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ในฟันกรามล่างซี่ที่หนึ่ง

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COMPARING ANESTHETIC EFFICACY OF INTRAOSSEOUS INJECTION VERSUS BUCCAL INFILTRATION IN MANDIBULAR FIRST MOLAR

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A Thesis Submitted in Partial Fulfillment of the Requirements
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ศิวพร ศิวาวุธ : การเปรียบเทียบประสิทธิภาพของการฉีดยาชาด้วยวิธีอินทราออซเซียสอินเจคชั่นกับบัคเคิลอินฟิลเตรชั่นในฟันกรามล่างซี่ที่หนึ่ง (COMPARING ANESTHETIC EFFICACY OF INTRAOSSEOUS INJECTION VERSUS BUCCAL INFILTRATION IN MANDIBULAR FIRST MOLAR) อ.ที่ปรึกษาวิทยานิพนธ์หลัก: รศ. ทญ. ปิยาณี พาณิชย์วิสัย, หน้า.

จุดประสงค์: เพื่อเปรียบเทียบประสิทธิภาพของวิธีการฉีดยาชาระหว่างอินทราออซเซียสอินเจคชั่นกับบัคเคิลอินฟิลเตรชั่นในฐานะที่เป็นเทคนิคแรกในการทำให้ฟันกรามล่างซี่ที่หนึ่งชา

วิธีวิจัย: ใช้รูปแบบการศึกษาแบบสองระยะไขว้กัน (crossover trial) โดยให้อาสาสมัครจำนวน 20 คน ได้รับการฉีดยาชาวิธีอินทราออซเซียสอินเจคชั่นด้วยอาร์ติเคนเข้มข้นร้อยละ 4 ผสมอิพิเนฟรินเข้มข้น 1:100,000 ปริมาณ 1.7 มิลลิลิตร หรือ วิธีบัคเคิลอินฟิลเตรชั่นด้วยอาร์ติเคนเข้มข้นร้อยละ 4 ผสมอิพิเนฟรินเข้มข้น 1:100,000 ปริมาณ 3.4 มิลลิลิตร แยกกันในการนัดหมายสองครั้ง ทำการทดสอบฟันกรามล่างซี่ที่หนึ่งด้วยเครื่องทดสอบไฟฟ้า (electric pulp tester) ทุกๆ 3 นาที เป็นระยะเวลา 60 นาที การชาของเนื้อเยื่อในถือว่าประสบความสำเร็จหากไม่มีการตอบสนองจากอาสาสมัครเมื่อเครื่องทดสอบไฟฟ้าอ่านค่าสูงสุด (80) จำนวน 2 ครั้งติดต่อกัน ให้อาสาสมัครทำการบันทึกระดับความเจ็บปวดของการฉีดยาชาแต่ละวิธี วิเคราะห์ข้อมูลโดยใช้การทดสอบทางสถิติแมกนีมาร์และวิลคอกซัน

ผลวิจัย: วิธีอินทราออซเซียสอินเจคชั่นและวิธีบัคเคิลอินฟิลเตรชั่นมีอัตราความสำเร็จอยู่ที่ 95% และ 80% ตามลำดับ ไม่พบความแตกต่างอย่างมีนัยสำคัญทางสถิติระหว่างสองวิธีในแง่อัตราความสำเร็จ ($P > 0.05$) อย่างไรก็ตาม พบว่าวิธีอินทราออซเซียสอินเจคชั่นทำให้เนื้อเยื่อในฟันเกิดการชาได้เร็วกว่าอย่างมีนัยสำคัญทางสถิติ ($P < 0.05$) ไม่พบความแตกต่างอย่างมีนัยสำคัญทางสถิติระหว่างสองวิธีในแง่ระดับความเจ็บปวดขณะฉีดยาชา หรือ ความเจ็บปวดหลังจากฉีดยาชา ($P > 0.05$)

บทสรุป: อัตราความสำเร็จของการฉีดยาชาในฟันกรามล่างซี่ที่หนึ่งที่ไม่มีอาการด้วยวิธีบัคเคิลอินฟิลเตรชั่นโดยใช้อาร์ติเคนเข้มข้นร้อยละ 4 ผสมอิพิเนฟรินเข้มข้น 1:100,000 จำนวน 2 หลอด เทียบกันได้กับอัตราความสำเร็จของวิธีอินทราออซเซียสอินเจคชั่นโดยใช้อาร์ติเคนเข้มข้นร้อยละ 4 ผสมอิพิเนฟรินเข้มข้น 1:100,000 จำนวน 1 หลอด ทั้งสองวิธีนี้สามารถใช้เป็นเทคนิคทางเลือกในการทำให้ฟันกรามล่างซี่ที่หนึ่งเกิดการชาได้

ภาควิชา ทันตกรรมหัตถการ ลายมือชื่อนิสิต .....

สาขาวิชา วิทยาเอ็นโดดอนต์ ลายมือชื่อ อ.ที่ปรึกษาหลัก .....

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5775824232 : MAJOR ENDODONTOLOGY
KEYWORDS: ARTICAINE / BUCCAL INFILTRATION / INTRAOSSEOUS / MANDIBULAR MOLAR

SIWAPORN SIWAWUT: COMPARING ANESTHETIC EFFICACY OF INTRAOSSEOUS INJECTION VERSUS BUCCAL INFILTRATION IN MANDIBULAR FIRST MOLAR. ADVISOR: ASSOC. PROF. PIYANEE PANITVISAI, pp.

Aim: To compare the anesthetic efficacy between intraosseous injection and buccal infiltration when used as a primary anesthesia technique for mandibular first molars. Methodology: Using a crossover design, 20 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 with an electric pulp tester at 3-minute cycles for 60 minutes after the injections. Successful pulpal anesthesia was defined as no response from the subject on two consecutive pulp tester readings of 80. Pain ratings for each injection were recorded. The data were analyzed using the McNemar and Wilcoxon signed ranks tests. Results: The success rate for the intraosseous injections and buccal infiltrations were 95% and 80%, respectively. There was no significant difference in success rate between the anesthetic techniques ($P > 0.05$). However, the onset of pulpal anesthesia was significantly faster with the intraosseous injections ($P < 0.05$). No significant differences were found between the two techniques for injection pain or postoperative pain ($P > 0.05$). Conclusions: The anesthetic success rate of buccal infiltration using 2 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.

Department:	Operative Dentistry	Student's Signature	.....
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CHAPTER I
INTRODUCTION

Background and rationale

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% (1-3). Anatomical variation and the technical difficulty of performing an IANB can lead to high failure rates. Additionally, the IANB can cause permanent paresthesia due to lingual and/or inferior alveolar nerve damage (4, 5). To improve the success of mandibular anesthesia, alternative techniques such as buccal infiltration and intraosseous injection have been evaluated in many studies (2, 6-8).

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% (2, 6, 9-14). Compared with an IANB, buccal infiltration is technically simpler, less risky of intravascular injection, and the risk of potential nerve damage is avoidable (15).

High success rates of primary intraosseous injection of the mandibular first molar ranging from 74%-100% have been reported (7, 8, 16-19). This technique requires specialized equipment to perforate the cortical bone. QuickSleeper (Dental Hi Tec, Cholet, France), a computer-controlled local anaesthetic delivery device, was used for intraosseous injection in the present study. It performs bone perforation and anaesthetic deposition through the lumen of the needle in a single step. This device is more convenient and less time-consuming compared with early intraosseous anaesthetic systems. Controlling the speed, rotation torque, and drilling time by the computer aids in reducing the risk of excessive heat generation or potential root damage (20).

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

Objectives

To compare efficacy of intraosseous injection by the QuickSleeper system and buccal infiltration using 4% articaine with 1:100,000 epinephrine as the primary anesthesia technique to anesthetize mandibular first molars. The efficacy is determined in 4 aspects;

1. Success rate of pulpal anesthesia
2. Onset of pulpal anesthesia
3. Duration of pulpal anesthesia
4. Injection pain and postoperative pain

Scope of Study

This study was scoped in healthy patients who had mandibular first molars with vital asymptomatic pulp tissues. QuickSleeper device was used for intraosseous anesthetic injection.

Expected Benefits

1. To choose anesthetic injection technique which be more efficacy and comfortable for the patients.
2. If the anesthetic efficacy of 4% articaine BI and IO are not significantly different, BI may be simpler technique for dentists to anesthetize mandibular molar because BI does not require the specialized equipment.

3. If the BI and IO with 4% articaine as primary techniques achieve high success rate of pulpal anesthesia, they might be useful alternative methods to the traditional IANB for the mandibular molar anesthesia.

CHAPTER II
LITERATURE REVIEW

Local anesthetics

The commonly used dental anesthetics are amide-based anesthetics in which lidocaine is considered the gold standard. Articaine is classified as an amide but contains a thiophene ring, instead of a benzene ring. This unique chemical structure increased lipid solubility of molecule to diffuse more readily through the lipid nerve membrane and surrounding tissues. Another molecular difference is the ester linkage incorporated into the articaine molecule, which results in hydrolysis of articaine by plasma esterases (21). 90 to 95% of articaine is metabolized in the blood by plasma esterases, with the remainder being broken down in the liver. The articaine solution's plasma half-life has been reported to be as short as 20 minutes (22), versus lidocaine's half-life of approximately 108 minutes in healthy pateints (23). The rapid breakdown of articaine to the inactive metabolite articainic acid is related to a very low systemic toxicity and consequently permits the use of articaine in higher concentrations than other amide-type local anesthetics (22).

Four percent of Articaine and prilocaine are suspected to be responsible for increased neurotoxic side events compared to 2% lidocaine. Although adverse effects from local anesthetics used in dentistry are rare, paresthesia was reported more commonly after use of 4% local anesthetic formulations in the IANB (4, 5, 24). Nevertheless, a recent study (25) compared neural cell toxicity of various amide local anesthetics (lidocaine, mepivacaine, prilocaine, articaine, bupivacaine, and ropivacaine) using the human neuroblastoma cell. Three groups of local anesthetics were identified in terms of toxicity. Ropivacaine and articaine have the lowest toxicity; mepivacaine, prilocaine, and lidocaine have medium toxicity; and

bupivacaine has the highest toxicity. Among dental anesthetics, articaine is the least neurotoxic in human neuroblastoma (SH-SY5Y) cells.

Allergy to the amide-type local anesthetics is extremely rare, whereas the ester-type is much more frequent. Allergy to one ester precludes the use of other ester, as the allergenic component is the breakdown product para-aminobenzoic acid, and metabolism of all esters yields this compound. In contrast, allergy to one amide does not preclude the use of other amide, because cross-allergenicity does not occur (26). Allergy to epinephrine is impossible in a living person. A patient may be allergic to other compounds in the anesthetic cartridge, such as methylparaben which is preservatives. However, it has been excluded from all single-use, dental local anesthetics cartridges (26). If there is a documented allergy to sulfites, it may be best to avoid a vasoconstrictor (26, 27). As metabisulfite is added as an antioxidant for vasoconstrictor, it is found in all dental local anesthetics cartridges that contain a vasoconstrictor. Vasoconstrictor can be used in patients with an allergy to the sulfa-type antibiotics (sulfonamides) because of no cross-allergenicity with sulfites (26, 27).

Articaine is available as a 4% solution with various concentration of epinephrine. Articaine has the maximum recommended dose of 7 mg/kg for the adult patient. For a healthy 70 kg adult, the maximum dose of 4% articaine equates to 7 cartridges (28).

A meta-analysis (29) has been published in which investigators compared the anesthetic success rates of articaine and lidocaine. They found that articaine had anesthetic success superior approximately 3.8 times to lidocaine when used with infiltration anesthesia. There was weak evidence of articaine being superior to lidocaine for mandibular block anesthesia, and no difference if they considered only symptomatic teeth.

Techniques for mandibular molar anesthesia

Although mandibular anesthesia traditionally has relied on inferior alveolar nerve block technique, success using this technique has been unpredictable even in teeth with normal pulp (1, 2, 30). Inability of the operator to deposit anesthetic solution in close proximity to the targeted nerve would lead to inadequate blockade and cause anesthetic failure of IANB. Additionally, it has potential for causing nerve damage (4, 5, 31). Alternative anesthetic techniques, such as buccal infiltration (6, 9-11, 32, 33) and intraosseous injection (7, 8, 16, 19) have been evaluated as the primary technique to provide anesthesia in mandibular molar.

Inferior alveolar nerve block (IANB)

The inferior alveolar nerve block is the local anesthesia technique of choice when treating mandibular molars. The IANB is approached in the pterygomandibular space at the mandibular foramen as the nerve enters the mandible. The IANB does not always result in successful pulpal anesthesia. Clinical studies in endodontics (1, 2, 32-37) have found success with the IANB between 23% and 69% of the time. Therefore, various attempts have been made to improve the success rate of IANB or to identify alternative methods of anesthesia. Nusstein et al (38) and Fowler and Reader (35) found no significant difference in the success between1.8 mL and 3.6 mL 2% lidocaine with 1:100,000 epinephrine for IANB. Although articaine has been speculated to have some advantages over lidocaine (21), clinical studies found that IANB of 4% articaine with 1:100,000 epinephrine was similarly effective to 2% lidocaine with 1:100,000 epinephrine in normal pulps (1) and irreversible pulpitis (33, 34, 37).

Regarding onset of pulpal anesthesia, previous studies (39, 40) of the IANB, using 1.8 mL of 2% lidocaine with 1:100,000 epinephrine, found onset times ranging from 8 to 11 minutes for the first molar. Mikesell et al (1) demonstrated that duration

of pulpal anesthesia following an IANB was maintained at least 60 minutes. Once subjects experienced pulpal anesthesia with the IANB using 1.8 mL of 2 % lidocaine with 1:100,000 epinephrine, they sustained pulpal anesthesia for an average of 2 hours and 24 minutes (41).

Mikesell et al (1) reported a 9% incidence of postinjection trismus, that may be the result of the medial pterygoid muscle injury by a needle during IANB. Another complication, nonsurgical paresthesia, could be a result of damage from the needle to the inferior alveolar or lingual nerves after mandibular nerve blocks (4, 5). Awaring of these complications, the other anesthetic techniques may be considered as alternative to IANB.

Buccal infiltration (BI)

The landmarks for both maxilla and mandible are the mucobuccal fold. Maxillary teeth can be successfully anesthetized by infiltration (42). In adult mandible, infiltration technique may not be the first choice because of the thickness of cortical bone. However, the success of the technique depended on the choice of anesthetic solution. Clinical studies found that success rates of primary buccal infiltration with 4% articaine with epinephrine in the mandibular first molars have ranged from 50-87% (2, 6, 9-11, 13, 14, 32, 33, 43) (Table 1). Although Roberson et al (6) reported high success up to 87%, most of these studies showed the success rate was less than 70% (2, 9-11, 13, 14, 32, 33). The anesthetic efficacy of 3.6 mL 4% articaine with 1:100,000 epinephrine is better than 1.8 mL of the same anesthetic solution in a primary mandibular buccal infiltration of the first molar (10).

Table 1 Previous studies of buccal infiltration with 4% articaine as the primary technique in the mandibular first molars

Author	n	Pulpal status	Volume (mL)	Success rate
Kanaa et al., 2006 (9)	31	normal	1.8	65%
Robertson et al., 2007 (6)	60	normal	1.8	87%
Corbett et al., 2008 (32)	31	normal	1.8	65%
Jung et al., 2008 (2)	35	normal	1.7	54%
Martin et al., 2011 (10)	86	normal	1.8	50%
			3.6	70%
McEntire et al., 2011 (11)	86	normal	1.8	59-67%
Poorni et al., 2011 (33)	132	pulpitis	1.8	65%
Kwon et al., 2014 (13)	29	normal	1.7	52%
Nydegger et al., 2014 (14)	60	normal	1.8	55%

The results of the double-blind randomized controlled trial in healthy adult participants showed that buccal infiltration of the mandibular first molar with 4% articaine with epinephrine could provide pulpal anesthesia higher than 2% lidocaine with epinephrine (6, 9). These results were confirmed by recent study with a similar design (14). Nydegger et al (14) showed that the 4% articaine formulation had the highest success rate and was statistically better than 4% lidocaine. Thus, the chemical makeup of the articaine, and not the concentration of the anesthetic formulation, appears to affect the anesthetic efficacy.

Concerning the epinephrine concentration, there is no significant differences between 4% articaine solutions of 1:100,000 epinephrine and 1:200,000 epinephrine when given as a primary buccal infiltration in the posterior mandible (11). Martin et al (10) have compared 1.8 mL and 3.6 mL 4% articaine with 1:100,000 epinephrine in a mandibular buccal infiltration of the first molar. They showed that the effectiveness of an infiltration of 4% articaine at the mandibular first molar depended on the dose

of solution injected. They found 1.8 mL provided anesthesia in 50% of the cases and 3.6 mL provided anesthesia in 70 % of the cases. The success was significantly difference between the two anesthetic volumes. However, there were no significant differences in the onset time of pulpal anesthesia and the pain of injection between two anesthetic volumes.

Splitting the administered dose between the buccal and lingual aspects was more effective than an injection on the buccal aspect alone in providing pulpal anesthesia in the mandibular incisor region (44). Nevertheless, this finding does not appear to be the case in the mandibular first molar region because there was no difference in effectiveness between a dose of 4% articaine and 2% lidocaine, both with 1:100,000 epinephrine, injected buccally compared with splitting the dose between the buccal and lingual aspects (32, 45). This finding suggests that accessory nerve supply from the lingual aspect is not important in mandibular molar innervation.

The success of the mechanism of infiltration at the mandibular first molar appeared to depend on the mental foramen (46). Meechan et al (47) conducted a trial to test whether this blockade is the result of infiltration through the cortex to the mandibular canal or entry into the canal via the mental foramen. The lingual infiltration cannot access the mental foramen and any effect would be caused by diffusion through the cortex. In this investigation, healthy adult participants received either a buccal or a lingual infiltration of 1.8 mL of 4% articaine with 1:100,000 epinephrine opposite the mandibular first molar. The results of this study showed that the buccal infiltration was more successful than the lingual infiltration for the first molars, first premolars and lateral incisors. In addition, the mechanism of action of articaine infiltration in the mandibular molar region may differ in male and female subjects. The study by Kwon et al. (13) showed that articaine buccal infiltration produced a higher anesthetic success rate in the mandibular second

premolar and first molar of Korean female patients. This may be associated with the higher prevalence of accessory mental foramens in Korean female patients (48). However, the prevalence of an accessory mental foramen varies between ethnic groups, appearing less frequently in Caucasian population (49). In addition, Robertson et al. (6) showed the pattern of anesthetic success for the four posterior mandibular teeth. The anesthetic solution appeared to diffuse anteriorly from the first molar site. That is, a higher success rate was recorded for both the premolar and first molar than for the second molar.

The efficacy of 4% articaine with epinephrine infiltration for the first molar pulpal anesthesia is comparable to an IANB with lidocaine or articaine (2, 32, 33). Monteiro et al (36) showed that articaine mandibular infiltration was superior as a primary technique to lidocaine IANB, and suggested that it could be an alternative to the gold standard IANB. However, single anesthetic techniques (BI or IANB) were not able to provide pain-free emergency endodontic treatment (Table 2).

Table 2 Comparison of the anesthetic success between buccal infiltration and IANB as the primary injection in the mandibular molars

Author	Pulpal status	BI		IANB		Difference
		Solution	Success rate	Solution	Success rate	
Corbett et al., 2008 (32)	normal	4% articaine	70%	2% lidocaine	56%	No sig.
Jung et al., 2008 (2)	normal	4% articaine	54%	4% articaine	43%	No sig.
Poorni et al., 2011 (33)	pulpitis	4% articaine	65%	2% lidocaine 4% articaine	65% 69%	No sig.
Monteiro et al., 2015 (36)	pulpitis	4% articaine	40%	2% lidocaine	10%	Sig.

The onset time and duration of anesthesia are important considerations when clinicians choose an anesthetic method for pulpal anesthesia. Previous studies reported the average onset time of 4-7 minutes when anesthetize mandibular first molar with articaine infiltration (2, 6, 10, 11, 32) which was significantly faster than did an IANB (2). However, pulpal anesthesia with buccal infiltration peaked between 16 and 28 minutes (14, 32) and then declined steadily during the 60 minutes (6, 10, 11, 43). A shorter duration of action may or may not be an advantage of articaine buccal infiltration over lidocaine IANB depending on the procedure undertaken, and a repeat infiltration may be required. Pabst et al (43) found that repeating an infiltration of a cartridge of 4% articaine at the mandibular first molar 25 minutes after the initial injection increased effectiveness from 28 through 109 minutes compared with results after a mock administration at 25 minutes.

Comparing with IANB, buccal infiltration is a simpler technique and has less unwanted soft tissue anesthesia (32). This is suitable for minimally procedures and may be preferred in certain patient groups such as those suffering from hemophilia which the buccal infiltration could reduce the chances of dangerous hemorrhage (32). Concerning the injection pain, the majority of patients experience mild pain with buccal infiltration (6, 10, 11).

Concerning the effect of epinephrine on pulpal blood flow, many studies reported a significant decrease in pulpal blood flow immediately after infiltration anesthesia followed by a gradual return to the pre-anesthetic state (50-52). However, adding epinephrine to local anesthetic solutions may help to retain the anesthetic in the pulp tissue by reducing the blood volume and flow in the pulp (53). Epinephrine potentiate and prolong the anesthetic efficacy (51).

Although there have been the reports of paresthesia associated with articaine use for mandibular nerve block (4, 5, 24), no subjects reported any paresthesia in previous buccal infiltration studies (6, 10, 11, 14), even though the injection site approximated the mental nerve. Gaffen and Haas (4) indicated that paresthesias are rare and unlikely with infiltration anesthesia.

Intraosseous (IO) injection

The intraosseous injection allows placement of a local anesthetic solution directly into the cancellous bone to anesthetize the sensory nerves of tooth. This technique requires a specialized equipment to perforate cortical bone. Examples of IO anesthetic system include the X-Tip (Dentsply Maillefer, Tulsa, USA.) and Stabident (Fairfax Dental Inc., Miami, USA.) which are two-step IO systems. They require an additional syringe for applying the anesthetic solution after the initial drilling step. IntraFlow (Pro-Dex Inc., Santa Ana, CA), Anesto (W&H Dentalwerk Bürmoos, Austria) and QuickSleeper (Dental Hi Tec, Cholet France) are single-step IO

systems with a rotary drilling syringe, allowing drilling and subsequent anesthetic solution application (20). Unlike other IO injection, the QuickSleeper is a computer-controlled anesthetic system.

Initially, the IO technique was used as a supplementary technique when the IANB failed, especially in cases of irreversible pulpitis. Studies have shown supplementary IO injection could substantially increase pulpal anesthetic success (54-56). The IO injection may lacked popularity because dentists were reluctant to drill into cortical bone and had difficulties inserting a needle precisely into the tight fit of the drilled hole in early techniques (57). However, many studies (7, 8, 16-19) used the IO injections as the primary technique for mandibular molars anesthesia and reported the success rates ranged from 74% to 100% (Table 3) which more reliable than the traditional IANB (8). Study results indicated that the onset after IO injection was almost immediate and duration of pulpal anesthesia steadily declined over the 60 minutes (7, 16, 19).

More recently developmental products such as QuickSleeper may gain in popularity as a primary technique for anesthetizing a single mandibular tooth. This technique can anesthetize multiple teeth depending on the injection site and volume of anesthetic injected. Various advantages of QuickSleeper IO injection have been reported such as less painful anesthesia and less soft tissue numbness (58, 59). Sixou and Barbosa-Rogier (59) used it for endodontic, restorative and extraction treatments and suggested it to be a good alternative or supplement to classic infiltration techniques in children and adolescents. However, it also has disadvantages. The duration of its application takes longer than conventional IANB, and the short duration of anesthetic effect makes it less favorable for long surgical treatments (58).

There was one study (60) that compared the degree of pulpal anesthesia obtained from the intraosseous and infiltration injections in maxillary lateral incisors.

The results showed no significant difference of the success rate between the two techniques. The mean time for the onset of pulpal anesthesia was significantly faster with the IO injection. And the infiltration injection resulted in a significantly longer duration of pulpal anesthesia.

When considering the cardiovascular effects, studies (16, 61) have reported a transient increase in heart rate after administration of vasopressor-containing anesthetic by IO injection. However, Pereira et al (18) and Replogle et al (61) showed that slow speed IO injection with vasopressor-containing anesthetic solutions did not induce significantly clinical changes in a healthy individual.

Table 3 Previous studies of intraosseous anesthesia as the primary technique in the mandibular molars

Author	n	IO system	Anesthetic solution	Volume (mL)	Pulpal status	Success rate
Coggins et al., 1996 (16)	40	Stabident	2% lidocaine with 1:100,000 epinephrine	1.8	normal	75%
Replogle et al., 1997 (19)	42	Stabident	2% lidocaine with 1:100,000 epinephrine	1.8	normal	74%
Gallatin et al., 2003 (17)	41	Stabident and X-tip	2% lidocaine with 1:100,000 epinephrine	1.8	normal	93-95%
Remmers et al., 2008 (8)	15	IntraFlow	2% lidocaine with 1:100,000 epinephrine	1.8	pulpitis	87%
Jensen et al., 2008 (7)	55	X-tip	2% lidocaine with 1:100,000 epinephrine	1.4	normal	94-100%
Pereira et al., 2013 (18)	60	X-tip	4% articaine with 1:100,000 or 1:200,000 epinephrine	0.9	pulpitis	93-97%

The computer-controlled local anesthetic delivery (C-CLAD) devices

The Computer-controlled local anesthetic delivery (C-CLAD) devices generally consist of a microprocessor and an electronically controlled motor. The devices are designed to reduce tissue distortion and reduce pain by controlling the volume, pressure and speed when anesthetic solution is delivered. These factors are difficult to control with the conventional needle and syringe (62).

The IO injection involves perforating the osseous cortex to permit deposition of local anesthetic within the cancellous bone. Adverse event such as separation of the metal perforator drills has been reported in previous studies (16, 61). Frictional heat that developed during perforation may have contributed to the failure of the perforator. Difficult penetrations requiring extended perforation times may generate more heat and therefore may be at higher risk for instrument separation (63). Furthermore, the frictional heat could be a consequential risk in damaging the adjacent bone. There were reports (16, 54, 61) of swelling and purulence at some Stabident injection sites with an incidence of 5% or less. These findings may be related to gingival or bone trauma during perforation (64).

Controlling speed, rotation torque and drilling time by computer is an approach to prevent instrument fractures (20). This was adopted by the QuickSleeper which is a computer-controlled local anesthetic delivery (C-CLAD) system. There was a study (20) compared different available IO systems on the risk of excessive heat generation and potential for root damage. It noted that a significantly lower torque was observed when advancing needle by the QuickSleeper system, as well as significantly less signs of heat generation.

Measurement of pulpal anesthesia

The use of electrical stimulation is considered a safe and precise method to evaluate pulpal anesthesia in vital asymptomatic teeth (65, 66). The absence of

perception to the maximum output of the pulp tester (80 reading) has been widely used as a criterion for pulpal anesthesia (1, 2, 6, 7, 9-11, 14, 16, 19, 32). However, a negative electric pulp test was no guarantee for pulpal anesthesia in irreversible pulpitis (37, 66). Driven et al. (66) found that 27% of the patients with irreversible pulpitis react to clinical instrumentation after not responding to the electric pulp tester. It may be that a maximum current output of the electric pulp tester was an inadequate stimulus.

Assessment of pain intensity

Four pain intensity rating scales, the Visual Analogue Scale (VAS), Numerical Rating Scale (NRS), Verbal Rating Scale (VRS), and Faces Pain Scale-Revised (FPS-R) are common measures of pain intensity used by clinicians and researchers (67). The VAS is a continuous scale consisting of a straight line, usually 100 mm in length, whose endpoints were represented by “no pain” and “worst imaginable pain”. The NRS is an 11-point scale consisting of integers from 0 through 10. Score 0 is “no pain” and score 10 is “worst imaginable pain”. The VRS is a 5-point scale consisting of phrases (no pain, mild pain, moderate pain, intense pain, maximum pain). The FPS-R is a 6-point scale with 6 different faces that represent increasing levels of pain intensity. Ferreira-Valente et al (67) found that the VAS and NRS responsiveness were superior than the other scales. The sensitivity was similar between the NRS and VAS (68).

Because, there are no guides for ratings other than the endpoints in the VAS, it may be difficult for the patient to use. Heft & Parker developed a graphic rating scale, so called Heft-Parker visual analog scale (69). It is a VAS with category word designations on the line that make it is easier to use than the traditional VAS. This Heft-Parker VAS was divided into 4 categories. No pain corresponded to 0 mm. Mild pain was defined as >0 mm and ≤54 mm (including the descriptors of faint, weak, and mild). Moderate pain was defined as >54 mm but <114 mm. Severe pain was

defined as ≥114 mm (including the descriptors strong, intense, and maximum possible). There were many clinical studies (6, 10, 11, 14) used the Heft-Parker VAS to identify the pain that subjects experienced during local anesthetic injections.

CHAPTER III

RESEARCH METHODOLOGY

Target Population

The mandibular first molars

Sample

The mandibular first molar (experimental tooth) and contralateral canine (control tooth) with vital asymptomatic pulp

Inclusion criteria

1. The subjects were students of Chulalongkorn university.
2. All subjects were in good health and were not taking any medication that would alter pain perception.
3. The subjects that have mandibular first molar and contralateral canine (unanesthetized control) with vital asymptomatic pulp.
4. Clinical examination indicated that all teeth were free of caries, large restorations, crowns, and periodontal disease and none had a history of trauma or sensitivity.

Exclusion criteria

We excluded subjects who were as follows;

1. Younger than 18 years of age.
2. Allergies to local anesthetics or sulfites, pregnancy, history of significant medical conditions (American Society Anesthesiologist classification 2 or higher), taking any medications that could affect anesthetic assessment.
3. There were active sites of pathosis and bony exostosis in the area of injection.
4. Inability to give informed consent.

Sample size calculation

Since, sample size calculation depended on the type of primary outcome measures which was the success rate of anesthetic techniques in this study. The sample size was calculated based on previous studies reporting 70% success rate of 4% articaine BI (10) and 100% success rate of 2% lidocaine IO (7), which had the difference of 30% in clinical success.

Martin et al (10) was used to calculate the sample size as this was the only one study that compared 3.6 mL and 1.8 mL of articaine. They showed that 3.6-mL volume of 4% articaine with 1:100,000 epinephrine produced a significantly higher success rate than the 1.8-mL volume in the mandibular first molar anesthesia.

Level of significance = 5%, Power = 80%, Type of test = two-sided

Formula of calculating sample size is (70)

$$n = \frac{(Z_{\alpha/2} + Z_{\beta})^2 \times [p_1(1-p_1)+p_2(1-p_2)]}{(p_1-p_2)^2}$$

where

n = sample size required in each group

p_1 = proportion of subject anesthetized by BI technique = 0.70

p_2 = proportion of subject anesthetized by IO technique = 1.00

p_1-p_2 = clinically significant difference = 0.30

$Z_{\alpha/2}$: This depends on level of significance, for 5% this is 1.96

Z_{β}: This depends on power, for 80% this is 0.84

Then $n = \frac{(1.96+0.84)^2 \times [0.7(0.3)+1(0)]}{(0.7-1)^2} = 18.3$

With a nondirectional alpha risk of 0.05 and a power of 80%, a sample size around 20 subjects was required to demonstrate a difference of ±30% in anesthetic success.

Independent Variable

Technique of anesthetic injection (intraosseous injection and buccal infiltration)

Dependent Variables

Anesthetic efficacy in 4 aspects;

1. Success rate of pulpal anesthesia
2. Onset of pulpal anesthesia
3. Duration of pulpal anesthesia
4. Injection pain and postoperative pain

Control variables

1. Type of local anesthetic agent (4% articaine with 1:100,000 epinephrine)
2. Gender of subjects (equal numbers of male and female)

Confounding Factors

Human error in anesthetic injection and measurement of anesthetic efficacy

Hypothesis

Ho: For mandibular first molars anesthesia;

1. Success rate of intraosseous injection was similar to buccal infiltration.
2. Onset of intraosseous injection was similar to buccal infiltration.
3. Duration of intraosseous injection was similar to buccal infiltration.

4. Injection pain and postoperative pain of intraosseous injection was similar to buccal infiltration.

Ethical Consideration

This research was approved from the Ethics Review Committee for Research Involving Human Research Subjects, Chulalongkorn University (HREC-DCU 2016-016).

Materials

1. QuickSleeper (Dental Hi Tec, Cholet France)
2. 4% articaine with 1:100,000 epinephrine (UbistesinTM forte; 3M ESPE, Seefeld, Germany)
3. Standard dental aspirating syringe
4. 30G-16 mm Needle (DHT, Dental Hi Tec)
5. 30G needle, 21 mm
6. Electric pulp tester (Kerr, Vitality Scanner 2006, SybronEndo, Orange, CA, USA)
7. Timer
8. Intraoral film

Methods

This study used a crossover design. The 20 asymptomatic subjects received 2 sets of intraosseous injection using 1.7 mL of 4% articaine with 1:100,000 epinephrine 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. Each subject serves as their own control. 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. The subjects were randomly assigned to each of the two anesthetic techniques using a blocked randomization list.

Pre-injection phase

1. Written informed consent was obtained from each subject.
2. Radiographs were taken to evaluate root proximity and tooth length.
3. Each subject was measured blood pressure and pulse rate.
4. Instructing the subject on how to rate the pain of the injection using a Heft-Parker visual analog scale (VAS).
5. The experimental mandibular first molars and the control contralateral canines were tested two times with an electric pulp tester to record baseline vitality. The teeth were isolated with cotton rolls and dried with an air syringe. Toothpaste was applied to the probe tip, which was placed in the middle third of the buccal surface of the tooth being tested. The current rate was set at 25 seconds to increase from no output (0) to maximum output (80). The value at the initial sensation was recorded.

Injection phase

6. The operator is a specialist who is familiar with both injection techniques. The following treatments were given by the same operator who had no involvement with assessing the outcome at two separated visit. The subjects were blindfolded during the operation:
    A. Buccal infiltration was administered by a standard dental aspirating syringe using 3.4 mL of 4% articaine with 1:100,000 epinephrine. The target site was centered over the buccal root apices of the mandibular first molar. A 30-gauge needle was gently placed at mucobuccal fold and advanced until the needle was estimated to be at or just superior to the apices of the tooth. The anesthetic solution was deposited over a period of 2 minute. During this injection, the subject heard the beeps and sounds that mimicked the operation of the QuickSleeper system.

B. Intraosseous injection using the QuickSleeper system and a 30-gauge needle 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 QuickSleeper injection was administered over a period of 2 minutes.

7. The blood pressure and pulse rate were monitored.

Post-injection phase

8. The subjects rated the injection pain on the VAS immediately after the injection
9. The blood pressure and pulse rate were monitored.
10. Pulpal anesthesia was monitored with the electric pulp tester by another investigator. 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.

11. All subjects were asked to complete postoperative surveys after each appointment using the same VAS. The subjects rated the 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 such as bruising, swelling, including duration of the problem.

Determination of Parameters

1. The pulpal anesthesia was no response from the subject at the maximum output, a reading of 80, on two consecutive measurements.
2. The onset of pulpal anesthesia was the time at the beginning of two consecutive maximum readings without sensation.
3. The duration of pulpal anesthesia was the time from the beginning of two consecutive maximum readings without sensation until the last of two responses at maximum output or the end of the 60 minutes of the trial, whichever was sooner.
4. Pain intensity was recorded by the Heft-Parker visual analog scale (Figure 1). The VAS was divided into 4 categories. No pain corresponded to 0 mm. Mild pain was defined as >0 mm and ≤54 mm (including the descriptors of faint, weak, and mild). Moderate pain was defined as >54 mm but <114 mm. Severe pain was defined as ≥114 mm (including the descriptors strong, intense, and maximum possible). Since all subjects of this study were Thai, the Heft-Parker VAS was translated into Thai language (Figure 2).

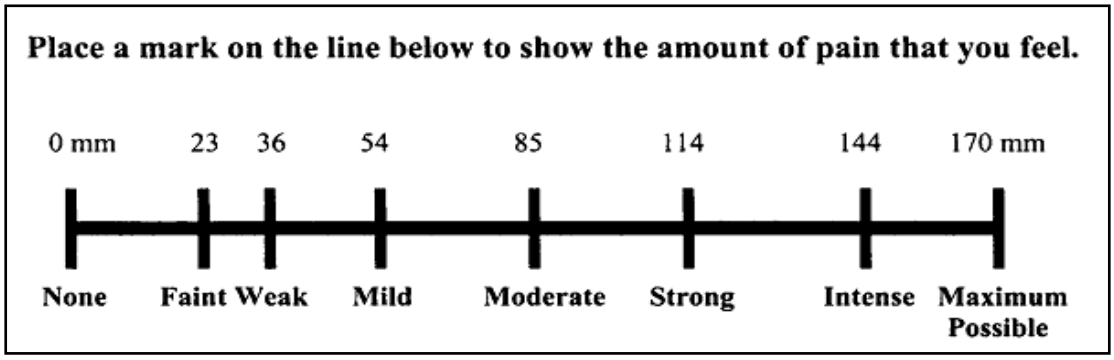


Figure 1 The Heft-Parker visual analog scale.

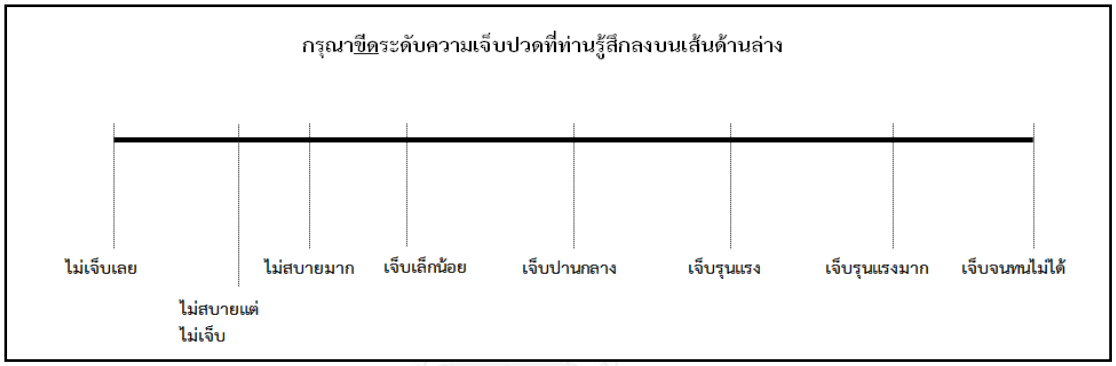


Figure 2 Translation of the Heft-Parker VAS to Thai.

Statistical analysis

The data were analyzed using Statistical Package for Social Science (SPSS) software (Version17; SPSS Inc., Chicago. IL). 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. Differences were considered significant at $P < 0.05$.

CHAPTER IV
RESEARCH RESULTS

Twenty subjects, consisting of 10 men and 10 women, participated in this study. All 20 subjects completed the trial. Mean age of the subjects was 24 years with a range of 18-30.

Success rates of pulpal anesthesia

The success rates of the two anesthetic techniques are presented in Table 4. 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 ($P > 0.05$).

Table 4 The anesthetic success of the intraosseous injection and buccal infiltration.

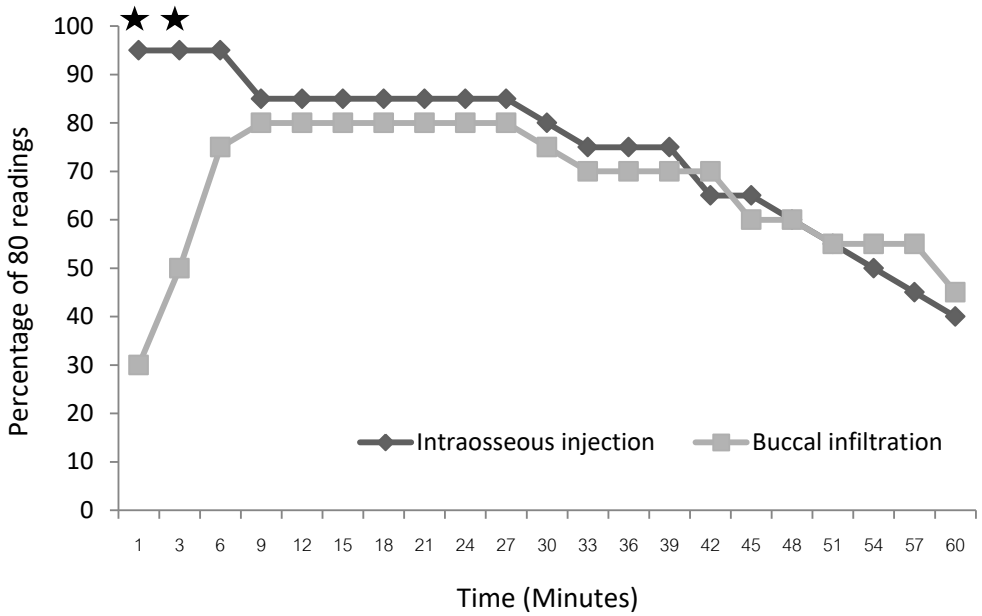
	Intraosseous injection	**Buccal infiltration**	***P* value**
Anesthetic success (%)	95 (19/20)	80 (16/20)	0.250*

n = 20

*There was no significant difference ($P > 0.05$) between the anesthetic techniques.

The incidence of pulpal anesthesia of the mandibular first molar as determined by lack of response to electric pulp testing at the maximum setting (percentage of 80 readings) at each postinjection time interval for the two anesthetic techniques is presented in Fig. 3. The intraosseous injections resulted in a significantly higher percentage occurred at 1 and 3 minutes ($P < 0.05$).

Figure 3 The percentage of 80 readings at each postinjection time interval for the intraosseous injection and buccal infiltration.



Significant differences ($P < 0.05$) are marked with a star (*).

Onset of pulpal anesthesia

The mean onset time of pulpal anesthesia was 1 minute for the intraosseous injection and 3.56 minutes for the buccal infiltration (Table 5). There was a significant difference between the two techniques ($P < 0.05$).

Table 5 The onset times of the intraosseous injection and buccal infiltration.

	Intraosseous injection	Buccal infiltration	*P* value
Onset time (min)	1	3.56 ± 2.58	0.004[†]

n = 16

[†]There was a significant difference ($P < 0.05$) between the anesthetic techniques.

Duration of pulpal anesthesia

The duration of pulpal anesthesia showed a steady decline over the 60-minute observation period for both anesthetic techniques (Fig.3). 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.

Injection pain and postoperative pain

The percentage of pain rating of each injection technique is presented in Table 6. There was no significant difference in injection pain between the two anesthetic techniques ($P > 0.05$). Similarly, there were no significant differences in the postoperative pain ratings between the anesthetic techniques ($P > 0.05$) (Table 7).

Table 6 The percentage and mean of pain ratings of each injection technique.

Injection pain	None (%)	Mild (%)	Moderate (%)	Severe (%)	Mean VAS ± SD (mm)
Intraosseous injection	0 (0/20)	60 (12/20)	40 (8/20)	0 (0/20)	47 ± 21
Buccal infiltration	10 (2/20)	65 (13/20)	20 (4/20)	5 (1/20)	36 ± 39
					$P = 0.082$*

SD, standard deviation.

n = 20

*There was no significant difference ($P > 0.05$) between the anesthetic techniques.

Table 7 The percentage and mean of pain ratings of postoperative survey

Injection phase	None (%)	Mild (%)	Moderate (%)	Severe (%)	Mean VAS ± SD (mm)
Day 0 (day of injection when soft tissue anesthesia wore off)					
Intraosseous injection	20 (4/20)	55 (11/20)	25 (5/20)	0 (0/20)	29 ± 33
Buccal infiltration	5 (1/20)	50 (10/20)	40 (8/20)	5 (1/20)	47 ± 31
					P = 0.079*
Day 1					
Intraosseous injection	25 (5/20)	55 (11/20)	20 (4/20)	0 (0/20)	32 ± 34
Buccal infiltration	5 (1/20)	75 (15/20)	20 (4/20)	0 (0/20)	35 ± 27
					P = 0.711*
Day 2					
Intraosseous injection	40 (8/20)	45 (9/20)	15 (3/20)	0 (0/20)	19 ± 24
Buccal infiltration	10 (2/20)	70 (14/20)	20 (4/20)	0 (0/20)	30 ± 27
					P = 0.223*
Day 3					
Intraosseous injection	55 (11/20)	45 (9/20)	0 (0/20)	0 (0/20)	7 ± 12
Buccal infiltration	30 (6/20)	60 (12/20)	10 (2/20)	0 (0/20)	23 ± 27
					P = 0.064*

SD, standard deviation.

n = 20

*There were no significant differences ($P > 0.05$) between the anesthetic techniques.

Postoperative complications

Several subjects reported postoperative 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.

CHAPTER V
DISCUSSION

Buccal infiltration and the intraosseous injection, alternative techniques to IANB, have been widely evaluated as a primary method for mandibular molar anesthesia (2, 6, 8-10, 13, 19). 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 Dreven *et al.* (66) and Certosimo and Archer (65) 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.* (7) who reported a 100% success rate of a primary intraosseous injection for mandibular first molar anesthesia. Similarly, Gallatin *et al*. (17) found a 93% success rate for the Stabident and X-tip intraosseous injections of 2% lidocaine with 1:100,000 epinephrine. In contrast, Coggins *et al.* (16) and Replogle *et al.* (19), 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 (16, 17, 19) 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. Coggins *et al*.(16) and Replogle et al. (61) also reported a transient increase in heart rate after the intraosseous injection of vasopressor-containing anesthetic. However, studies by Pereira *et al*. (18) and Replogle *et al*. (61) found that slow speed intraosseous injection did not induce a clinically significant heart rate change in healthy individuals. 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.* (10) 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, 2 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. Roberson *et al.* (6) found a success rate of 87%. However, most studies have reported success rates not exceeding 70% (2, 9-14, 32).

Gender may be a factor affecting the success rate of buccal infiltration of the mandibular first molar. Kwon *et al.* (13) 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 foramina in Korean female patients (48). There is evidence supporting that the mental foramen is important in the mechanism of action of buccal infiltration of the mandibular first molar (47). It plays an important part in allowing the anaesthetic solution access to the inferior alveolar nerve. In addition, cortical bone thickness may be a factor that determines the effectiveness of articaine infiltration (71). 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 finishing the intraosseous injections. Previous studies (7, 17, 60) 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.* (10) 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 (2, 6, 10-12, 32) 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. 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 (7, 16, 17, 19) and buccal infiltration (6, 10-12) have shown a similar effect.

In the present study, 2 subjects lost pulpal anaesthesia in 9 minutes after intraosseous injection which was not clinically practical. This may be because the anaesthetic solution leaked during the injection or the needle position 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 (10, 11, 72).

The postoperative pain ratings were not significantly different between the two anesthetic techniques for day 0 through day 3. The incidence of postoperative pain decreased over the 3 days. However, there was a difference in the character of the postoperative 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 (10, 16, 19). 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 postoperative pain level felt by study subjects. Martin *et*

al. (10) and Pabst *et al.* (43) reported that their subjects experienced more postoperative 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 (16, 19, 72) 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 (6, 10, 11, 14, 43).

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 (73).

Limitations

The results may not apply to children or the elderly, because our study used a young adult population. 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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APPENDIX

APPENDIX A

DATA FORM

Subject No. ..... Name .....

Visit 1: Code ..... Date .....

Visit 2: Code ..... Date .....

Injection phase	Visit 1		Visit 2	
	Blood pressure	Pulse rate	Blood pressure	Pulse rate
Before	/		/	
During	/		/	
After	/		/	

EPT record of mandibular 1st molar (test)

V	Minutes																					
	0	1	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48	51	54	57	60
1																						
2																						

EPT record of contralateral canine (control)

Visit	Minutes																					
	0		3			12			21			30			39			48			57	
1																						
2																						

APPENDIX B

Table 8 Raw data of the anesthetic success and onset time of intraosseous injection and buccal infiltration.

No.	Success (1 = yes, 0 = no)		Onset time (minutes)	
	IO	BI	IO	BI
1	1	1	1	1
2	1	1	1	6
3	1	1	1	1
4	1	1	1	3
5	1	1	1	1
6	1	1	1	9
7	1	1	1	1
8	0	0	-	-
9	1	1	1	1
10	1	1	1	6
11	1	0	1	-
12	1	0	1	-
13	1	1	1	6
14	1	1	1	1
15	1	1	1	6
16	1	1	1	3
17	1	1	1	3
18	1	1	1	6
19	1	1	1	3
20	1	0	1	-

Table 9 Raw data of the incidence of pulpal anesthesia at each postinjection time interval for intraosseous injection.

No.	Intraosseous injection																				
	Postinjection time (minutes)																				
	1	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48	51	54	57	60
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0
2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0
4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0
5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
6	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
7	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0
10	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
11	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
12	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
13	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0
14	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
16	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
17	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
19	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0
20	1	0	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0

1 = Success in pulpal anesthesia.

0 = Failure to achieve pulpal anesthesia.

Table 10 Raw data of the incidence of pulpal anesthesia at each postinjection time interval for buccal infiltration.

No.	Buccal infiltration																				
	Postinjection time (minutes)																				
	1	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48	51	54	57	60
1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	0	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0
3	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
4	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
6	1	1	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0
7	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
10	1	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0
11	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
14	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
15	1	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
16	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
17	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0
18	1	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
19	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

1 = Success in pulpal anesthesia.

0 = Failure to achieve pulpal anesthesia.

Table 11 Raw data of the injection pain and postoperative pain.

No.	Injection pain (mm.)		Postoperative pain (mm.)							
	IO	BI	IO0	IO1	IO2	IO3	BI0	BI1	BI2	BI3
1	51	59	40	25	0	0	114	54	45	28
2	23	10	11	0	0	0	78	63	62	54
3	49	18	5	48	58	30	33	25	24	3
4	62	9	0	0	0	0	45	63	57	54
5	51	0	23	1	0	0	55	26	6	3
6	54	12	0	0	0	0	3	0	0	0
7	23	36	0	85	36	23	36	23	36	23
8	69	160	0	25	3	0	97	88	89	89
9	48	58	3	7	50	3	79	75	67	57
10	16	18	65	97	48	2	58	26	18	0
11	16	0	78	45	7	3	2	7	0	0
12	69	68	99	54	0	0	61	54	52	48
13	64	2	89	54	16	0	23	14	4	0
14	45	3	72	94	62	29	64	50	23	11
15	66	54	17	0	0	0	56	54	54	54
16	37	51	6	12	6	1	18	4	1	0
17	57	26	25	70	63	30	0	12	11	0
18	58	79	14	0	0	0	42	6	2	2
19	6	2	11	23	26	17	42	50	50	23
20	85	45	19	5	1	0	26	7	4	2

APPENDIX C

Table 12 McNemar Test with SPSS program

Intraosseous Injection & Buccal Infiltration

	Buccal Infiltration	
Intraosseous Injection	failure	success
failure	1	0
success	3	16

Test Statistics[b]

	Intraosseous Injection & Buccal Infiltration
N	20
Exact Sig. (2-tailed)	.250[a]

a. Binomial distribution used.

b. McNemar Test

Table 13 Descriptive Statistics with SPSS program

Descriptive Statistics

	N	Mean	Std. Deviation	Minimum	Maximum
onsetIO	19	1.00	.000	1	1
onsetBI	16	3.56	2.581	1	9

Descriptive Statistics

	N	Mean	Std. Deviation	Minimum	Maximum
IO injection pain	20	47.45	21.087	6	85
BI injection pain	20	35.50	38.804	0	160

Descriptive Statistics

	N	Mean	Std. Deviation	Minimum	Maximum
IO postop pain day0	20	28.85	32.832	0	99
BI postop pain day0	20	46.60	30.882	0	114
IO postop pain day1	20	32.25	33.817	0	97
BI postop pain day1	20	35.05	26.637	0	88
IO postop pain day2	20	18.80	24.317	0	63
BI postop pain day2	20	30.25	27.401	0	89
IO postop pain day3	20	6.90	11.539	0	30
BI postop pain day3	20	22.55	27.185	0	89

Table 14 Normality test with SPSS program

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
IO injection pain	.160	20	.190	.946	20	.305
BI injection pain	.180	20	.088	.814	20	.001

a. Lilliefors Significance Correction

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
IO postop pain day0	.247	20	.002	.809	20	.001
IO postop pain day1	.185	20	.072	.855	20	.007
IO postop pain day2	.286	20	.000	.753	20	.000
IO postop pain day3	.382	20	.000	.627	20	.000
BI postop pain day0	.087	20	.200*	.970	20	.762
BI postop pain day1	.183	20	.078	.919	20	.096
BI postop pain day2	.162	20	.179	.899	20	.039
BI postop pain day3	.264	20	.001	.802	20	.001

a. Lilliefors Significance Correction

*. This is a lower bound of the true significance.

Table 15 Wilcoxon Signed Ranks Test with SPSS program

Test Statistics[b]

	onsetBI - onsetIO
Z	-2.859[a]
Asymp. Sig. (2-tailed)	.004

a. Based on negative ranks.

b. Wilcoxon Signed Ranks Test

Test Statistics[b]

	BI injection pain - IO injection pain
Z	-1.736[a]
Asymp. Sig. (2-tailed)	.082

a. Based on positive ranks.

b. Wilcoxon Signed Ranks Test

Test Statistics[b]

	BI postop pain day0 - IO postop pain day0	BI postop pain day1 - IO postop pain day1	BI postop pain day2 - IO postop pain day2	BI postop pain day3 - IO postop pain day3
Z	-1.755[a]	-.370[a]	-1.220[a]	-1.850[a]
Asymp. Sig. (2-tailed)	.079	.711	.223	.064

a. Based on negative ranks.

b. Wilcoxon Signed Ranks Test

VITA

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