Adjuncts to Local Anesthesia: Separating Fact from Fiction

(Traitements d'appoint à l'anesthésie locale : séparer les faits de la fiction)

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Sommaire

Selon certains, les techniques d'anesthésie locale complémentaires et leur arsenal thérapeutique — comme les injections intra-osseuses, les systèmes informatisés d'administration d'anesthésie, l'injection intraligamentaire et les pistolets à injection sans aiguille — comporteraient des avantages particuliers par rapport aux méthodes traditionnelles d'anesthésie locale. Nous décrivons dans cet article l'utilisation de chacune de ces techniques et le matériel propre à chacune et passons en revue la documentation à l'appui de leur utilisation.

Mots clés MeSH : *anesthesia, dental/methods; anesthesia, local/methods; equipment design*

Cet article a fait l'objet d'une révision par des pairs.

The achievement of successful local anesthesia is a continual challenge in dentistry. Adjunctive local anesthetic techniques and their armamentaria are often marketed to clinicians as a panacea, but they are not without their own disadvantages and complications. Such techniques and equipment include intraosseous (IO) injection systems, computer-controlled systems for delivery of local anesthetic, periodontal ligament (PDL) injection and needleless jet-injection systems. The purpose of this article is to review the niche applications of these techniques and to summarize the scientific literature appraising their use.

Defining Success in Local Anesthesia

Success rates for local anesthetic techniques are critically dependent on the particular criteria used to define success. Quoted rates may be misleading or meaningless if they do not state the specifics of the particular stimuli, teeth and pulpal states involved. Pulpal anesthesia as evaluated by standard electrical pulp testing (EPT) criteria has provided a consistent basis for elucidating the value of traditional approaches to local anesthesia as well as the benefits of adjunctive techniques.[1] Despite subjective lip numbness, success rates for pulpal anesthesia in vital asymptomatic mandibular first molars after conventional inferior alveolar nerve block (IANB) are poor, averaging 69% even after deposition of up to 3.6 mL of local anesthetic[2-7] (see Table 1, Success rates for conventional inferior alveolar nerve block, http://www.cda-adc.ca/jadc/vol-67/issue-7/391.html). In mandibular first molars with irreversible pulpitis, success rates are even worse, averaging 30%[8,9] (see Table 2, Success rates for conventional inferior alveolar nerve block in patients with irreversible pulpitis, http://www.cda-adc.ca/jadc/vol-67/issue-7/391.html). Subjective lip numbness is a poor indicator of local anesthetic success as assessed by EPT.

Reasons for Failure of Conventional Local Anesthetic Techniques

Factors contributing to the failure of conventional local anesthetic techniques must be considered before examining the rationale for any local anesthetic adjunct. These factors can be broadly classified as related to the armamentarium, the patient and the operator (see Table 3, Reasons for failure of conventional anesthetic techniques, http://www.cda-adc.ca/jadc/vol-67/issue-7/391.html).

Armamentarium-related factors such as deflection of the needle tip have been suggested to result in inaccurate needle placement and higher failure rates with IANB.[10] However, even with accurate placement, the unpredictable spread of local anesthetic solution may contribute to failure.[11]

Patient-related factors include anatomical factors such as cross-innervation in the mandibular incisor region[12] and accessory innervation in the mandibular posterior region (by the

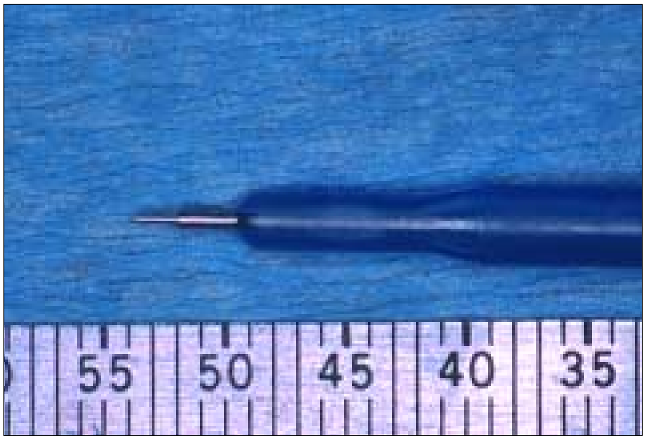

Figure 1: *The Hypo intraosseous injection system has a 32-mm 30-gauge needle compatible with standard breech-loading syringes.*

Figure 2a: *The Stabident system's perforator is a 27-gauge 0.43-mm diameter solid core wire imbedded into a plastic sheath designed to engage a standard latch angle.*

Figure 2b: *The most apical extent of the attached gingival margins of adjacent teeth is used as a landmark for locating the appropriate perforation point.*

Figure 2c: *After application of topical anesthetic and infiltration of local anesthetic into gingival mucosa, perforation is performed mesial or distal to the tooth.*

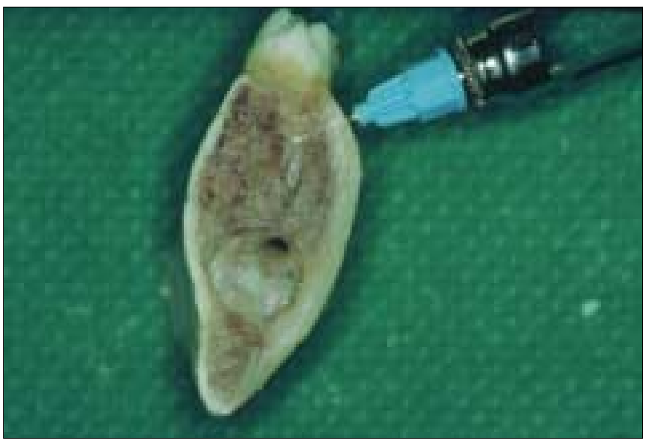

Figure 2d: *After removal of the perforator, the injection needle is introduced to deliver local anesthetic into periradicular medullary bone.*

lingual, long buccal and mylohyoid nerves, for example), which may allow nociceptive inputs despite complete IANB. The thick cortex of the mandible and the zygomatic process of the maxilla impede diffusion of anesthetic solution and may result in local anesthetic failure. Intravascular injection invariably results in failure. Pathological states such as the presence of pulpal inflammation are associated with higher rates of failure of local anesthesia.[13]

Operator-related factors such as inexperience and poor technique may also contribute to failure. For example, unfamiliarity with the Gow-Gates mandibular block may lead the operator to inadvertently allow the patient to close his or her mouth and inappropriately displace critical anatomical targets such as the neck of the condyle out of the trajectory of the needle.

The reader is encouraged to refer to the comprehensive review articles discussing this subject,[10-13] which is beyond the scope of the current article.

Intraosseous Injection

IO injection is the introduction of local anesthetic directly into periradicular cancellous bone. The rationale is that efficacy will be increased by minimizing or eliminating armamentarium, patient and operator-related factors contributing to failure of traditional nerve block.

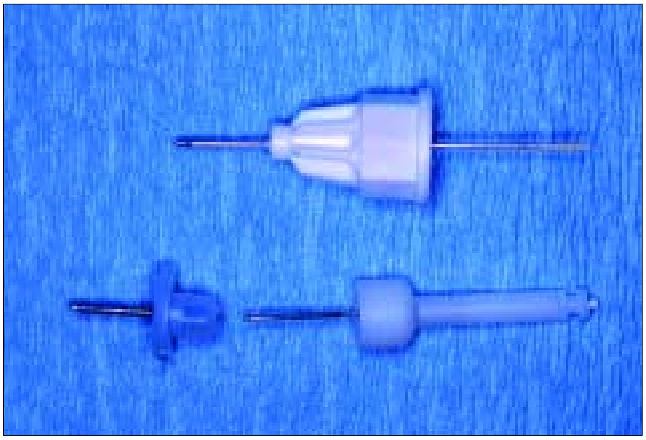

Figure 3a: *The X-Tip system consists of a perforator assembly (solid-core needle with overlying guide sleeve and handle consisting of a stainless steel sheath and plastic hub) and 27-gauge 0.4-mm diameter ultrashort injection needle.*

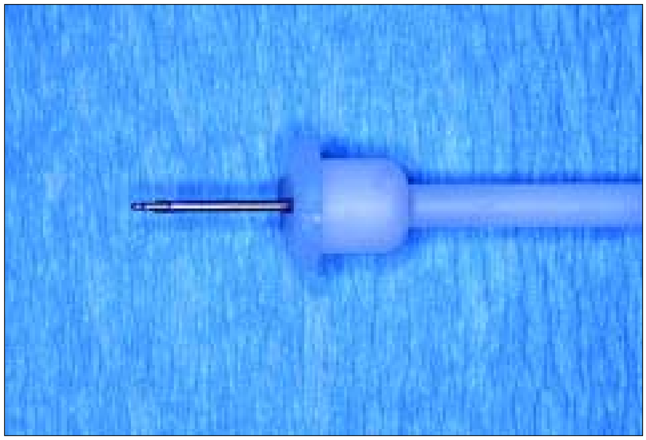

Figure 3b: *Guide sleeve and handle over perforator needle.*

Figure 4: *The Wand is a computer-controlled system consisting of pump unit, foot pedal, transfuser tubing, handpiece assembly, luer-lock needles and standard anesthetic cartridges.*

IO injection is not a new concept, and its evolution has resulted in convenient prepackaged kits (see Table 4, Comparison of various systems for adjunctive local anesthesia, http://www.cda-adc.ca/jadc/vol-67/issue-7/391.html; Figs. 1 to 3) marketed under the names Hypo (MPL Technologies, Franklin Park, IL), Stabident (Fairfax Dental, Miami, FL) and X-Tip (X-Tip Technologies, Lakewood, NJ).

IO injection has been purported to result in greater success of anesthesia, more rapid onset of anesthesia, and less residual soft-tissue anesthesia; it is apparently less painful and reportedly allows use of lower doses than are needed for conventional nerve block techniques. In virtually all studies investigating these claims (and cited in the following paragraphs), the Stabident system has been arbitrarily selected for analysis.

When used to supplement failed primary IANB, IO injection has reliably increased success[2,4-6,8,9,17] (see Table 5, Success rates for conventional inferior alveolar nerve block with supplemental intraosseous injections, and Table 6, Success rates for conventional inferior alveolar nerve block with supplemental intraosseous injection in irreversible pulpitis, http://www.cda-adc.ca/jadc/vol-67/issue-7/391.html). In the cited studies, success was defined as no response to maximal EPT output (80 readings) on 2 consecutive tests 60 minutes after application of the anesthetic. Supplemental IO injection improved the average success rate to 97% in vital asymptomatic mandibular first molars[2,4,5,6,17] (Table 5) and to 83% in first molars with pulpitis[8,9] (Table 6). However, anesthesia declined to as low as 76% after one hour.[12]

IO injection is less successful as a primary technique in mandibular first molars, for which success rates average 75%[18,19] and decline steadily with time to less than 50% after one hour.[18] This method appears to have no advantages over IANB as a primary means to achieve anesthesia.

Claims that anesthesia is immediate are fairly consistent with clinical findings. Onset of anesthesia has been within one minute after injection and therefore can be deemed rapid, if not immediate.[2,4,6]

Maximal discomfort was rated as mild to moderate pain and occurred on insertion of the needle for infiltration before perforation, rather than during the perforation itself (which was rated as causing no discomfort or as mildly painful).[18] This effect is attributed to the absence of sensory innervation in cortical bone, in contrast to the richly innervated periosteum.[18]

The duration of anesthesia is less with plain solutions than with vasoconstrictor.[2,19] According to the single study available, there appears to be less soft-tissue anesthesia (42%) with primary IO injections compared to IANB.[18]

Claims have been made that reducing the volume of local anesthetic injected does not affect the success rate of the IO approach. Only the supplemental IO injection has been studied in this respect. It appears that reducing the volume from 1.8 mL to 0.9 mL does not appreciably reduce success.[4,17] There have been no studies of potential differences in anesthetic success with reduced anesthetic doses in primary IO injection.

IO injection is advantageous in specific clinical situations, such as treatment of patients with coagulopathy, in whom the risk and consequences of hematoma through nerve block

Figure 5: *N-Tralig PDL injection syringe shown with conventional needle and cartridge.*

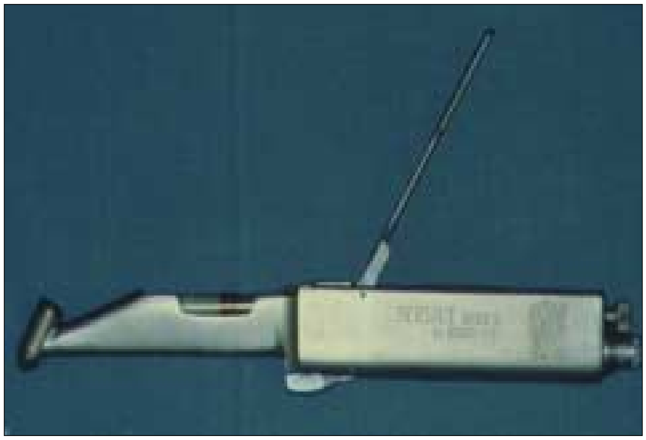

Figure 6a: *Syrijet Mark II jet-injection system: Syrijet syringe, standard dental anesthetic cartridge and plunger rod.*

Figure 6b: *Oral tissues are dried and nozzle is rested gently against attached gingiva at right angles. Release of trigger delivers anesthetic.*

Figure 6c: *Small residual hematoma and erythema of palatal tissues follows application of jet injection.*

anesthesia are significant; bilateral restorations; and treatment in which residual soft-tissue anesthesia is especially undesirable.

Considerations

Cardiovascular effects associated with IO injections, potential postoperative complications and relative contraindications merit comment.

Increases in heart rate have been subjectively and objectively measured in approximately 74% of patients after IO injection of 18 µg of epinephrine.[2,6,9,18,20] Mean increases were approximately 24 beats/minute, and heart rate returned to baseline within 4 minutes in over 85% of subjects.[6] Increases in heart rate are of little clinical significance in healthy patients[6] unless patients interpret them as emotionally or psychologically disturbing. In this case, plain solutions (such as 3% mepivacaine without vasoconstrictor) are acceptable alternatives, since no subjective increases in heart rate have been reported with their use.[5,6] For similar reasons, it may be prudent to use solutions without vasoconstrictor for any patient with cardiovascular disease for whom the proposed procedure is appropriately brief.

Reported postoperative complications include perceived hyperocclusion (6%)[2,6,18] and infection at the site of perforation (3%).[2,18]

If the patient has narrow attached gingiva at the proposed site of IO injection or has severe periodontal disease, IO injection is contraindicated.[18,20]

Computer-Controlled Systems for the Delivery of Local Anesthetic

The Wand (Milestone Scientific, Livingston, NJ) is a computer-controlled pump modelled after those used in intravenous administration of general anesthetics (Table 4; Fig. 4). It can deliver a constant volume of anesthetic at constant pressure, which purportedly enables less painful delivery of the anesthetic. This claim is based upon the premise that pain due to local anesthetic injection is attributable to factors such as fluid pressure on injection and flow rate. Other purported advantages include greater tactile sensitivity and less intrusive appearance. Relative disadvantages are higher cost and speed of injection — at the slowest pump rate, a total of 4 minutes is required to completely express a cartridge.

In a blinded, controlled trial, Asarch and others[21] showed no difference in pain ratings, pain behaviour or overall satisfaction with dental treatment in pediatric patients receiving infiltration, IANB and palatal injections with the Wand and a conventional syringe technique. There are few if any other unbiased blinded, controlled trials upon which to base any conclusions regarding the benefits of computer-controlled delivery systems.

Two other computer-controlled delivery systems have been recently released: the Comfort Control Syringe (Midwest-Dentsply, Des Plaines, IL) and the Quicksleeper (Dental Hitech, ZI Champ Blanc, France).

Periodontal Ligament Injection

PDL injection is also known as intraligamentary injection, transligamentary anesthesia and intraperiodontal anesthesia. Originally described in 1924, its application has since been the impetus for the design of specialized syringes, including the N-Tralig (Miltex Instrument Company, Inc. Bethpage) (Table 4; Fig. 5), the Ligamaject (Healthco Inc., Boston, MA), and the Peripress (Universal Dental Implements, Edison, NJ).

The term PDL injection is something of a misnomer. With this technique, anesthetic fluid spreads primarily along the outer surface of the alveolar plate and under the periosteum, moving into crestal marrow spaces along vascular channels and not through the PDL as previously assumed.[22] Therefore, what is termed PDL injection should be considered a form of IO injection.[22]

The technique involves use of a 25- or 27-gauge short needle or a 30-gauge ultrashort needle.[15] Empirical evidence suggests that longer, smaller-gauge needles are more apt to buckle on insertion; however, PDL injection has been performed successfully with all needle lengths and gauges in both standard syringes and specialized pressure syringes (Fig. 5).[15]

The most objective measure of success — the onset, duration and rating of pain associated with primary PDL injection — is response to EPT (where success is defined as no response to maximal EPT output).[23,24] The following discussion applies to mesial and distal injections (0.2 mL of 2% lidocaine and 1:100,000 epinephrine for each injection) with a Ligamaject syringe.

Onset of anesthesia is rapid, if not immediate (within 2 minutes of completion of the injection).[23] For a primary PDL injection, the success rate at 2 minutes was 79% in mandibular and 75% in maxillary first molars.[23] However, the success rate at 2 minutes was only 18% in mandibular and 39% in maxillary lateral incisors.[23] In addition, success rates declined with use of plain solutions.[24]

When PDL injection was used as a supplement to conventional IANB, the success rate was 78% for first molars. This improvement was maintained for approximately 20 minutes, after which success was similar to that observed with IANB alone (63%).[7]

Duration of anesthesia is brief for the primary PDL injection (combination of 0.2 mL for the mesial injection and 0.2 mL for the distal injection), with only 20% of mandibular and 25% of maxillary first molars anesthetized 10 minutes after injection, and only 10% of mandibular and 30% of maxillary later incisors anesthetized at this time point.[23] It is not clear whether use of 0.5% bupivacaine significantly prolongs the duration of anesthesia with primary PDL injection.[25]

Without topical anesthetic, insertion of the needle itself is rated as mildly to moderately painful and generally contributes to most of the perceived discomfort.[23] Needle insertion is more painful in PDL injection for anesthesia of the maxillary lateral incisor than for other teeth.[23]

The ability of PDL injection to produce anesthesia of a single tooth is unpredictable, and therefore its use as an aid in endodontic diagnosis is questionable.[26]

Considerations

Cardiovascular effects, postoperative sequelae, and potential damage to pulp and periodontal structures merit discussion.

The distribution of injected solutions is primarily intraosseous and perivascular, and rapid systemic absorption is likely.[27] Cardiovascular effects such as changes in mean arterial pressure and heart rate were similar for PDL, IO and intravenous injections of 3 µg of epinephrine in dogs (0.3 mL lidocaine 1:100,000).[27]

Postoperative sequelae are common but self-limiting.[23,24] Pain of mild or moderate severity was reported by 83% of patients after 24 hours.[23] Hyperocclusion was reported by 36% of patients after 24 hours and by 7% after 3 days.[23] Swollen interdental papillae were reported by 13% of patients.[23]

Damage to the crestal bone and cementum from needle trauma is possible, but is minor and reversible.[28] Epithelial and connective tissue attachment to enamel are not disturbed by needle puncture.[29] Injection of the solution is not damaging. Pulpal changes after PDL injections are mild and reversible.[30]

Needleless Jet-Injection Syringe Systems

First described in 1866, jet-injection devices were originally developed for mass immunization. Modern designs have been approved for intramuscular and subcutaneous delivery of medications such as hepatitis B vaccine and insulin.[31]

Needleless jet injectors such as the Syrijet Mark II system (Mizzy Inc., Cherry Hill, NJ) are marketed for use in the dental setting (Table 4; Figs. 6a to 6c). Acceptance of this needleless instrument is high among adult (90%)[32] and pediatric (75%) populations.[33] Situations in which this system might be appropriate include placement of rubber dam clamps, placement of retraction cords, creation of drainage incisions for abscesses, and placement of orthodontic bands or space maintainers.

Controlled studies evaluating efficacy are lacking, and reports are primarily anecdotal. Soft-tissue anesthesia, determined by probing unattached gingiva, was reported as "good."[34] The success rate for pulpal anesthesia of permanent maxillary lateral incisors was poor (13%), as assessed by pulp tests[34]; however, Saravia and Bush[33] reported that anesthesia during 11 extractions of deciduous teeth and 2 pulpotomies was completely successful in a group of children averaging 10 years of age.

Adverse effects are rare. There has been one report of clinically significant hematoma formation after jet injection with the Syrijet.[35]

The advantages of needleless systems for delivery of local anesthetic include rapid onset of anesthesia, predictable topical anesthesia of soft tissues, controlled delivery of anesthetic dose, obviation of needle-stick injury, obviation of intravascular injection and high patient acceptance, especially in instances of needle-phobia. The disadvantages are cost, the potential to frighten patients with the sudden noise and pressure sensation that occur on delivery of the anesthetic, the intrusive appearance of the device, the possibility of small residual hematomas, leakage of anesthetic and questionable efficacy for pulpal anesthesia.

Conclusion

IO injection provides profound anesthesia for 60 minutes when used as a supplement to failed IANB. This is an appropriate alternative primary technique for procedures of short duration (less than 20 minutes) and in situations in which residual soft-tissue anesthesia is undesirable or nerve block carries a significant risk of hematoma. An increase in heart rate comparable to that experienced with mild exercise should be anticipated and is of little consequence in healthy patients.

Computer-controlled delivery systems have not been demonstrated conclusively to afford less painful delivery of local anesthesia relative to conventional syringes.

PDL injection may be performed equally well with conventional syringes and pressure syringes. When used as a primary technique, both methods are just as effective as conventional IANB in achieving pulpal anesthesia, but the duration of action is much shorter. PDL injections are most effective in supplementing failed IANB. Postoperative sequelae such as soreness at injection sites are common but transient.

Jet-injection systems appear to represent an effective alternative means to achieve topical anesthesia of oral mucous membranes. Their use in effecting pulpal anesthesia is questionable. Relative drawbacks include a potentially startling discharge of compressed gas. The primary advantages include obviation of needle-stick injuries and much better patient acceptance than for needle delivery.

In conclusion, knowledge of adjunctive anesthetic techniques may broaden the dentist's ability to provide appropriate local anesthesia. It is important to critically evaluate any new method to determine its merit. Techniques with proven value may provide a beneficial supplement to traditional means of achieving local anesthesia. ❖

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Références

1. Certosimo AJ, Archer RD. A clinical evaluation of the electric pulp tester as an indicator of local anesthesia. *Oper Dent* 1996; 21(1):25-30.

2. Dunbar D, Reader A, Nist R, Beck M, Meyers WJ. Anesthetic efficacy of the intraosseous injection after an inferior alveolar nerve block. *J Endod* 1996; 22(9):481-6.

3. Clark S, Reader A, Beck M, Meyers WJ. Anesthetic efficacy of the mylohyoid nerve block and combination inferior alveolar nerve block/mylohyoid nerve block. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 1999; 87(5):557-63.

4. Reitz J, Reader A, Nist R, Beck M, Meyers WJ. Anesthetic efficacy of the intraosseous injection of 0.9 mL of 2% lidocaine (1:100,000 epinephrine) to augment an inferior alveolar nerve block. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 1998; 86(5):516-23.

5. Gallatin E, Stabile P, Reader A, Nist R, Beck M. Anesthetic efficacy and heart rate effects of the intraosseous injection of 3% mepivacaine after an inferior alveolar nerve block. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2000; 89(1):83-7.

6. Guglielmo A, Reader A, Nist R, Beck M, Weaver J. Anesthetic efficacy and heart rate effects of the supplemental intraosseous injection of 2% mepivacaine with 1:20,000 levonordefrin. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 1999; 87(3):284-93.

7. Childers M, Reader A, Nist R, Beck M, Meyers WJ. Anesthetic efficacy of the periodontal ligament injection after an inferior alveolar nerve block. *J Endod* 1996; 22(6):317-20.

8. Reisman D, Reader A, Nist R, Beck M, Weaver J. Anesthetic efficacy of the supplemental intraosseous injection of 3% mepivacaine in irreversible pulpitis. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 1997; 84(6):676-82.

9. Nusstein J, Reader A, Nist R, Beck M, Meyers WJ. Anesthetic efficacy of the supplemental intraosseous injection of 2% lidocaine with 1:100,000 epinephrine in irreversible pulpitis. *J Endod.* 1998; 24(7):487-91.

10. Jeske AH, Boshart BF. Deflection of conventional versus nondeflecting dental needles in vitro. *Anesth Prog* 1985; 32(2):62-4.

11. Hannan L, Reader A, Nist R, Beck M, Meyers WJ. The use of ultrasound for guiding needle placement for inferior alveolar nerve blocks. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 1999; 87(6):658-65.

12. Rood JP. Some anatomical and physiological causes of failure to achieve mandibular analgesia. *Br J Oral Surg* 1977; 15(1):75-82.

13. Parente SA, Anderson RW, Herman WW, Kimbrough WF, Weller RN. Anesthetic efficacy of the supplemental intraosseous injection for teeth with irreversible pulpitis. *J Endod* 1998; 24(12):826-8.

14. Friedman MJ, Hochman MN. The AMSA injection: a new concept for local anesthesia of maxillary teeth using a computer-controlled injection system. *Quintessence Int* 1998; 29(5):297-303.

15. Walton RE, Abbott BJ. Periodontal ligament injection: a clinical evaluation. *J Am Dent Assoc* 1981; 103(4):571-5.

16. Bennett CR, Mundell RD, Monheim LM. Studies on tissue penetration characteristics produced by jet injection. *J Am Dent Assoc* 1971; 83(3):625-9.

17. Reitz J, Reader A, Nist R, Beck M, Meyers WJ. Anesthetic efficacy of a repeated intraosseous injection given 30 min following an inferior alveolar nerve block/intraosseous injection. *Anesth Prog*. 1998; 45(4):143-9.

18. Coggins R, Reader A, Nist R, Beck M, Meyers WJ. Anesthetic efficacy of the intraosseous injection in maxillary and mandibular teeth. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 1996; 81(6):634-41.

19. Replogle K, Reader A, Nist R, Beck M, Weaver J, Meyers WJ. Anesthetic efficacy of the intraosseous injection of 2% lidocaine (1:100,000 epinephrine) and 3% mepivacaine in mandibular first molars. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 1997; 83(1):30-7.

20. Replogle K, Reader A, Nist R, Beck M, Weaver J, Meyers WJ. Cardiovascular effects of intraosseous injections of 2 percent lidocaine with 1:100,000 epinephrine and 3 percent mepivacaine [see comments]. *J Am Dent Assoc* 1999; 130(5):649-57.

21. Asarch T, Allen K, Petersen B, Beiraghi S. Efficacy of a computerized local anesthesia device in pediatric dentistry. *Pediatr Dent* 1999; 21(7):421-4.

22. Tagger M, Tagger E, Sarnat H. Periodontal ligament injection: spread of the solution in the dog. *J Endod* 1994; 20(6):283-7.

23. White JJ, Reader A, Beck M, Meyers WJ. The periodontal ligament injection: a comparison of the efficacy in human maxillary and mandibular teeth. *J Endod* 1988; 14(10):508-14.

24. Schleder JR, Reader A, Beck M, Meyers WJ. The periodontal ligament injection: a comparison of 2% lidocaine, 3% mepivacaine, and 1:100,000 epinephrine to 2% lidocaine with 1:100,000 epinephrine in human mandibular premolars. *J Endod* 1988; 14(8):397-404.

25. McLean ME, Wayman BE, Mayhew RB. Duration of anesthesia using the periodontal ligament injection: a comparison of bupivacaine to lidocaine. *Anesth Pain Control Dent* 1992; 4(1):207-13.

26. D'Souza JE, Walton RE, Peterson LC. Periodontal ligament injection: an evaluation of the extent of anesthesia and postinjection discomfort. *J Am Dent Assoc* 1987; 114(3):341-4.

27. Smith GN, Walton RE. Periodontal ligament injection: distribution of injected solutions. *Oral Surg Oral Med Oral Pathol* 1983; 55(3):232-8.

28. Walton RE. Distribution of solutions with the periodontal ligament injection: clinical, anatomical, and histological evidence. *J Endod* 1986; 12(10):492-500.

29. Walton RE, Garnick JJ. The periodontal ligament injection: histologic effects on the periodontium in monkeys. *J Endod* 1982; 8(1):22-6.

30. Torabinejad M, Peters DL, Peckham N, Rentchler LR, Richardson J. Electron microscopic changes in human pulps after intraligamental injection. *Oral Surg Oral Med Oral Pathol* 1993; 76(2):219-24.

31. Lindmayer I, Menassa K, Lambert J, Moghrabi A, Legendre L, Legault C, and others. Development of new jet injector for insulin therapy. *Diabetes Care*. 1986; 9(3):294-7.

32. Bennett CR, Monheim LM. Production of local anesthesia by jet injection. A clinical study. *Oral Surg Oral Med Oral Pathol* 1971; 32(4):526-30.

33. Saravia ME, Bush JP. The needleless syringe: efficacy of anesthesia and patient preference in child dental patients. *Journal of Clinical Pediatr Dent* 1991; 15(2):109-12.

34. Lehtinen R. Efficiency of jet injection technique in production of local anesthesia. *Proc Finn Dent Soc* 1979; 75(1-2):13-4.

35. Tabita PV. Side effect of the jet injector for the production of local anesthesia. *Anesth Prog*. 1979; 26(4):102-4.

Table 1 **Success rates for conventional inferior alveolar nerve block**

Authors	Drugs used	Total no. of patients	No. of patients with successful anesthesia[a] (% success)
Dunbar and others[2]	2% lidocaine, 1:100,000 epinephrine	40	17 (43)
Clark and others[3]	2% lidocaine, 1:100,000 epinephrine	30	22 (73)
Reitz and others[4]	2% lidocaine, 1:100,000 epinephrine	38	27 (71)
Gallatin and others[5]	3% mepivacaine plain	48	39 (81)
Guglielmo and others[6]	2% mepivacaine, 1:20,000 levonordefrin	40	32 (80)
Childers and others[7]	2% lidocaine, 1:100,000 epinephrine	40	25 (63)
Total		236	162 (69)

[a]*Vital asymptomatic mandibular first molar teeth demonstrating no response to maximum electrical pulp testing output (80 readings) on 2 consecutive tests over 60 minutes in patients who received up to 3.6 mL of local anesthetic to achieve subjective lip numbness at baseline.*

Table 2 Success rates for conventional inferior alveolar nerve block in patients with irreversible pulpitis[a]

Author	Drugs used	Total no. of patients	No. of patients with successful anesthesia[b] (% success)
Reisman and others[8]	3% mepivacaine plain	44	11 (25)
Nusstein and others[9]	2% lidocaine, 1:100,000 epinephrine	26	10 (38)
Total		70	21 (30)

[a]Irreversible pulpitis defined as acute pain, positive response to electrical pulp testing and cold test, sensitivity to percussion and radiographic evidence of a widened periodontal ligament space.

[b]Success defined as mandibular posterior teeth demonstrating no response to maximum electrical pulp testing output (80 readings) or no response to endodontic access 5 minutes after IANB in patients who received up to 3.6 mL of local anesthetic to achieve subjective lip numbness at baseline.

Table 3 **Reasons for failure of conventional local anesthetic techniques**

Armamentarium-related factors	
Deflection of needle tip	
	Inappropriate bevel direction
	Incorrect needle gauge
Patient-related factors	
Anatomical	
	Accessory innervation (e.g., mylohyoid nerve)
	Barriers to diffusion (e.g., zygomatic buttress)
	Cross-innervation
	Intravascular injection
	Variation in location of soft- and hard-tissue landmarks relative to mandibular canal
	Unpredictable spread of local anesthetic solution
Pathological	
	Local infection
	Trismus
	Pulpal inflammation
Psychological	
Operator-related factors	
Inexperience	
	Poor technique

Table 4 Comparison of various systems for adjunctive local anesthesia

Type of system	System components	Method	Comments
Hypo intraosseous injection system (**Fig. 1**)	32-mm 30-gauge needle compatible with standard breech-loading syringes; distal 6 mm of needle reinforced with retractable stainless steel sheath (to prevent needle deformation during penetration)	Needle is driven with manual pressure through interproximal interseptal bone or maxillary periapical cortical bone; anesthetic solution is then injected	Obviates need to reintroduce needle after perforation Effectiveness reduced in some situations (e.g., mandibular molar region) because of difficulty in penetrating thicker cortical bone
Stabident intraosseous injection system (**Figs. 2a** to **2d**)	Single-use perforator (27-gauge, 0.43-mm diameter solid-core wire embedded into plastic sheath designed to engage standard latch angle) and injection needle (0.4-mm diameter hollow-bore bevelled or nonbevelled tipped instrument compatible with standard breech-loading syringes)	Most apical extent of attached gingival margins of adjacent teeth used as landmark for locating appropriate perforation point (cortical bone in mandibular molar region is thinnest within crestal third of alveolar process); after application of topical anesthetic and infiltration of local anesthetic into gingival mucosa, perforation is performed mesial or distal to tooth; after removal of perforator, injection needle is introduced to deliver local anesthetic into periradicular medullary bone	
X-Tip intraosseous injection system (**Figs. 3a** and **3b**)	Perforator assembly (solid-core needle with overlying guide sleeve and handle consisting of a stainless steel sheath and plastic hub) and 27-gauge 0.4-mm diameter ultrashort injection needle	Guide sleeve and handle are positioned over perforator needle, which is used to pierce cortical bone, a process that simultaneously introduces the guide sleeve and detachable handle; perforator needle is retracted, and guide sleeve and handle are left in place to facilitate reintroduction of injector needle	Guide sleeve and handle marketed as a means to facilitate reintroduction of injector needle as well as to perform supplemental injections, if required
Wand anesthetic delivery system (**Fig. 4**)	Computer-controlled system consisting of pump unit, foot pedal, transfuser tubing, handpiece assembly, luer-lock needles and standard anesthetic cartridges	Topical anesthetic is applied, flow is initiated at slow rate, and needle is advanced slowly	Unit may be used for infiltration or nerve block anesthesia May be particularly suited for injection into PDL[14]
N-Tralig PDL injection system (**Fig. 5**)	Hand-held injector gun	Needle is inserted at a 30° angle from the long axis of the tooth and directed into proximal gingival sulcus to point of maximum penetration; needle tip is thus wedged between crestal bone and root surface in faciolingual midline[15]; 0.2 mL of anesthetic is injected under definitive, sustained back pressure; if back pressure is not attained initially, repositioning or insertion at a more apical location is suggested[15]	Bevel always directed away from root surface Finger or hemostat may be used to stabilize needle on insertion[15] Injection under marked back pressure is associated with significantly better anesthetic success than injection without such pressure
Siryjet Mark II jet-injection system (**Figs. 6a** to **6c**)	Siryjet syringe, standard dental anesthetic cartridge and plunger rod	Syringe is loaded with anesthetic cartridge, and plunger rod is inserted; rubber nozzle hood is positioned, and syringe is cocked; volume of anesthetic to be dispensed is selected (0.05, 0.10, 0.15, or 0.20 mL); oral tissues are dried, and nozzle is rested gently against attached gingiva (at right angles); release of trigger delivers anesthetic; precise volume can be delivered rapidly under controlled pressure through nozzle penetrating the mucosa or skin (but not hard tissues) to a depth of 1.0-1.5 cm[16]	To avoid alarming patient, practitioner must discuss procedure with patient in advance, as there is a noticeable popping sound and brief mechanical pressure on activation of the system Small residual hematoma and erythema of palatal tissues follows application of jet injection

PDL = periodontal ligament.

Table 5 **Success rates for conventional inferior alveolar nerve block with supplemental intraosseous injection**

Author	Drugs used	Total no. of patients	No. of patients with successful anesthesia[a] (% success)
Dunbar and others[2]	2% lidocaine, 1:100,000 epinephrine	40	36 (90)
Reitz and others[4]	0.9 mL 2% lidocaine, 1:100,000 epinephrine	38	36 (95)
Gallatin and others[5]	3% mepivacaine plain	48	48 (100)
Reitz and others[17]	0.9 mL 2% lidocaine, 1:100,000 epinephrine	36	34 (94)
Guglielmo and others[6]	2% lidocaine, 1:100,000 epinephrine	40	40 (100)
Guglielmo and others[6]	2% mepivacaine, 1:20,000 levonordefrin	40	40 (100)
Total		242	234 (97)

[a]*Success defined as mandibular first molars demonstrating no response to maximum electrical pulp testing output (80 readings) on 2 consecutive tests. Patients received up to 3.6 mL of local anesthetic to achieve subjective lip numbness at baseline 2 minutes before the tests.*

Table 6 **Success rates for conventional inferior alveolar nerve block with supplemental intraosseous injection in irreversible pulpitis[a]**

Author	Drugs used	Total no. of patients	No. of patients with successful anesthesia[b] (% success)
Reisman and others[8]	3% mepivacaine plain	44	35 (80)
Nusstein and others[9]	2% lidocaine, 1:100,00 epinephrine	21	19 (90)
Total		65	54 (83)

[a]Irreversible pulpitis defined as acute pain, positive response to electrical pulp testing and cold test, sensitivity to percussion and radiographic evidence of a widened periodontal ligament space.

[b]Success defined as mandibular posterior teeth demonstrating no response to maximum electrical pulp testing output (80 readings) or no response to endodontic access 5 minutes after IANB and intraosseous injection. All patients received up to 3.6 mL of local anesthetic to achieve subjective lip numbness at baseline.