# Anesthetic Efficacy of a Repeated Intraosseous Injection Given 30 Min Following an Inferior Alveolar Nerve Block/Intraosseous Injection

**Jonathan Reitz, DDS, MS,* Al Reader, DDS, MS,* Robert Nist, DDS, MS,* Mike Beck, DDS, MA,† and William J. Meyers, DMD, MEd***

*Section of Graduate Endodontics and †Department of Health Sciences Research, College of Dentistry, The Ohio State University, Columbus, Ohio

To determine whether a repeated intraosseous (IO) injection would increase or prolong pulpal anesthesia, we measured the degree of anesthesia obtained by a repeated IO injection given 30 min following a combination inferior alveolar nerve block/intraosseous injection (IAN/IO) in mandibular second premolars and in first and second molars. Using a repeated-measures design, we randomly assigned 38 subjects to receive two combinations of injections at two separate appointments. The combinations were an IAN/IO injection followed approximately 30 min later by another IO injection of 0.9 ml of 2% lidocaine with 1:100,000 epinephrine and a combination IAN/IO injection followed approximately 30 min later by a mock IO injection. The second premolar, first molar, and second molar were blindly tested with an Analytic Technology pulp tester at 2-min cycles for 120 min postinjection. Anesthesia was considered successful when two consecutive readings of 80 were obtained. One hundred percent of the subjects had lip numbness with IAN/IO and with IAN/IO plus repeated IO techniques. Rates of anesthetic success for the IAN/IO and for the IAN/IO plus repeated IO injection, respectively, were 100% and 97% for the second premolar, 95% and 95% for the first molar, and 87% and 87% for the second molar. The repeated IO injection increased pulpal anesthesia for approximately 14 min in the second premolar and for 6 min in the first molar, but no statistically significant differences ($P > 0.05$) were shown. In conclusion, the repeated IO injection of 0.9 ml of 2% lidocaine with 1:100,000 epinephrine given 30 min following a combination IAN/IO injection did not significantly increase pulpal anesthesia in mandibular second premolars or in first and second molars.

**Key Words:** Local anesthesia; Intraosseous injection; Inferior alveolar nerve block.

The intraosseous injection (IO) allows placement of a local anesthetic directly into the cancellous bone adjacent to the tooth to be anesthetized. Currently, there is an IO system marketed under the trade name Stabident (Fairfax Dental Inc., Miami, FL). This system is composed of a slow-speed, handpiece-driven perforator (a solid 27-gauge wire with a beveled end) that drills a small hole through the cortical plate. The anesthetic solution is delivered into the cancellous bone through a 27-gauge ultrashort injector needle placed into the hole made by the perforator.

The Stabident IO injection has been evaluated both as a primary and as a supplemental injection. Leonard[1] reported that a majority of extractions were successful with this system. Coggins et al[2] used the system as a primary injection in various groups of maxillary and mandibular teeth. They reported a success rate of 75% for the mandibular first molar. Replogle et al[3] reported that a primary IO injection of 2% lidocaine with 1:

Received March 25, 1998; accepted for publication December 17, 1998.

Address correspondence to Dr. Al Reader, Section of Endodontics, College of Dentistry, The Ohio State University, Columbus, OH 43210.

Anesth Prog 45:143–149 1999

ISSN 0003-3006/99/$9.50
SSDI 0003-3006(99)

100,000 epinephrine in mandibular first molars was more successful and resulted in a longer duration of pulpal anesthesia than 3% mepivacaine. Dunbar et al[4] evaluated the Stabident IO system in mandibular first molars as a supplemental injection to the inferior alveolar nerve (IAN) block. They recorded a high incidence of pulpal anesthesia (100%), with 90% of the first molars still anesthetized at 60 min. Nusstein et al[5], in a clinical study, found that a supplemental mandibular IO injection of 1.8 ml of 2% lidocaine with 1:100,000 epinephrine was 90% successful in gaining total pulpal anesthesia for teeth diagnosed with irreversible pulpitis. Reisman et al[6] reported that a supplemental IO injection of 1.8 ml of 3% mepivacaine increased success in mandibular teeth diagnosed with irreversible pulpitis to 80% when compared to the IAN block alone, which achieved 25% success. A repeated IO injection of 3% mepivacaine increased success to 98%. Coggins et al,[2] Replogle et al,[3] and Dunbar et al[4] all used an IO injection site distal to the first molar and 1.8 ml of anesthetic solution. Reitz et al[7] used an IO injection site distal to the second premolar and 0.9 ml of 2% lidocaine with 1:100,000 epinephrine intraosseously following an IAN block. They found that the incidence of anesthesia was significantly increased in the second premolar (for 50 min) and in the first molar (for 20 min) with the combination IAN/IO injection, compared with the IAN block alone. However, pulpal anesthesia in the second premolar started to decline after 30 min.[7] No objective study has evaluated the effectiveness in increasing or prolonging pulpal anesthesia of a repeated Stabident injection 30 min following a combination IAN/IO injection. If pulpal anesthesia could be prolonged, dentists would be able to reinject intraosseously to maintain anesthesia for an additional 30 to 60 min. The purpose of this study was to determine the anesthetic efficacy of a repeated IO injection of 0.9 ml of 2% lidocaine with 1:100,000 epinephrine given 30 min following an IAN/IO injection in mandibular posterior teeth. Solution deposition pain, subjective heart rate increase, and postoperative healing were also assessed for the repeated IO injection.

## MATERIALS AND METHODS

Thirty-eight adult subjects participated in the study: 28 men and 10 women, aged 18 to 43 yr, with an average age of 25 yr. Sample size was determined statistically to detect a change of 25% in anesthetic success. These calculations were based on an alpha risk of 0.05 and a beta risk of 0.10. 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; written informed consent was obtained from each subject.

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

Two appointments at least 4 wk apart were scheduled for each of the 38 subjects. By means of a repeated-measures design, each subject randomly received either a combination inferior alveolar nerve block/intraosseous injection (IAN/IO) plus a repeated IO injection 30 min following the initial injections, or a combination IAN/IO injection plus a repeated mock IO injection. The order in which each subject received the two combinations was randomly determined.

At the beginning of each appointment and before any injections were given, the experimental teeth and the control canine tooth were tested three times with an Analytic Technology pulp tester (Analytic Technology Corp., Redmond, WA) to record baseline vitality. After 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 of the tooth to be tested. The current rate was set at 25 sec to increase from no output (0) to the maximum output (80). The output number at the time of the subject's initial sensation was recorded. All preinjection and postinjection tests were performed by trained personnel who were blind to the repeated IO or mock IO injections administered.

The standard IAN block[8] was administered with a 27-gauge 1.5-inch needle (Monoject; Sherwood Medical, St. Louis, MO) using 1.8 ml of 2% lidocaine with 1:100,000 epinephrine (Astra Pharmaceutical Products Inc., Westborough, MA). After the needle reached the target area and aspiration was performed, the solution was deposited over a period of 1 min.

The IO injection that completed the IAN/IO was administered 5 min following completion of the IAN block if subjective lip numbness was recorded by the subject. To determine lip numbness, each subject was asked "Is your lip numb?" every minute for 5 min. If lip numbness did not occur within 5 min, the subject was reappointed. McLean et al[9] found that the mean onset of lip numbness is 5 min for the IAN block, and this calculation was used for the onset of lip numbness. All subjects had profound lip numbness following the IAN block.

The IO injection was given with the Stabident system. The technique has been described in detail elsewhere.[2–7] In this study, the soft tissue at the determined perforation site was anesthetized with an infiltration of approximately

**Table 1.** Percentages and Numbers for Discomfort Ratings for Solution Deposition of the Repeated Intraosseous Injection[a]

| Solution Deposition | Pain Ratings % (number) | | | |
|---|---|---|---|---|
| | None | Mild | Moderate | Severe |
| Mock | 100 (38) | 0 (0) | 0 (0) | 0 (0) |
| Intraosseous | 89 (34) | 3 (1) | 8 (3) | 0 (0) |

[a] $N = 38$.

0.1 ml of 2% lidocaine with 1:100,000 epinephrine, deposited through a 27-gauge needle attached to a standard aspirating syringe. The cortical bone was perforated with the Stabident perforator on the distal aspect of the second premolar. A standard syringe was held in a pen-gripping fashion, allowing the researcher to insert the ultrashort Stabident needle into the perforation site and to deliver 0.9 ml of 2% lidocaine with 1:100,000 epinephrine over a 1-min time period.

The repeated IO injection was administered approximately 30 min following completion of the combination IAN/IO injection (approximately 38 to 39 min after the IAN block). After identifying the initial IO perforation site, the ultrashort needle was inserted into the same perforation opening, and 0.9 ml of 2% lidocaine with 1:100,000 epinephrine was delivered over a 1-min time period. The mock IO injection was given in a similar manner, except that no anesthetic solution was deposited. The length of time for the mock IO injection was identical to the actual IO injection. Additionally, each subject was instructed to close his or her eyes during all injections to blind the techniques. Subjects were questioned during solution deposition and for 2 min following the repeated and mock IO injections to determine whether they noticed an increase in heart rate.

The subjects were instructed to rate the pain of the solution deposition for the repeated IO injection. 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 initial IO injection (9 min after completion of the IAN block), the first and second molars were pulp-tested. At 2 min, the second premolar and the contralateral canine tooth (control) were tested. The control canine tooth was tested with an inactive pulp tester every 6 min to test the reliability of the subjects. The cycle of testing was repeated every 2 min until pulp testing had been done for 30 min. The repeated IO or mock IO injection was then given (this time was approximately 38 to 39 min after the completion of the IAN block). Pulp testing resumed 1 min after completion of the repeated IO or mock IO injection. All testing was stopped at 120 min post–intraosseous injection.

**Table 2.** Percentages and Number of Subjects Who Experienced Anesthetic Success[a]

| Tooth | IAN/IO[b] % (number) | IAN/IO + Repeated IO[b] % (number) |
|---|---|---|
| Second premolar | 100 (38) | 97 (37) |
| First molar | 95 (36) | 95 (36) |
| Second molar | 87 (33) | 87 (33) |

Abbreviations: IAN, inferior alveolar nerve; IO, intraosseous.
[a] There were no significant differences when IAN/IO was compared with IAN/IO + repeated IO ($P > 0.05$).
[b] $N = 38$.

A lack of subject response to the maximum output (80) of the pulp tester was used as the criterion for pulpal anesthesia. Anesthesia was considered successful when the subject did not respond to two consecutive 80 readings.

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

The çomparison for anesthetic success between the IAN/IO and the IAN/IO plus repeated IO injection was analyzed nonparametrically using Bonferroni-adjusted McNemar tests. Comparisons between techniques for the percentage of pulpal anesthesia were analyzed using Bonferroni-adjusted Wilcoxon signed-ranks tests. Comparisons were considered significant at $P < 0.05$.

## RESULTS

The discomfort ratings for solution deposition of the repeated IO and mock injections are presented in Table 1. The majority of the ratings were in the none to mild categories. No perforators broke in this study.

One hundred percent of the subjects had profound lip numbness with the IAN/IO and with the IAN/IO plus repeated IO techniques. Anesthetic success is presented in Table 2. Anesthetic success for the IAN/IO and for the IAN/IO plus repeated IO injection were, respectively, 100% and 97% for the second premolar, 95% and 95% for the first molar, and 87% and 87% for the second molar. The repeated IO injection increased pulpal anesthesia for approximately 14 min in the second premolar, for 6 min in the first molar, and only slightly for the second molar, but no statistically significant differences ($P > 0.05$) were shown (Figures 1 through 3). Sixty-one percent of the subjects had a subjective increase in heart rate with the repeated IO injection.

The postinjection discomfort ratings for the IAN/IO and for the IAN/IO plus repeated IO injection are pre-

**Table 3.** Summary of Pain Ratings for Postinjection Survey with the IAN/IO and IAN/IO + Repeated IO Injection[a]

| Time | Technique | Pain Ratings % (number) | | | |
|---|---|---|---|---|---|
| | | None | Mild | Moderate | Severe |
| Day 0[b] | IAN/IO | 71 (27) | 18 (7) | 11 (4) | 0 (0) |
| | IAN/IO + Repeated IO | 53 (20) | 32 (12) | 16 (6) | 0 (0) |
| Day 1 | IAN/IO | 71 (27) | 24 (9) | 5 (2) | 0 (0) |
| | IAN/IO + Repeated IO | 74 (28) | 21 (8) | 5 (2) | 0 (0) |
| Day 2 | IAN/IO | 82 (31) | 18 (7) | 0 (0) | 0 (0) |
| | IAN/IO + Repeated IO | 82 (31) | 13 (5) | 5 (2) | 0 (0) |
| Day 3 | IAN/IO | 92 (35) | 8 (3) | 0 (0) | 0 (0) |
| | IAN/IO + Repeated IO | 92 (35) | 3 (1) | 5 (2) | 0 (0) |

Abbreviations: IAN, inferior alveolar nerve; IO, intraosseous.
[a] N = 38.
[b] Rating at time subjective numbness wore off.

sented in Table 3. The majority of the ratings were in the none to mild categories. No subject reported postinjection swelling. Five percent (2 of 38) of the subjects reported that the first molar "felt high" during chewing for a few days.

## DISCUSSION

The use of the pulp tester's 80 reading as a criterion for pulpal anesthesia was based on the studies of Dreven et al[10] and of Certosimo and Archer.[11] These studies[10,11] showed that no response to an 80 reading ensured pulpal anesthesia in vital asymptomatic teeth. Additionally, Certosimo and Archer[11] demonstrated that pulp tester readings of less than 80 resulted in pain during operative procedures in asymptomatic teeth.

In this study, we chose a time interval of 30 min after the first IO injection (approximately 38 to 39 min after completion of the IAN block) for the repeated IO injection based on the study of Reitz et al.[7] They demonstrated a decline in pulpal anesthesia in the second premolar after 30 min of pulp testing when 0.9 ml of 2% lidocaine with 1:100,000 epinephrine was given as an IO injection distal to the second premolar following the IAN block.[7] In this study, Figure 1 illustrates this decline.

For the IAN/IO, anesthetic success was 100% for the second premolar, with approximately 84% of the premolars still anesthetized at 60 min (Table 2 and Figure 1). The IAN/IO plus repeated IO injection resulted in a

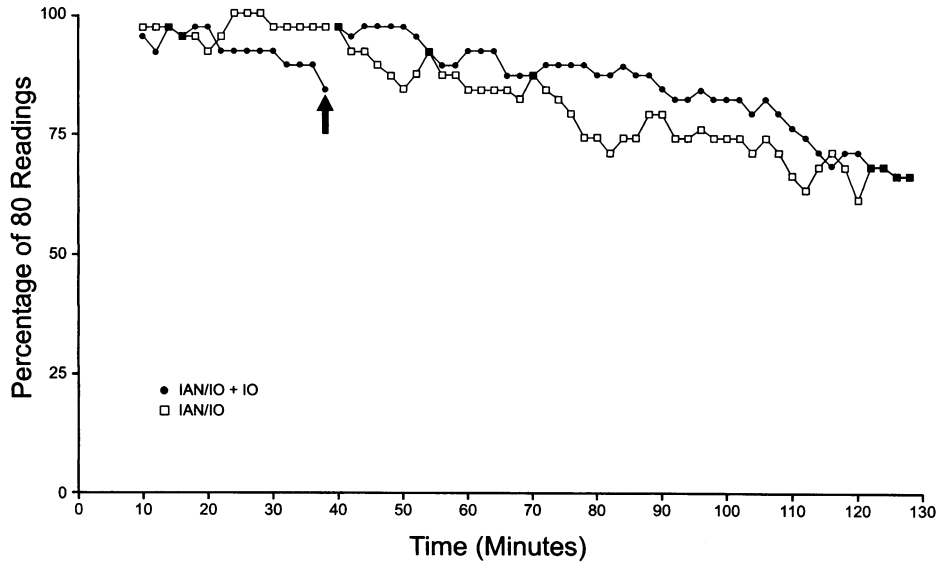


**Figure 1.** Incidence of second premolar anesthesia, expressed as the percentage of subjects who had no response to an electrical pulp tester at the maximal setting (80), at each postinjection time interval, for the IAN/IO and for the IAN/IO plus repeated IO injection. There were no significant differences between the techniques. The time at which the repeated IO injection was given is indicated by the arrow.

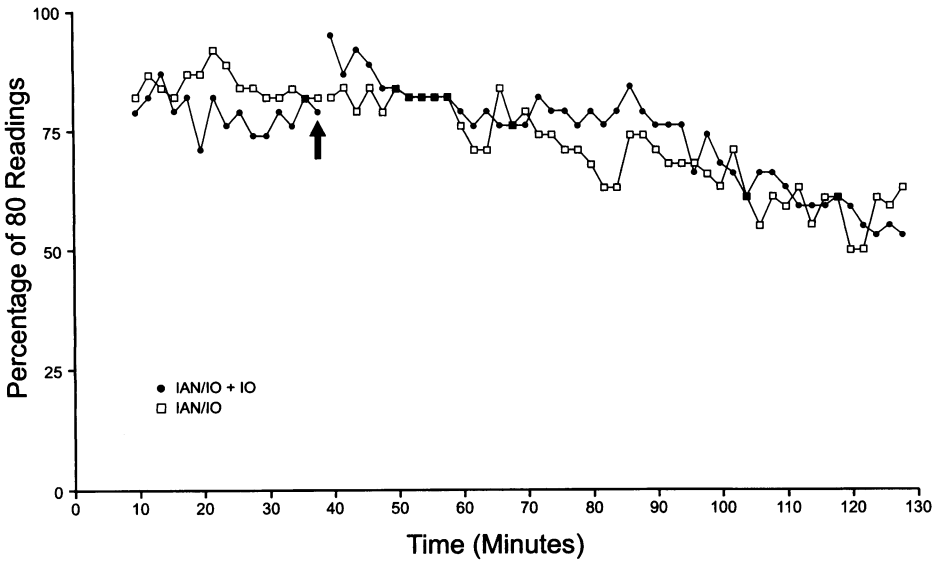


**Figure 2.** Incidence of first molar anesthesia, expressed as the percentage of subjects who had no response to an electrical pulp tester at the maximal setting (80), at each postinjection time interval, for the IAN/IO and for the IAN/IO plus repeated IO injection. There were no significant differences between the techniques. The time at which the repeated IO injection was given is indicated by the arrow.

success rate of 97%, with approximately 92% of the premolars still anesthetized at 60 min. Compared with the IAN/IO, the IAN/IO plus repeated IO injection did not statistically significantly increase anesthetic success or incidence of anesthesia ($P > 0.05$; Table 2 and Figure 1). Figure 1 shows an increase in pulpal anesthesia for approximately 14 min following the repeated IO injection and higher readings until 114 min. Pulpal anesthesia was above 80% for most of this time, but unfortunately, it was not 100%. Therefore, the IAN/IO plus repeated IO injection did not statistically significantly increase success in the second premolar over the IAN/IO injection alone.

Of the three teeth tested, the highest incidence and longest duration of anesthesia with the IAN/IO plus repeated IO injection occurred in the second premolar; the anesthetic success is most likely due to the selection of the IO injection site distal to the second premolar. Replogle et al,[3] Coggins et al,[2] and Dunbar et al[4] all found that the incidence of anesthesia was lower for the second premolar when an IO injection site distal to the first molar was selected. Reitz et al[7] showed a significant increase in success between the IAN block alone (60%) and IAN block plus IO injection (100%) in the second premolar when an IO injection site distal to the second premolar was selected. In their study, the highest success rate was found in the second premolar.[7] Therefore, the greatest effect for the repeated IO injection, in this study, would be expected in the second premolar.

For the IAN/IO, anesthetic success was 95% for the first molar, with approximately 76% of the first molars still anesthetized at 60 min (Table 2 and Figure 2). The IAN/IO plus repeated IO injection resulted in a success rate of 95%, with approximately 79% of the first molars still anesthetized at 60 min (Table 2 and Figure 2). Compared with the IAN/IO, the anesthetic success rate of the IAN/IO plus repeated IO was not statistically significant ($P > 0.05$; Table 2). Figure 2 shows an increase in pulpal anesthesia for approximately 6 min after the repeated IO injection, but the effect was not sustained. Therefore, a repeated IO injection 30 min following an IAN/IO injection did not statistically significantly increase success in the first molar over the IAN/IO block alone. Reitz et al[7] showed a significant increase in success between the IAN block alone (71%) and the IAN block plus IO injection (95%) in the first molar when an IO injection site distal to the second premolar was selected. Dunbar et al[4] found that an IO injection site distal to the first molar, as a supplemental injection to the IAN block, resulted in a high incidence of pulpal anesthesia (100%). Although the degree of anesthesia varied between the two studies, it may be that a repeated IO injection at an IO injection site distal to the first molar may result in better anesthesia of the first molar than an IO injection site distal to the second premolar. Further research is needed in this area.

For the IAN/IO alone, anesthetic success was 87% for the second molar, with approximately 82% of the second molars still anesthetized at 60 min (Table 2 and Figure 3). For the IAN/IO plus repeated IO injection, anesthetic success was 87%, with 74% of the second molars still anesthetized at 60 min (Table 2 and Figure 3). Figure 2 shows that the repeated IO injection had a slight effect after 30 min. When compared with the

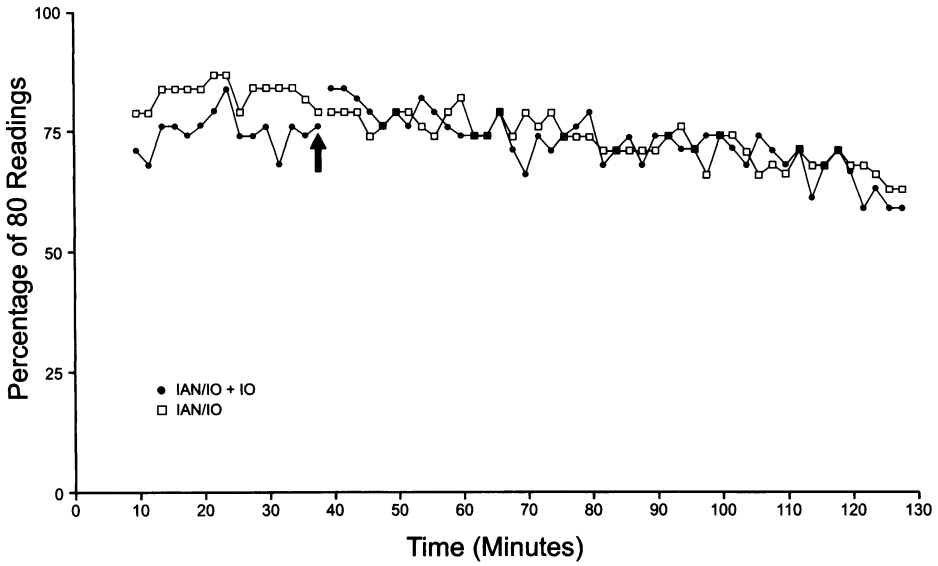


**Figure 3.** Incidence of second molar anesthesia, expressed as the percentage of subjects who had no response to an electrical pulp tester at the maximal setting (80), at each postinjection time interval, for the IAN/IO and for the IAN/IO plus repeated IO injection. There were no significant differences between the techniques. The time at which the repeated IO injection was given is indicated by the arrow.

IAN/IO alone, the anesthetic success rate of the IAN/IO plus repeated IO was not statistically significant ($P > 0.05$; Table 2). Therefore, the repeated IO injection did not statistically increase success in the second molar over the IAN/IO technique alone. Reitz et al[7] showed no significant differences between the IAN block and the IAN block plus IO injection in the second molar when an IO injection site distal to the second premolar was selected. Therefore, the spread of a repeated IO injection of 0.9 ml of anesthetic solution to the second molar, from an IO injection site distal to the second premolar, does not appreciably change the success of pulpal anesthesia in this tooth.

Why would the addition of a repeated IO injection of 0.9 ml of 2% lidocaine with 1:100,000 epinephrine not statistically significantly increase pulpal anesthesia and sustain it for an extended amount of time? We don't know the answer to this question. We found it disappointing that the repeated IO injection of half a cartridge of anesthetic solution resulted in so little effect. It was our hope that pulpal anesthesia could be significantly increased and prolonged for 1.5 to 2 hr with a repeated IO injection. Reitz et al[7] showed a significant increase in the incidence of pulpal anesthesia (over 40%) in the second premolar for an IO injection of 0.9 ml of 2% lidocaine with 1:100,000 epinephrine following an IAN block. The differences were significant through 50 min for the second premolar. Reisman et al[6] showed that a repeated IO injection, when the first supplemental IO injection failed, statistically increased success in mandibular posterior teeth diagnosed with irreversible pulpitis. However, the repeated IO injection in the study of Reisman et al was given within approximately 5 min of the initial IO injection. It is also possible that the sample size in the present study may have been too small to detect a difference between the groups. Considering the results of Reitz et al[7] and of Reisman et al,[6] future studies may want to address the volume of anesthetic solution, the timing of the repeated IO injection, and the IO injection site (either mesial or distal to the tooth) to determine if pulpal anesthesia can be increased or prolonged appreciably.

Reitz et al[7] evaluated the duration of IO anesthesia past 60 min. They studied the effects of adding an IO injection, using 0.9 ml of 2% lidocaine with 1:100,000 epinephrine, to the IAN block. They did not find a significant difference in pulpal anesthesia past 60 min for the IAN/IO technique when compared with the IAN block alone. In this study, no significant differences were shown past 60 min for any of the teeth with the repeated IO injection. For clinical procedures lasting longer than 60 min, therefore, a repeated IO injection given 30 min following the first IO injection will not be better statistically than a combination IAN/IO injection, if one uses the volumes and solution tested in this study.

For the IAN/IO plus repeated IO injection, solution deposition resulted in low pain ratings, with three reports of moderate pain (Table 1). The low ratings were probably due to the anesthesia provided by the IAN block and by the initial IO injection. Similar results for the supplemental IO injection after the IAN block have been reported by Dunbar et al[4] and by Reitz et al.[7]

At the time when subjective numbness wore off, postinjection pain was rated as none to mild in 85% of the IAN/IO injections and in 89% of the IAN/IO plus repeated IO injections; 11% to 16% of subjects reported moderate pain (Table 3). The pain ratings decreased over the next 3 days. Pain ratings, when subjective numbness wore off, have been measured for an initial IO injection by Dunbar et al[4] as 2% of subjects reporting moderate pain, by Coggins et al[2] as 2% to 15% reporting moderate pain, by Replogle et al[3] as 2% to 5% reporting moderate pain, and by Reitz et al[7] as 11% reporting moderate pain.

Various authors[2–5,7] have reported a transient increase in heart rate (46% to 85% of the time) with the Stabident IO injection of epinephrine-containing solutions. Sixty-one percent (23 of 38) of the subjects in this study reported a subjective increase in heart rate either during solution deposition or for 2 min after the repeated IO injection; only 5% of subjects reported a subjective heart rate increase during the mock repeated IO injection. Reitz et al[7] reported that 68% of their subjects had a subjective increase in heart rate with the initial IO injection. Coggins et al[2] reported that 85% of subjects experienced a subjective increase in heart rate with a first IO injection, and 71% of subjects reported a subjective increase in heart rate with a second IO injection given in a different jaw location 1 min later. Replogle et al[12] found that the subjective reporting of heart rate changes correlated with objective electrocardiograph recordings. Clinically, it appears that the majority of subjects will report an increased heart rate following a repeated IO injection of epinephrine-containing solutions using the Stabident system. The patient should be informed of this likelihood to lessen the potential for anxiety.

Although no animal study has investigated the effects of the Stabident IO injection on gingiva and bone, Dunbar et al,[4] Coggins et al,[2] and Replogle et al[3] have reported swelling and purulence at Stabident IO injection sites. Generally, the incidence of these adverse effects in these studies[2–4] has been less than 5%. These changes are probably related to gingival or bone trauma during perforation. In the current study, no subjects reported postinjection swelling or exudate.

Five percent (2 of 38) of the subjects reported that the first molar "felt high" when chewing for a few days. Other studies[2–4] using the Stabident technique have reported an incidence of 4% to 13% of subjects reporting this feeling. We feel the most likely cause of the feeling of being high in occlusion is an increased awareness of biting that results from soreness in the area caused by damage from perforation or inflammation of the bone. No subjects reported symptoms of a pulpal nature postoperatively, and all subjects who received the repeated IO injection at the first appointment had similar baseline pulp test readings at the second appointment.

In conclusion, the repeated IO injection of 0.9 ml of 2% lidocaine with 1:100,000 epinephrine, given 30 min following a combination IAN/IO injection, did not significantly increase pulpal anesthesia in mandibular second premolars or in first and second molars.

## ACKNOWLEDGMENT

The authors are grateful to the Graduate Endodontic Student Research Fund for funding this Master's Thesis.

## REFERENCES

1. Leonard M: The efficacy of an intraosseous injection system of delivering local anesthetic. J Am Dent Assoc 1995; 126:81–86.

2. Coggins R, Reader A, Nist R, Beck M, Meyers W: Anesthetic efficacy of the intraosseous injection in maxillary and mandibular teeth. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1996;81:634–641.

3. Replogle K, Reader A, Nist R, et al: 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;83:30–37.

4. Dunbar D, Reader A, Nist R, Beck M, Meyers W: Anesthetic efficacy of the intraosseous injection after an inferior alveolar nerve block. J Endod 1996;22:481–486.

5. 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;24:487–491.

6. 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;84:676–682.

7. Reitz J, Reader A, Nist R, Beck M, Meyers W: 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;86:516–523.

8. Malamed SF: Handbook of Local Anesthesia, 4th ed. St Louis, CV Mosby, 1997:195–6.

9. McLean C, Reader A, Beck M, Meyers WJ: An evaluation of 4% prilocaine and 3% mepivacaine compared to 2% lidocaine (1:100,000 epinephrine) for inferior alveolar nerve block. J Endod 1993;19:146–150.

10. Dreven L, Reader A, Beck M, Meyers W, Weaver J: An evaluation of the electric pulp tester as a measure of analgesia in human vital teeth. J Endod 1987;13:233–238.

11. Certosimo A, Archer R: A clinical evaluation of the electric pulp tester as an indicator of local anesthesia. Oper Dent 1996;21:25–30.

12. Replogle K, Reader A, Nist R, et al: Cardiovascular effects of the intraosseous injection of 2% lidocaine with 1:100,000 epinephrine and 3% mepivacaine. J Am Dent Assoc 1999. In press.