Original Article

Anesthetic efficacy of intraosseous and buccal infiltration techniques: a randomized controlled crossover clinical trial

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Abstract

Background/objectives This randomized controlled crossover clinical trial aimed to compare the anesthetic efficacy between intraosseous and buccal infiltration techniques as a primary anesthesia for mandibular first molars.

Materials and methods Twenty adult subjects randomly received intraosseous injection of 1.7 ml 4% articaine with 1:100,000 epinephrine or buccal infiltration of 3.4 ml 4% articaine with 1:100,000 epinephrine at 2 separate appointments. The mandibular first molars were tested for anesthesia with an electric pulp tester at 3-minute cycles for 60 minutes after the injections. Pain ratings for each injection were recorded. The data were analyzed using the McNemar and Wilcoxon signed ranks tests.

Results There was no significant difference ($p = 0.250$) in success rate between the intraosseous injections (95%) and buccal infiltrations (80%). However, the onset of pulpal anesthesia was significantly faster with the intraosseous injections ($p = 0.004$). No significant differences were found for injection or postinjection pain ($p > 0.05$).

Conclusion The success rate of buccal infiltration using two cartridges of 4% articaine with 1:100,000 epinephrine is comparable to that of intraosseous injection using a single cartridge of 4% articaine with 1:100,000 epinephrine in asymptomatic mandibular first molars. Both techniques can be useful alternatives for inducing mandibular first molar anesthesia.

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Keywords: *anesthetic efficacy; articaine; buccal infiltration; intraosseous injection; mandibular molar*

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Introduction

Mandibular molar anesthesia is generally performed using an inferior alveolar nerve block (IANB). However, this technique does not achieve a predictable outcome, even in vital asymptomatic teeth, with success rates ranging from 32%-56% (Mikesell et al., 2005; Jung et al., 2008; Kanaa et al., 2009). Anatomical variation and the technical difficulty of performing an IANB can lead to substantial failure rates. Additionally, lingual and/or inferior alveolar nerve injury following an IANB can occur(Gaffen & Haas, 2009; Garisto et al., 2010). To improve the success of mandibular anesthesia, alternative techniques such as buccal infiltration and intraosseous injection have been evaluated in many studies. (Robertson et al., 2007; Jensen et al., 2008; Jung et al., 2008; Remmers et al., 2008)

Buccal infiltration of 4% articaine with 1:100,000 epinephrine as a primary technique for the mandibular first molars has success rates of 50%-87% (Kanaa et al., 2006; Robertson et al., 2007; Jung et al., 2008; Martin et al., 2011; McEntire et al., 2011; Kwon et al., 2014; Nydegger et al., 2014; Shurtz et al., 2015). Compared with an IANB, buccal infiltration is technically simpler, less risky of intravascular injection, and the risk of potential nerve damage is avoidable (Meechan, 2010).

High success rates of primary intraosseous injection of the mandibular first molar ranging from 74%-100% have been reported (Coggins et al., 1996; Replogle et al., 1997; Gallatin et al., 2003; Jensen et al., 2008; Remmers et al., 2008; Pereira et al., 2013). This technique requires specialized equipment to perforate the cortical bone. QuickSleeper (Dental Hi Tec, Cholet, France), an intraosseous system, is a computer-controlled local anesthetic delivery device. It performs bone perforation and anesthetic deposition through the lumen of the needle in a single step. The computer controls the speed, rotation torque, and drilling time that aids in reducing the risk of excessive heat generation or potential root damage (Graetz et al., 2013).

No previous studies have directly compared the anesthetic efficacy of these two alternative methods for mandibular molar anesthesia. The purpose of this prospective, randomized, controlled, crossover study was to compare the anesthetic efficacy of intraosseous injection with that of buccal infiltration when used as a primary anesthetic technique for mandibular first molars.

Materials and Methods

This study was approved by the Human Research Ethics Committee of the Faculty of Dentistry, Chulalongkorn University (HREC-DCU 2016-016). The experiments were undertaken with the understanding and written consent of each subject. The trial was registered at Thai Clinical Trial Registry, number TCTR20161014001.

The sample size calculation was determined using power analysis based on previous studies reporting 70% success rate of buccal infiltration (Martin et al., 2011) and 100% success rate of intraosseous injection (Jensen et al., 2008). Calculation of sample size is based on Sakpal (Sakpal, 2010). With a nondirectional alpha risk of 0.05 and a power of 80%, a sample size of 20 subjects was required to demonstrate a difference of 30% in anesthetic success rate. Twenty subjects, 10 men and 10 women, participated in the study. Mean age of the subjects was 24 years with a range of 18-30. The subjects were in good health and were not taking any medication that would alter pain perception. Subjects with major medical problems, allergies to local anesthetics, pregnancy, active sites of pathosis or bony exostosis in the injection area were excluded. The teeth evaluated in this study were mandibular first molars. The contralateral canines served as the unanesthetized control teeth to

determine the reliability of the pulp tester and the subjects. Clinical examinations indicated that tested molars and canines were free of caries, large restorations, periodontal disease, and had no history of trauma or sensitivity.

Using a crossover design, 20 subjects received 2 sets of intraosseous injection using 1.7 ml of 4% articaine with 1:100,000 epinephrine (Ubistesin™ forte; 3M ESPE, Seefeld, Germany) or buccal infiltration using 3.4 ml of 4% articaine with 1:100,000 epinephrine at 2 separate appointments spaced at least 2 weeks apart. Thus, forty injections were administered in total and each subject served as their own control. Twenty injections were administered on the left and right side. The side chosen for the first injection was used again for the second injection. All injections were administered by a specialist who is familiar with both injection techniques. The operator had no involvement with assessing the outcome. The subjects were randomly assigned to each of the two anesthetic techniques using a blocked randomization list (computerized random numbers), which was prepared by a research assistant. Only the random numbers were recorded on the data collection sheets.

Before the experiment, radiographs were taken to evaluate root proximity and tooth length. Each subject was instructed on how to rate the injection pain using a Heft-Parker visual analog scale (VAS) (Heft & Parker, 1984). The VAS was divided into 4 categories. No pain corresponded to 0 mm. Mild pain was defined as > 0 mm and ≤ 54 mm and had the descriptors of faint, weak, and mild pain. Moderate pain was defined as $>$ 54 mm but $<$ 114 mm and had the descriptor of moderate. Severe pain was defined as $\geq$ 114 mm and had the descriptors of strong, intense, and maximum possible.

At the beginning of each appointment and before the injection, the mandibular first molar and the control contralateral canine were tested twice with the electric pulp tester (Kerr, Vitality Scanner, SybronEndo, Orange, CA, USA) to record baseline vitality. The teeth were isolated with cotton rolls and dried with an air syringe. Toothpaste was used as a contact medium, and the pulp tester tip was placed in the middle third of the buccal surface of the tooth. The current rate was set to increase from 0-80 (the maximum output) over 25 seconds. The value at the initial sensation was recorded.

All subjects were blindfolded during both injections. The intraosseous injection using the QuickSleeper system and a 30-gauge needle (DHT, Dental Hi Tec, Cholet, France) was administered in 2 phases per the manufacturer's instructions. First, mucosal anesthesia was induced by injecting 0.2 ml of 4% articaine with 1:100,000 epinephrine into the distal papilla of the mandibular first molar. The angulation of the needle was approximately parallel to the mucosa and the needle's bevel faced the mucosal surface. The needle was removed from the papilla and the direction of the needle was adjusted to 15-30 degrees of the long axis of the tooth. After contacting bone, the rotation pedal was pushed until 3/4 of the needle's length moved into the bone. After sufficient penetration of the needle tip, the rotation pedal was released and the injection pedal was pushed to deposit the remaining 1.5 ml of the anesthetic solution. The intraosseous injection was administered over 2 minutes.

The buccal infiltration was administered with a standard aspirating syringe and a 30-gauge needle. The needle was inserted at the mucobuccal fold and advanced until it was estimated to be at or just above the apices of the mandibular first molar. The 3.4 ml of 4% articaine with 1:100,000 epinephrine was deposited over a 2-minute period. During this injection, the subject heard the beeps and sounds that mimicked the operation of the QuickSleeper system.

At both appointments, the subjects rated the injection pain on the VAS, Heft-Parker visual analog scale (Figure 1) immediately after the injection. Pulpal

anesthesia was monitored with the electric pulp tester. The mandibular first molar was tested at 1 minute and 3 minutes after completion of the injection, and the testing continued at 3-minute cycles thereafter for 60 minutes. At 3 minutes and every third cycle, the contralateral canine was tested using an inactivated pulp tester to test the reliability of the subject. If the subject responded positively to the inactivated pulp tester, he/she was not included in the study. No subject was excluded because of this reason. The anesthesia was considered successful if the subject did not respond to the maximum output (80) of the pulp tester on two consecutive measurements. The onset of pulpal anesthesia was recorded as the time of the first of two consecutive 80 readings.

The subjects were asked to complete postinjection surveys after each appointment using the same VAS. The subjects rated pain in the injection area immediately after the numbness wore off and in the morning for the next 3 days. The subjects were also instructed to record any problems other than pain, and were observed for symptoms of a pulpal nature postoperatively.

Differences between the intraosseous injection and the buccal infiltration for anesthetic success rate and incidence of pulpal anesthesia were analyzed using the McNemar test. Differences between the two anesthetic techniques for onset time and pain intensity were determined using the Wilcoxon matched-pairs signed rank tests as the data were not normally distributed. Differences were considered significant at $p < 0.05$.

Results

The subjects enrolled in the clinical trial are presented on the flow diagram (Figure 1). All 20 subjects completed the trial.

The anesthetic success rates and onset time of pulpal anesthesia of intraosseous injection and buccal infiltration are presented in Table 1. The anesthetic success rate of the intraosseous injection of 1.7 mL of 4% articaine with 1:100,000 epinephrine and the buccal infiltration of 3.4 mL of 4% articaine with 1:100,000 epinephrine was 95% and 80%, respectively. There was no significant difference in success rates between the two anesthetic techniques ($p = 0.250$). The mean onset time of pulpal anesthesia was 1 minute for the intraosseous injection and 3.56 minutes for the buccal infiltration. There was a significant difference in onset time of the pulpal anesthesia ($p = 0.004$).

The incidence of pulpal anesthesia at each post injection time interval for the two anesthetic techniques is presented in Figure 3. The intraosseous injections resulted in a significantly higher percentage at 1 (95% vs 30%) and 3 minutes (95% vs 50%).

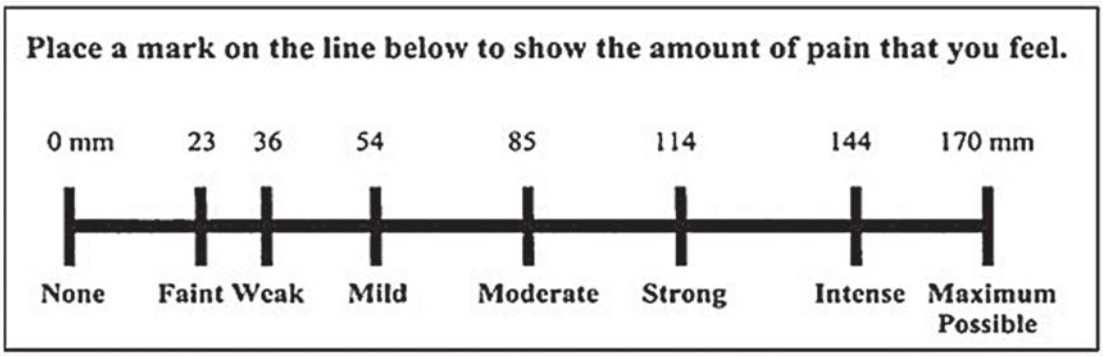

Figure 1: The Heft-Parker visual analog scale (VAS).

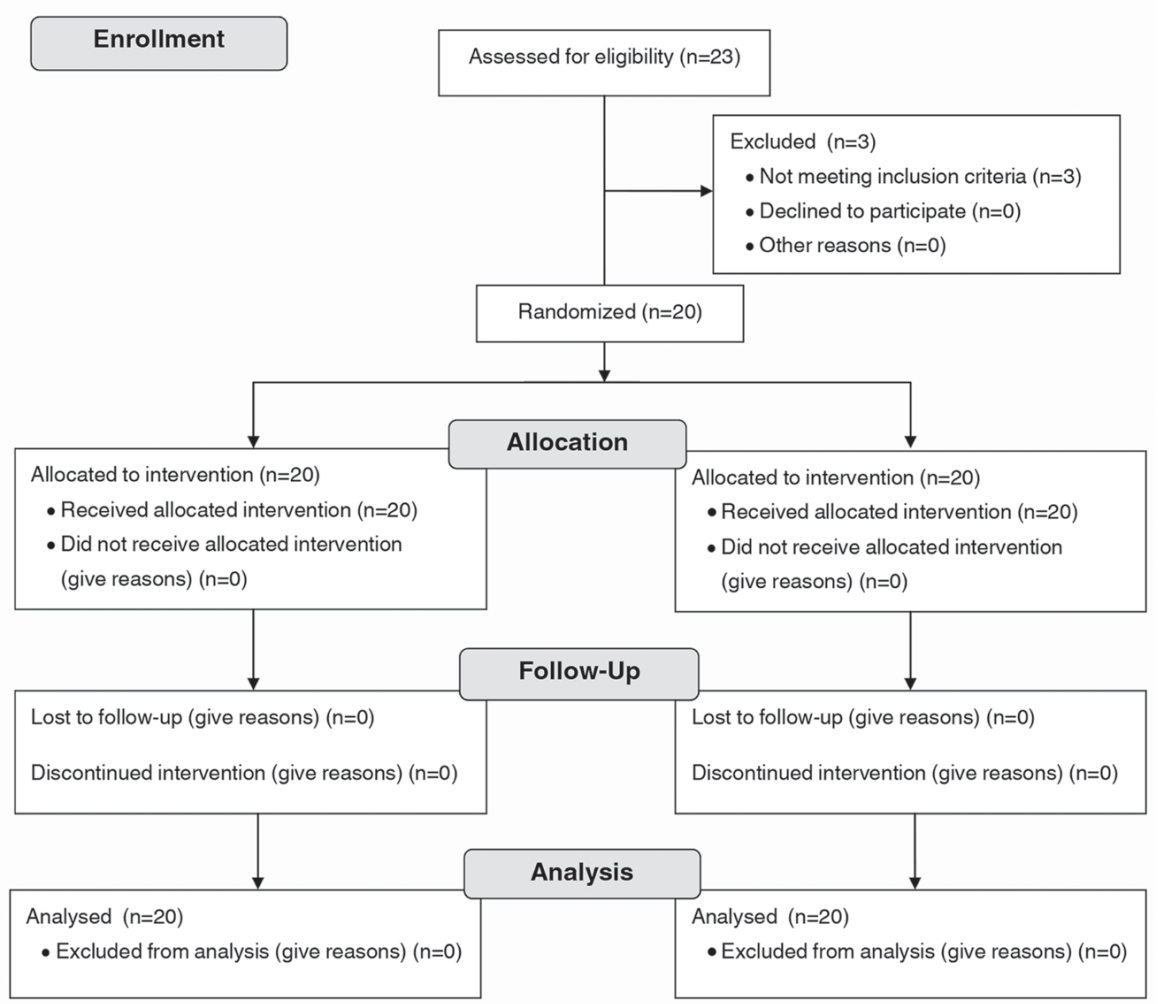

Figure 2: Consort 2010 flow diagram. All procedures were completed in the postgraduate clinic.

Table 1: The anesthetic success and onset time of intraosseous injection and buccal infiltration

	Intraosseous injection	**Buccal infiltration**	***p*-value**
Anesthetic success (%)	95 (19/20)	80 (16/20)	0.250†
Onset time (min)	1	3.56 ± 2.58	0.004*

n = 20 for anesthetic success, n = 16 for onset time of pulpal anesthesia.

†There was no significant difference ($p > 0.05$) between the anesthetic techniques.

*There was a significant difference ($p < 0.05$) between the anesthetic techniques.

Table 2: Mean ± SD of injection and postinjection pain ratings for intraosseous injection and buccal infiltration.

	Mean pain ratings ± SD (mm)		*p*-value
	Intraosseous injection	**Buccal infiltration**	
Injection pain	47 ± 21	36 ± 39	0.082†
Postinjection pain			
Day 0‡	29 ± 33	47 ± 31	0.079†
Day 1	32 ± 34	35 ± 27	0.711†
Day 2	19 ± 24	30 ± 27	0.223†
Day 3	7 ± 12	23 ± 27	0.064†

n = 20.

†There were no significant differences ($p > 0.05$) between the anesthetic techniques.

‡Day of injection when soft tissue anesthesia wore off.

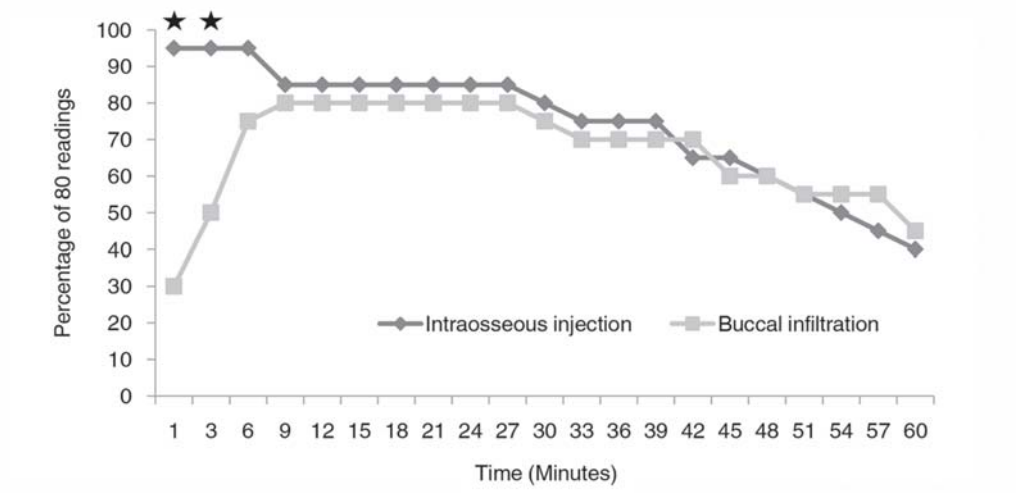

Figure 3: The percentage of 80 readings at each postinjection time interval for intraosseous injection and buccal infiltration. Significant differences ($p < 0.05$) are marked with a star (★).

The mean pain ratings of each injection technique are presented in Table 2. There was no significant difference in injection pain between the two anesthetic techniques ($p = 0.082$). Similarly, there were no significant differences in the postinjection pain ratings between the anesthetic techniques ($p > 0.05$). However, several subjects reported postinjection complications. Three subjects (15%) reported slight swelling and 1 subject (5%) reported bruising in the buccal infiltration area. Two subjects (10%) developed an apthous ulcer at the intraosseous injection sites.

Discussion

The present study compared the anesthetic efficacy of intraosseous injection and buccal infiltration using the pulp test reading of 80 as the criterion for determining pulpal anesthesia. The clinical studies of Drevenet al. (1987) and Certosimo and Archer (1996) showed that the absence of a subject's response to the maximum output (80) of the pulp tester indicated pulpal anesthesia in vital asymptomatic teeth.

The present study found that intraosseous injections for the mandibular first molars using the QuickSleeper system and a cartridge of 4% articaine with 1:100,000 epinephrine produced a success rate of 95%. This result is consistent with the result of Jensen et al. (2008) who reported a 100% success rate of a primary intraosseous injection for mandibular first molar anesthesia. Similarly, Gallatin et al. (2003) found a 93% success rate for the Stabidentand X-tip intraosseous injections of 2% lidocaine with 1:100,000 epinephrine. In contrast, Coggins et al. (1996) and Replogle et al. (1997), using the Stabident system and 2% lidocaine with 1:100,000 epinephrine, reported an anesthetic success rate of approximately 75%. Back-pressure during solution deposition resulting in anesthetic solution leakage may be related to the lower success rates found in these studies.

The QuickSleeper manual states that there is no lip numbness when intraosseous anesthesia is performed. In the present study, lip numbness subjectively occurred in 60% of the QuickSleeper injections. However, the degree of lip numbness was much less than that of the soft tissue numbness that occurred from the buccal infiltration. Previous studies (Coggins et al., 1996; Replogle et al., 1997; Gallatin et al., 2003) also reported lip numbness in at least half of the subjects when using 2% lidocaine with 1:100,000 epinephrine in a primary intraosseous injection of the mandibular first molar.

In the present study, 75% (15/20) of the subjects reported a perceived increase in heart rate after the QuickSleeper injections of 4% articaine with 1:100,000 epinephrine. Coggins et al. (1996) and Replogle et al. (1999) also reported a transient increase in heart rate after the intraosseous injection of epinephrine-containing anesthetic solutions. The pressures generated in the cancellous bone, which is a low-compliance site, may have forced the solution into the vascular circulation. However, slow intraosseous injection did not induce a clinically significant heart rate change in healthy individuals (Replogle et al., 1999; 2013). The patient should be informed of this phenomenon to lessen the anxiety.

We found that the success rate of the buccal infiltration for the mandibular first molar using 3.4 mL of 4% articaine with 1:100,000 epinephrine was 80%. This success rate was higher than that of the results of Martin et al. (2011) who conducted a study comparing 1.8 mL and 3.6 mL of 4% articaine with 1:100,000 epinephrine as a primary buccal infiltration for the mandibular first molar. These authors reported that the 3.6 mL volume provided anesthesia at a 70% success

rate that was significantly higher compared with the 50% success rate of the 1.8 mL volume. However, they found no significant differences in the onset time of pulpal anesthesia and the injection pain between the two anesthetic volumes. Because the efficacy of a 4% articaine buccal infiltration has been shown to be dependent on the amount of the solution injected, double cartridges of 4% articaine were used for the buccal infiltrations in the present study to compare with the single cartridge intraosseous injections, which have a high success rate.

The primary buccal infiltration using a cartridge of 4% articaine with epinephrine in asymptomatic mandibular first molars has been evaluated in multiple studies. Robertson et al. (2007) found a success rate of 87%. However, most studies have reported success rates not exceeding 70% (Kanaa et al., 2006; Corbett et al., 2008; Jung et al., 2008; Martin et al., 2011; McEntire et al., 2011; Kwon et al., 2014; Nydegger et al., 2014; Shurtz et al., 2015).

Gender may be a factor affecting the success rate of buccal infiltration of the mandibular first molar. Kwon et al. (2014) showed that articaine buccal infiltration produced a significantly higher success rate in the mandibular first molar of Korean female patients compared with their male counterparts. This result may be associated with the higher prevalence of accessory mental foraminain Korean female patients (Hu et al., 2006). There is evidence supporting that the mental foramen is important in the mechanism of action of buccal infiltration of the mandibular first molar (Meechan et al., 2011). It plays an important part in allowing the anesthetic solution access to the inferior alveolar nerve. In addition, cortical bone thickness may be a factor that determines the effectiveness of articaine infiltration (Flanagan, 2016). Therefore, an equal number of men and women were enrolled in the present study without an aim of assessing gender-related differences. However, we found that the 4 subjects who failed to obtain pulpal anesthesia after the buccal infiltration consisted of 1 woman and 3 men. Men may be better served by receiving the intraosseous injection.

We found that the onset of pulpal anesthesia occurred at the first minute after completing the intraosseous injections. Previous studies (Gallatin et al., 2003; Nusstein et al., 2005; Jensen et al., 2008) have reported 1-2 minutes for the onset of pulpal anesthesia from intraosseous injection. The onset time of pulpal anesthesia for the buccal infiltrations averaged 3.56 minutes. Our onset time results are in line with those of prior studies. A study by Martin et al. (2011) evaluating the buccal infiltration of mandibular first molars using 2 cartridges of 4% articaine with 1:100,000 epinephrine reported an onset time of 4.4 minutes. Other studies (Robertson et al., 2007; Corbett et al., 2008; Jung et al., 2008; Martin et al., 2011; McEntire et al., 2011; Shurtz et al., 2015) using 1 cartridge of 4% articaine with 1:100,000 epinephrine for the buccal infiltration found onset times of 4-7 minutes. Thus, the intraosseous injection results in a faster onset of anesthesia compared with that of buccal infiltration.

Predictable anesthetic duration is 27 minutes and pulpal anesthesia declined over the 60-minute observation period for both anesthetic techniques (Figure 2). At 30 minutes, 80% of the subjects were anesthetized from the intraosseous injection and 75% of the subjects were anesthetized from the buccal infiltration. At 60 minutes, 40% of the subjects were still anesthetized from the intraosseous injection and 45% of the subjects were still anesthetized from the buccal infiltration. Other studies of the primary intraosseous injection (Coggins et al., 1996; Replogle

et al., 1997; Gallatin et al., 2003; Jensen et al., 2008) and buccal infiltration (Robertson et al., 2007; Martin et al., 2011; McEntire et al., 2011; Shurtz et al., 2015) have shown a similar effect. In the present study, 2 subjects lost pulpal anesthesiain 9 minutes after intraosseous injection, which was not clinically practical. This may be because the anesthetic solution leaked during the injection or the needle was not placed properly.

The injection pain was not significantly different between the intraosseous injection and buccal infiltration. The mean pain ratings for the two anesthetic techniques were in the mild category (≤ 54 mm on the VAS), which were similar to the results of other studies (Gallatin et al., 2003; Martin et al., 2011; McEntire et al., 2011).

The postinjection pain ratings were not significantly different between the two anesthetic techniques for day 0 through day 3. The incidence of postinjection pain decreased over the 3 days. However, there was a difference in the character of the postinjection pain between the two anesthetic techniques. The intraosseous injection subjects reported soreness for a few days when chewing. This soreness may be due to the needle tip placement and solution deposition near the periodontal ligament. The buccal infiltration subjects reported tenderness in the injection area. Mild-moderate pain on day 3 was reported by 45% of the subjects with the intraosseous injection and 70% of the subjects with the buccal infiltration. Lower percentages of mild-moderate pain were reported in previous studies (Coggins et al., 1996; Replogle et al., 1997; Martin et al., 2011). The variation in these percentages between studies may relate to operator technique or differences in subject populations. The articaine dose of the buccal infiltration has been shown to affect the postinjection pain level felt by study subjects. Martin et al. (2011) and Pabst et al. (2009) reported that their subjects experienced more postinjection pain when 2 cartridges of 4% articaine were used.

Ten percent (2/20) of the subjects in our study reported an apthous ulcer from the intraosseous injection. These findings can be considered minor sequelae. Previous studies (Coggins et al., 1996; Replogle et al., 1997; Gallatin et al., 2003) found that 3%-20% of the subjects reported swelling or purulence postoperatively. In the present study, following buccal infiltration, 15% (3/20) of the subjects reported slight swelling and 5% (1/20) of the subjects reported bruising in the injection area. These complications were also found in previous studies (Robertson et al., 2007; Pabst et al., 2009; Martin et al., 2011; McEntire et al., 2011; Nydegger et al., 2014).

Although the present study does not provide evidence to support the superiority of the intraosseous injection over the buccal infiltration in terms of anesthetic success rate, the intraosseous injection produced less unwanted soft tissue anesthesia, which is an advantage for minimally invasive procedures. However, the buccal infiltration is a simpler technique because it does not require the specialized equipment needed for intraosseous delivery. For patients with coagulopathies, infiltration and intraosseous anesthetic techniques are considered as potential alternatives to nerve blocks to reduce the chance of dangerous hemorrhage (Gupta et al., 2007).

A limitation of the present study is that the results may not apply to children or the elderly, because our study used a young adult population. This study was only performed in healthy mandibular first molars using 4% articaine with 1:100,000 epinephrine. The efficacy of the anesthetic techniques

in patients with inflamed pulp tissue is unclear and needs to be investigated further to determine their success rates.

Conclusion

The anesthetic success rate of buccal infiltration using two cartridges of 4% articaine with 1:100,000 epinephrine is comparable to that of intraosseous injection using a single cartridge of 4% articaine with 1:100,000 epinephrine as a primary anesthetic technique for the mandibular first molar. However, intraosseous injection resulted in a faster onset of pulpal anesthesia compared with that of buccal infiltration. Both techniques can be useful alternatives for mandibular first molar anesthesia.

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