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Anesthetic Efficacy of the Intraosseous Injection after an Inferior Alveolar Nerve Block

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The purpose of this study was to determine the contribution of the intraosseous (IO) injection to the inferior alveolar nerve (IAN) block in human first molars. Using a repeated-measures design, 40 subjects randomly received either a combination IAN block + IO injection (on the distal of the first molar) using 2% lidocaine with 1:100,000 epinephrine or an IAN block + mock IO injection (gingival penetration only) at two successive appointments. The first molar and adjacent teeth, and contralateral canine (± controls) were blindly tested with an Analytic Technology pulp tester at 2-min cycles for 60 min. An 80 reading was used as the criterion for pulpal anesthesia.

One hundred percent of the subjects had lip numbness with the IAN block. For the first molar, anesthetic success, defined as achieving an 80 reading within 15 min and keeping this reading for 60 min, was 42% with the IAN and 90% with the IAN + IO. Anesthetic failure defined as never achieving two 80 readings during the 60 min was 32% with the IAN and 0% with the IAN + IO. The onset of anesthesia was immediate with the IO injection. Eighty percent of the subjects sampled had a subjective increase in heart rate with the IO injection. The IO injection and postinjection questionnaire recorded low pain ratings.

The intraosseous (IO) injection allows placement of a local anesthetic directly into the cancellous bone adjacent to the tooth to be anesthetized. Methods of accessing the cancellous space have included drilling a hole through the cortical bone using a round bur, endodontic reamer, or Buetelrock drill (1–4). Currently, there is an IO system marketed under the trade name Stabident. This system is comprised of a slow-speed handpiece-driven perforator, a solid 27-gauge wire with a beveled end that when activated will drill a small hole through the cortical plate. The corresponding 27-gauge ultrashort injector needle is placed into the hole made by the perforator to deliver anesthetic solution to the cancellous bone.

The IO injection has been evaluated as a primary and supplemental injection in limited clinical studies. Lilienthal (3), using 1.8 ml of 2% lidocaine with 1:80,000 noradrenalin, achieved profound anesthesia of maxillary and mandibular teeth with the IO technique. Magnes (1), using 2% lidocaine with 1:100,000 epinephrine in mandibular anterior teeth, found the IO injection effective 95 to 99% of the time. Pearce (4) used the IO injection when the inferior alveolar nerve (IAN) block did not result in profound anesthesia in mandibular molars. Anesthesia was improved ~90% of the time.

Although the IO injection has been studied clinically, no experimental study has evaluated the IO injection combined with an IAN block using the Stabident system. The purpose of this study was to determine the anesthetic efficacy of an IO injection when added to an IAN block in mandibular first molars.

MATERIALS AND METHODS

Forty adult subjects, 26 males and 14 females ranging in age from 18 to 39 yr with an average age of 25 yr, participated in this study. The subjects were in good health and were not taking any medications that would alter pain perception. The study was approved by The Ohio State University Human Subjects Review Committee, and written informed consent was obtained from each subject.

An equal number of mandibular right and left sides were tested, with the first molar, second premolar, and second molar chosen as the test teeth. The contralateral canine was used as the unanesthetized control to ensure that the pulp tester was operating properly and the subject would respond during the experiment. Clinical examinations indicated that all teeth were free of caries, large restorations, and periodontal disease, and that none had a history of trauma or sensitivity.

Using a repeated-measures design, each subject randomly received either a combination IAN block + IO injection or a combination IAN block + mock IO injection (gingival penetration only) at two successive appointments spaced at least 1 wk apart. Each subject was randomly assigned to the combinations to determine the order in which the IO injections were administered.

At each appointment and before injection, the experimental teeth and control canine were tested three times with an Analytic Technology pulp tester (Analytic Technology Corp., Redmond, WA) to record base line vitality. Following isolation with cotton

rolls and drying with gauze, toothpaste was applied to the probe tip, which was placed midway between the gingival margin and the occlusal edge. The current increased from no output (0) to the maximum output of 80 in 25 s. The number at initial sensation was recorded. All pre- and postinjection tests were performed by trained personnel who were blinded to the IO injections administered.

The standard IAN block (5–7) was administered with a 27-gauge 1 ½-inch needle (Monoject; Sherwood Medical, St. Louis, MO) using 1.8 ml of 2% lidocaine with 1:100,000 epinephrine (Lidocaine, Graham Chemical Co., Jamaica, NY). After reaching the target area and performing aspiration, the solution was deposited over a period of 2 min.

The IO injection or mock injection was administered 5 min following completion of the IAN block, if subjective lip numbness was recorded by the subject. Each subject was asked, "Is your lip numb?" every min for 5 min. If lip numbness did not occur within 5 min, the subject was reappointed.

The IO injection was given using the Stabident system (Fairfax Dental, Inc., Miami, FL). With the subjects in a reclining position, the area of perforation was determined using the horizontal line of the buccal gingival margins of the first and second molars and a vertical line that passed through the interdental papilla on the distal of the first molar. A point ~2 mm below the intersection of these lines was selected as the perforation site if the site was in attached gingiva. If this point was in alveolar mucosa (two subjects), the injection site was moved just above the junction of the attached gingiva and alveolar mucosa. The soft tissue at the determined perforation site was anesthetized using an infiltration of ~0.1 ml of 2% lidocaine with 1:100,000 epinephrine deposited through a 30-gauge needle attached to a standard aspirating syringe. The cortical bone was immediately perforated using the Stabident perforator (a beveled-ended solid wire attached to a plastic hub) in a contra-angle, slow-speed handpiece. The perforator was placed through the gingiva at the infiltration site and was oriented perpendicular to the cortical plate. With the point gently resting against bone, the handpiece was activated in a series of short bursts, using light pressure, until a "break-through" feeling was observed or until 2 to 5 s had elapsed. Before inserting the 27-gauge, ultrashort Stabident needle through the perforation, the needle was bent at the hub to a 45-degree angle to allow for ease of insertion. The area of perforation was blotted with a sterile cotton roll to control hemorrhage and identify the perforation site (a small dot of hemorrhage on the blanched gingiva). Holding the standard syringe in a "pen-gripping" fashion, the needle was inserted into the perforation site and 1.8 ml of 2% lidocaine with 1:100,000 epinephrine was delivered over a 30-s time period. If back-pressure was encountered upon solution deposition (six subjects), the needle was rotated approximately a quarter turn and deposition was reattempted. If this was not successful, the needle was removed and checked for blockage. If not blocked, it was reinserted or the site was reperforated with a new perforator and the injection completed. The mock injection was given in a similar manner except only the attached gingiva was perforated. Before administration of the mock injection, the needle used to engage the cartridge was bent so it would not penetrate the rubber diaphragm. The length of time for the "perforation and solution deposition" was identical to the actual IO injection. In addition, each subject was instructed to close his/her eyes during all injections to help blind the techniques. With the last 20 subjects, the thumb of the free hand of the operator was used to retract the subjects' cheek, while the index and middle finger were used to palpate the carotid artery to determine subjectively an increase in heart rate during the injection.

The subjects were instructed to rate the pain of all IO injections. The rating scale was: 0, no pain; 1, mild pain (pain that is recognizable, but not discomforting); 2, moderate pain (pain that is discomforting, but bearable); and 3, severe pain (pain that causes considerable discomfort and is difficult to bear).

At 1 min after the IO injection, the first and second molars were pulp-tested. At 2 min, the second premolar and contralateral, control canine were tested. This cycle of testing was repeated every 2 min. The negative control canine was tested every third cycle with an inactive pulp tester to test the reliability of the subjects. All testing was stopped at 60-min postinjection.

No subject response to the maximum output (80 reading) of the pulp tester was used as the criterion for pulpal anesthesia. Anesthesia was considered successful when an 80 reading was obtained within 15 min, and this reading was sustained for the remainder of the 60-min test period. Anesthesia was considered a failure if the subject never achieved two consecutive 80 readings during the 60 min. Anesthesia was of slow onset if the subject achieved two consecutive 80 readings after 15 min. Anesthesia was of short duration if the subject achieved two consecutive 80 readings initially, lost the 80 reading, and never regained the 80 reading within the 60 min.

A postinjection questionnaire asked the subjects to rate the pain, and any side effects, in the area of the IAN block and area of the IO injection at the time initial numbness wore off, and in the morning for 3 days following the appointment.

Anesthetic success, failure, slow onset, short duration, and incidence of pulpal anesthesia were analyzed nonparametrically using McNemar tests (Bonferroni adjusted for pulpal incidence). Comparisons were considered significant at $p < 0.05$.

RESULTS

The discomfort ratings for the infiltration and IO injections are presented in Table 1.

One hundred percent of the subjects had subjective lip numbness. Anesthetic success, failure, slow onset, and short duration are presented in Table 2. For the first molar, success was 42% with the IAN and 90% with the IAN + IO; failure was 32% with the IAN and 0% with the IAN + IO; and slow onset was 18% with the IAN and 0% with the IAN + IO. The differences were significant ($p < 0.05$) between the two techniques. Short duration was 12% with the IAN and 10% for the IAN + IO, and the difference was not significantly different ($p > 0.05$).

The incidence of pulpal anesthesia at different time intervals after injection and significant differences of the two techniques are presented in Fig. 1 to 3. For the IAN + IO in the first molar, significant differences were shown for all postinjection times (Fig. 1). The highest incidences of pulpal anesthesia for the IAN block and the combination IAN + IO injection, respectively by tooth, were as follows: first molar, 60%, 100%; second molar, 68%, 98%; and second premolar, 65%, 93%.

The postinjection discomfort ratings for the IAN and IO injections are presented in Table 3. One incidence of an initial nonhealing perforation site was reported with the IO injection.

TABLE 1. Percentages and discomfort ratings of the infiltration and IO injections

Injection Phase	None	Mild	Moderate	Severe
Infiltration injection				
Needle insertion	54% (43/80)	45% (36/80)	1% (1/80)	0% (0/80)
Solution deposition	82% (66/80)	12% (10/80)	5% (4/80)	0% (0/80)
IO injection 40)				
Perforation				
Mock	100% (40/40)	0% (0/40)	0% (0/40)	0% (0/40)
IO	92% (37/40)	8% (3/40)	0% (0/40)	0% (0/40)
Needle insertion				
Mock	100% (40/40)	0% (0/40)	0% (0/40)	0% (0/40)
IO	92% (37/40)	8% (3/40)	0% (0/40)	0% (0/40)
Solution deposition				
Mock	100% (40/40)	0% (0/40)	0% (0/40)	0% (0/40)
IO	85% (34/40)	12% (5/40)	2% (1/40)	0% (0/40)

TABLE 2. Percentages and number of subjects who experienced anesthetic success, failure, slow onset, and anesthesia of short duration*

Tooth	IAN	IAN + IO	p
Anesthetic success			
First molar	42% (17/40)	90% (36/40)	0.000†
Second molar	45% (18/40)	88% (35/40)	0.000†
Second premolar	38% (15/40)	72% (29/40)	0.003†
Anesthetic failure			
First molar	32% (13/40)	0% (0/40)	0.002†
Second molar	28% (11/40)	2% (1/40)	0.002†
Second premolar	32% (13/40)	8% (3/40)	0.003†
Slow onset of anesthesia			
First molar	18% (7/40)	0% (0/40)	0.016†
Second molar	10% (4/40)	0% (0/40)	NS‡
Second premolar	22% (9/40)	0% (0/40)	0.004†
Anesthesia of short duration			
First molar	12% (5/40)	10% (4/40)	NS
Second molar	17% (7/40)	10% (4/40)	NS
Second premolar	12% (5/40)	20% (8/40)	NS

* Percentages may be greater than the total number of subjects, because slow onset and anesthesia of short duration may have occurred in the same subject.
† Significantly different when IAN was compared with IAN + IO ($p < 0.05$).
‡ NS, not significant.

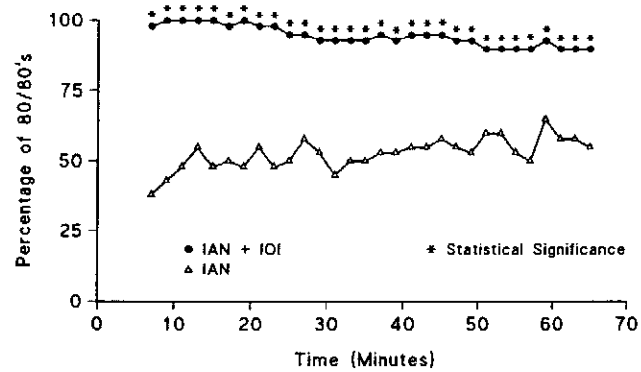

FIG 1. Incidence of first molar anesthesia as determined by lack of response to electrical pulp testing at the maximal setting (percentage of 80/80's) at each postinjection time interval, for the two injection techniques. Significant differences ($p < 0.05$) between IAN and IAN + IOI (intraosseous injection) are indicated by an *asterisk*.

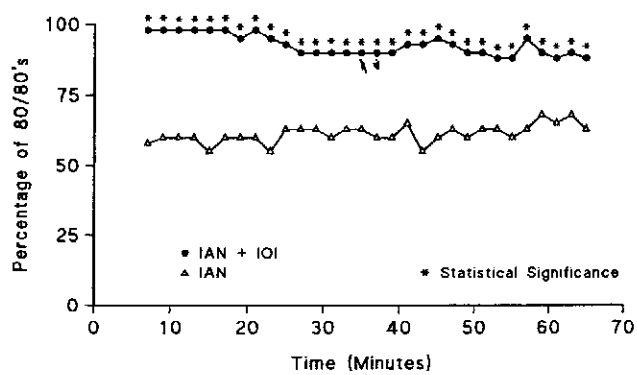

FIG 2. Incidence of second molar anesthesia as determined by lack of response to electrical pulp testing at the maximal setting (percentage of 80/80's) at each postinjection time interval, for the two injection techniques. Significant differences ($p < 0.05$) between IAN and IAN + IOI (intraosseous injection) are indicated by an *asterisk*.

DISCUSSION

The 100% incidence of lip numbness indicated that the IAN block alone was "clinically successful." Figures 1 to 3 demonstrate a lower incidence of pulpal anesthesia; therefore, lip numbness after an IAN block may not guarantee successful pulpal anesthesia as defined in this study.

Anesthetic success with the IAN block occurred in 42% of the first molars, 45% of the second molars, and 38% of second premolars (Table 2). The success rates are similar to the results of previous studies (5–7) using a similar methodology. Theories for inadequate anesthesia with the IAN block were discussed by Vreeland et al. (5).

Anesthetic success for the combination IAN + IO injection occurred in 90% of the first molars (Table 2). When compared with the IAN, the IAN + IO anesthetic success rate was statistically significant. The combination IAN + IO showed significant differences for the incidence of pulpal anesthesia at all postinjection times for the first molar (Fig. 1). Childers et al. (8) found that the duration of pulpal anesthesia was ~23 min when the periodontal ligament (PDL) injection was added to the IAN block. In terms of duration, our results would indicate that the IO injection is more successful than the PDL injection when used as a supplemental technique. Figure 1 and Table 2 (anesthesia of short duration) demonstrate that the duration of anesthesia decreased ~5% at 25

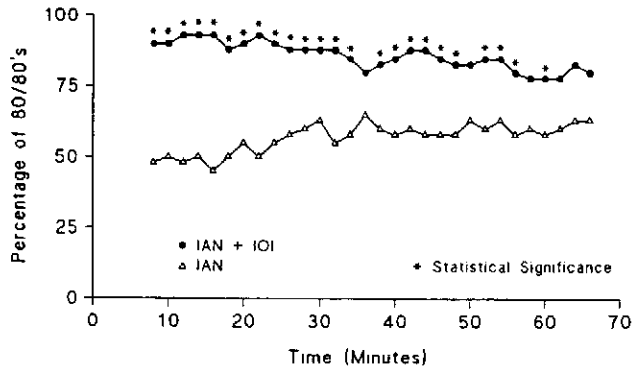

FIG 3. Incidence of second premolar anesthesia as determined by lack of response to electrical pulp testing at the maximal setting (percentage of 80/80's) at each postinjection time interval, for the two injection techniques. Significant differences ($p < 0.05$) between IAN and IAN + IOI (intraosseous injection) are indicated by an *asterisk*.

TABLE 3. Summary of pain ratings for postinjection survey with the IAN block and IO injections

Technique	Pain Ratings			
	None (0)	Mild (1)	Moderate (2)	Severe (3)
IAN block				
Day 0*	76% (61/80)	19% (15/80)	5% (4/80)	0% (0/80)
Day 1	88% (70/80)	11% (9/80)	1% (1/80)	0% (0/80)
Day 2	100% (80/80)	0% (0/80)	0% (0/80)	0% (0/80)
Day 3	100% (80/80)	0% (0/80)	0% (0/80)	0% (0/80)
IO injection				
Day 0*				
Mock	92% (37/40)	8% (3/40)	0% (0/40)	0% (0/40)
IOI†	78% (31/40)	20% (8/40)	2% (1/40)	0% (0/40)
Day 1				
Mock	95% (38/40)	5% (2/40)	0% (0/40)	0% (0/40)
IOI	85% (34/40)	15% (6/40)	0% (0/40)	0% (0/40)
Day 2				
Mock	100% (40/40)	0% (0/40)	0% (0/40)	0% (0/40)
IOI	93% (37/40)	8% (3/40)	0% (0/40)	0% (0/40)
Day 3				
Mock	100% (40/40)	0% (0/40)	0% (0/40)	0% (0/40)
IOI	98% (39/40)	2% (1/40)	0% (0/40)	0% (0/40)

* Rating at time subjective numbness wore off.
† IOI, intraosseous injection.

min to ~10% at 50 min through 65 min. It is unknown if additional solution delivered through the perforation site would increase the level of anesthesia after 25 min; nor is the duration of anesthesia past 65 min known. Since asymptomatic teeth were used in this study, it is not known if the results would be similar in teeth with irreversible pulpitis.

Local anesthetics such as 3% mepivacaine and 4% prilocaine that do not contain vasoconstrictors, or bupivacaine and etidocaine that have reduced vasoconstrictor concentrations, should be studied to determine if they could provide a similar level of anesthetic success to that found in this study. It is unlikely that the success rates would be as high based on the findings of Schleder et al. (9), Johnson et al. (10), Kaufman et al. (11), and Gray et al. (12) who used these type of solutions intraosseously via the PDL injection technique.

Anesthetic failure with the IAN block occurred in 32% of first molars, 28% of second molars, and 32% of second premolars (Table 2). The failure rates were similar to previous experimental studies (5–7). The failure rate with the combination IAN + IO injection was 0% for the first molar (Table 2). The difference between the two injection techniques was statistically significant. Childers et al. (8) reported a failure rate of 5% in the first molar when the PDL injection was combined with the IAN block. Both the IO and PDL injections, when combined with the IAN block, will decrease the number of anesthetic failures.

Slow onset of anesthesia with the IAN block occurred in 18% of first molars, 10% of second molars, and 22% of second premolars (Table 2). Again, the results were similar to previous studies (5, 7). When the IAN block was combined with the IO injection, the rate of slow onset was 0% for the first molar. As illustrated in Fig. 1, the addition of the IO injection provided almost a 100% incidence of anesthesia initially. This would indicate immediate onset.

Anesthesia of adjacent teeth showed significant differences between the IAN block and IAN + IO when success and failure were compared (Table 2). There were also significant differences in incidence of anesthesia when the combination IAN + IO injection was used (Figs. 2 and 3). In the second molar, all postinjection times showed significance. In the second premolar, significant differences were shown at most times up to 60 min (Fig. 3). Childers et al. (8) found the combination of the IAN block and PDL injection resulted in anesthesia of adjacent teeth but the success rates were lower than in this study. This is probably because of the increased volume of solution and/or the increased efficacy of the IO injection used in the current study. Clinically, the supplemental IO injection, with the volume used in this study, may be more successful than a PDL injection in anesthetizing adjacent teeth and would be important in restorative dentistry when multiple teeth are treated. However, as shown in Fig. 3, the incidence of anesthesia was lower in the second premolar than in the molars (Figs. 1 and 2). It may be that less anesthetic solution spread to the premolar. If profound anesthesia is needed for the premolar, the injection site could be moved to the distal of the premolar or between the premolars. Although the *Stabident Instruction Manual* recommends the IO injection not be performed between the mandibular premolars because of the mental foramen, a correctly placed injection would be clear of this structure.

The perforation site selection, as described in the *Stabident Instruction Manual*, allowed the perforation to be made through a minimal thickness of cortical bone and generally would be equidistant between adjacent root structures. Additionally, the site is in attached gingiva that is less mobile than alveolar mucosa allowing an easier location for needle insertion. In some cases, the width of the attached gingiva was not adequate, and the perforation site was moved just above the mucogingival line. Generally, the mean width of attached gingiva is 2.2 to 2.7 mm (13, 14) and allows site selection to be in attached gingiva. The lack of healthy tissue, inadequate spacing of adjacent teeth, and periodontal pocketing would indicate that the injection be moved from the suggested site or possibly contraindicated all together.

During perforation, the "breakthrough" represents the point at which the perforator enters cancellous bone, and although present with most of the perforations, "breakthrough" was not always observed. If this feeling is not noticed and the perforator meets significant resistance, it may be that it is hitting the root of an adjacent tooth. The perforator should be moved to another site. In a pilot study, with fresh pig mandibles, it was found that the perforator would drill into teeth, but only when extreme pressure was applied by the operator. The tactile difference between bone

and tooth was easily detected. The "break-through" feeling is also related to the thickness of buccal cortical bone and gingiva. Denio et al. (15) reported the mean width of cortical bone in the mandibular molars to be from 2.7 to 3.0 mm. The mean thickness of attached gingiva has been reported to be 1.25 mm by Goaslind et al. (16). This data would indicate the thickness of cortical bone and attached gingiva would be between 3.95 and 4.25 mm. In measuring 100 perforators, the mean length was 8.4 mm, with a range of 8 to 9 mm. Therefore, the length of the perforator should be adequate to gain entrance into most cancellous bone. The observation of no feeling of "breakthrough" in some cases may be related to dense cortical bone or not placing the perforator perpendicular to the bone resulting in drilling through an additional thickness of cortical bone.

It has been reported that only light pressure is needed to inject solution into cancellous bone with the IO technique (1, 3, 4). In this study, 15% (6 of 40) of the injections required greater than light finger pressure to deposit the anesthetic solution. Three of these cases initially had back-pressure caused by clogged or bent needles. The other three cases can be explained by not perforating the full depth of cortical bone, placement of the needle into a cancellous bone trabeculation or PDL space, or a constricted cancellous space. Although reperforation to gain additional length and rotation of the needle to move the lumen away from a ligament space or bone trabeculation was attempted, back-pressure was still encountered.

For the infiltration injection given before the IO injection, needle insertion was rated as mildly painful 45% of the time, with one report of moderate pain (Table 1). Pain of solution deposition was rated as mildly painful 12% of the time, with four reports of moderate pain. The pain ratings were likely related to the lack of anesthesia of the buccal gingiva. Although previous studies (5, 7) have shown that buccal anesthesia may or may not be obtained with the IAN block alone, it was the intent of this study to determine the pain ratings of the infiltration injection without the long buccal injection. Administering a long buccal injection before infiltration injection may reduce the pain ratings, but may itself be painful.

For the IO injection, needle insertion, perforation, and solution deposition resulted in low pain ratings, and were similar to the pain ratings for the mock IO injection (Table 1). The low ratings were the result of soft tissue and bone anesthesia provided by the IAN block and infiltration injection. The *Stabident Instruction Manual* suggests that the IO injection technique, when used as a primary technique, is not painful if the infiltration injection is successful. Although this was true in the present study, we did not use the technique as a primary injection.

Postinjection pain for the IAN block was rated as none to mild (at the time subjective numbness wore off) in 95% of the injections, and the ratings decreased over the next 3 days (Table 3). Nist et al. (6) reported a higher incidence of moderate pain (17%) for postinjection ratings with the IAN block. Generally, there is a modest potential for moderate postinjection pain with the IAN block when anesthesia wears off, and this potential decreases thereafter. Postinjection pain for the IO injection was rated as none to mild (at the time subjective numbness wore off) in 100% of the mock injections, and in 98% of the IO injections (Table 3). The pain ratings decreased over the next 3 days. Therefore, the IO injection has a small potential for moderate postinjection pain. When compared with the PDL injection, the IO injection is less likely to cause postinjection discomfort in the first molar based on the study by White et al. (17). They found 32% of the subjects reported moderate pain at the mandibular first molar when subjective numbness wore off. At 2 days 14% had moderate pain, and at 3 days there were no reports of moderate pain.

Various authors (18, 19) have reported an increase in heart rate with the IO injection of epinephrine-containing solutions with the effects lasting 2 to 3 min. The last 20 subjects participating in this study were subjectively monitored for changes in heart rate. Eighty percent (16 of 20) of these subjects reported an increase in heart rate during the IO solution deposition, compared with none during the mock IO injection. No adverse cardiac symptoms were reported. In healthy subjects, as were used in this study, the IO injection of 2% lidocaine with 1:100,000 epinephrine seems to be safe. The present study was only concerned with the subjective occurrence of an increased heart rate; future studies should objectively monitor the cardiovascular parameters of the Stabident IO injection. Clinically, it seems that the majority of subjects will report an increased heart rate following IO injection using the Stabident system. The patient should be informed of this to lessen his/her anxiety.

Although no experimental study has investigated the effects of the IO injection on gingiva and bone, Bourke (2) clinically found no incidence of infections following IO injections. In the current study, one subject reported that a "bump" had appeared at the IO injection site 3 days after the IO injection. It resolved without incident at 7 days postinjection but recurred at 2 wk. The "bump" presented as a round elevation of 2.5 mm × 2.5 mm, which was probeable into the gingiva but not bone. The area bled easily, but there was no purulence. Sulcus depths and radiographic examination were within normal limits. Further evaluations at 1 wk and 1 month revealed normal gingival architecture, and the subject was without symptoms. The etiology of this problem was likely gingival or bone trauma during perforation.

Four of 40 subjects reported the first molar "felt high" when chewing for a few days. The incidence of "feeling high" with the IO injection (10%) is lower than reported with the PDL injection (36 to 49%) (9, 17). This feeling is most likely an increased awareness to biting, resulting from soreness in the area caused by damage to the PDL from perforation or inflammation of the bone.

The effects of the IO injection on the pulp have not been studied. Because the IO injection is similar to a PDL injection, except the duration is prolonged when 1.8 ml is delivered, we would expect that the pulpal effects of the two injection techniques may be comparable (9, 17, 20). We had no reported symptoms of a pulpal nature, and all teeth that received the IO injection at the first appointment had similar base line pulp test readings at the second appointment. Therefore, it seems unlikely that the addition of the IO injection to the IAN block would cause pulpal necrosis with restorative procedures.

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