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Review Article

# Intraosseous Anesthesia as a Primary Technique for Local Anesthesia in Dentistry

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- Intraosseous anesthesia
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**Abstract**

**Objective:**The aim of this study was to conduct a literature review to determine reasons for which local anesthesia in dentistry can fail and to assess solutions to these failures.

**Material and Methods:**Research was carried out through searches on PubMed and ScienceDirect, manual searches in textbooks, and Internet searches for techniques, products, and devices.

**Results:** Local anesthesia in dentistry can fail for a number of reasons including ineffective anesthetic solution, complex oral anatomy, and improper technique. In the mandible, conventional injections (e.g. IANB) often fail as the thick cortical bone prevents effective infiltration and anesthesia of nearby nerves. Recent studies however, suggest use of intraosseous anesthesia as a more effective primary alternative. When administered with a computerized device such as QuickSleeper®, intraosseousinjection (4% articaine w/ 1:100,000 epinephrine in adults and w/ 1:200,000 epinephrine in children) is fast acting, suitable in duration for conservative treatments, highly successful in mandibular molars, and preferred by most patients. Other advantages to the technique include comfort upon injection and lack of numbness in the lip and tongue.

**Conclusions:** Computer-controlled intraosseous anesthesia is an effective primary technique for limited procedures involving one or two posterior teeth in the mandible. Compared to traditional local anesthetic techniques, intraosseous anesthesia (1.5-1.8 mL of 4% articaine with 1:100,000 epinephrine for adults and 0.6-0.8 mL of 4% articaine with 1:200,000 epinephrine for children) offers high success rates, easy administration, fast onset times, and significant patient comfort.

## ABBREVIATIONS

**IANB:** Inferior Alveolar Nerve Block; **IAN:** Inferior Alveolar Nerve; **HCl:** Hydrochloric acid; **IO:**Intraosseous (injection); **PDL:** Periodontal Ligament (injection); **C-CLAD**: Computer-Controlled Local Anesthetic Delivery; **PAR:** Permanent Analysis of Resistance; **PSA:** Posterior Superior Alveolar; **MSA:** Middle Superior Alveolar; **ASA:** Anterior Superior Alveolar; **STA:** Single Tooth Anesthesia

## INTRODUCTION

Since Dr. Horace Wells' initial experimentation with laughing gas (nitrous oxide) in 1844 [1], local anesthesia in dentistry has seen great advances. To this day, new techniques, products, and devices for administering local anesthesia continue to revolutionize the field of dentistry.

As its name suggests, 'local'anesthesia is a reversible process that triggers a regional loss of sensitivity (pain) around the administration site (infiltration anesthesia) or along the path of a nerve (nerve block anesthesia). Available as a topical cream and as an injectable solution, local anesthesia in dentistry induces an analgesic effect by interacting with neuronal cell membranes and disturbing calcium binding. The resulting closure of voltage gated sodium channels prevents action potentials from occurring and accounts for approximately 90% of local anesthetic activity [1].

Of the amide based local anesthetic solutions, the most commonly used within clinical dentistry include: bupivacaine, articaine, lidocaine, prilocaine, and mepivacaine. Relatively insoluble, instable, and weak in basicity, local anesthetics contain buffering hydrochloric acid (HCl) to stabilize the pH of the amide. Since amides cause vasodilation and hence decrease the efficacy of the local anesthesia, vasoconstrictors such as epinephrine and felypressin are often added to compensate for the vasodilation, reduce the blood flow at the injection site and enhance the duration of the local anesthetic effect [1].

The largest and strongest bone of the face, the mandible is made up of highly dense cortical bone that can often hinder effective infiltration and anesthesia of nerves nearby. Despite this hindrance, the following techniques have been reported to anesthetize the teeth in the mandible with some success: inferior alveolar nerve block (IANB or mandibular block,), buccal nerve block, nerve blocks of the mental and incisive nerves, Gow Gates mandibular nerve block, Vazirani-Akinosi closed-mouth mandibular block, and supplementary intraosseous anesthesia techniques such as intraseptal, periodontal ligament (PDL), and traditional (direct) intraosseous (IO) injection [2]. Table 1 summarizes the different techniques just mentioned. Failing to anesthetize for dental procedures causes discomfort and pain to the patient.

Failing as much as 20% of the time, the IANB has the highest percentage of clinical failures amongst most nerve blocks. Its use in quadrant dentistry notwithstanding, the IANB can be disadvantageous for a number of reasons including: the unreliability of intraoral landmarks, pain upon injection, wide area of anesthesia for limited treatments, and high percentage of positive aspiration. While the unreliability of landmarks makes locating the nerve and achieving an anesthetic effect less likely (resulting in supplemental injections and greater patient discomfort), the broad range of anesthesia can cause further discomfort from lingual soft tissue anesthesia. With regard to the mental and buccal nerve blocks, although these techniques have relatively high success rates and easy administration, they are rarely necessary and provide only soft tissue anesthesia. Also reported within the literature, the Gow Gates and Vazirani-Akinosi nerve blocks anesthetize the pulps of some or all of the mandibular teeth in a quadrant but may bring discomfort to both the patient and administrator if the latter lacks adequate clinical experience. The lingual anesthesia and long onset time of the Gow Gates technique, as well as the absence of bony contact and potential trauma of contacting the periosteum with the Vazirani-Akinositechnique [2], make these injections rather inconvenient, uncomfortable, and less favorable. The remaining intraosseous anesthesia techniques (IO, PDL, and intraseptal injections) anesthetize 1 or more teeth in a quadrant (depending on the injection location, concentration and volume of solution injected [3] and provide atraumatic pulpal and periodontal anesthesia without the lingual and facial anesthesia induced by mandibular nerve blocks. The first step is to anesthetize the periosteum, which is accomplished by infiltration anesthesia of the area where the bone will be perforated. A very small amount of local anesthetic is needed for this step. Subsequently the cortical bone can be perforated and the cancellous bone penetrated. By injecting the product directly into the cancellous bone adjacent to the tooth to be anesthetized, intraosseous anesthesia techniques provide effective, localized pulpal and periodontal anesthesia without extensivecollateral soft tissue anesthesia and the need for other injections [2]. The following devices have been reported within the literature to provide intraosseous anesthesia:

## MANUAL DEVICES

### Stabident® (Fairfax Dental, Miami, Florida)

The Stabident® system features a 27-gauge perforator rod (beveled at the free end and mounted at the other end with a plastic shank) and a conventional 27-gauge ultra-short 8-mm injection needle. After attaching the plastic base to a latch-type slow-speed contra-angle hand piece, the operator anesthetizes the gingiva with the ultra short needle and an amide anesthetic with vasoconstrictor, and then drills a small hole into the alveolar bone using the perforator (Figure 1). Once the perforator has been removed, the user is advised to use light pressure upon inserting the injection needle into the hole (Figure 2) and inject slowly for enhanced patient comfort [4].

### X-Tip® (Dentsply International Inc., Tulsa, OK, USA)

X-Tip® was designed to solve the problem created by the Stabident® system of having to locate the perforated hole for injection needle insertion. Components of X-Tip® consist of a 27-gauge perforator drill, a 25-gauge guide sleeve that fits over the drill, and a 27-gauge ultra-short needle (Figure 4). Once the drill leads the guide sleeve into the cancellous bone, it is removed and the guide sleeve left in place (through which the needle is directed into the cancellous bone (Figure 3)) [5].

### IntraFlow® (Pro-Dex Incorporated, Santa Ana, CA, USA)

Equipped with a hand piece, 24-gauge hollow perforator, and disposable transfuser(Figure 6), IntraFlow® allows the operator to perforate the bone and deposit the solution all in one

**Table 1:** Mandibular Local Anesthesia Techniques.

| Technique | Description |
|---|---|
| 1. Inferior Alveolar Nerve Block (IANB) | Blocks the inferior alveolar, incisive, mental, and lingual nerves, has however, the highest percentage of clinical failures |
| 2. Gow-Gates Mandibular Block | Blocks the IAN, lingual, mylohyoid, mental, incisive, auriculotemporal, and buccal nerves |
| 3. Vazirani-Akinosi closed-mouth mandibular block | Used in limited mandibular opening, blocks the IAN, incisive, mental, lingual, mylohyoid nerves |
| 4. Nerve Block for Mental, Buccal, Incisive Nerves | Local anesthetic deposited close to the main trunk of the target nerves |
| 5. Intraosseous (IO) | Often used after nerve block failure, local anesthetic deposited directly into the interproximal bone between two teeth |
| 6. Intraligamentary (PDL) | Often used after nerve block failure, local anesthetic deposited directly into periodontal tissues surrounding the root |
| 7. Intraseptal | Used when inflammation or infection precludes use of PDL, local anesthetic deposited interdentally into papilla adjacent to the tooth |

Abbreviations: **IAN:** Inferior Alveolar Nerve step, after the attached gingiva and the periosteum have been anesthetized with local anesthesia. Highly efficient, IntraFlow® utilizes low speed, high torque, and steady pressure to penetrate the bone and deliver the solution. Once the perforator penetrates the bone, the transfuser directs solution from the cartridge to the perforator for infusion (Figure 5) [4].

## Computer-Controlled Local Anesthetic Delivery (C-CLAD) Systems

**QuickSleeper®** (Dental HiTec, Cholet, France): Computer-controlled, QuickSleeper® consists of a hand piece with a pen grip for maximum precision, a control unit, and a foot pedal. Featuring 4-programmed injection speeds (including a 'low' mode for especially sensitive cases: patients with very dense cancellous bone) and rotation of the needle, QuickSleeper®(Figure 7) allows the operator to perforate and inject without pain, trauma, and heating up the tissues. The Permanent Analysis of Resistance system ensures a regular injection whatever the density of the infiltrated tissue, without the operator having to exert any muscular effort. In addition to IO injection, QuickSleeper® may be used to perform intraseptal, intraligamentary, and conventional anesthesia techniques, like infiltration. The newest model, QuickSleeper S4® (Figure 8), is 40% lighter and 19% reduced in diameter, compared to the previous model. New and improved features include a wireless and battery-less pedal, automatic and continuous injection system to limit needle obstruction, and a high performance ball bearing system that reduces vibration during needle rotation and increases user comfort [16]. The device requires specially developed needles (perforation and injection are managed with the same needle).

**SleeperOne®** (Dental HiTec, Cholet, France): Similar in

**Figure 1** Stabident® perforation of bone.

**Figure 2** Stabident® needle injection.

**Figure 3** X-Tip® needle insertion.

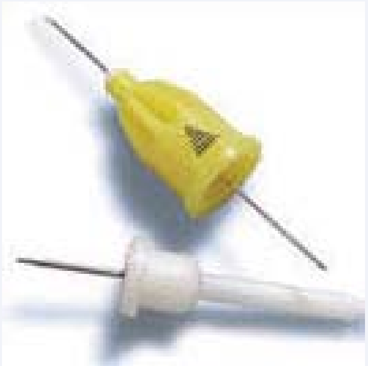

**Figure 4** X-Tip® components.

**Figure 5** IntraFlow® perforation and injection.


**Figure 6** IntraFlow® components.

design to the QuickSleeper® system, SleeperOne® also features a pen grip hand piece, a control unit, a foot pedal, PAR system, and 4-injection speeds. What distinguishes the two systems however, is that SleeperOne® (Figure 9) does not feature a rotating needle and therefore excludes transcortical and osteocentral use. Highly efficient for PDL injections, SleeperOne® may also be used for intraseptal (ideally in pediatric patients), infiltration, nerve block, and palatal infiltration anesthesia [17].

**Wand/CompuDent®** (Milestone Scientific, Inc., Livingston, NJ): The CompuDent® system (Figure 11) consists of a computerized base unit, a foot pedal, and single use Wand® hand piece. While light pressure on the foot pedal triggers a slow injection speed of 0.005 mL/s for needle insertion, PDL, and palatal injections, increased pressure activates a faster injection of 0.03 mL/s (1 cartridge per minute) for infiltration and nerve blocks. The pen-like design of the hand piece gives the operator greater precision and allows for faster onset and higher anesthetic success. Computer control of the delivery instrument reduces injection pain and enhances patient comfort [18]. Additional features include a third higher injection rate of 0.06 mL/s and aspiration warning mechanism [4].

**STA®** (Single Tooth Anesthesia®-Milestone Scientific, Inc., Livingston, NJ): With built-in CompuFlo® and Dynamic Pressure Sensing technology, Milestone Scientific's newest dental CCLAD system (Figure 12) provides visual and audible feedback while continuously monitoring the pressure of the solution throughout the injection. Sensing needle-tip pressure, these features advise the user on ideal needle placement for PDL injection and prevent dangerously high pressure flow during injection [4].

**Comfort Control Syringe®**(Dentsply International, York, PA, USA): Unlike CompuDent® and STA®, the Comfort Control

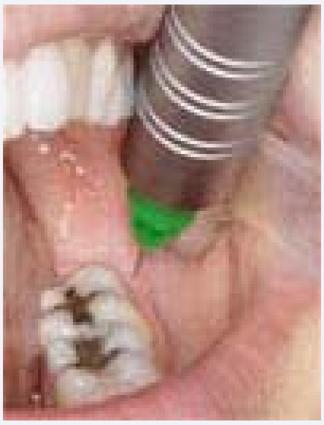

**Figure 7** Intraosseous anesthesia with QuickSleeper®.

**Figure 8** QuickSleeper S4®.

**Figure 9** Intraligamentary injection with SleeperOne®.

**Figure 10** SleeperOne 2®.


**Figure 11** CompuDent®.

Syringe® (Figure 13) does not use a foot pedal to control injection. Instead, injection and aspiration are both controlled by the hand piece, which has 5 pre-programmed speeds for 5 injections: infiltration, block, IO, PDL, and palatal. However a note should be made that use of the Syringe involves a trade off between manual control (rather than pedal control) and using a larger, clumsier syringe [4].

In contrast to the thick cortical bone of the mandible, the anatomically thinner maxilla allows for easy diffusion of product and high anesthetic success (95-100%). The following techniques (Table 2) have been reported for local anesthesia within the maxilla: supraperiosteal infiltration (local infiltration), nerve blocks of the posterior superior alveolar (PSA), middle superior alveolar (MSA), anterior superior alveolar (ASA), palatal approach-anterior superior alveolar (P-ASA), anterior


**Figure 12** STA®.

**Figure 13** Comfort Control Syringe®.

**Table 2:** Maxillary Local Anesthesia Techniques.

| Techniques | Description |
|---|---|
| 1. Supraperiosteal (Local Infiltration) | Local anesthetic deposited into small terminal nerve endings |
| 2. Nerve Block: Posterior Superior Alveolar (PSA), Middle Superior Alveolar (MSA), Anterior Superior Alveolar (ASA), Palatal approach-Anterior Superior Alveolar (P-ASA), Anterior Middle Superior Alveolar (AMSA), Maxillary, Greater Palatine, Nasopalatine Nerves | Local anesthetic deposited close to the main trunk of the target nerve |
| 3. Intraosseous (IO), Intraligamentary (PDL), Intraseptal | Identical to mandibular equivalents |

middle superior alveolar (AMSA), maxillary, greater palatine, and nasopalatine nerves, periodontal ligament injection (PDL), intraseptal injection, intracrestal injection, and traditional intraosseous injection (IO). Nevertheless, due to the great success of infiltration in the maxilla, achieving successful local anesthesia is of greater concern in the mandible [2].

From cringing patients to waiting periods of time for a local anesthetic effect to appear or even fail, achieving successful local anesthesia is no easy task. In addition to incorrect technique and anatomical difficulty or unfamiliarity, local anesthesia can also fail by other means such as inflammation, infection, and even patient anxiety. In cases as severe as pulpitis or apical periodontitis, infection can create an acidic pH that interferes with product dissociation while inflammation can induce hyperesthesia that heightens patient sensitivity. Anxious or even fearful patients may continue to feel pain even after local anesthesia has been achieved [22].

The aim of this paper is to review the literature on local anesthesia in dentistry to assess for solutions and techniques that offer the greatest efficiency, efficacy, and comfort to the patient and administrator.

## MATERIALS AND METHODS

This literature review on local anesthesia in dentistry was searched manually through local anesthesia textbooks as well as Internet searched for techniques, products, and devices. The PubMed and ScienceDirect databases were also searched for articles going back a maximum of 10 years in the literature on topics of local anesthesia in dentistry, local anesthetic agents, products, devices, and techniques, technique success and failure, and intraosseous anesthesia. Though 'anesthetic', 'agent', 'product', and 'solution' were used interchangeably in the literature, 'anesthetic', 'agent' and 'product' refer to local anesthetics of any form while 'solution' specifically refers to injectable products.

## RESULTS

In 2013, Malamed et al., found that injection with alkalinized 2% lidocaine with epinephrine 1:100,000, yielded faster onset time and greater comfort than the same product in its non-alkalinized form. As lidocaine in dental cartridges typically contains a pH ranging from 2.9 to 4.4, less than 0.1% of the acidic anesthetic is in the de-ionized or 'active' form. By activating and alkalinizing their products to a neutral pH of about 7, clinicians can begin procedures more quickly and inject with increased patient comfort.

In addition to alkalinizing their products for faster onset and greater comfort, clinicians can use epinephrine in proportion of 1:100,000 rather than 1:200,000 for greater efficacy and patient comfort. According to Lima et al., 4% articaine with 1:100,000 epinephrine is more effective in eliminating pain than with 1: 200,000 epinephrine for extraction of maxillary third molars in the presence of pericoronitis. The vasoconstricting properties of epinephrine allow for greater diffusion of the product and a stronger anesthetic effect [1].

For a longer lasting anesthetic effect, it has been found that injection with 4% articaine results in faster onset and longer duration of pulpal anesthesia during IANB than injections of 2% lidocaine [25]. The high fat solubility of articaine allows for easier product dissociation across nerve cell membranes and stronger effects than other less fat-soluble products like lidocaine.

In addition to ineffective anesthetics, local anesthesia can also fail from incorrect technique. Using the mandibular block as an example, injecting too low will produce only lingual anesthesia, injecting too deep into the parotid space may temporarily paralyze the facial nerve, and injecting too mesially into the pterygoid muscle can result in trismus [22]. In attempts to resolve these issues, a group of researchers in 2013 developed a new method for teaching dental students how to administer nerve blocks more confidently. Using special three-dimensional anatomical models, which reproduced all innervations, Canellas et al. created instructional videos and pictures to help dental students in Brazil identify anatomical landmarks for correct needle placement and identify the paths of nerves. After the presentation, 88% of the student subjects rated the material as excellent and 70% felt confident about being able to successfully administer the nerve block in patients. Seeing that improved knowledge of the less explored regions of IANB should make the administration of IANBs safer and more effective, Khoury, et al. addresses the essentiality of clinicians having a better understanding of anatomy and technique.

In recent years, a number of studies have begun to support the use of intraosseous anesthesia as an effective mandibular local anesthetic technique. Usually administered as a supplementary injection when nerve blocks have failed, intraosseous anesthesia, when used as a primary technique, has shown to work quickly and provide significant patient comfort.

## BENEFITS OF INTRAOSSEOUS ANESTHESIA

Compared to conventional techniques, manual intraosseous (IO) injection is reported to be efficient, effective, and preferred by most patients for conservative treatments. According to Penarrocha-Oltra et al., manual IO injection of 3% mepivacaine using Stabident® provides shorter latency periods of 0.89+/-0.73 minutes (versus 8.52+/-2.44 minutes with conventional techniques), sufficient anesthesia lasting 2.5 minutes (versus 1-3 hours with conventional techniques), and 78% anesthetic success (versus 89% with vestibular infiltration and mandibular nerve block). During the study, one patient reported mild pain with conventional techniques while 5 experienced mild pain during IO anesthesia. Based on the 61% patient preference, lack of numbness, short latency, and suitable duration of anesthesia, the authors concluded that IO anesthesia is a technique that should be taken into account for conservative and endodontic treatments. In 2008, a different study compared the efficacies of IntraFlow® delivered IO injection and IANB (1.8 mL 2% lidocaine w/ 1:100,000 epinephrine) in anesthetizing mandibular posterior teeth with irreversible pulpitis. Finding IntraFlow® controlled IO injection to be highly successful (achieving 87% success versus just 60% with IANB), Remmers et al. concluded that IntraFlow® may be used as a primary technique to achieve predictable pulpal anesthesia.

In recent years, IO injection using CCLAD devices has also garnered support from within the dental community. According to Beneito-Brotons et al., intraosseous injection with 4% articaine and 1:100,000 adrenalin using the computerized device QuickSleeper®, is effective, works more quickly than conventional techniques, and provides anesthesia long enough for limited treatments. After receiving both treatments in a split-mouth design for restorations, endodontic procedures, and simple extractions, 69.7% of the adult participants preferred intraosseous anesthesia (despite 46.3% reporting discomfort during injection). With an average latency period of 0.48+/-0.32 minutes, versus 7.1+/-2.23 minutes using conventional methods, computer-controlled IO injection worked quickly and lasted 1.6 minutes, just long enough for treatment. Ozer et al. also found IO anesthesia with QuickSleeper® to be less painful upon injection than IANB, providing less soft tissue numbness and quicker onset. Compared to conventional methods, which resulted in just 35% anesthetic success, IO anesthesia with 1.5 mL of 4% articaine and 1:100,000 epinephrine was successful 82.5% of the time. Considering its fast onset and short duration of anesthesia, IO injection was concluded to be a highly practical method for restorative treatment, endodontic treatment, tooth preparation, and tooth extraction. Four percent articaine solution was preferred for IO and IANB injections because it was considered it to be effective in terms of its duration and depth in surgical procedures.

Within children, computerized IO injection with 4% articaine and 1:200,000 epinephrine using QuickSleeper® is highly successful (91.9% efficacy) and relatively long lasting (28.0 +/- 15.0 minutes) for endodontic treatments, restorations, and extractions (44.1% maxillary and 55.9% mandibular). Though 24.1% said they felt sensitivity from the anesthetic being deposited (pressure rather than pain itself), there were no reports of biting of the mucosa, post injection pain, or local tissue damage in the patients due to the low mean volume of solution required for sufficient anesthesia (0.80 mL). From these results, the authors concluded that IO injection, when administered with a computer-controlled system, can be considered as a good alternative or supplement to infiltration techniques in children [32]. A follow-up study in 2009 evaluated the pain associated with QuickSleeper® controlled IO injection in children and found that the majority of children (58.9%) preferred computerized IO anesthesia delivered with a mean volume of 0.6 mL of 4% articaine and 1:200,000 epinephrine to traditional infiltration methods as providing greater comfort [33].

In addition to traditional IO injection, intraligamentary injection has also been supported within the literature as an effective primary technique for local anesthesia. According to Jing et al., computer-controlled PDL injection of 0.5 mL 4% articaine and 1:100,000 epinephrine is highly effective, with 92.1%, 53.0%, and 93.1% anesthetic success having being reported in the mandibular pre-, first, and second molar teeth respectively, of patients with irreversible pulpitis. With high rates of efficacy and no resulting irreversible damage to periodontal soft tissue, computer-controlled PDL injection was regarded to be a safe and effective primary technique for endodontic access to mandibular posterior teeth with irreversible pulpitis.

Comparing the clinical efficacy of PDL injections using a computer-controlled device (STA®) and a mechanical pressure syringe (VarioJect INTRA®), Kammerer et al. found that the two methods yielded similar success rates and duration of pulpal anesthesia. Though manual injection generated less pain during treatment, both methods overall induced less injection pain and soft tissue anesthesia than the IANB. Overall, the authors of the study concluded that while both PDL techniques are effective in achieving sufficient anesthesia for routine dental treatments, dental students should receive more clinical daily experience with the two techniques in their curriculum.

While both IO and PDL injections serve as effective alternative approaches to providing local anesthesia in the mandible, adverse reactions to intraosseous anesthesia such as increased heart rate, injection pressure discomfort, and postoperative tenderness have been reported [36]. According to Malamed, these complications may be avoided with correct positioning of the needle and avoidance of excessive injection pressure (minimum 20 seconds for PDL) and volume (0.2-0.4 mL for PDL and 0.45-0.6 mL for IO).

In 2013, Biocanin et al. compared computerized intraseptal and PDL injections at different doses (0.4, 0.6, 0.8 mL) in adult mandibular premolars. Using an electrical pulp tester (EPT) to measure efficacy, onset, and duration, the researchers found that intraseptal injection with 4% articaine and 1:100,000 epinephrine achieved 90% anesthetic success in doses of 0.6 and 0.8 mL (versus 50-70% efficacy for PDL at all volumes). While immediate onset was observed during both injections, duration of anesthesia was much higher for the intraseptal injection (9.4 +/- 12min, 14.7+/- 10.7 min, and 24.2+/- 17.0 min, respectively, for all three doses versus 6.2+/- 8.7 min, 9.2+/- 11.8 min, 10.4+/- 9.3 min for the PDL injections). Complications included sensitivity to biting in 10 patients who received the PDL injection and slight hematoma in 3 patients who received the intraseptal injection. Both techniques produced stable parameters of cardiovascular function. Based on these results, the authors concluded CCLAD intraseptal injection with 4% articaine and 1:100,000 epinephrine to be an effective, adequate, and safe local anesthetic technique in healthy individuals.

Often painful to deliver but painless in effect, local anesthesia is a game of give and take. However, due to the latest line of local anesthesia instruments, anesthetic solutions can be administered with little to no pain at all. In addition to the IO anesthesia delivery systems already listed, a number of other CCLAD devices, vibrotactile devices, and jet pressure injectors have also been reported to deliver more comfortable injections. Computer-controlled, both Anaeject® (Nippon ShikaYakuhin, Shimonoseki, Japan) and the Comfort Control Syringe® have been reported to provide less painful injections than traditional syringes [38,39]. A vibrotactile device, DentalVibe® uses high-frequency vibrations to effectively distract adolescents from the sensation of pain [40]. One study on jet injectors shows 70% of patients preferring use of the needleless MADAjet® over classic infiltration syringes in providing a more comfortable injection [41].

## DISCUSSION

Intraosseous anesthesia confers many benefits and advantages. Despite the limited number of studies published on intraosseous anesthesia in recent years, the existing literature indicates considerable support for its use. Compared to conventional methods (IANB, infiltration, and palatal anesthesia), traditional IO injection using computer-controlled devices delivers more effective, efficient, and comfortable anesthesia for limited mandibular procedures. Using QuickSleeper®, Ozer et al. reported 82.5 % success (47.5% higher than IANB) with IO injection using 1.5 mL of 4% articaine with 1:100,000 epinephrine. Within children, Sixou et al. reported 91.9% efficacy using QuickSleeper® (0.80 mL 4% articaine w/ 200,000 epinephrine). Though IO injection with IntraFlow® proves to be just as effective in the mandible (87% efficacy versus 60% with IANB) [29], IO injection with Stabident® has shown to cause mild pain in some patients [28]. The latter is due to the fact that one cannot maintain a slow injection speed when injecting manually, as does a computer-controlled device. Paramount in the IO technique is to obtain good periosteum anesthesia, prior to cortical bone perforation. Aninfiltration anesthesia of soft tissues at perforation site to anesthetize the periosteum, guarantees a painless perforation of the cortical bone. Subsequently the correct position of the needle/perforator on the cortical bone needs to be obtained. In children, no needle rotation is required as due to the thin and porous nature of their bone, while in adolescent and adult patients, a rotation (drilling) is required to perforate the cortical plate. Once the needle is at the correct depth inside the cancellous bone, it is imperative to inject the local anesthetic (with a vasoconstrictor) slowly. Despite the high efficacy rates reported within many of the articles, one reports an IO injection success of just 78% with 3% mepivacaine and no vasoconstrictor (compared to 89% efficacy using 2% lidocaine and 1:100,000 adrenalin for conventional methods) [28]. Obviously the absence of adrenalin in the IO injections will have lowered the strength of the anesthetic and thus the efficacy rate of the technique. The comparative study design might have been more impartial if the type of solution and concentration of epinephrine for both methods of anesthesia had been controlled for. Intraosseous anesthesia should not be performed without the use of a vasoconstrictor.

Overall, both hand and computer-controlled IO injections show to be highly effective, fast acting, comfortable, preferred by most patients (children and adults), and lasting long enough for limited treatments. Regardless of the technique, a local anesthetic should not be administered in the presence of infection or severe inflammation as changes in pH make the anesthetic less effective. While palpitation, fistula formation, and perforation of the lingual plate have been reported, use of less concentrated epinephrine, gentle pecking with the hand piece, and careful technique should preclude these complications [2].

Though even fewer studies were found on the intraligamentary injection as a primary form of local anesthesia, the technique when administered with a CCLAD device was found to be both effective and less painful than the IANB [35]. Based on the high efficacy rates of computerized PDL anesthesia (92.1% and 93.1% in pre- and secondary mandibular molars respectively using 1.5 mL of 4% articaine and 1:100,000 epinephrine) and lack of irreversible pulpal damage, Jing et al. concluded the PDL injection to be an effective and safe primary technique in endodontic procedures for mandibular posterior teeth with irreversible pulpitis. Usually these are very hard to anesthetize with conventional IANB. While sensitivity to biting [37]and pain have been reported after computerized PDL injection (versus manual injection), both manual and CCLAD controlled injections were found to induce less soft tissue anesthesia and pain than the IANB [35].

According to Malamed, potential complications of the PDL injection such as pain during needle insertion, solution injection, and postinjection, may be avoided by keeping the needle against the tooth and not the soft tissue, avoiding inflamed and infected tissue, and injecting slowly (minimum of 20 seconds for 0.2 mL per tooth). If the solution is not retained, the clinician is advised to reposition the needle at a different site until the solution is deposited and retained. Other contraindications of the PDL injection include use in primary teeth, when there is infection or inflammation at the injection site, and in patients who require numbing for psychological comfort [2]. While the majority of the literature supports use of the PDL injection, more studies are needed to investigate the efficacy of PDL anesthesia versus conventional techniques, use of the injection within children, and patient preference. It is understandable that a space as narrow as the periodontal ligament space requires adjusted injection needles in order to minimize the risk of damaging the tissues. As injection pressure plays an important role, too high of an injection pressure will not only cause injection fluid to be ejected through the crevicular sulcus, but will also result in a less efficient anesthetic effect.

With respect to the intraseptal injection, only one study was found on its primary use. When delivered with a CCLAD device, the technique is reported with good success (90%) in mandibular premolars (with 0.6-0.8 mL 4% articaine w/1:100,000 epinephrine), with slight hematoma having been reported in the papilla region [37]. Despite the significant success of the technique, more research is necessary to support and encourage its greater use in clinical dentistry. If results on efficacy, safety, and comfort (comparable to the IO and PDL injections) are repeated with good consistency, the intraseptal injection may be considered a suitable primary technique for local anesthesia in dentistry. For optimum comfort and success with the method, the operator is advised to avoid injecting too rapidly, with too much solution (0.2-0.4 maximum per site), and into inflamed, infected tissue [2]. However, in pediatric dentistry the technique is well accepted and works adequately. This is probably because the intercrestal bone is thinner in children and the cancellous bone more sparse. Both enable the needle to be placed into the bone easily and the injection to be performed with minimal pressure. The SleeperOne® is especially designed for these tasks.

Though the application of anatomical models as a teaching tool is a plausible solution to technique failure, the results on student confidence and material excellency provided by Cannellas et al. are based solely on student opinion. The study design would have been more convincing if the researchers had further evaluated student clinical performance and anesthetic success after presentation of the models and videos. High clinical efficacy would indicate an advantage towards wider use of these models. Nonetheless, it would be beneficial for dental students to learn more about anatomy and local anesthetic techniques in their daily curriculum to gain confidence in a clinical setting. Informal inquiries in different dental schools have revealed that local anesthesia is not always taught as a real separate course in the dental curriculum. Regarding use of other local anesthetic devices such as Anaeject®, the Comfort Control Syringe®, DentalVibe®, and MADAjet®, although they show to give more comfortable injections than traditional syringes [38-41], little is known on the efficacy they induce when used to administer more challenging injections such as the mandibular nerve block.

By depositing solution directly into the cancellous bone near the apex of the tooth, intraosseousinjection eliminates soft tissue numbness and prolonged anesthesia of the teeth, and allows for fast, comfortable onset of anesthesia. Combined with reduced pain from computer-controlled delivery speeds, intraosseousinjection has earned high preference from patients (58.9-69.7%) over conventional techniques [33, 28,30]. In a clinical setting, the fast onset, short duration, and high efficacy of CCLAD delivered IO anesthesia should allow operators to start their procedures more quickly and see more patients throughout the day (especially advantageous for clinicians performing conservative procedures). Another advantage of using IO anesthesia is that one can treat bilateral teeth in the same appointment without having to administer two IANBs, which are very uncomfortable for patients. Moreover, palatal injections to place rubber dam clasps become redundant, as the IO anesthesia anesthetizes the periodontal ligament, the pulp, and the attached gingiva around the tooth.

It is important to emphasize that while the handbooks can be very thorough and great sources for understanding fundamental techniques (proper hand, needle positions), indications, contraindications, advantages, and disadvantages of each local anesthetic method, certain texts can be outdated compared to the more current journal and web articles. In the 2004 5th edition Malamed handbook for instance, the technique described for the IO injection pertained only to hand delivery systems (X-Tip®, Stabident®, and IntraFlow®). Also excluded was mention of technique efficacy rates, which the aim of this literature review focuses primarily on. Since this literature review was performed in the English literature only, one needs to realize that scientific papers published in other languages may contain more updated and detailed information on these techniques. Despite the interest of the dental research community to investigate the efficacy and comfort of a certain device, such as the QuickSleeper®, some have never been used for studies in the USA for instance, because they are simply not available. The results of this study should be interpreted with care, as also 'dental cultural' differences exist between continents.

## CONCLUSION

The results of this study support the use of computer-controlled intraosseous injection as a primary technique for local anesthesia in dentistry. Compared to conventional methods such as the IANB, C-CLAD delivered intraosseous injection shows high success rates, easy administration, fast onset, significant patient comfort, and duration long enough for endodontic and limited treatment of 1-2 posterior teeth in the mandible. For the best results, the recommended doses are 1.5-1.8 mL of 4% articaine with 1:100,000 epinephrine for adults, and 0.6-0.8 mL of 4% articaine with 1:200,000 epinephrine for children. To encourage greater use and confidence with the intraosseous injection in a clinical setting, it is suggested that the technique be taught within the regular dental curriculum. The latter will benefit many other patients, besides those who are hard to anesthetize.

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