Clinical Oral Investigations
https://doi.org/10.1007/s00784-018-2500-4

ORIGINAL ARTICLE

Anesthetic efficacy of mental/incisive nerve block compared to inferior alveolar nerve block using 4% articaine in mandibular premolars with symptomatic irreversible pulpitis: a randomized clinical trial

Sholeh Ghabraei[1] · Ashraf Shubbar[1] · Mohammad H. Nekoofar[1,2] · Ali Nosrat[3,4]

Received: 7 January 2018 / Accepted: 29 May 2018

Abstract

Objectives The aim of this study was to compare the onset, success rate, injection pain, and post-injection pain of mental/incisive nerve block (MINB) with that of inferior alveolar nerve block (IANB) using 4% articaine in mandibular premolars with symptomatic irreversible pulpitis. The accuracy of electrical pulp test (EPT) in determining pulpal anesthesia was also examined.

Materials and methods The study was designed as a randomized clinical trial with two study arms—MINB and IANB. Injections were performed using a standardized technique. Root canal treatment was initiated 10 min after the injection. Success was defined as no pain or mild pain during access cavity preparation and instrumentation. Injection pain and post-injection pain (up to 7 days) were recorded. All pain ratings were done using Heft-Parker Visual Analog Scale (HP VAS).

Results Sixty-four patients were enrolled. The success rate of MINB (93.8%) was higher than IANB (81.2%) but the difference was not significant ($p > 0.05$). The onset of anesthesia with MINB was significantly quicker, and injection pain was significantly less ($p < 0.05$), but post-injection pain was significantly higher during the first 4 days ($p < 0.001$). The accuracy of EPT in determining pulpal anesthesia was 96.88%.

Conclusions MINB and IANB with 4% articaine had similar efficacy in anesthetizing mandibular premolars with irreversible pulpitis. Post-injection pain with MINB was higher than with IANB.

Clinical relevance MINB and IANB with 4% articaine can be used interchangeably to anesthetize mandibular premolars with irreversible pulpitis.

Keywords 4% articaine · Local anesthesia · Mental/incisive nerve block · Inferior alveolar nerve block · Pain

Sholeh Ghabraei and Ashraf Shubbar contributed equally to this work.

Electronic supplementary material The online version of this article (https://doi.org/10.1007/s00784-018-2500-4) contains supplementary material, which is available to authorized users.

✉ Mohammad H. Nekoofar
nekoofar@tums.ac.ir

✉ Ali Nosrat
Nosrat@umaryland.edu

[1] Department of Endodontics, School of Dentistry, Tehran University of Medical Sciences, Tehran, Iran

[2] Endodontology Research Group, School of Dentistry, College of Biomedical and Life Sciences, Cardiff University, Cardiff, UK

[3] Division of Endodontics, Department of Advanced Oral Sciences and Therapeutics, School of Dentistry, University of Maryland Baltimore, 650 West Baltimore Street, 4th floor, Baltimore, MD 21201, USA

[4] Iranian Center for Endodontic Research, Dental Research Center, School of Dentistry, Shahid Beheshti University of Medical Sciences, Tehran, Iran

Introduction

Mandibular posterior teeth are usually anesthetized by regional blockade of the inferior alveolar nerve. Inferior alveolar nerve blocks (IANB) alone are not 100% effective in obtaining pulpal anesthesia in mandibular teeth [1]. Combining the IANB with supplemental injections such as intra-osseous injections [2] or buccal infiltration of 4% articaine [2, 3] is recommended to increase the success rate.

Several mechanisms for the superior efficacy of 4% articaine have been explored. Some researchers hypothesized that 4% articaine is more effective because of the higher concentration compared to other anesthetic solutions. However, a clinical study showed that a buccal infiltration of 4% articaine was significantly more effective compared to 4% lidocaine and 4% prilocaine [4]. Also, there was no significant difference between 2 and 4% articaine when used for IANB [5]. Articaine has an additional unique property of lipophilicity,

Published online: 07 June 2018

which enhances its diffusion through membranes and connective tissues. Articaine is lipophilic because of its ability to form an intramolecular hydrogen bond. Skjevik et al. [6] suggested that this intramolecular hydrogen bond is a novel solvent-dependent mechanism for modulation of lipophilicity of articaine. They also showed that articaine's unique chemical structure (i.e., thiophene ring), which does not exist in other local anesthetic agents, may facilitate better diffusion of the anesthetic solution [6]. Potocnik et al. [7] studied the effect of 2% lidocaine, 2% articaine, and 4% articaine on nerve conduction in rats. They showed that both 2 and 4% articaine more effectively depressed the action potential of the A and C fibers compared to 2% lidocaine [7].

The mental/incisive nerve block (MINB) is often used as an alternative to IANB for anesthetizing mandibular premolars. A clinical study showed no significant difference in the efficacy of MINB and IANB using 2% lidocaine in mandibular premolars with irreversible pulpitis [8]. However, use of 4% articaine for MINB might add the benefit of local infiltration to the regional blockade of the mental/incisive nerve. Previous studies showed relatively high success rates for anesthetizing mandibular premolars with MINB/buccal infiltration of 4% articaine in healthy volunteers [9, 10].

There is no study on the anesthetic efficacy of MINB using 4% articaine in mandibular premolars with irreversible pulpitis. The primary aim of this study was to compare the success rate of MINB with that of IANB using 4% articaine for anesthetizing mandibular premolars with symptomatic irreversible pulpitis. The secondary aims were to determine and compare the onset, injection pain, and post-injection pain of the two anesthetic techniques. The accuracy of electric pulp test in determining pulpal anesthesia was also examined.

Materials and methods

The study was designed as a randomized, parallel, double-blind, superiority clinical trial where the observer and the biostatistician were blinded to the process. The study design and the language of the consent form were approved by the Ethics Committee at Tehran University of Medical Sciences (TUMS) (approval code: IR.TUMS.REC.1394.1906). The study was registered in the Iranian Registry of Clinical Trials (www.irct.ir) under the following code: IRCT2015072123278N1. The study was conducted in TUMS, and the data were collected and analyzed in TUMS.

A power analysis based on previous studies showed that a minimum sample size of 32 for each study arm will give 80% statistical power to detect a 25% difference in the success rate of experimental groups (with type I error equal to 0.05). The primary outcome (endpoint) was "successful anesthesia," which was defined as the ability to perform a full pulpectomy (i.e., access cavity preparation and root canal instrumentation to master apical size) with no pain or mild pain.

Inclusion criteria were as follows:

- Patient aged 18 to 65 with a mandibular premolar diagnosed with symptomatic irreversible pulpitis
- Positive response to electrical pulp test (EPT) (Parkell Inc., Farmingdale, NY) and cold test (Roeko Endo Frost; Roeko, Hangenav, Germany)
- Bleeding observed upon entry into pulp chamber

For electric pulp testing, the teeth were isolated with cotton rolls and dried with an air syringe. Colgate Total ® tooth paste was applied to the EPT probe tip which was placed in the middle third of the buccal surface of the tooth. The current was set to increase from no output (0) to the maximum output (80) in 30 s. The diagnosis of symptomatic irreversible pulpitis was made based on a chief complaint of lingering throbbing pain on cold/hot irritants which could be reproduced clinically.

Patients younger than 18, older than 65, pregnant women, patients who had taken analgesics and/or anti-inflammatory medications before the procedure, patients with any systemic diseases (American Society of Anesthesiologists class II or higher), patients with a history of drug abuse, and patients with a lesion or swelling at the site of injection were excluded from this study. Using a parallel design, the participants were randomly allocated into the two study arms. The randomization was done using a permuted block method with a block size of four. The allocation of participants and the implementation took place centrally in TUMS to ensure concealment. The results of randomization were placed in sealed opaque envelopes.

All participants signed an informed consent form. Before any injection, each subject was instructed on how to rate the pain using a Heft-Parker Visual Analog Scale (HP VAS). The 170-mm HP VAS was divided into four categories as follows: no pain = 0 mm; 0 mm < mild pain ≤ 54 mm; 54 mm < moderate pain < 114 mm; severe pain ≥ 114 mm. Anesthesia was considered successful if the patient reported no pain or pain up to 54 mm on HP VAS scale upon access cavity preparation or during instrumentation. In case of pain during the treatment, the procedure was stopped, and the patient was asked to rate the pain on HP VAS.

The area of injection was dried by using sterile gauze. Patients in the IANB group received the standard IANB injection using 1.8 mL of 4% articaine with 1:100,000 epinephrine (Inibsa Dental S.L.U, Barcelona, Spain) using a 27-G 31-mm needle. The technique described by Malamed [11] was used for IANB. Patients in the MINB group received MINB injection with the same anesthetic solution, volume, and needle. For MINB, the estimate root length for mandibular premolars was determined using the pre-operative periapical

radiographs, and the injections were placed between the apices of the two mandibular premolars. If the second premolar was missing, the injection was administered distal to the apex of the first premolar. If the first premolar was missing, the injection was performed at the apex of the second premolar. The lip was gently retracted, and the needle was gently placed into the alveolar mucosa with the face of the bevel directed towards the bone. For both groups, no anesthetic solution was deposited as the needle was advanced to the target site. Aspiration was conducted before depositing anesthetic solution. The anesthetic solution was deposited slowly, over a period of 60 s, in both groups.

All injections and procedures were done by the same operator. Immediately after performing the injection, the patient was asked to rate the injection pain using HP VAS. Ten minutes after injection, the patient was asked whether he/she had lip numbness. Any patient without lip numbness at this stage was excluded from the study.

As described in previous studies [9, 12], EPT was done every 2 min to determine the onset of anesthesia, i.e., the time elapsed between the end of injection to the first of two consecutive readings of 80 without response. For all patients who had lip numbness 10 min after the initial injection, root canal treatment was started, regardless of the EPT results. The tooth was isolated with a rubber dam; an access cavity was prepared, and the root canal treatment procedure was initiated. The success of the anesthesia was confirmed clinically when there was no pain or mild pain on access cavity preparation and during instrumentation. If moderate or severe pain occurred at the time of access preparation or during instrumentation, the injection was considered a failure. The failed cases were then supplemented with the technique opposite to the initial technique (IANB for the failed MINB; MINB for the failed IANB). Ten minutes later, the procedure was resumed, and the pain level was recorded. Intra-osseous injection of 2% lidocaine was considered as the final resort for patients who still had moderate to severe pain.

After the procedure, each patient was handed seven printed and dated HP VAS records to rate their pain/discomfort/soreness at the injection site for another 7 days. A mirror was handed to the patient and the area of injection was shown. Patients were asked to rate the pain in the soft tissues where the injection was done and were educated on how to distinguish between post-operative pain in the tooth and post-injection pain in the soft tissue area of the injection.

Fisher's exact test was used to compare the categorical data (i.e., success rate) between the two study arms. The success rate was calculated as the percentage of patients with zero or mild pain during the procedure. Independent Student's t test was done to compare the parametric data (i.e., pre-operative pain level, mean injection pain, and mean onset) and repeated measures ANOVA for mean post-injection pain. Statistical analyses were performed using SPSS (Version 21, IBM, Armonk, NY). Statistical significance was set at $p < 0.05$ and all analyses were planned two-tailed.

The accuracy of EPT in determining the success of anesthesia was calculated using the following formula:

"Successful cases with negative EPT + Unsuccessful cases with positive EPT" divided by "total number of cases."

Results

Seventy patients were assessed for eligibility. Six patients were excluded due to systemic diseases and use of analgesics before the treatment appointment. Sixty-four patients (28 male and 36 female) were enrolled and randomly allocated into the two study arms. All enrolled patients completed the study (Fig. 1). The baseline data are presented in Table 1. There was no significant difference between the two groups regarding distribution of teeth (first vs second premolar) ($p = 0.31$) or the pre-operative pain scores ($p = 0.21$). All patients reported lip numbness after the initial injections. The success rate was 93.8% (95% CI 79.19–99.23) for MINB, and 81.2% (95% CI 63.56–92.79) for IANB. The difference was not significant ($p = 0.26$) (Table 2, Fig. 2). Overall, the success rates were slightly higher for the first premolars in both study arms (Fig. 2). The success rates varied from 94.4% (MINB in 1st premolars) to 78.9% (IANB in 2nd premolars) (Fig. 2). The combination of both techniques was 100% successful in the failed cases (2 in MINB group; 6 in IANB group). The mean injection pain score for IANB was significantly higher than for MINB ($p = 0.034$) (Table 2). The onset of anesthesia for MINB was significantly quicker than for IANB ($p < 0.001$) (Table 2). In all successful cases (both groups), the duration of anesthesia was sufficient to complete instrumentation. The mean post-injection pain score was significantly higher for MINB up to day 4 (repeated measures ANOVA; $p < 0.001$) (Fig. 3) than for IANB. No pain or discomfort was reported for either of techniques after day 5 (Fig. 3). The overall accuracy of EPT to determine pulpal anesthesia was 96.88%. Positive EPT showed 100% predictive value for failed anesthesia (Table 3). Negative EPT showed 93.7% predictive value for successful anesthesia (Table 3).

Slight subjective swelling was the most common adverse effect associated with MINB (3/32) followed by tenderness to palpation at the injection site (1/32). In IANB group, one patient reported prolonged numbness which resolved after 2 days.

Discussion

This is the first study to investigate the efficacy of mental/incisive nerve block using 4% articaine to anesthetize mandibular premolars with irreversible pulpitis. The project was

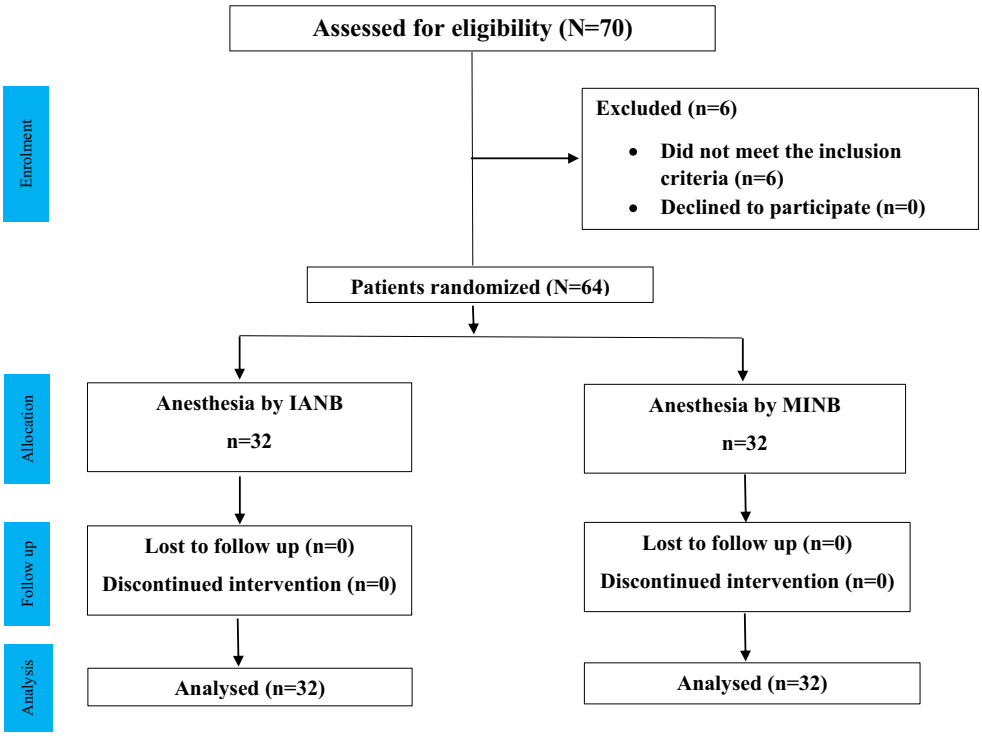

Fig. 1 The CONSORT flow chart

designed as a randomized double-blind clinical trial to reduce bias [13]. Randomized clinical trials provide the best design to show the effect of a treatment [14, 15]. This clinical trial showed a higher success rate for MINB compared to IANB for anesthetizing mandibular premolars with irreversible pulpitis. Although the difference was not statistically significant (93.8 vs 81.2%; $p = 0.26$), the findings are clinically important. The slightly higher success rate of MINB compared to IANB was consistent with the findings of other studies [8].

Several studies have been done on the efficacy of MINB/buccal infiltration using different anesthetic solutions for anesthetizing mandibular premolars in healthy volunteers [9, 16–18]. Buccal infiltration of 4% articaine at the area of first molar resulted in full anesthesia in 77% of first premolars in one study [16] and in 90% of first premolars in another study [19]. MINB using 4% articaine successfully anesthetized 72% of first premolars and 80% of second premolars [9]. The success rates in this study were significantly higher for 4% articaine than for 2% lidocaine [9]. Studies by Whitworth et al. [17] and Jaber et al. [18] on MINB using 2% lidocaine showed success rates of 84.2 and 89.5%, respectively. A study by Dressman et al. [10] showed that the success of buccal infiltration using 4% articaine in mandibular premolars can be increased from 87% up to 94% by doubling the injection volume from one cartridge to two cartridges. Our study showed a success rate of 93.8% for MINB using 4% articaine in anesthetizing mandibular premolars with irreversible pulpitis.

An important aspect of the present study is that all enrolled cases had irreversible pulpitis. Obtaining complete pulpal anesthesia is often difficult in patients with preoperative endodontic pain and pulpal pathosis. Nerves within an area of tissue inflammation have altered resting potentials and decreased excitability thresholds [20]. An animal study looking at the differences in nerve impulse transmission between normal and inflamed pulps showed that local anesthetics were unable to prevent impulse transmission in inflamed pulps, because of the lowered excitability

Table 1 Baseline data. Pre-operative pain scores were measured as mm on HP VAS

Injection technique	Gender M/F (%)	Age (mean ± SD)	1st/2nd premolar *n* (%)	Pre-operative pain (mm, mean ± SD)
MINB	14/18 (44/56)	37.4 ± 11.62	18/14 (56/44)	125 ± 17
IANB	14/18 (44/56)	35 ± 9.97	13/19 (41/59)	122 ± 16

Table 2 Comparison of success rate, injection pain (mm on HP VAS), and onset of anesthesia (minutes) for MINB and IANB. Onset of anesthesia was defined as two consecutive negative response to 80 EPT reading. Asterisks show the significant difference

	Success *n* (%)	Injection pain (mm; mean ± SD)	Onset (min; mean ± SD)
MINB	30 (93.8)	33 ± 17	3 ± 0.8
IANB	26 (81.2)	42 ± 17	7.2 ± 2.3
p value	0.26	0.034*	< 0.001*

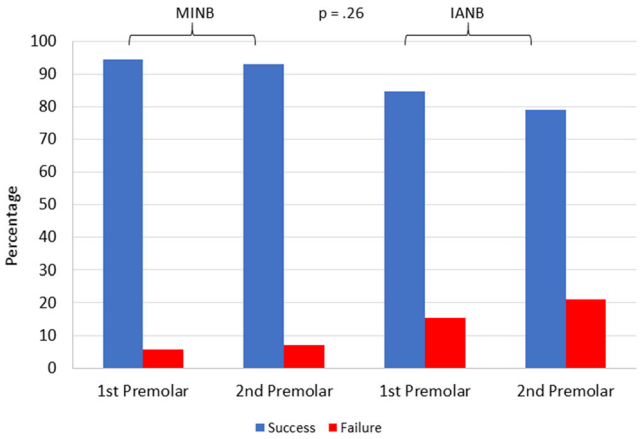

Fig. 2 Success rate of MINB and IANB categorized based on tooth type. There was no significant difference between the two techniques

thresholds [20]. Development and activation of tetrodotoxin-resistant (TTX-R) sodium channels and capsaicin-sensitive TRPV1 nociceptors in inflamed pulps which are resistant to the effect of local anesthetics are additional reasons for difficulty in achieving anesthesia in teeth with irreversible pulpitis [21, 22].

An advantage of MINB over IANB is the quicker onset of anesthesia. Previous studies reported a range of 2 to 6 min for the average onset time of MINB [9, 10, 16, 17]. The average onset time in our study was 3 min. Even though the methodology used to determine onset time follows previous research [9, 12], it is worth noting that the 2-min time lapse between EPT tests reduces the accuracy of this measurement. Studies have indicated that a disadvantage of MINB/buccal infiltration injection in mandibular premolars is the decline of pulpal anesthesia after 20–30 min [9, 10, 17, 23]. A study by Batista da Silva et al. [9] showed that the duration of pulpal anesthesia in mandibular premolars for MINB using 4% articaine was significantly longer than if using 2% lidocaine. Except one, all previous studies on the success of MINB/buccal infiltration injections were done on healthy volunteers where successful anesthesia was

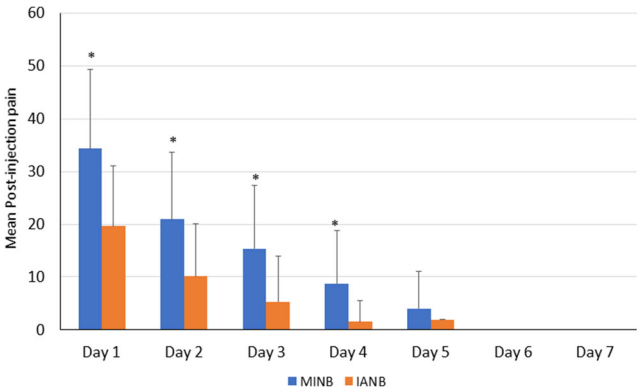

Fig. 3 Plot for the mean post-injection pain (results of repeated measures ANOVA). Pain is measured as mm on HP VAS. The asterisks show the significant differences

Table 3 Correlation between EPT results and success/failure of the local anesthesia

	MINB		IANB	
	Success	Failure	Success	Failure
EPT negative	30	2	26	0
EPT positive	0	0	0	6

measured as no response to EPT [9, 10, 16–18]. There is only one study on mandibular premolars with irreversible pulpitis where the pain level was measured during access cavity preparation and instrumentation [8]. The anesthetic solution used in that study was 2% lidocaine [8].

In the present study, the success rate of IANB was 83.1%. The data on success rate of IANB using 4% articaine in mandibular premolars is limited. Study by Mikesell et al. [24] showed that the IANB using 4% articaine can induce successful anesthesia in more than 75% of mandibular premolars within 30–40 min from the injection time. However, the overall success rate was less due to strict criteria for success in healthy volunteers: "negative 80 EPT readings for 60 min." A study by Claffey et al. [25] on IANB using 4% articaine in posterior teeth with irreversible pulpitis showed an overall low success rate of 24%. However, there were only four premolars included [25]. Also, variables like the speed of injection (slow vs fast) [26] and volume of injection (3.6 vs 1.8 mL) [27, 28] have been shown to improve the success rate of IANB injections (regardless of the type of anesthetic solution) in mandibular molars and premolars. All injections were done with a slow speed (over 60 s) in this study.

The average injection pain in both groups was considered as "mild." Most studies on MINB showed that injection pain is mild [9, 17]. Anesthetic solution was deposited slowly (over 60 s) in both groups. Whitworth et al. [17] reported that pain from slow injections (60 s) was significantly less than from fast injections (10 s) for MINB. Aggarwal et al. [29] reported significantly less injection pain when IANB was done slowly. We followed the "slow injection" strategy for both groups and found significantly less injection pain for MINB compared to IANB. This finding can be due to technique-related variables such as the depth of needle penetration into the non-anesthetized tissue before the injection starts.

Post-injection pain ratings were significantly higher in the MINB group in the first 4 days. This finding is a disadvantage of MINB compared to IANB. However, the mean pain ratings were still in the "mild pain" range, and it decreased sharply day by day (Fig. 3). The level of post-injection pain and the quick reduction of pain over time is similar to findings in previous studies [10].

In the present study, one patient in the IANB group reported prolonged lip numbness, which resolved by day 2

without further treatment. None of the patients in the MINB group developed paresthesia. Previous studies have reported paresthesia following use of 4% articaine [30, 31]. Most of these cases were IANB injections with the paresthesia presenting as prolonged tongue or lip numbness [30]. Reports of paresthesia following MINB are very rare (less than 5% of total reports) [30]. It is also worth noting that paresthesia following injection can be due to direct mechanical trauma from the needle.

In previous clinical studies on healthy volunteers, successful local anesthesia was defined as two consecutive negative 80 readings with EPT. We used this technique to determine the onset of anesthesia. We also examined the accuracy of this test in determining pulpal anesthesia. When assessing the accuracy of a test in determining pulpal anesthesia, two values need to be considered: (A) the value of a positive response (i.e., the probability of a failed anesthesia when the response is positive) and (B) the value of a negative response (i.e., the probability of a successful anesthesia when the response is negative). In the present study, positive EPT showed 100% predictive value for failed anesthesia. This means whenever the response to EPT was positive, the anesthesia was failed. However, the negative response to EPT was an indication of a successful anesthesia in 93.7% of cases (Table 3). The accuracy of negative EPT readings in determining pulpal anesthesia is a controversial subject [32]. Dreven et al. [33] reported an accuracy of 100% for EPT readings in asymptomatic teeth compared to 73% in symptomatic teeth. Sampaio et al. [34] showed that the accuracy of EPT readings in determining pulpal anesthesia in teeth with irreversible pulpitis can be as low as 20%. Tortamano et al. [35] showed a 100% accuracy for determining pulpal anesthesia using EPT when 4% articaine was used (all negative EPT readings had no pain; all positive EPT readings experienced pain). However, the same study showed a poor accuracy for EPT when 2% lidocaine was used [35]. Our study showed a relatively high accuracy for EPT in determining pulpal anesthesia in mandibular premolars with irreversible pulpitis (96.88%). This subject deserves further investigation.

In conclusion, neither of the two techniques achieved a 100% success rate. MINB using 4% articaine showed similar success rate as IANB using 4% articaine in anesthetizing mandibular premolars with irreversible pulpitis. The onset of anesthesia was quicker for MINB and the injection pain was less. The post-injection pain for MINB was higher than for IANB. Both techniques showed an overall similar efficacy.

Acknowledgements The authors gratefully acknowledge Dr. Prashant Verma, at University of Maryland School of Dentistry, for the scientific and grammar editing of the manuscript.

Funding This work was supported by Tehran University of Medical Sciences in Tehran, Iran.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval All procedures performed involving human participants in this study were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included in the study.

References

1. Kung J, McDonagh M, Sedgley CM (2015) Does articaine provide an advantage over lidocaine in patients with symptomatic irreversible pulpitis? A systematic review and meta-analysis. J Endod 41:1784–1794
2. Kanaa MD, Whitworth JM, Meechan JG (2012) A prospective randomized trial of different supplementary local anesthetic techniques after failure of inferior alveolar nerve block in patients with irreversible pulpitis in mandibular teeth. J Endod 38:421–425
3. Kanaa MD, Whitworth JM, Corbett IP, Meechan JG (2009) Articaine buccal infiltration enhances the effectiveness of lidocaine inferior alveolar nerve block. Int Endod J 42:238–246
4. Nydegger B, Nusstein J, Reader A, Drum M, Beck M (2014) Anesthetic comparisons of 4% concentrations of articaine, lidocaine, and prilocaine as primary buccal infiltrations of the mandibular first molar: a prospective randomized, double-blind study. J Endod 40:1912–1916
5. Kammerer PW, Schneider D, Palarie V, Schiegnitz E, Daublander M (2017) Comparison of anesthetic efficacy of 2 and 4% articaine in inferior alveolar nerve block for tooth extraction-a double-blinded randomized clinical trial. Clin Oral Investig 21:397–403
6. Skjevik AA, Haug BE, Lygre H, Teigen K (2011) Intramolecular hydrogen bonding in articaine can be related to superior bone tissue penetration: a molecular dynamics study. Biophys Chem 154:18–25
7. Potocnik I, Tomsic M, Sketelj J, Bajrovic FF (2006) Articaine is more effective than lidocaine or mepivacaine in rat sensory nerve conduction block in vitro. J Dent Res 85:162–166
8. Aggarwal V, Singla M, Miglani S, Kohli S (2016) Comparative evaluation of mental incisal nerve block, inferior alveolar nerve block, and their combination on the anesthetic success rate in symptomatic mandibular premolars: a randomized double-blind clinical trial. J Endod 42:843–845
9. Batista da Silva C, Berto LA, Volpato MC, Ramacciato JC, Motta RH, Ranali J et al (2010) Anesthetic efficacy of articaine and lidocaine for incisive/mental nerve block. J Endod 36:438–441
10. Dressman AS, Nusstein J, Drum M, Reader A (2013) Anesthetic efficacy of a primary articaine infiltration and a repeat articaine infiltration in the incisive/mental nerve region of mandibular premolars: a prospective, randomized, single-blind study. J Endod 39:313–318
11. Malamed S (2013) Handbook of local anesthesia. 6th ed. Elsevier Mosby, St. Louis
12. Corbett IP, Kanaa MD, Whitworth JM, Meechan JG (2008) Articaine infiltration for anesthesia of mandibular first molars. J Endod 34:514–518

13. Torabinejad M, Bahjri K (2005) Essential elements of evidenced-based endodontics: steps involved in conducting clinical research. J Endod 31:563–569
14. Nekoofar MH, Sheykhrezae MS, Meraji N, Jamee A, Shirvani A, Jamee J et al (2015) Comparison of the effect of root canal preparation by using WaveOne and ProTaper on postoperative pain: a randomized clinical trial. J Endod 41:575–578
15. Torabinejad M, Nosrat A, Verma P, Udochukwu O (2017) Regenerative endodontic treatment or mineral trioxide aggregate apical plug in teeth with necrotic pulps and open apices: a systematic review and meta-analysis. J Endod 43:1806–1820
16. Currie CC, Meechan JG, Whitworth JM, Corbett IP (2013) Is mandibular molar buccal infiltration a mental and incisive nerve block? A randomized controlled trial. J Endod 39:439–443
17. 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. J Endod 33:1149–1154
18. Jaber A, Whitworth JM, Corbett IP, Al-Baqshi B, Jauhar S, Meechan JG (2013) Effect of massage on the efficacy of the mental and incisive nerve block. Anesth Prog 60:15–20
19. Meechan JG, Jaber AA, Corbett IP, Whitworth JM (2011) Buccal versus lingual articaine infiltration for mandibular tooth anaesthesia: a randomized controlled trial. Int Endod J 44:676–681
20. Modaresi J, Dianat O, Soluti A (2008) Effect of pulp inflammation on nerve impulse quality with or without anesthesia. J Endod 34:438–441
21. Roy ML, Narahashi T (1992) Differential properties of tetrodotoxin-sensitive and tetrodotoxin-resistant sodium channels in rat dorsal root ganglion neurons. J Neurosci 12:2104–2111
22. Chaudhary P, Martenson ME, Baumann TK (2001) Vanilloid receptor expression and capsaicin excitation of rat dental primary afferent neurons. J Dent Res 80:1518–1523
23. 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. J Endod 18:455–459
24. Mikesell P, Nusstein J, Reader A, Beck M, Weaver J (2005) A comparison of articaine and lidocaine for inferior alveolar nerve blocks. J Endod 31:265–270
25. 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. J Endod 30:568–571
26. Kanaa MD, Meechan JG, Corbett IP, Whitworth JM (2006) Speed of injection influences efficacy of inferior alveolar nerve blocks: a double-blind randomized controlled trial in volunteers. J Endod 32:919–923
27. Aggarwal V, Singla M, Miglani S, Kohli S, Singh S (2012) Comparative evaluation of 1.8 mL and 3.6 mL of 2% lidocaine with 1:200,000 epinephrine for inferior alveolar nerve block in patients with irreversible pulpitis: a prospective, randomized single-blind study. J Endod 38:753–756
28. Abazarpoor R, Parirokh M, Nakhaee N, Abbott PV (2015) A comparison of different volumes of articaine for inferior alveolar nerve block for molar teeth with symptomatic irreversible pulpitis. J Endod 41:1408–1411
29. Aggarwal V, Singla M, Miglani S, Kohli S, Irfan M (2012) A prospective, randomized single-blind evaluation of effect of injection speed on anesthetic efficacy of inferior alveolar nerve block in patients with symptomatic irreversible pulpitis. J Endod 38:1578–1580
30. Garisto GA, Gaffen AS, Lawrence HP, Tenenbaum HC, Haas DA (2010) Occurrence of paresthesia after dental local anesthetic administration in the United States. J Am Dent Assoc 141:836–844
31. Gaffen AS, Haas DA (2009) Retrospective review of voluntary reports of nonsurgical paresthesia in dentistry. J Can Dent Assoc 75:579
32. 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. J Endod 24:487–491
33. Dreven LJ, Reader A, Beck M, Meyers WJ, Weaver J (1987) An evaluation of an electric pulp tester as a measure of analgesia in human vital teeth. J Endod 13:233–238
34. Sampaio RM, Carnaval TG, Lanfredi CB, Horliana AC, Rocha RG, Tortamano IP (2012) Comparison of the anesthetic efficacy between bupivacaine and lidocaine in patients with irreversible pulpitis of mandibular molar. J Endod 38:594–597
35. Tortamano IP, Siviero M, Costa CG, Buscariolo IA, Armonia PL (2009) A comparison of the anesthetic efficacy of articaine and lidocaine in patients with irreversible pulpitis. J Endod 35:165–168