local anaesthesia while at the same time avoiding the possible side effects associated with commonly used local anaesthetic agents and the inconvenience of post-operative anaesthetic effect [29]. Another study suggested EDA could be indicated for needle-phobic children; however, studies that have tested its effectiveness in children are few [30]. Results of clinical studies are currently limited and widely varied.

An interesting study showed that EDA increased tooth pain threshold and reduced the cardiovascular stress during placement of a rubber dam clamp in children [31]. EDA is more effective in anterior than posterior teeth [32]. Also, the depth of the restoration makes a difference on the pain perception and effectiveness [32]. EDA is highly successful in periodontal procedures but is mainly unsuccessful in surgical and endodontic procedures [33]. A few studies compared the effectiveness and efficacy of EDA with traditional syringe and showed EDA was less effective than the injection of local anaesthetic in controlling pain during dental procedures [34].

A recent literature review showed additional potential applications of EDA device using Tens technology, however the authors concluded that its analgesic effect can be used in the management of a variety condition affecting the maxillofacial region but can't replace the use of local anesthesia [35]

Overall, it can be concluded that the effectiveness of EDA in dental procedures is related to the patient's dental anxiety, type of procedure, and level of operator skill.

JET INJECTORS

Jet-Injection devices were originally developed in 1866 for mass immunization and then extended for intra-muscular and subcutaneous delivery of medications, such as hepatitis B vaccine and insulin [36]. The mechanism of action by which jet-injection produces anaesthesia is based on the principle of using a mechanical energy source to create a release of pressure, sufficient to push a dose of liquid medication through a very small orifice. Indeed, a thin column of fluid is created with enough force that it can penetrate directly into the subcutaneous tissue without a needle [37].

Needleless jet injectors are believed to offer advantages over traditional needle syringe by being fast and easy to use, with little or no pain, less tissue damage, fast drug absorption at the injection site, and avoidance of post-operative complications and side effects [38]. The disadvantages are cost, the potential to frighten patients with the sudden noise and pressure sensation that occur on delivery of the anaesthetic, the intrusive appearance of the device, and the possibility of residual haematomas [39].

To date, the effectiveness of jet injectors in dentistry has been reported as limited [7]. Despite limited clinical evidence, situations in which this system might be used include placement of rubber dam clamps, creation of drainage incisions for abscesses, placement of retraction cords and placement of orthodontic bands or space maintainers [7]. Jet injectors have been described to provide 96.3%, 83.5%, 100%, and 100% successful pain control in children for extraction, pulp therapy, tooth preparation, and miscellaneous clinical procedures (abscess drainage, rubber dam clamp placement etc), respectively [38]. Its use in pulpal anaesthesia, on the other hand, has been questioned in two studies [40,41]. The most common jet injector devices are Syrijet Mark II (Keystone Industries, [aka Mizzy], Cherry Hill, NJ, USA) and MED-JET (Medical International Technologies, Montreal, QC, Canada) [40,41].

IONTOPHORESIS

Iontophoresis was first introduced in 1993 as a suitable alternative for application of a drug in achieving surface

anaesthesia. In many therapeutically active drugs, molecules are hydrophilic and possess high molecular weights [42]. The highly lipophilic nature of the skin restricts its permeation through the stratum corneum into the systemic circulation.

Iontophoresis is simply defined as the application of an electrical potential that maintains a constant low voltage in order to enhance the delivery of ionized, as well as unionized molecules. It is a form of active transport by extending its sensory component and delivering drugs into the area-surface [43]. When direct current electric field is applied over a longer duration, an electrochemical polarization occurs in the skin which decreases the magnitude of current flow through the skin. This affects the amount of drug ions driven across the skin. It can cause skin irritation at higher current voltage or upon longer application, therefore must be used with caution [44].

IONTOPHORESIS IN DENTISTRY

Iontophoresis has a wide range of application in dentistry, one of which is to produce a non-invasive technique of anaesthesia. It can be used as a means of delivering local anaesthetics to deeper tissues after topical application. It aids in the penetration of positively charged agents such as lignocaine and adrenaline to tissues under the influence of electrical charge [12]. 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 [43]:

1. Treatment of hypersensitive dentine (e.g. in teeth sensitive to air and cold liquids) using negatively charged fluoride ions
2. Treatment of oral ulcers (‘canker sores’) and herpes labialis lesions (‘fever blisters’) using negatively charged corticosteroids and antiviral drugs, respectively;
3. Topical anaesthesia.

There is a lack of recent studies regarding the application of iontophoresis in dentistry. A clinical study published in 1994 reported the use of iontophoresis for surgical extraction of deciduous teeth. Initial reports have shown an encouraging response from patients; however, further research was warranted [44].

COMPUTER-CONTROLLED LOCAL ANAESTHETIC DELIVERY SYSTEMS

Computer-controlled Local anaesthetic delivery (CCLAD) is a new concept for delivering dental anaesthesia, born in the middle of 1990. These devices incorporated computer technology to control the rate of the flow of the anaesthetic solution through a needle [45].

A constant volume of anaesthetic solution is delivered at a pre-set pressure which purportedly enables less painful delivery of anaesthetic. This claim is based upon the premise that pain due to local anaesthetic is attributable to factors such as fluid pressure on injection and flow rate. Other advantages include better tactile sensitivity and less intrusive appearance.

Relative disadvantages include higher cost and speed of injection at the slowest pump rate, where a total of 4 minute is required to completely express a cartridge; this may cause impatience and stress amongst patients [45,46]. Another disadvantage is the fact that this method does not eliminate the use of a needle and this may lead to refusal of its use by the anxious patient.

The first of these CCLAD devices, the Wand™ (Milestone Scientific, Inc., Livingston, N.J, USA), was introduced in 1997. Subsequent versions from same manufacturers were named Wand Plus and then CompuDent™. In 2001, the Comfort Control Syringe™ (Dentsply International, York, PA, USA) was marketed as an alternative to the Wand [47].

The main benefits of these CCLAD devices are attributed to ability of administering small quantities of LA solution with a steady infusion mode reducing the discomfort associated with less controlled injections.

The CCLAD devices are better tolerated by patients and produce less disruptive behaviour, and have been shown to be successfully used for restorations, pulpal therapies and extractions in adult and paediatric dentistry [10].

A Recent literature review indicated that CCLAD resulted in less pain and are more effective in adults than children, however the authors highlighted the need of more accurate assessment indices and methods for pain and anxiety and more clinical studies to support the use of CCLAD in dentistry [48].

THE WAND

The Wand introduced by Milestone Scientific has three main components, base unit, foot pedal and disposable headpiece assembly. Base unit consists of a micro-processor and connects to the foot pedal and Handpiece assembly that accepts the LA cartridge. LA solution from the cartridge passes through the microbore tubing in the Handpiece assembly and attached needle into the target tissue. The foot pedal controls the rate of injection and if aspiration feature is enabled, it prevents inadvertent intravascular injections. Three possible rate-mode injections are available: slow (0.005 ml/s), fast (0.03 ml/s) and turbo (0.06 ml/s) [32].

The major benefit using the Wand is a significantly improved injection experience due to the greater control over the syringe and the fixed flow rates of the LA drug as demonstrated in many clinical studies conducted with CCLAD devices in dentistry [32,45,46].

Koyuturk et al. [47] reported on the use of the Wand in paediatric patients. He showed that the Wand was more comfortable than a traditional syringe and reduced the disruptive behaviour of children during the initial moments of an injection, even when there weren't any differences in pain perception compared with a traditional syringe.

SINGLE TOOTH ANAESTHESIA (STA)

In 2006, Milestone Scientific introduced a new device, Single Tooth Anaesthesia (STA). STA incorporates dynamic pressure-sensing (DPS) technology that provide a constant monitoring of the exit pressure of the local anaesthetic solution in real time during all phases of the drug's administration. DPS also provides continuous feedback to the user about the pressure at the needle tip to identify the ideal needle placement for PDL injections. With STA system, a great volume of LA can be administered since the pressure is calculated by the system instead of operator, and provides increased comfort and less tissue damage than traditional syringe or PDL pressure device [49].

STA has three rate-modes of injection:1. STA mode: single, slow rate of injection; 2. Normal mode: emulates the CompuDent device; and 3. Turbo mode: faster rate of injection – 0.06 ml/s.

Initially, DPS technology was designed to provide epidural regional anaesthesia in medicine. STA utilises an adaptation of DPS to dentistry as means of overcoming of the problems associated with PDL injection, and simplifies AMSA and P-ASA injection. The device can be used for all traditional intraoral injection techniques [50,51].

COMFORT CONTROL SYRINGE

The Comfort Control Syringe is a new device that differs from the other CCLAD systems in that there is no foot pedal. CCS has two main components: a base unit and a syringe. The injection and aspiration can be controlled directly from the syringe, and this feature seems to make its use easier than the traditional manual syringe [52,53].

The rate of injection has five pre-programmed speeds for different injection techniques and can be used for all anaesthetic procedures into the oral cavity. The unit uses

two-stage delivery rates to every injection. Initially, the LA is delivered at an extremely low rate; after 10 seconds, the rate increases to the pre-programmed value for the selected injection technique. Although the use of CCS can give to the practitioner more perceptive sense by hand and much more control, the syringe is bulky and more difficult to use than the other computer-controlled devices [54].

A comparison between the traditional dental syringe and the Comfort Control Syringe revealed no meaningful differences in ease of administration, injection pain and efficacy, and patient acceptability [55].

COMPUTER-CONTROLLED INTRAOSSEOUS ANAESTHESIA SYSTEM (CCIAS) - Quicksleeper®

Intraosseous anaesthesia (IA) is a technique whereby an anaesthetic solution is injected into the cancellous alveolar bone supporting the teeth. Its advantages include use of smaller dosages of the anaesthetic solution and reduced soft tissue anaesthesia compared to conventional regional block and infiltration techniques [56], and rapid onset of profound pulpal anaesthesia [57].

It is beyond the scope of this paper to expand on the success of traditional IA injection systems. However, unlike other IA injection systems (Stabident System, Fairfax Dental, Miami; X-Tip, Dentsply Maillefer, Tulsa, Okla), Quicksleeper® (Dental Hi-Tec, Cholet France) is a computer-controlled anaesthetic system. Each of its different carriers and needles makes it possible to administer different types of injections including IA injections. Its asymmetric triple bevel needle tip allows a painless and easy perforation into the bone [58]. It has a double foot pedal which separately activates the slow injection of anaesthetic solution and the rotation of the needle touching the bone. Using this computer-controlled IA system (CCIAS) involves a three-step procedure, including anaesthesia of the mucosa, computerised rotation of the needle distal to the tooth in question to penetrate the cancellous bone, and computerised injection of the anaesthetic solution [59].

In addition to the benefits mentioned above, Quicksleeper5® exhibits advantages such as less painful anaesthesia, and the provision of palatal/lingual, as well as buccal, anaesthesia with a single needle penetration [60]. On the negative side, it requires additional application time compared to conventional anaesthetic methods, and shortened duration of the anaesthesia [61]. Quicksleeper5® would be ideal in short-lasting, non-surgical procedures [60].

Due to the early stages of this device in the dental armamentarium, there is limited but promising evidence in the current literature about its use for different dental procedures. In a recent case series study of 50 children receiving IA using the Quicksleeper5®, the majority of children felt no pain or felt only mild discomfort [scores 0-2 for 91.8% (Face Pain Scale) and 83.9% (Visual Analogue Scale) of cases]. 58.9% of children with previous experience of dental anaesthesia reported that computerized IA was more comfortable than traditional infiltration methods [59].

According a study by Özer et al. IA with Quicksleeper5® is a less painful infection method compared to conventional inferior alveolar nerve block techniques, however it proved to be inadequate for the extraction of lower third molars. This may be accounted for by the variability of bone density, duration of operation, and reduced anaesthesia because of haemorrhage [57]. In a two-case report, Han and Kim [60] described the successful use of Quicksleeper5® for non-surgical periodontal therapy of moderate chronic periodontitis.

Despite the limited current evidence in the literature, the authors believe this technique holds promise for its use in restorative treatment, endodontic treatment, tooth preparation, and tooth extraction but it is self-limiting to simpler procedures of short duration.

CONCLUSION

The most known method for pain control is achieved

typically by administering local anaesthetic with an injection, which although highly effective, is the most anxiety-provoking procedure for both children and adults. In recent years, researchers have developed different methods to provide dental anaesthesia without needle insertion. The most known alternative methods of delivering anaesthesia in dentistry are: topical anaesthesia, electronic dental anaesthesia, jet-injectors, iontophoresis, and computerized control local anaesthesia delivery systems. Even if these procedures are well accepted by patients to date, the efficacy of such techniques in general dentistry has been reported to be limited. The computerized control local anaesthesia delivery systems seem to be the most effective procedures to deliver local anaesthetic without pain. However, the high costs and time required to enable dental anaesthesia must be taken into consideration.

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REFERENCES

1. Milgrom P, Coldwell SE, Getz T, Weinstein P, Ramsay DS. Four dimensions of fear of dental injections. J Am Dent Assoc 1997; 128: 756-66.
2. Oztas N, Ulusu T, Bodur H, Dogan C. The Wand in pulp therapy: an alternative to inferior alveolar nerve block. Quintessence Int 2005; 36: 559-64.
3. Pinkham JR, Casamassimo PS, Fields HW, McTigue DJ, Nowak AJ. Pediatric Dentistry In: Infancy through Adolescence. 4th ed. St Louis, Mo. Elsevier Saunders 2005, pp394-413.
4. ten Berge M, Veerkamp JS, Hoogstraten J, Prins PJ. Childhood dental fear in the Netherlands: prevalence and normative data. Community Dent Oral Epidemiol 2002; 30: 101-7.
5. Szmuk, P, Szmuk E, Ezri, T. Use of needle-free injection systems to alleviate needle phobia and pain at injection. Expert Rev Pharmacoecon Outcomes Res 2005; 5: 467-77.
6. Milgrom P, Weinstein P, Getz T. A Patient Management Handbook In: Treating Fearful Dental Patients. 2nd ed, Seattle, University of Washington Continuing Dental Education, 1995.
7. Dabarakis NN, Alexander V, Tsirlis AT, Parissis NA, Nikolaos M. Needle-less local anesthesia: clinical evaluation of the effectiveness of jet anesthesia injex in local anesthesia in dentistry. Quintessence Int 2007; 38: E572-6.
8. Eloesser L. Recent advances in regional (local) anesthesia Cal State Med J 1912 ; 10: 90-7.
9. Moore PA, Hersh EV, Boynes SG. Preface update of dental local anaesthesia. Dent Clin N Am 2010; 54: 13-4.
10. Sharma SS, Aruna Sharma S, Saravanan C, Sathyabama. Newer local anaesthetic drugs and delivery systems in dentistry – an update. J Dent Med Sci 2012; 1: 10-16.
11. Malamed SF. Handbook of local anesthesia, 4th ed, St Louis, CV Mosby; 1997.
12. Meechan JG. Intra-oral topical anaesthetics: a review. J Dent 2000; 28: 3-14.
13. Evers H. Present research in local analgesics. Br J Oral Maxillofac Surg 1988; 26: 390-4.
14. Lim S, Julliard K. Evaluating the efficacy of EMLA topical anesthetic in sealant placement with rubber dam. Pediatr Dent 2004; 26: 497-500.
15. AstraZeneca. Instructions for application: EMLA cream (lidocaine 2.5% and prilocaine 2.5%). Wilmington, Del: AstraZeneca; 2002.
16. Meechan JG, Thomason JM. A comparison of 2 topical anaesthetics on the discomfort of intraligamentary injections. : a double-blind, split-mouth volunteer clinical trial. Oral Surg Oral Med Oral pathol Oral Radiol Endod 1999; 87: 362-5
17. Svensson P, Petersen JK, Svensson H. Efficacy of a topical anesthetic on pain and unpleasantness during scaling of gingival pockets. Anesth Prog 1994; 41: 35-9.

18. Donaldson D, Meechan JG. A comparison of the effects of EMLA cream and topical 5% lidocaine on discomfort during gingival probing. Anesth Prog 1995; 42: 7-10.
19. Pere P, Iizuka T, Rosenberg PH, Lindqvist C. Topical application of 5% eutectic mixture of lignocaine and prilocaine (EMLA) before removal of arch bars. Br J Oral Maxillofac Surg 1992; 30: 153-6.
20. Taware CP, Mazumdar S, Pendharkar M, Adani MH, Devarajan PV. A bioadhesive delivery system as an alternative to infiltration anaesthesia. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1997; 84: 609-15.
21. Greengrass SR, Andrzejowski J, Ruiz K. Topical bupivacaine for pain control following simple dental extractions. Br Dent J 1998; 184: 354-5.
22. Tehnodent.org. TehnoDent - Desensetin − Gel for topical anesthesia. [online] Available at: http://www.tehnodent.org/en/products/auxiliary-materials/desensetin-%E2%80%93-gel-for-topical-anesthesia [Accessed 23 Jan. 2018].
23. Septodont.co.uk. Xylonor Gel - PAIN MANAGEMENT category - Septodont. [online] Available at: http://www.septodont.co.uk/products/xylonor-gel [Accessed 23 Jan. 2018].
24. Woolf CJ, Thompson JW. Stimulation fibre-induced analgesia: transcutaneous electrical nerve stimulation (TENS) and vibration. In : Wall PD, Melzack R, editors. Textbook of Pain, 3rd Ed, Edinburgh, Churchill Livingstone, 1994, pp1191-1208,.
25. Shealy CN, Taslitz N, Mortimer JT, Becker DP. Electrical inhibition of pain: experimental evaluation. Anesth Analg 1967; 46: 299-305.
26. Black RR. Use of transcutaneous electrical nerve stimulation in dentistry. J Am Dent Assoc 1986; 113: 649-52.
27. Payal Saxena, Saurabh K Gupta, Vilas Newaskar, Anil Chandra. Advances in dental local anesthesia techniques and devices: an update. Natl J Maxillofac Surg 2013; 4: 19-24.
28. Munshi AK, Hedge AM, Girdhar D. Clinical evaluation of electronic dental anesthesia for various procedures in pediatric dentistry. J Clin Paediatr Dent 2000; 24: 199-204.
29. Dhindsa A, Pandit IK, Srivastava N, Gugnani N. Comparative evaluation of the effectiveness of electronic dental anesthesia with 2% lignocaine in various minor pediatric dental procedures: a clinical study. Contemp Clin Dent 2011; 2: 27-30.
30. Cho SY, Drummond BK, Anderson MH, Williams S. Effectiveness of electronic dental anesthesia for restorative care in children. Pediatr Dent 1998; 20: 105-11.
31. Abdulhameed SM, Feigal RJ, Rudney JD, Kajander KC. Effect of peripheral electrical stimulation on measures of tooth pain threshold and oral soft tissue comfort in children. Anesth Prog 1989; 36: 52-7.
32. Quarnstrom F. Electronic dental anesthesia. Anesth Prog 1992; 39: 162-77
33. Clark MS, Silverstone LM, Lindenmuth J, Hicks MJ, Averbach RE, Kleier DJ, et al. An evaluation of the clinical analgesia/anesthesia efficacy on acute pain using the high frequency neural modulator in various dental settings. Oral Surg Oral Med Oral Pathol 1987; 63: 501-5.
34. Wilson S, Molina LL, Preisch J, Weaver J. The effect of electronic dental anesthesia on behavior during local anesthetic injection in the young, sedated dental patient. Pediatr Dent 1999; 21: 12-7.
35. Kasat V, Gupta A, Ladda R, Kathariya M, Saluja H, Farooqui AA. Transcutaneous electric nerve stimulation (TENS) in dentistry- a review. J Clin Exp Dent 2014; 6: e562-e568.
36. Clark TM, Yagiela JA. Advanced techniques and armamentarium for dental local anesthesia. Dent Clin North Am 2010; 54: 757-68.
37. Bennett CR, Monheim LM. Production of local anesthesia by jet injection. a clinical study. Oral Surg Oral Med Oral Pathol 1971; 32: 526-30.
38. Munshi AK, Hegde A, Bashir N. Clinical evaluation of the efficacy of anesthesia and patient preference using the needle-less jet syringe in pediatric dental practice. J Clin Pediatr Dent 2001; 25: 131-6.
39. Saravia ME, Bush JP. The needleless syringe: efficacy of anesthesia and patient preference in child dental patients. J Clin Pediatr Dent 1991; 15: 109-12.
40. Wong JK. Adjunct to local anesthesia: separating fact from fiction. J Can Dent Assoc 2011; 67: 391-7.
41. Lehtinen R. Efficiency of jet injection technique in

production of local anesthesia. Proc Finn Dent Soc 1979; 75: 13-4.
42. Khan A, Yasir M, Asif M, Chauhan I, Singh AP, Sharma R, et al. Iontophoretic drug delivery: history and applications. J App Pharm Sci 2011; 1: 11-24
43. Gangarosa LP, Park NH, Fong BC, Scott DF, Hill JM. Conductivity of drugs used for iontophoresis. J Pharm Sci 1978; 67: 1439-43.
44. Tharian EB, Tandon S. Iontophoresis. a novel drug administration for extraction of deciduous teeth. a clinical evaluation. Indian J Dent Res 1994; 5: 97-100.
45. Friedman MJ, Hochman MN. A 21st century computerized injection system for local pain control. Compend Contin Educ Dent 1997; 18: 995-1000, 1002-4.
46. Second YLK, Neelakantan P. Local anesthetics in dentistry –newer methods of delivery. Int J Pharm Clin Res 2014; 6: 4-6.
47. Koyuturk AE, Avsar A, Sumer M. Efficacy of dental practitioners in injection techniques: computerized device and traditional syringe. Quintessence Int. 2009; 40: 73-7.
48. Kwak EJ, Pang NS, Cho JH, Jung BY, Kim KD, Park W. Computer-controlled local anesthetic delivery for painless anesthesia: a literature review. J Dent Anesth Pain Med 2016; 16: 81-8.
49. Nicholson JW, Berry TG, Summitt JB, Yuan CH, Witten TM. Pain perception and utility: a comparison of the syringe and computerized local injection techniques. Gen Dent 2001; 49: 167-72.
50. Fukayama H, Yoshikawa F, Kohase H, Umino M, Suzuki N. Efficacy of anterior and middle superior alveolar (AMSA) anesthesia using a new injection system: the wand. Quintessence Int. 2003; 34: 537-41.
51. Perry DA, Loomer PM. Maximizing pain control. the AMSA injection can provide anesthesia with few injections and less pain. Dimens Dent Hyg 2003; 1: 28-33.
52. Gibson RS, Allen K, Hutfless S, Beiraghi S. The wand vs. traditional injection: a comparison of pain related behaviors. Pediatr Dent 2000; 22: 458-62.
53. Ferrari M, Cagidiaco MC, Vichi A, Goracci C. Efficacy of the computer-controlled injection system STATM, ligmaject, and the dental syringe for intraligamentary anesthesia in restorative patients. Int Dent SA 2008; 11: 4-12.
54. Grace EG, Barnes DM, Reid BC, Flores M, George DL. Computerized local dental anesthetic systems: Patient and dentist satisfaction. J Dent 2003; 31: 9-12.
55. Hochman MN. Single-tooth anesthesia: Pressure sensing technology provides innovative advancement in the field of dental local anesthesia. Compend Contin Educ Dent 2007; 28: 186-93.
56. Meechan JG. Supplementary routes to local anaesthesia. Int Endod J 2002; 35: 885-896.
57. Özer S, Yaltirik M, Kirli I, Yargic I. A comparative evaluation of pain and anxiety levels in 2 different anesthesia techniques: locoregional anesthesia using conventional syringe versus intraosseous anesthesia using a computer-controlled system (Quicksleeper). Oral Surg Oral Med Oral Pathol Oral Radiol 2012; 114: S132-9.
58. Dental Hi Tec. The keys to success with Quicksleeper. User manual and clinical guide. Cholet, France: Dental Hi Tec
59. Sixou J, Marie-Cousin A, Huet A, Hingant B, Robert JC. Pain assessment by children and adolescents during intraosseous anaesthesia using a computerized system (QuickSleeper™). Int J Paediatr Dent 2009; 19: 360-6.
60. Han K, Kim J. Intraosseous anesthesia using a computer-controlled system during non-surgical periodontal therapy (root planing): two case reports. J Dent Anesth Pain Med 2018; 18: 65-9.
61. Beneito-Brotons R, Penarrocha-Oltra D, Ata-Ali J, Penarrocha M. Intraosseous anesthesia with solution injection controlled by a computerized system versus conventional oral anesthesia: a preliminary study. Med Oral Patol Oral Cir Bucal 2012; 17: e426-9.