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 anesthetic2-7 (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 region12 and accessory innervation in the mandibular posterior region (by the
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.
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 (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 (Table 5) and to 83% in first molars with pulpitis (Table 6). However, anesthesia declined to as low as 76% after one hour.

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

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...
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. Mean increases were approximately 24 beats/minute, and heart rate returned to baseline within 4 minutes in over 85% of subjects. Increases in heart rate are of little clinical significance in healthy patients 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. 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%) and infection at the site of perforation (3%).

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

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\(^2^1\) 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.\(^2^2\) Therefore, what is termed PDL injection should be considered a form of IO injection.

The technique involves use of a 25- or 27-gauge short needle or a 30-gauge ultrashort needle.\(^1^5\) 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).\(^1^5\)

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).\(^2^3,2^4\) 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).\(^2^3\) For a primary PDL injection, the success rate at 2 minutes was 79% in mandibular and 75% in maxillary first molars.\(^2^3\) However, the success rate at 2 minutes was only 18% in mandibular and 39% in maxillary lateral incisors.\(^2^3\) In addition, success rates declined with use of plain solutions.\(^2^4\)

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.\(^2^3\) It is not clear whether use of 0.5% bupivacaine significantly prolongs the duration of anesthesia with primary PDL injection.\(^2^5\)

Without topical anesthetic, insertion of the needle itself is rated as mildly to moderately painful and generally contributes to most of the perceived discomfort.\(^2^3\) Needle insertion is more painful in PDL injection for anesthesia of the maxillary lateral incisor than for other teeth.\(^2^3\)

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.\(^2^6\)

**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.\(^2^7\) 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).\(^2^7\)

Postoperative sequelae are common but self-limiting.\(^2^3,2^4\) Pain of mild or moderate severity was reported by 83% of patients after 24 hours.\(^2^3\) Hyperocclusion was reported by 36% of patients after 24 hours and by 7% after 3 days.\(^2^3\) Swollen interdental papillae were reported by 13% of patients.\(^2^3\)

Damage to the crestal bone and cementum from needle trauma is possible, but is minor and reversible.\(^2^8\) Epithelial and connective tissue attachment to enamel are not disturbed by needle puncture.\(^2^9\) Injection of the solution is not damaging. Pulpal changes after PDL injections are mild and reversible.\(^3^0\)

**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.\(^3^1\)

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%)\(^3^2\) and pediatric (75%) populations.\(^3^3\) 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."\(^3^4\) The success rate for pulpal anesthesia of permanent maxillary lateral incisors was poor (13%), as assessed by pulp
tests; however, Saravia and Bush 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. 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. 

Références

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

<table>
<thead>
<tr>
<th>Authors</th>
<th>Drugs used</th>
<th>Total no. of patients</th>
<th>No. of patients with successful anesthesia&lt;sup&gt;a&lt;/sup&gt; (%) success</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dunbar and others&lt;sup&gt;2&lt;/sup&gt;</td>
<td>2% lidocaine, 1:100,000 epinephrine</td>
<td>40</td>
<td>17 (43)</td>
</tr>
<tr>
<td>Clark and others&lt;sup&gt;3&lt;/sup&gt;</td>
<td>2% lidocaine, 1:100,000 epinephrine</td>
<td>30</td>
<td>22 (73)</td>
</tr>
<tr>
<td>Reitz and others&lt;sup&gt;4&lt;/sup&gt;</td>
<td>2% lidocaine, 1:100,000 epinephrine</td>
<td>38</td>
<td>27 (71)</td>
</tr>
<tr>
<td>Gallatin and others&lt;sup&gt;5&lt;/sup&gt;</td>
<td>3% mepivacaine plain</td>
<td>48</td>
<td>39 (81)</td>
</tr>
<tr>
<td>Guglielmo and others&lt;sup&gt;6&lt;/sup&gt;</td>
<td>2% mepivacaine, 1:20,000 levonordefrin</td>
<td>40</td>
<td>32 (80)</td>
</tr>
<tr>
<td>Childers and others&lt;sup&gt;7&lt;/sup&gt;</td>
<td>2% lidocaine, 1:100,000 epinephrine</td>
<td>40</td>
<td>25 (63)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>236</td>
<td>162 (69)</td>
</tr>
</tbody>
</table>

<sup>a</sup>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

<table>
<thead>
<tr>
<th>Author</th>
<th>Drugs used</th>
<th>Total no. of patients</th>
<th>No. of patients with successful anesthesia (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reisman and others</td>
<td>3% mepivacaine plain</td>
<td>44</td>
<td>11 (25)</td>
</tr>
<tr>
<td>Nusstein and others</td>
<td>2% lidocaine, 1:100,000 epinephrine</td>
<td>26</td>
<td>10 (38)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>70</strong></td>
<td><strong>21 (30)</strong></td>
</tr>
</tbody>
</table>

*aIrreversible 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.

*bSuccess 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

<table>
<thead>
<tr>
<th>Category</th>
<th>Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Armamentarium-related factors</td>
<td>Deflection of needle tip, Inappropriate bevel direction, Incorrect needle gauge</td>
</tr>
<tr>
<td>Patient-related factors</td>
<td>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</td>
</tr>
<tr>
<td>Operator-related factors</td>
<td>Inexperience, Poor technique</td>
</tr>
<tr>
<td>Type of system</td>
<td>System components</td>
</tr>
<tr>
<td>---------------</td>
<td>-------------------</td>
</tr>
<tr>
<td>Hypo intraosseous injection system (Fig. 1)</td>
<td>32-mm 30-gauge needle compatible with standard breach-loading syringes; distal 6 mm of needle reinforced with retractable stainless steel sheath (to prevent needle deformation during penetration)</td>
</tr>
<tr>
<td>Stabident intraosseous injection system (Figs. 2a to 2d)</td>
<td>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 breach-loading syringes)</td>
</tr>
<tr>
<td>X-Tip intraosseous injection system (Figs. 3a and 3b)</td>
<td>Perforator assembly</td>
</tr>
<tr>
<td>Wand anesthetic delivery system (Fig. 4)</td>
<td>Computer-controlled system consisting of pump unit, foot pedal, transfuser tubing, handpiece assembly, luer-lock needles and standard anesthetic cartridges</td>
</tr>
<tr>
<td>N-Tralig PDL injection system (Fig. 5)</td>
<td>Hand-held injector gun</td>
</tr>
<tr>
<td>Sirjet Mark II jet-injection system (Figs. 6a to 6c)</td>
<td>Sirjet syringe, standard dental anesthetic cartridge and plunger rod</td>
</tr>
</tbody>
</table>

PDL = periodontal ligament.
**Table 5  Success rates for conventional inferior alveolar nerve block with supplemental intraosseous injection**

<table>
<thead>
<tr>
<th>Author</th>
<th>Drugs used</th>
<th>Total no. of patients</th>
<th>No. of patients with successful anesthesia* (% success)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dunbar and others²</td>
<td>2% lidocaine, 1:100,000 epinephrine</td>
<td>40</td>
<td>36 (90)</td>
</tr>
<tr>
<td>Reitz and others⁴</td>
<td>0.9 mL 2% lidocaine, 1:100,000 epinephrine</td>
<td>38</td>
<td>36 (95)</td>
</tr>
<tr>
<td>Gallatin and others⁵</td>
<td>3% mepivacaine plain</td>
<td>48</td>
<td>48 (100)</td>
</tr>
<tr>
<td>Reitz and others¹⁷</td>
<td>0.9 mL 2% lidocaine, 1:100,000 epinephrine</td>
<td>36</td>
<td>34 (94)</td>
</tr>
<tr>
<td>Guglielmo and others⁶</td>
<td>2% lidocaine, 1:100,000 epinephrine</td>
<td>40</td>
<td>40 (100)</td>
</tr>
<tr>
<td>Guglielmo and others⁶</td>
<td>2% mepivacaine, 1:20,000 levonordefrin</td>
<td>40</td>
<td>40 (100)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>242</td>
<td>234 (97)</td>
</tr>
</tbody>
</table>

*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

<table>
<thead>
<tr>
<th>Author</th>
<th>Drugs used</th>
<th>Total no. of patients</th>
<th>No. of patients with successful anesthesia (% success)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reisman and others(^a)</td>
<td>3% mepivacaine plain</td>
<td>44</td>
<td>35 (80)</td>
</tr>
<tr>
<td>Nusstein and others(^b)</td>
<td>2% lidocaine, 1:100,00 epinephrine</td>
<td>21</td>
<td>19 (90)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>65</strong></td>
<td><strong>54 (83)</strong></td>
</tr>
</tbody>
</table>

\(^a\)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.