

# Articaine buccal infiltration enhances the effectiveness of lidocaine inferior alveolar nerve block

M. D. Kanaa, J. M. Whitworth, I. P. Corbett & J. G. Meechan

School of Dental Sciences, Newcastle University, Newcastle upon Tyne, UK

## Abstract

**Kanaa MD, Whitworth JM, Corbett IP, Meechan JG.**

Articaine buccal infiltration enhances the effectiveness of lidocaine inferior alveolar nerve block. *International Endodontic Journal*, 42, 238–246, 2009.

**Aim** To compare mandibular tooth pulpal anaesthesia and reported discomfort following lidocaine inferior alveolar nerve block (IANB) with and without supplementary articaine buccal infiltration.

**Methodology** In this prospective randomized double-blind cross-over study, thirty-six healthy adult volunteers received two IANB injections of 2 mL lidocaine 2% with epinephrine 1 : 80 000 over two visits. At one visit, an infiltration of 2 mL of articaine 4% with epinephrine 1 : 100 000 was administered in the mucobuccal fold opposite a mandibular first molar. At the other visit, a dummy injection was performed. Injection discomfort was recorded on 100 mm visual analogue scales. Pulpal anaesthesia of first molar, premolar, and lateral incisor teeth was assessed with an electronic pulp tester until 45 min post-injection. A successful outcome was recorded in

the absence of sensation on two or more consecutive maximal pulp tester stimulations. Data were analysed using McNemar and Student's *t*-tests.

**Results** The IANB with supplementary articaine infiltration produced more success than IANB alone in first molars (33 volunteers vs. 20 volunteers respectively,  $P < 0.001$ ), premolars (32 volunteers vs. 24 volunteers respectively,  $P = 0.021$ ) and lateral incisors (28 volunteers vs. 7 volunteers respectively,  $P < 0.001$ ). Buccal infiltration with articaine or dummy injection produced less discomfort than IANB injection ( $t = 4.1$ ,  $P < 0.001$ ;  $t = 3.0$ ,  $P = 0.005$  respectively).

**Conclusions** The IANB injection supplemented with articaine buccal infiltration was more successful than IANB alone for pulpal anaesthesia in mandibular teeth. Articaine buccal infiltration or dummy buccal infiltration was more comfortable than IANB.

**Keywords:** articaine, dental local anaesthesia, inferior alveolar nerve block, infiltration anaesthesia, lidocaine, teeth.

Received 30 April 2008; accepted 18 October 2008

## Introduction

Local anaesthetics provide adequate pain relief for the majority of dental procedures, however, failures do occur. These may be the result of anatomical, pharmacological, pharmaceutical, pathological, psychological or technical factors (Byers *et al.* 1990, Wong &

Jacobsen 1992, Quinn 1998, Hargreaves & Keiser 2002, Meechan 2005).

Anaesthesia for adult mandibular teeth is usually obtained by regional block of the inferior alveolar nerve (IANB) (Nist *et al.* 1992, McLean *et al.* 1993, Dunbar *et al.* 1996). Wong & Jacobsen (1992) stated that half of the local anaesthetic injections in the United States each year were IANB. The reported success of IANB injection is varied ranging between 30% and 97% (Montagnese *et al.* 1984, Donkor *et al.* 1990, Nist *et al.* 1992, McLean *et al.* 1993, Dagher *et al.* 1997, Hannan *et al.* 1999, Yonchak *et al.* 2001a).

Correspondence: John G. Meechan, School of Dental Sciences, Newcastle University, Framlington Place, Newcastle upon Tyne NE2 4BW, UK (e-mail: j.g.meechan@ncl.ac.uk).

Methods used to overcome failure of IANB include the use of supplementary techniques such as intraligamentary or intraosseous injections (Nusstein *et al.* 2005, Prohic *et al.* 2005, Bigby *et al.* 2006).

The aim of the present study was to investigate the effectiveness of supplementary buccal infiltration anaesthesia as a means of increasing the efficacy of IANB. Articaine has previously been shown to provide more effective anaesthesia than lidocaine when administered as a mandibular infiltration (Kanaa *et al.* 2006b, Robertson *et al.* 2007) and so the former drug was the agent employed for the supplemental injection. The null hypothesis was that lidocaine IANB and lidocaine IANB supplemented by articaine buccal infiltration are equally effective in securing pulpal anaesthesia in mandibular teeth.

## Materials and methods

### Study design

A randomized controlled double-blind cross-over study design was employed. Each subject received two treatments at an interval of at least 1 week in a dental surgery within a Dental Hospital. All local anaesthetic injections were given by the same operator (IPC). The volunteers and the investigator of anaesthetic outcome (MDK) were blinded to the local anaesthetic technique used at each visit.

### Power calculation

Using data from an earlier study (Rood 1976), a power calculation dictated that a study with 36 subjects had 90% power to detect a difference in success rate of 21% in a continuous outcome measure assuming a significance level of 5% and a correlation of 0.5 between responses from the same subject.

### Official clearances

This study was approved by the institutional review board, the local research ethics committee and the UK Medicines and Healthcare products Regulatory Agency.

### Study population and technique applications

An information sheet explaining the details of the study was given to every volunteer who participated in the

trial. The previous medical history was recorded on a standard proforma. Eligibility criteria included volunteers aged 18 years and over with a vital mandibular first molar, first or second premolar and lateral incisor on one side of the mouth. Exclusion criteria included allergy to amide local anaesthetics, pregnancy, bleeding disorders and neurological conditions. Participants provided informed, written consent. An IANB injection using the Halstead approach with 2.0 mL lidocaine 2% with epinephrine 1 : 80 000 (Lignospan Special, Septodont, Maidstone, UK) was administered over 60 s on two occasions separated by at least 1 week. A standard aspirating dental cartridge syringe (Ultra Safety Plus XL; Septodont, St Maur Des Fosses, France) fitted with a 27-gauge, 35-mm needle was used. At one visit, following the IANB a dummy injection without drug administration was performed in the mucobuccal fold adjacent to the mandibular first molar. The dummy injection involved inserting a 30-gauge, 25-mm needle for 30 s (treatment 1). Alternatively, a supplementary buccal infiltration of 2.0 mL 4% articaine with 1 : 100 000 epinephrine (Septanest, Septodont) was administered in the mucobuccal fold adjacent to the mandibular first molar over 30 s using a 30-gauge, 25-mm needle (treatment 2). This dose was chosen as it was similar to that used in earlier investigations that demonstrated articaine infiltration to be effective in obtaining pulpal anaesthesia in the mandibular first molar (Kanaa *et al.* 2006b, Robertson *et al.* 2007). The order of dummy penetration or articaine infiltration was randomized using a computer generated programme of random numbers (JGM). All injections were given by the same operator (IPC), who had no involvement in assessing outcome. All volunteers received both treatments on the right hand side of their mouth. Aspiration was performed before depositing any local anaesthetic solution. Immediately on needle withdrawal, volunteers were asked to self-record the discomfort associated with the injection on standard 100 mm visual analogue scales (VAS) with endpoints tagged as 'no pain' (0 mm) and 'unbearable pain' (100 mm). The individual testing anaesthetic efficacy (MDK) was blinded to the randomized injection treatment over the visits. Pulp sensitivity was determined with an Analytic Technology Pulp Tester (Analytic Technology, Redmond, WA, USA). The pulp tester was set to deliver a 0-80 digital reading on a rate setting of five, corresponding to a nonlinear increasing voltage, zero to maximum, over 30 s. Calibration of the pulp tester demonstrated a maximum voltage of 270 V at an output impedance of 140 K $\Omega$ . Testing was

performed on the mandibular first molar, first or second premolar (all in first premolars except six who had received orthodontic treatment where their first premolars were removed) and lateral incisor of the anaesthetized side of the mandible twice before injection to establish a baseline reading. Baseline pulp sensation was taken as the mean of these two readings. Pulp testing was then repeated every 2 min after injection for the first 10 min and then at 5-min intervals for 45 min post-injection. In order to test the validity of the reading, the canine on the other side of the lower jaw was also tested at base line twice, at 10 min and at the end of the trial (45 min). The criterion for successful anaesthesia was no response to maximum stimulation on two or more consecutive readings. The number of episodes of no response at the maximal stimulation of 80 reading was also recorded. The onset of pulpal anaesthesia was considered as the first episode of no response to maximal stimulation (two or more consecutive 80 readings). The duration of anaesthesia was similarly taken as the time from the first of at least two consecutive maximum readings without sensation until the onset of more than two responses at less than maximum stimulation or the end of the 45 min of the trial, whichever was sooner.

Data were analysed by McNemar and Student's *t*-tests in SPSS (SPSS 14.0, SPSS Inc., Chicago, IL, USA).

## Results

Thirty-six healthy adult volunteers were recruited; predominantly from the local University population, including dental students. The volunteers were recruited between September 2006 and February 2007. All those recruited completed the trial. Eighteen subjects of each gender with an age range of 20–37 years

(mean 23.8 years, SD 3.2) participated. Eighteen volunteers received articaine buccal infiltration with IANB at the first visit.

### Number of episodes of maximal stimulation (80 reading) without sensation

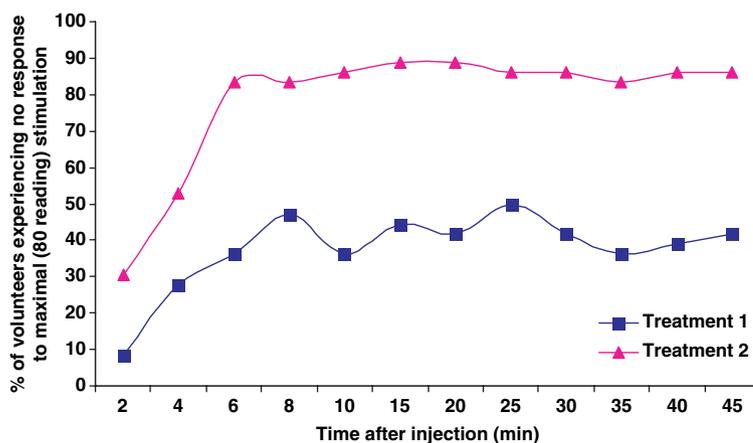
Figures 1, 2 and 3 show the percentage of volunteers with no pulp response to maximal pulp tester stimulation (80 reading) in first molars, premolars and lateral incisors respectively at time intervals after the two interventions. IANB with supplemental articaine buccal infiltration produced significantly more episodes of no response than IANB alone for first molars (339 cases vs. 162 cases respectively, McNemar test  $P < 0.001$ ), premolars (333 cases vs. 197 cases respectively, McNemar test  $P < 0.001$ ) and lateral incisors (227 cases vs. 63 cases respectively, McNemar test  $P < 0.001$ ).

### Successful pulpal anaesthesia

Table 1 shows that thirty-three (91.7%) volunteers experienced anaesthetic success in first molar teeth (two or more consecutive episodes of maximal stimulation without sensation) following lidocaine IANB injection supplemented with articaine buccal infiltration (treatment 2) compared to 20 (55.6%) after lidocaine IANB injection alone (treatment 1). This difference was significant ( $P < 0.001$ ).

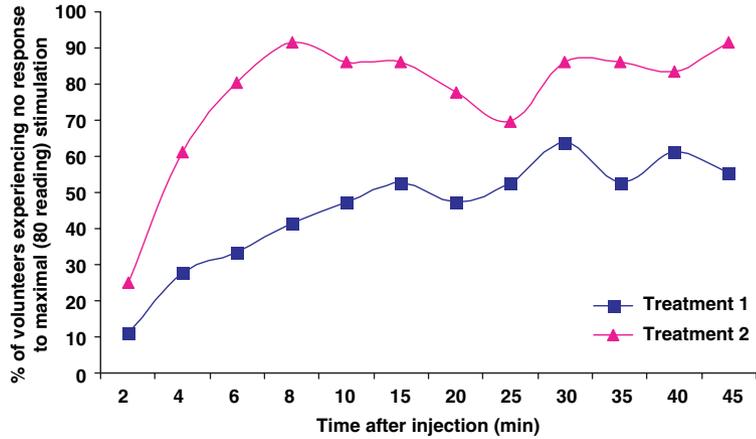
Thirty-two (88.9%) volunteers experienced anaesthetic success in premolars following treatment 2, compared to 24 (66.7%) after treatment 1 (Table 1). This difference was significant ( $P = 0.021$ ).

Twenty-eight (77.8%) volunteers experienced anaesthetic success in lateral incisors following treatment 2,

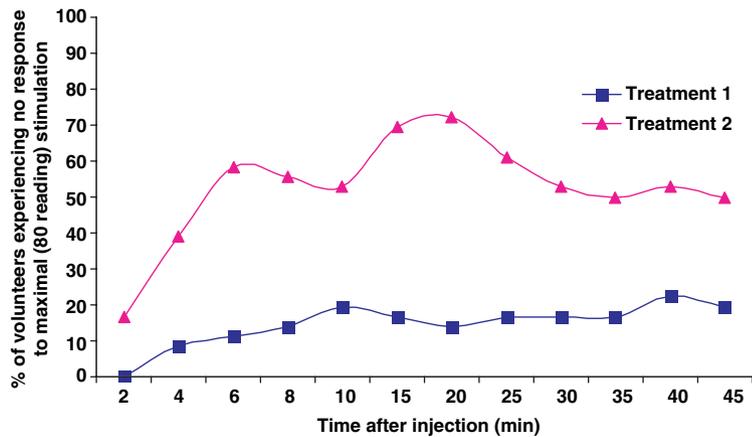


**Figure 1** Percentage of volunteers reporting no sensation on maximum stimulation (80 reading) in first molars at time intervals after IANB with articaine buccal infiltration (treatment 2) compared to IANB with dummy buccal injection (treatment 1).

**Figure 2** Percentage of volunteers reporting no sensation on maximum stimulation (80 reading) in premolars at time intervals after IANB with articaine buccal infiltration (treatment 2) compared to IANB with dummy buccal injection (treatment 1).



**Figure 3** Percentage of volunteers reporting no sensation on maximum stimulation (80 reading) in lateral incisors at time intervals after IANB with articaine buccal infiltration (treatment 2) compared to IANB with dummy buccal injection (treatment 1).



**Table 1** Number (n) and percentage (%) of anaesthetic success for the 36 volunteers' first molars, premolars and lateral incisors after IANB with articaine buccal infiltration compared to IANB with dummy buccal injection

Anaesthesia success ≥2 consecutive 80 reading	IANB with arti- caine buccal		IANB with dum- my buccal		McNemar test, P-value
	Failure, n (%)	Success, n (%)	Failure, n (%)	Success, n (%)	
First molar	3 (8.3)	33 (91.7)	16 (44.4)	20 (55.6)	<0.001
Premolars	4 (11.1)	32 (88.9)	12 (33.3)	24 (66.7)	0.021
Lateral incisors	8 (22.2)	28 (77.8)	29 (80.6)	7 (19.4)	<0.001

IANB, inferior alveolar nerve block.

compared to 7 (19.4%) after treatment 1 (Table 1). This difference was again significant ( $P < 0.001$ ).

### Onset of pulp anaesthesia

Table 2 shows the onset of pulpal anaesthesia for first molars, premolars and lateral incisors after treatments

1 and 2. Onset of premolar pulp anaesthesia was significantly quicker after treatment 2 than treatment 1 ( $P = 0.002$ ) although no differences between the two treatments were noted in first molars ( $P = 0.06$ ) or lateral incisors ( $P = 0.40$ ).

### Duration of pulp anaesthesia

Table 3 shows the duration of pulpal anaesthesia for first molars, premolars and lateral incisors after treatments 1 and 2. First molar and premolar pulp anaesthesia lasted longer after treatment 2 than treatment 1 ( $P = 0.001$ ,  $P = 0.013$  respectively) although this was not noted in lateral incisor teeth ( $P = 0.90$ ).

### Injection discomfort

Table 4 shows that dummy buccal injection and buccal infiltration with articaine produced less discomfort than IANB injections ( $t = 3.0$ ,  $P = 0.005$ ;  $t = 4.1$ ,  $P < 0.001$  respectively). There was no significant

**Table 2** Ranges of onset of pulpal anaesthesia for the 36 volunteers' first molars, premolars and lateral incisors after IANB plus dummy buccal injection (T1) compared to IANB plus articaine buccal infiltration (T2)

Onset of pulp anaesthesia	First molar		Premolar		Lateral incisor	
	T1	T2	T1	T2	T1	T2
Number	20	33	24	32	7	28
Mean (min)	6.8	4.5	8.9	4.2	10.9	6.9
Median (min)	5.0	4.0	6.0	4.0	6.0	5.0
SD (min)	5.8	2.7	7.9	1.8	11.3	6.2
Minimum (min)	2.0	2.0	2.0	2.0	4.0	2.0
Maximum (min)	25.0	15.0	30.0	8.0	35.0	30.0
Independent test	$t = 1.9, P = 0.06$		$t = 3.3, P = 0.002$		$t = 1.3, P = 0.40$	

IANB, inferior alveolar nerve block; SD, standard deviation.

**Table 3** Ranges of duration of pulpal anaesthesia for the 36 volunteers' first molars, premolars and lateral incisors after IANB plus dummy buccal penetration (treatment 1: T1) compared to IANB plus articaine buccal infiltration (treatment 2: T2)

Duration of anaesthesia	First molar		Premolar		Lateral incisor	
	T1	T2	T1	T2	T1	T2
Number	20	33	24	32	7	28
Mean (min)	29.0	38.8	31.3	37.8	29.1	30.0
Median (min)	36.5	41.0	37.0	41.0	39.0	34.5
SD (min)	13.9	6.0	10.9	8.1	15.7	12.8
Minimum (min)	2.0	17.0	6.0	9.0	4.0	5.0
Maximum (min)	43.0	43.0	43.0	43.0	41.0	43.0
Independent test	$t = 3.5, P = 0.001$		$t = 2.6, P = 0.013$		$t = 0.13, P = 0.90$	

IANB, inferior alveolar nerve block; SD, standard deviation.

**Table 4** Discomfort recorded on VAS (0–100 mm) after each injection for 36 volunteers after both treatments

VAS (mm)	Treatment 1		Treatment 2	
	IANB injection	Buccal penetration	IANB injection	Buccal infiltration
Mean	32.2	21.5	34.7	21.7
SD	19.9	17.0	18.7	18.1
Median	28.5	15.0	28.3	17.3
Minimum	7.0	0.0	4.0	0.0
Maximum	81.0	71.0	76.0	77.0
Paired samples test	$t = 3.0, P = 0.005$		$t = 4.1, P < 0.001$	

VAS, visual analogue scales; IANB, inferior alveolar nerve block; SD, standard deviation.

difference between IANB injections between visits (Paired samples test:  $t = 0.61, P = 0.54$ ) or between dummy buccal injection and articaine buccal infiltrations (Paired samples test:  $t = 0.07, P = 0.95$ ).

### Adverse events

No adverse events were reported during the investigation.

## Discussion

Earlier investigations have studied the effects of lidocaine infiltration as a means of supplementing IANB. One study (Rood 1976) showed an increase in success when supplementary lidocaine buccal infiltration was used to overcome failed IANB injections during different dental procedures. A more recent study reported that lidocaine buccal or lingual infiltration supplementary to lidocaine IANB did not produce better pulpal anaesthesia than lidocaine IANB injection alone (Foster *et al.* 2007). Based on earlier findings (Kanaa *et al.* 2006b), Foster *et al.* (2007) suggested that articaine infiltration may be a more beneficial supplementary injection to lidocaine IANB injection.

### Anaesthetic efficacy

In the current study, lidocaine IANB injection supplemented with an articaine buccal infiltration (treatment 2) produced significantly more episodes of no pulp response to the maximal stimulation on pulp testing than lidocaine IANB injection alone (treatment 1) in first molars, premolars and lateral incisors (Figs 1–3). Recent

studies using a similar volume of anaesthetic in the buccal sulcus found that articaine infiltration was more effective than lidocaine in posterior teeth pulp anaesthesia (Kanaa *et al.* 2006b, Robertson *et al.* 2007). The results of the present study showed that lidocaine IANB injection supplemented with an articaine buccal infiltration was significantly more successful than lidocaine IANB injection alone for mandibular first molar, premolar and lateral incisor pulp anaesthesia. It is not possible to state what amount of anaesthetic is required during the buccal infiltration to achieve this effect as the present study only investigated a single dose.

The results presented in the current study for success with IANB alone appear to be low in comparison to those clinicians experience in practice (Rood 1976, Hintze & Paessler 2006); however, this study employed very stringent criteria to define success. Electronic pulp testing has become the standard method of assessing the efficacy of pulpal anaesthesia in local anaesthetic trials (McLean *et al.* 1993, Dagher *et al.* 1997, Hannan *et al.* 1999, Yonchak *et al.* 2001b, Kanaa *et al.* 2006b, Meechan *et al.* 2006). The use of an electronic pulp tester to assess pulpal anaesthesia can be criticized in that it is possible to elicit a response from the periodontium. The technique, however allows some degree of standardization between studies and a recent review considered it a useful means for measurement of local anaesthesia in the research setting (Lin & Chandler 2008). The results of the present investigation for first molar pulp anaesthesia following IANB alone are comparable to those published recently (Foster *et al.* 2007, Jung *et al.* 2008) and within the range (42–73%) of previous reports (Nist *et al.* 1992, McLean *et al.* 1993, Dunbar *et al.* 1996, Reitz *et al.* 1998, Clark *et al.* 1999) when similar criteria are employed. In the present study, similar results were found for premolar pulp anaesthesia with IANB injected alone in comparison with Foster *et al.*'s study (54–67%) and within the range (23–93%) of others (Nist *et al.* 1992, Childers *et al.* 1996, Dunbar *et al.* 1996, Reitz *et al.* 1998, Clark *et al.* 1999).

There are a number of reasons why the supplementary articaine injection improved anaesthesia. One could argue that the higher success may be due to the increased dose of local anaesthetic solution, however, as mentioned above Foster *et al.* (2007), found no significant improvement when a lidocaine infiltration was added to an IANB. Therefore, an increase in anaesthetic dose is not the whole explanation. Other reasons for the increase in efficacy afforded by the articaine infiltration could be the result of articaine diffusing through the buccal cortex to reach the inferior

alveolar nerve or by diffusion through the mental foramen to reach this nerve (Whitworth *et al.* 2007). The design of the present study cannot differentiate between these two possibilities but this is currently being considered in further investigations. Interestingly, the success of first molar pulpal anaesthesia following lidocaine IANB supplemented by articaine buccal infiltration in the present study was higher than that reported following IANB injection plus incisive or mental nerve block (Nist *et al.* 1992, Clark *et al.* 1999) or intraligamentary anaesthesia plus IANB (Childers *et al.* 1996). For premolars, the current success was comparable to the study of Nist *et al.* (1992) when a similar definition of success was applied. Another possibility is that the buccal infiltration counters any accessory supply from nerves approaching the pulps from sources other than the inferior alveolar nerve such as the long buccal or cervical nerves (Heasman & Beynon 1986); however, the results of Foster *et al.* (2007) do not support such a hypothesis.

Intraosseous anaesthesia (IO) has been reported as a successful supplementary technique when conventional IANBs fail to provide adequate pulp anaesthesia (Nusstein *et al.* 1998, Bigby *et al.* 2006). The success of first molar pulp anaesthesia following IANB plus IO anaesthesia has been reported as 100% in some research studies (Guglielmo *et al.* 1999, Gallatin *et al.* 2000, Stabile *et al.* 2000). Data from the present study using articaine buccal infiltration as a supplement to lidocaine IANB produced similar success for first molar pulpal anaesthesia to IO injection as a supplementary technique to IANB in first molars in other repeated outcome measure studies (Dunbar *et al.* 1996, Reitz *et al.* 1998). In premolars, the current study reported lower success (88.9%) than that reported in second premolars by Reitz *et al.* (1998) (97–100%) and within the range (77–97%) reported by Guglielmo *et al.* (1999).

In lateral incisors, 77.8% of volunteers experienced anaesthetic success following IANB with articaine buccal infiltration, compared to 19.4% after IANB alone. The success of lateral incisor pulp anaesthesia, reported in the literature following IANB injection only, ranges between 30% and 50% (Nist *et al.* 1992, McLean *et al.* 1993, Clark *et al.* 1999). This increased from 40% when IANB injection was administered alone to 62% when additional labial infiltration was added to IANB (Clark *et al.* 2002). Another study reported complete central incisor pulp anaesthesia when IANB was supplemented with buccal infiltration (Rood 1977). Our success for lateral incisor pulp anaesthesia was less than that reported in the study of Rood (1977)

and this is probably the result of buccal infiltration in the first molar region, not the incisor area.

It is important to emphasize that this study was performed in volunteers with healthy teeth and intact non-inflamed pulps. The efficacy of supplemental buccal infiltration with articaine in teeth with pulpal pathology may differ.

### Onset of pulpal anaesthesia

In the present study, the anaesthetic effect for mandibular first molars peaked 25 min post-injection after treatment 1 and 6 min after treatment 2. Robertson *et al.* (2007) reported a peak effect in first molars between 10 and 20 min after articaine buccal infiltration. Foster *et al.* (2007) noted the peak effect for first molars was between 12 and 20 min for IANB injection supplemented by lidocaine buccal infiltration. Nist *et al.* (1992) showed a similar peak effect for onset of first molar pulp anaesthesia following IANB plus incisive nerve block (17 min). This was delayed to 53 min when IANB was injected alone (Nist *et al.* 1992).

In this study, the anaesthetic effect for mandibular premolars peaked 30 min post-injection after treatment 1 and 8 min after treatment 2. Nist *et al.* (1992) found that peak effect of first and second premolar pulp anaesthesia was 22 and 26 min respectively following lidocaine IANB plus incisive nerve block. This was delayed to 50 and 38 min respectively when IANB was injected alone (Nist *et al.* 1992).

For lateral incisors, the anaesthetic effect peaked 40 min post-injection after treatment 1 (lidocaine IANB alone) and 20 min after treatment 2 (lidocaine IANB plus articaine buccal infiltration in the first molar region). Nist *et al.* (1992) showed a similar peak effect for onset of lateral incisor pulp anaesthesia following IANB plus incisive nerve block (19 min). This was delayed to 47 min when IANB was injected alone (Nist *et al.* 1992). Previous studies have reported that the peak anaesthetic effect of infiltration anaesthesia in the anterior mandible is around 8–10 min post-injection (Yonchak *et al.* 2001a, Meechan & Ledvinka 2002).

In the current study, there were significant differences between treatments for onset of pulp anaesthesia in premolars (means: 4.2 min for treatment 2 and 8.9 min for treatment 1,  $t = 3.3$ ,  $P = 0.002$ ). Although a quicker onset of pulp anaesthesia was recorded in first molars after treatment 2 than treatment 1 this was not significant (means: 4.5, 6.8 min respectively,  $t = 1.9$ ,  $P = 0.06$ ). Similarly, onset of lateral incisor pulp anaesthesia was quicker after

treatment 2 than treatment 1 but the difference was not significant (means: 6.9, 10.9 min respectively,  $t = 1.3$ ,  $P = 0.40$ ).

### Duration of pulp anaesthesia

The maximum duration of local anaesthesia possible in this trial was 43 min. Table 3 shows that the mean duration of pulp anaesthesia was significantly longer after treatment 2 than treatment 1 for first molars and premolars but not for lateral incisors. This agrees with the findings of other studies that found a longer duration of pulp anaesthesia with articaine compared to lidocaine buccal infiltration (Oliveira *et al.* 2004, Costa *et al.* 2005, Kanaa *et al.* 2006b, Robertson *et al.* 2007).

### Injection discomfort

Visual analogue scales are widely used in local anaesthetic research studies (Malamed *et al.* 2000, Meechan & Ledvinka 2002, Gallatin *et al.* 2003, Claffey *et al.* 2004, Oliveira *et al.* 2004, Meechan *et al.* 2006, Uckan *et al.* 2006, Robertson *et al.* 2007, Whitworth *et al.* 2007) to report injection discomfort. In the current study (Table 4), buccal infiltration and simulated buccal injection were more comfortable than IANB injection. The discomfort of IANB is influenced by the rate of injection (Kanaa *et al.* 2006a) and in the present study a rate of 60 s per injection produced moderate discomfort (Collins *et al.* 1997).

### Conclusions

- Lidocaine IANB injection with articaine buccal infiltration was more successful than lidocaine IANB alone for mandibular first molar, premolar and lateral incisor pulp anaesthesia.
- Articaine infiltration increased the duration of pulpal anaesthesia in premolar and first molar teeth when given in combination with a lidocaine IANB and produced quicker onset for premolars.
- Articaine buccal infiltration and dummy buccal injection were more comfortable than an IANB injection with lidocaine.

### Acknowledgements

This study was supported by the 2006 British Endodontic Society research award. The authors express their gratitude to the British Endodontic Society Council for their support. The assistance of the Syrian

government and Aleppo University is also gratefully acknowledged.

## References

- Bigby J, Reader A, Nusstein J, Beck M, Weaver J (2006) Articaine for supplemental intraosseous anesthesia in patients with irreversible pulpitis. *Journal of Endodontics* **32**, 1044–7.
- Byers MR, Taylor PE, Khayat BG, Kimberly CL (1990) Effects of injury and inflammation on pulpal and periapical nerves. *Journal of Endodontics* **16**, 78–84.
- Childers M, Reader A, Nist R, Beck M, Meyers WJ (1996) Anesthetic efficacy of the periodontal ligament injection after an inferior alveolar nerve block. *Journal of Endodontics* **22**, 317–20.
- Claffey E, Reader A, Nusstein J, Beck M, Weaver J (2004) Anesthetic efficacy of articaine for inferior alveolar nerve blocks in patients with irreversible pulpitis. *Journal of Endodontics* **30**, 568–71.
- Clark S, Reader A, Beck M, Meyers WJ (1999) Anesthetic efficacy of the mylohyoid nerve block and combination inferior alveolar nerve block/mylohyoid nerve block. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontics* **87**, 557–63.
- Clark K, Reader A, Beck M, Meyers WJ (2002) Anesthetic efficacy of an infiltration in mandibular anterior teeth following an inferior alveolar nerve block. *Anesthesia Progress* **49**, 49–55.
- Collins SL, Moore RA, McQuay HJ (1997) The visual analogue pain intensity scale: what is moderate pain in millimetres? *Pain* **72**, 95–7.
- Costa CG, Tortamano IP, Rocha RG, Francischone CE, Tortamano N (2005) Onset and duration periods of articaine and lidocaine on maxillary infiltration. *Quintessence International* **36**, 197–201.
- Dagher FB, Yared GM, Machtou P (1997) An evaluation of 2% lidocaine with different concentrations of epinephrine for inferior alveolar nerve block. *Journal of Endodontics* **23**, 178–80.
- Donkor P, Wong J, Punnia-Moorthy A (1990) An evaluation of the closed mouth mandibular block technique. *International Journal of Oral and Maxillofacial Surgery* **19**, 216–9.
- Dunbar D, Reader A, Nist R, Beck M, Meyers WJ (1996) Anesthetic efficacy of the intraosseous injection after an inferior alveolar nerve block. *Journal of Endodontics* **22**, 481–6.
- Foster W, Drum M, Reader A, Beck M (2007) Anesthetic efficacy of buccal and lingual infiltrations of lidocaine following an inferior alveolar nerve block in mandibular posterior teeth. *Anesthesia Progress* **54**, 163–9.
- Gallatin E, Stabile P, Reader A, Nist R, Beck M (2000) Anesthetic efficacy and heart rate effects of the intraosseous injection of 3% mepivacaine after an inferior alveolar nerve block. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontics* **89**, 83–7.
- Gallatin J, Nusstein J, Reader A, Beck M, Weaver J (2003) A comparison of injection pain and postoperative pain of two intraosseous anesthetic techniques. *Anesthesia Progress* **50**, 111–20.
- Guglielmo A, Reader A, Nist R, Beck M, Weaver J (1999) Anesthetic efficacy and heart rate effects of the supplemental intraosseous injection of 2% mepivacaine with 1 : 20 000 levonordefrin. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontics* **87**, 284–93.
- Hannan L, Reader A, Nist R, Beck M, Meyers WJ (1999) The use of ultrasound for guiding needle placement for inferior alveolar nerve blocks. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontics* **87**, 658–65.
- Hargreaves KM, Keiser K (2002) Local anesthetic failure in endodontics. *Endodontic Topics* **1**, 26–39.
- Heasman PA, Beynon AD (1986) Clinical anatomy of regional analgesia: an approach to failure. *Dental Update* **13**, 71–4, 76.
- Hintze A, Paessler L (2006) Comparative investigations on the efficacy of articaine 4% (epinephrine 1 : 200 000) and articaine 2% (epinephrine 1 : 200 000) in local infiltration anaesthesia in dentistry—a randomised double-blind study. *Clinical Oral Investigation* **10**, 145–50.
- Jung IY, Kim JH, Kim ES, Lee CY, Lee SJ (2008) An evaluation of buccal infiltrations and inferior alveolar nerve blocks in pulpal anesthesia for mandibular first molars. *Journal of Endodontics* **34**, 11–3.
- Kanaa MD, Meechan JG, Corbett IP, Whitworth JM (2006a) Speed of injection influences efficacy of inferior alveolar nerve blocks: a double-blind randomized controlled trial in volunteers. *Journal of Endodontics* **32**, 919–23.
- Kanaa MD, Whitworth JM, Corbett IP, Meechan JG (2006b) Articaine and lidocaine mandibular buccal infiltration anesthesia: a prospective randomized double-blind cross-over study. *Journal of Endodontics* **32**, 296–8.
- Lin J, Chandler NP (2008) Electric pulp testing: a review. *International Endodontic Journal* **41**, 365–74.
- Malamed SF, Gagnon S, Leblanc D (2000) A comparison between articaine HCl and lidocaine HCl in pediatric dental patients. *Pediatric Dentistry* **22**, 307–11.
- McLean C, Reader A, Beck M, Meyers WJ (1993) An evaluation of 4% prilocaine and 3% mepivacaine compared with 2% lidocaine (1 : 100 000 epinephrine) for inferior alveolar nerve block. *Journal of Endodontics* **19**, 146–50.
- Meechan JG (2005) Why does local anaesthesia not work every time? *Dental Update* **32**, 66–8, 70–2
- Meechan JG, Ledvinka JI (2002) Pulpal anaesthesia for mandibular central incisor teeth: a comparison of infiltration and intraligamentary injections. *International Endodontic Journal* **35**, 629–34.
- Meechan JG, Kanaa MD, Corbett IP, Steen IN, Whitworth JM (2006) Pulpal anaesthesia for mandibular permanent first molar teeth: a double-blind randomized cross-over trial

- comparing buccal and buccal plus lingual infiltration injections in volunteers. *International Endodontic Journal* **39**, 764–9.
- Montagnese TA, Reader A, Melfi R (1984) A comparative study of the Gow-Gates technique and a standard technique for mandibular anesthesia. *Journal of Endodontics* **10**, 158–63.
- Nist RA, Reader A, Beck M, Meyers WJ (1992) An evaluation of the incisive nerve block and combination inferior alveolar and incisive nerve blocks in mandibular anesthesia. *Journal of Endodontics* **18**, 455–9.
- Nusstein J, Reader A, Nist R, Beck M, Meyers WJ (1998) Anesthetic efficacy of the supplemental intraosseous injection of 2% lidocaine with 1 : 100 000 epinephrine in irreversible pulpitis. *Journal of Endodontics* **24**, 487–91.
- Nusstein J, Claffey E, Reader A, Beck M, Weaver J (2005) Anesthetic effectiveness of the supplemental intraligamentary injection, administered with a computer-controlled local anesthetic delivery system, in patients with irreversible pulpitis. *Journal of Endodontics* **31**, 354–8.
- Oliveira PC, Volpato MC, Ramacciato JC, Ranali J (2004) Articaine and lignocaine efficiency in infiltration anaesthesia: a pilot study. *British Dental Journal* **197**, 45–6; discussion 33.
- Prohic S, Sulejmanagic H, Secic S (2005) The efficacy of supplemental intraosseous anesthesia after insufficient mandibular block. *Bosnian Journal of Basic Medical Sciences* **5**, 57–60.
- Quinn CL (1998) Injection techniques to anesthetize the difficult tooth. *Journal of the Californian Dental Association* **26**, 665–7.
- Reitz J, Reader A, Nist R, Beck M, Meyers WJ (1998) 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 Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontics* **86**, 516–23.
- Robertson D, Nusstein J, Reader A, Beck M, McCartney M (2007) The anesthetic efficacy of articaine in buccal infiltration of mandibular posterior teeth. *Journal of the American Dental Association* **138**, 1104–12.
- Rood JP (1976) The analgesia and innervation of mandibular teeth. *British Dental Journal* **140**, 237–9.
- Rood JP (1977) The nerve supply of the mandibular incisor region. *British Dental Journal* **143**, 227–30.
- Stabile P, Reader A, Gallatin E, Beck M, Weaver J (2000) Anesthetic efficacy and heart rate effects of the intraosseous injection of 1.5% etidocaine (1 : 200 000 epinephrine) after an inferior alveolar nerve block. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontics* **89**, 407–11.
- Uckan S, Cilasun U, Erkman O (2006) Rare ocular and cutaneous complication of inferior alveolar nerve block. *Journal of Oral and Maxillofac Surgery* **64**, 719–21.
- Whitworth JM, Kanaa MD, Corbett IP, Meechan JG (2007) Influence of injection speed on the effectiveness of incisive/mental nerve block: a randomized, controlled, double-blind study in adult volunteers. *Journal of Endodontics* **33**, 1149–54.
- Wong MK, Jacobsen PL (1992) Reasons for local anesthesia failures. *Journal of the American Dental Association* **123**, 69–73.
- Yonchak T, Reader A, Beck M, Clark K, Meyers WJ (2001a) Anesthetic efficacy of infiltrations in mandibular anterior teeth. *Anesthesia Progress* **48**, 55–60.
- Yonchak T, Reader A, Beck M, Meyers WJ (2001b) Anesthetic efficacy of unilateral and bilateral inferior alveolar nerve blocks to determine cross innervation in anterior teeth. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontics* **92**, 132–5.