REVIEW
Supplementary routes to local anaesthesia

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Abstract

The satisfactory provision of many dental treatments, particularly endodontics, relies on achieving excellent pain control. Unfortunately, the administration of a local anaesthetic solution does not always produce satisfactory anaesthesia of the dental pulp. This may be distressing for both patient and operator. Fortunately, failure of local anaesthetic injections can be overcome. This is often achieved by using alternative routes of approach for subsequent injections. Nerves such as the inferior alveolar nerve can be anaesthetized by a variety of block methods. However, techniques of anaesthesia other than the standard infiltration and regional block injections may be employed successfully when these former methods have failed to produce adequate pain control. This paper describes some supplementary local anaesthetic techniques that may be used to achieve pulpal anaesthesia for endodontic procedures when conventional approaches have failed. Although some of these techniques can be used as the primary form of anaesthesia, these are normally employed as ‘back-up’. The methods described are intraligamentary (periodontal ligament) injections, intraosseous anaesthesia and the intrapulpal approach. The factors that influence the success of these methods and the advantages and disadvantages of each technique are discussed. The advent of new instrumentation, which permits the slow delivery of local anaesthetic solution has led to the development of novel methods of anaesthesia in dentistry. These new approaches are discussed.

Keywords: dental local anaesthesia, intraligamentary anaesthesia, intraosseous anaesthesia, intrapulpal anaesthesia

Routes for local anaesthesia
Successful local anaesthesia is the basis for many aspects of dental treatment. One of the problems with local anaesthesia is that it is not 100% successful at the first attempt. Kaufman et al. (1984) reported that 13% of general practitioners experienced failure of local anaesthesia in a 5-day period resulting in up to 10% of treatments having to be abandoned. The most common failures were inferior alveolar nerve blocks. Similar findings amongst dental students have been reported (Milgrom et al. 1984). Unsuccessful local anaesthesia is perhaps most apparent in the management of endodontically involved teeth (Cohen et al. 1993). Fortunately, when local anaesthesia fails, this can be managed effectively in most cases. This may involve modification of conventional techniques to overcome anatomical problems such as variations in the location of the mandibular foramen (Afsar et al. 1998); for example, the use of ‘high’ blocks such as the Gow-Gates (1973) or Akinosi (1977) techniques (Fig. 1). These latter methods also help to counter any accessory nerve supply from sources such as the mylohyoid nerve which may not be anaesthetized by standard approaches (Wilson et al. 1984, Heasman & Beynon 1986). However, there are other methods which are also useful in overcoming failure in both jaws. This paper describes supplementary intraoral techniques available for administering local anaesthetics to provide pulpal anaesthesia when conventional infiltration and regional block methods prove unsatisfactory.
Intraligamentary (periodontal ligament) anaesthesia

Intraligamentary anaesthesia or periodontal ligament anaesthesia are, in a sense, misnomers. Solution injected via the periodontal ligament reaches the pulpal nerve supply by entering the cancellous bone through natural perforations in the socket wall, not by travelling down the length of the ligament (Fig. 2). Thus, this method is a form of intraosseous anaesthesia. However, the term intraosseous anaesthesia refers to a specific method that is described below.

Technique

Prior to the injection, it is recommended that the site of penetration is swabbed with an antiseptic solution. The injection can be performed using either conventional or specialized syringes. The choice of syringe does not affect efficacy (Malamed 1982, Smith et al. 1983).

The needle is inserted at $30^\circ$ to the long axis of the tooth at the mesio-buccal aspect of the root(s). The needle is forced to maximum penetration until it is wedged between the tooth and the crestal bone, advancement...
deep into the periodontal ligament is usually not possible (Dreyer et al. 1983). Success is independent of needle gauge (Walton & Abbott 1981, Malamed 1982, Smith et al. 1983). Some authors recommend that the needle bevel should face the alveolar wall (Status Report 1983) as this reduces the chances of blockage and increases the efficacy of the injection (Kim 1986). On the other hand, Malamed (1997) claims that the orientation of the needle is unrelated to the success of the technique and advocates that the bevel should face the root as this allows easier advancement of the needle. Yet another recommendation is to advance with the bevel facing the root, and then rotate the needle, so that the bevel is facing the bone during the injection (Sykes 1991). Once the needle is correctly positioned, the solution is injected under back-pressure. The amount of solution injected into the periodontal ligament is little. It is recommended that 0.2 mL solution is deposited into the periodontium of each root (Malamed 1997), however, this is simply a recommendation and whether or not this is the optimum volume has not been evaluated. When using the specialized syringes, it is important to maintain the needle in position for about 5–10 s following depression of the lever to allow escape of solution from the cartridge (Roberts & Rosenbaum 1991). Removing the needle from the periodontal ligament too soon will result in loss of solution from the cartridge into the mouth. Walton & Abbott (1981) demonstrated that the most critical factor governing success of the technique is that the injection is performed against resistance. Rapid onset of anaesthesia is a striking feature of intraligamentary anaesthesia. Anaesthesia is achieved within 30 s and can be immediate (Walton & Abbott 1981, Khedari 1982, Kaufman et al. 1983, Status Report 1983).

### Duration of intraligamentary anaesthesia

The duration of intraligamentary anaesthesia is variable. Kaufman et al. (1984) noted the differences in duration between individuals was marked (for example, with lidocaine and 1:50 000 adrenaline pulpal anaesthesia ranged from 0 to 67 min). Cowan (1986) estimated the duration of pulpal anaesthesia to be around 15 min for single-rooted teeth and rather less for lower molars. Kaufman et al. (1983) reported that the duration of anaesthesia following intraligamental injections was sufficient for cavity preparation, pulpectomy and extractions but some advanced restorative procedures required a second injection after 10–15 min.

### Spread of intraligamentary anaesthesia

Intraligamentary anaesthesia is not a single tooth anaesthetic (Kim 1986). Smith & Walton (1983) have shown that in dogs, solutions injected into the periodontal ligament of one tooth reach the periapical region and pulps of adjacent teeth. D’Souza et al. (1987) found that the spread of anaesthesia to adjacent teeth in humans occurred with both specialized and conventional syringes but that it happened more frequently with the former type. Schleder et al. (1988) reported that spread to adjacent teeth was dependent upon the solution injected, 2% lidocaine with 1:100 000 adrenaline anaesthetizing a greater number of adjacent teeth than plain mepivacaine and lidocaine solutions, a finding confirmed by White et al. (1988).

### Factors influencing efficacy

Efficacy, spread and duration of anaesthesia are dependent upon the following factors:

#### The anaesthetic solution

The presence of a vasoconstrictor significantly increases efficacy. Gray et al. (1987) reported that lidocaine with adrenaline was effective in 91.6% of periodontal ligament injections whereas without the vasoconstrictor the success rate was only 42%. Meechan (1989) reported 55% success when plain 2% lidocaine was used whereas 2% lidocaine with 1:80 000 adrenaline was successful in 82% of extractions. Kim (1986) noted the concentration of adrenaline employed also affected the efficacy of 2% lidocaine during intraligamentary anaesthesia, recording 81% success when the vasoconstrictor was present as a 1:100 000 solution compared to 88% success with a 1:50 000 concentration. Kaufman et al. (1984) claim that the duration of anaesthesia varies with the type of solution used, pulpal anaesthesia ranging from a mean of 1.05 min with 2% lidocaine to 27.05 min when 2% lidocaine containing 1:50 000 adrenaline was employed. Studies comparing the efficacy of long-acting local anaesthetic agents such as etidocaine (Johnson et al. 1985), mepivacaine (Schleder et al. 1988) and bupivacaine (Kaufman et al. 1984) to lidocaine for intraligamentary anaesthesia have concluded that success is more related to the concentration of vasoconstrictors employed than to the anaesthetic agent used. Schleder et al. (1988) found 3% mepivacaine more effective than 2% lidocaine (41.9 and 13.8% success, respectively) when injected into the periodontal ligament of human mandibular premolars, however, both solutions were
significantly less effective than 2% lidocaine with 1:100 000 adrenaline (86.7% success). Kaufman et al. (1994) noted no difference in success between different concentrations of lidocaine but confirmed the importance of adrenaline in relation to efficacy. The injection of 1:100 000 adrenaline alone into the periodontal ligament does not produce dental anaesthesia (Schleder et al. 1988).

The operative procedure The greatest success is achieved prior to exodontia and the least for endodontic procedures (Malamed 1982, Kaufman et al. 1983, Miller 1983). Malamed (1982) reported a 60% success rate prior to endodontics compared to 100% when the technique was employed before extractions; in the study of Miller (1983), the equivalent success rates were 72 and 98.4%, respectively.

The type of tooth Cowan (1986) found significant differences in the efficacy of intraligamentary anaesthesia between the jaws, recording 55% success in the mandible and 83.3% in the maxilla. On the other hand, White et al. (1988) reported no difference in the incidence of pulpal anaesthesia between maxillary and mandibular teeth.

Kaufman et al. (1983) reported the technique to be successful in anaesthetizing canines in 46% of cases compared to at least 85% success for other teeth. Similarly, Meechan (1989) claimed the poorest success with canines (78%) when intraligamental injections were used prior to dental extractions, incisors (94%) being the easiest to successfully anaesthetize. Grundy (1984) found significantly poorer success with lower third molars compared to lower first molars. White et al. (1988) reported least success for pulpal anaesthesia with mandibular lateral incisors (18.2% success). The low success rate for pulpal anaesthesia with lateral incisors may be owing to the paucity of perforations within the mandibular incisor sockets and the limited cancellous space in this region making it difficult for the anaesthetic solution to enter intraosseously (White et al. 1988). Davidson & Craig (1987) noted that, in children receiving intraligamental anaesthesia for restorative procedures, the efficacy was significantly greater for those teeth with both mesial and distal contact points.

Advantages of intraligamental anaesthesia
1 Smaller doses are required compared to conventional infiltration and block anaesthesia. As mentioned earlier the normal dose is 0.2 mL per root. It has been suggested that the use of computerized delivery systems will allow the administration of a greater dose per root (Williams 2001).
2 This method overcomes failed conventional anaesthesia. Walton & Abbott (1981) looked at a series of 120 failed conventional local anaesthetic injections for conservative and endodontic procedures. They found that after one periodontal ligament injection 63% of the teeth were successfully anaesthetized and a second intraligamental injection was effective in 71% of the rest. In other words, a success rate of 92% in teeth in which conventional anaesthetic methods failed. In a similar study, Smith et al. (1983) reported an overall success of 93% for periodontal ligament injections in patients in whom conventional techniques had failed.
3 There is limited soft tissue anaesthesia. The elimination of unwanted soft tissue anaesthesia can be of considerable benefit, particularly in the mandible. Apart from the obvious advantages in relation to four-quadrant dentistry, this can be especially useful for procedures in permanent teeth in children by eliminating the self-inflicted trauma to the lower lip which can occur after mandibular block anaesthesia (Bedi et al. 1984). Loss of soft tissue anaesthesia, however, is not absolute. Matthews & Stables (1985) recorded that 27% of patients reported lower lip anaesthesia after periodontal ligament injections to mandibular molars. Similarly, intraligamentary injections for lower premolars can produce a mental anaesthesia (Kaufman et al. 1983).
4 This technique can be used for mandibular anaesthesia in patients with bleeding diatheses. Intraligamentary anaesthesia injections have been shown to be effective when used for restorative procedures in haemophiliac patients. In studies reported by Ah Pin (1987) and Spuller (1988), no complications related to haemorrhage or haematoma formation were recorded in haemophiliac patients who had received periodontal ligament injections for restorative dentistry without administration of Factor VIII.

Disadvantages of intraligamental anaesthesia
1 Intraligamental injections produce a bacteraemia. Roberts et al. (1997) reported that a significant bacteraemia occurred following over 95% of intraligamental injections in children. Thus the injection represents a potential cause of endocarditis in ‘at-risk’ groups.
2 There is rapid entry of local anaesthetic and vasoconstrictor into circulation. Although direct entry of the needle into the lumen of a blood vessel is unlikely; using the periodontal ligament technique, the solution does reach the vasculature via the socket walls (Smith & Walton...
of cementoblasts, osteoblasts and osteocytes and there were areas of necrosis. One week following the injection-damaged tissue was being replaced by a cell-rich vascular granulation tissue and osteoclastic activity was apparent. At 2 weeks, the appearance was returning to normal with new bone and young collagen and cementoblasts at the sites of root repair. One area of possible irreversible damage was noted, this being the interdental septal crest when periodontal ligament injections were administered to adjacent teeth. In such cases, sloughing of the interdental papilla occurred and the crestal bone became necrotic. Walton & Garnick (1982), using a similar model, also reported some bone resorption in the crestal region. On the other hand, Galili et al. (1984) noted no damage to bone or cementum in monkeys who had received intraligamentary injections. These workers found that the damage produced was localized, minor and reversible. They found no damage apical to the needle penetration site and in most cases all signs of damage had gone by 8 days. Similarly, Walton & Garnick (1982) noted no damage apical to the needle insertion point. Fuhs et al. (1983) could find no evidence of damage to the periodontium in dogs sacrificed within 28 days of intraligamentary anaesthesia. Pertot & Dejou (1992) noted osteoclastic activity and bone resorption in dogs 7 days after intraligamental injections. This had healed by 25 days. These authors correlated the degree of resorption with the force of injection. List et al. (1988) measured the gingival crevicular fluid flow before and following intraligamentary injections in volunteers. They concluded that the amount of inflammation was minimal.

Roahen & Marshall (1990) demonstrated external root resorption in dogs following intraligamentary injections. Saroff et al. (1986) reported a case of external root resorption in a lower left second permanent molar in a 40-year-old patient which arose following the administration of a periodontal ligament injection. Lovsund-Johannesson et al. (1986) reported reversible root-surface changes in children's teeth subject to intraligamentary anaesthesia. These authors concluded that the technique was safe in children.

5 Intraligamentary anaesthesia may damage pulp. Kim (1986) reported a dramatic reduction in pulpal blood flow when vasoconstrictor-containing solutions were administered via the periodontal ligament in dogs. However, histological studies (also in dogs) performed by Plamondon et al. (1990) and Roahen & Marshall (1990) revealed no long-term deterioration in the pulp following periodontal ligament injections. Similarly, Lin et al. (1985) reported no histological changes in the
pulp of cat teeth subjected to intraligamental injections of 2% lignocaine with 1 : 50 000 and 1 : 100 000 adrenaline and Peurach (1985) found no deterioration in pulpal tissue after intraligamental injections in the monkey model. Plamondon et al. (1990) investigated the additive effects of cavity preparation and intraligamental injections of lignocaine with adrenaline and found no more serious reaction in teeth treated this way compared to those subjected to cavity preparation alone. Torabinejad et al. (1993) in an electron microscopy study, noted no deleterious effects in pulpal tissue of human teeth subjected to intraligamentary injections of 2% lidocaine with 1 : 100 000 adrenaline.

Intraosseous anaesthesia may damage unerupted teeth. The pressure used during periodontal ligament injections can force the anaesthetic solution into underlying tooth germs (Brannstrom et al. 1982). Brannstrom et al. (1984) investigated this possibility in monkeys. Permanent teeth whose deciduous predecessors had received intraligamentary injections exhibited defects in enamel. In addition, in both treatment groups, other permanent teeth in the same quadrants as the treated teeth (but not in control un.injected quadrants) showed areas of enamel hypomineralization. However, such effects have never been reported in humans.

Injection equipment may be damaged. Local anaesthetic cartridge fracture has been reported by a number of authors (Malamed 1982, Miller 1983, Status Report 1983). This occurs because the specialized syringes allow the application of more force during intraligamentary injections than traditional equipment. Pressures of around 5 MPa can be produced within the cartridge during intraligamentatory anaesthesia (Walmsley et al. 1989). This will fracture around 1% of glass cartridges but will cause about 75% of plastic cartridges to fail at room temperature (Meechan et al. 1990). Plastic cartridges stored at body temperature will be more susceptible to failure (Meechan et al. 1995). The solution to the problem is to avoid the use of plastic cartridges and to inject slowly. Grundy (1984) recommends the rate employed should be at least 20 s for each 0.2 mL injected.

Intraosseous anaesthesia

The use of intraosseous anaesthesia was described by Lilienthal in (1975) and this author notes the reluctance at that time of operators to use the method. Since that time, specialized delivery systems have been introduced and this may increase the acceptance of the technique (Leonard 1995).

Technique

The method is as follows: the point of perforation is infiltrated with 0.2 mL local anaesthetic and 50–60 s allowed to pass to ensure gingival anaesthesia (Leonard 1995). This point should lie in attached gingiva and is determined by imagining two lines running at right angles to one another. The horizontal line runs along the buccal gingival margins of the teeth and the vertical line bisects the distal interdental papilla of the tooth of interest. The point of penetration is 2 mm apical to the intersection of these lines. If this point lies within the reflected mucosa, an area of attached gingiva coronal to this is chosen. While using the specialized equipment, the perforator (attached to a slow-speed handpiece) is advanced through the anaesthetized gingiva and bone until a characteristic ‘give’ indicating penetration through to the cancellous bone is experienced (Fig. 3). At this stage, the perforator is removed, the short (8 mm) 27 gauge needle is inserted through the perforation into the cancellous space and around 1.0 mL solution is delivered slowly (over a 2-min period). The technique anaesthetizes the tooth of interest and will also anaesthetize the teeth mesial and distal to that tooth in the majority of cases (Repogle et al. 1997). Problems may arise if the needle is too large for the perforation as variations in diameter have been noted (Leonard 1995). Similarly, if the approach is made through reflected rather than attached gingiva the perforation in the alveolus may be difficult to locate (Parente et al. 1998). Limitations to the technique include active periodontal disease, limited attached gingiva and little interradicular bone (Parente et al. 1998).

Duration of anaesthesia

The onset of intraosseous anaesthesia is rapid (Cogginset al. 1996, Repogle et al. 1997). Leonard (1995) noted that the onset of anaesthesia ranged from 10 to 120 s. The success falls of rapidly over 1 h. Repogle et al. (1997) reported that 30 min after injection pulpal anaesthesia was present in 52% of subjects who had received 2% lidocaine with 1 : 100 000 adrenaline as intraosseous anaesthesia for mandibular first molars. Cogginset al. (1996) reported that the decline in anaesthesia is more rapid with anterior teeth.

Factors governing success

1 Anaesthetic solution. As was the case with intraligamentary anaesthesia, the efficacy of intraosseous...
injections is poor in the absence of a vasoconstrictor. Repogle et al. (1997) reported less than 50% success in mandibular first molars when a plain 3% mepivacaine solution was injected compared to 74% success with lidocaine and adrenaline. In addition to increasing the success, the duration of anaesthesia was longer with the adrenaline-containing solution (Repogle et al. 1997).

2 Type of tooth. Again, as with intraligamentary injections, the efficacy of the intraosseous technique varies between teeth. Coggins et al. (1996) reported a 75% success rate with mandibular first molars compared to 93% success with maxillary first molars. These authors suggest that variations in success are owing to differences in the cancellous space between sites.

Advantages of intraosseous anaesthesia

1 Smaller doses are used than in conventional regional block anaesthesia.
2 The amount of soft tissue anaesthesia produced is less than that caused by infiltration and regional block methods (Leonard 1995).
3 The method can overcome failure after conventional techniques. When used in combination with inferior alveolar nerve blocks the method increases the success rate for pulpal anaesthesia (Dunbar et al. 1996). Similarly, supplemental anaesthesia via the intraosseous route has been shown to be effective in teeth with irreversible pulpitis where conventional methods have failed (Reisman et al. 1997, Nusstein et al. 1998, Parente et al. 1998). Reisman et al. (1997) showed that in pulptic teeth where an initial inferior alveolar nerve block was successful in only 25% of cases an intraosseous injection increased success to 80% and a subsequent intraosseous injection increased success to 98%.

Disadvantages of intraosseous anesthesia

1 The method is technically more difficult than infiltration anaesthesia.
2 Although not absolutely essential specialized equipment may be required.
3 There is rapid entry of local anaesthetic and vasoconstrictor into the circulation. Systemic effects attributable to catecholamine entry into the circulation occur early after intraosseous injection (Lilienthal & Reynolds 1975). Many subjects report an increase in heart rate during intraosseous anaesthesia with adrenaline-containing solutions (Coggins et al. 1996).
4 Post-injection discomfort may occur. Repogle et al. (1997) reported a 5% incidence of postoperative swelling and exudate after intraosseous injections. Coggins et al. (1996) noted 3% of patients had slow-healing perforation sites. Two patients required antibiotics. However, all subjects had returned to normal at 14 days.
5 The method may damage teeth. The perforators used to drill the hole in bone can penetrate teeth. However, there is a tactile change detectable and strong pressure has to be used for this to occur (Coggins et al. 1996).

Intrapulpal anaesthesia

Technique

This method relies on deposition of solution directly into the pulp chamber. It will normally be administered...
following the injection of an anaesthetic solution by another route. It is important that the solution is injected into the pulp under pressure. An opening into the pulp should be made with a small round bur to allow the snug fit of the needle. If a large opening is present in the pulp chamber, then the needle should be advanced into the canal until the fit is tight (Fig. 4). The important point is that the injection must be administered under pressure. The amount of solution injected is around 0.2 mL (Malamed 1998). A number of methods such as obliterating a large pulpal opening with gutta-percha (Birchfield & Rosenberg 1975) or a cotton pledget (VanGheluwe & Walton 1997) have been suggested to aid in the buildup of pressure. However, Smith & Smith (1983) claim the only way to ensure no back flow is to introduce the needle through a small pulpal opening.

It has been suggested that an alternative method of obtaining anaesthesia via the pulp is to allow local anaesthetic solution to bathe an exposed pulp for a period of 30 s (Malamed 1998). In addition, anecdotal accounts of the use of topical anaesthetics applied to the pulp have been reported (DeNunzio 1998). However, published studies (see below) indicate that the method described above is preferred.

Factors influencing efficacy

Although some authors claim that efficacy is dependent upon the anaesthetic solution (Gurney 1967, Malamed 1998) a recent double-blind study has shown that intrapulpal anaesthesia may be obtained just as effectively by injecting saline compared to a local anaesthetic solution (VanGheluwe & Walton 1997). These authors reported successful anaesthesia in 33 of 35 teeth injected intrapulpally with either 2% lidocaine with 1 : 100 000 adrenaline or saline. That study confirmed the results of Birchfield & Rosenberg (1975) who achieved similar success with saline or lidocaine with 1 : 50 000 adrenaline after intrapulpal injection. In the latter, failure was owing to leakage of solution and all the failed teeth were successfully anaesthetized when the leak was plugged with gutta percha and the pulps reinjected.

Advantages of intrapulpal anaesthesia

1 As mentioned above the method does not require a local anaesthetic.
2 The method provides a useful means of overcoming failure in teeth where conventional techniques have been unsuccessful. Birchfield & Rosenberg (1975) reported success in 53 out of 56 teeth which had failed anaesthesia after conventional approaches.
3 Although theoretically this technique uniquely could provide single-tooth anaesthesia, the fact that it is normally administered after failure of another method precludes this possibility in most cases.
The systemic effects of intrapulpal anaesthesia appear to be negligible. Pashley (1986) demonstrated in dogs that the injection of 0.3 mL local anaesthetics containing 1:100 000 adrenaline produced no cardiovascular response unlike the events after an injection of the same amount via the periodontal ligament (see above).

Disadvantages of intrapulpal anaesthesia

1. The injection may be painful (Malamed 1998).
2. The technique has limited application as it involves pulpal exposure. Interestingly, however, one study on the use of intrapulpal anaesthesia for pulpotomy suggested that the injection did not affect healing of pulpotomized teeth, although no histological examination was performed (Teixeira et al. 1999).
3. This method is not indicated as a primary method of anaesthesia as it can be uncomfortable and is only employed after an initial anaesthetic failure.

Future prospects

The introduction of computerized local anaesthetic delivery systems (Fig. 5) has introduced novel techniques such as the palatal anterior superior alveolar nerve block and the anterior middle superior alveolar nerve block. These palatal approaches are possible as the slow injection of solution allowed by computerized systems permits greater volumes of solution to be injected without discomfort into the palate.

The palatal anterior superior alveolar nerve block is a means of anaesthetizing the upper anterior teeth (canine to canine and sometimes the premolars as well) by depositing solution deep in the incisive canal. (Friedman & Hochman 1998, Williams 2001). The method is reputed to provide pulpal anaesthesia of the maxillary anterior teeth bilaterally without loss of sensation labially (Friedman & Hochman 1999). After entry into the incisive foramen around 1.0 mL solution is deposited slowly as the needle advances deep into the canal.

The anterior middle superior alveolar nerve block is also claimed to provide pulpal anaesthesia without facial numbness. It is a palatal approach to both the anterior and middle superior alveolar nerves. The point of injection is midway between the gingival margin and the mid-line of the palate between the first and second premolars. Around 1.0 mL solution is deposited slowly at this site. It is claimed that this will produce anaesthesia of the teeth on that side from the central incisor to the second premolar. It has been suggested that excessive blanching of the tissues during injection with this method can lead to ulceration of the palatal mucosa (Friedman & Hochman 1998).

The palatal anterior superior alveolar nerve block and the anterior middle superior alveolar nerve block have not received thorough appraisal at this time, but the advent of computerized delivery systems may result in scientific evaluation of these potentially useful techniques.

Other routes to pulpal anaesthesia which have been investigated include the application of anaesthetics topically. The advent of more powerful topical anaesthetics including novel delivery systems such as incorporation into liposomes (Zed et al. 1996) and the use of iontophoresis (Won et al. 1995) may lead to advances in this area. Although limited degrees of success relating to pulpal anaesthesia after topical application has been reported (Vickers & Punnia Moorthy 1993), there is still scope for development in this area.

Nonpharmacological methods of anaesthesia such as transcutaneous electronic nerve stimulation (TENS)
have been used both as a means of reducing the discomfort of injections and as a method of achieving pulpal anaesthesia. Meechan et al. (1998) reported that the use of intraoral TENS decreased the discomfort of inferior alveolar nerve block injections compared to the use of topical anaesthetics and no pretreatment. Wilson et al. (1999) reported that TENS reduced the discomfort of maxillary infiltrations in young children receiving treatment under sedation. This method of anaesthesia can provide pain control for operative dentistry in some patients, however, success is poor for endodontic procedures (Clark et al. 1987). Quarnstrom (1992) has reviewed the history and use of electronic anaesthesia in dentistry.

Conclusion
This paper has described supplementary techniques available to provide pulpal anaesthesia. The methods described are useful when conventional techniques fail as all have been shown to increase the incidence of pulpal anaesthesia when used in combination with standard techniques. Knowledge of the various methods is useful as these techniques might be required to provide pain control for teeth that prove difficult to anaesthetize by the operator's normal route.

References


