Original Article

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Anesthetic efficacy of supplemental buccal infiltration versus intraligamentary injection in mandibular first and second molars with irreversible pulpitis: a prospective randomized clinical trial

Nazanin Zargar[1], Shiva Shojaeian[1], Mohammadreza Vatankhah[2], Shirin Heidaryan[3], Hengameh Ashraf[1], Alireza Akbarzadeh Baghban[4], Omid Dianat[5]

[1]Department of Endodontics, School of Dentistry, Shahid Beheshti University of Medical Sciences, Tehran, Iran
[2]Center for Craniofacial Molecular Biology, Herman Ostrow School of Dentistry, University of Southern California, Los Angeles, USA
[3]Shahid Beheshti University of Medical Sciences, Tehran, Iran
[4]Proteomics Research Center, School of Rehabilitation, Shahid Beheshti University of Medical Sciences, Tehran, Iran
[5]Division of Endodontics, Department of Advanced Oral Sciences and Therapeutics, University of Maryland, Baltimore, Maryland, USA.

Background: To compare the anesthetic efficacy of supplemental buccal infiltration (BI) (1.7 ml) versus intraligamentary (IL) injection containing 0.4 ml of 4% articaine with 1:100.000 epinephrine after an inferior alveolar nerve block (IANB) with 1.7 ml 2% lidocaine in the first and second mandibular molars diagnosed with irreversible pulpitis (IP).

Methods: One hundred subjects diagnosed with IP of either the mandibular first (n = 50) or second molars (n = 50) and failed profound anesthesia following an IANB were selected. They randomly received either the IL or BI techniques of anesthesia. Pain scores on a 170 mm Heft-Parker visual analog scale were recorded initially, before, and during supplemental injections. Furthermore, pulse rate was measured before and after each supplemental injection. During the access cavity preparation and initial filing, no or mild pain was assumed to indicate anesthetic success. The chi-square test, Mann-Whitney U test, and independent samples t-test were used for the analyses.

Results: The overall success rates were 80% in the IL group and 74% in the BI group, with no significant difference (P = 0.63). In the first molars, there was no significant difference between the two techniques (P = 0.088). In the second molars, IL injection resulted in a significantly higher success rate (P = 0.017) than BI. IL injection was statistically more successful (P = 0.034) in the second molars (92%) than in the first molars (68%). However, BI was significantly more successful (P = 0.047) in the first molars (88%) than in the second molars (64%). The mean pulse rate increase was significantly higher in the IL group than in the BI group (P < 0.001).

Conclusions: Both the IL and BI techniques were advantageous when used as supplemental injections. However, more favorable outcomes were observed when the second molars received IL injection and the first molars received BI.

Keywords: Articaine; Dental Anesthesia; Infiltration; Intraligamentary Injection; Irreversible Pulpitis; Molar.

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Corresponding Author: Omid Dianat, Division of Endodontics, Department of Advanced Oral Sciences and Therapeutics, University of Maryland, Baltimore, Maryland, 650 West Baltimore St., Baltimore, Maryland 21201, USA
Tel: +1 (949) 527-8377 E-mail: omiddianat@umaryland.edu

INTRODUCTION

Achieving profound anesthesia in mandibular molars with irreversible pulpitis (IP) is one of the most challenging situations that dentists and endodontists routinely face in everyday practice [1]. The success rate of an inferior alveolar nerve block (IANB) has been reported to be 19-56% in patients with IP [2-4]. Therefore, administration of supplemental injections (SIs) such as intraligamentary (IL), intraosseous or intrapulpal injections, or buccal infiltration (BI) of articaine is recommended and often required to ensure successful anesthesia in cases with IP [5]. Although a high success rate has been reported for intraosseous injection, it requires not only special equipment but also imposes high costs and may cause root-structure damage, systemic problems, pain, and post-injection discomfort [6,7]. Intrapulpal injections are painful and entail pulpal exposure. In contrast, BI and IL injections usually have fewer complications and manifest acceptable success rates and are therefore used more commonly [5].

Studies have shown that the success rates of supplemental BI after IANB range from 42% to 88% [7-10]. In two consecutive randomized clinical trials, Rogers et al. and Shapiro et al. compared the efficacy of supplemental BI with articaine versus lidocaine in the mandibular molars and revealed that articaine is significantly more effective than lidocaine. Moreover, a similar success rate of approximately 62% has been reported for supplemental BI of articaine in the first and second molars in previous studies [11,12].

The success rate of supplemental IL injection has been reported to be 50-96% during endodontic treatments [13-15]. In the IL technique, anesthetic solution diffuses through the medullary bone to reach the target [15]. Shahi et al. reported success rates of 75% and 65.6% for IL injection and BI of 4% articaine in mandibular first molars, respectively [16].

Based on the lack of evidence comparing BI and IL injection between the first and second mandibular molars, this prospective randomized clinical trial aimed to compare the anesthetic efficacy (outcome) of BI (intervention) with IL injection (comparison) consisting of 4% articaine after a failed IANB with 2% lidocaine in the first and second mandibular molars diagnosed with IP (population).

METHODS

1. Trial design

This prospective, two-armed, parallel-designed, randomized clinical trial followed the Consolidated Standards of Reporting Trials (CONSORT) guidelines.

2. A priory protocol

This study was approved by the Ethics Committee of Shahid Beheshti University of Medical Sciences, Tehran, Iran (ethics code: IR.SBMU.RIDS>REC>1394.24) and registered in the Iranian Registry of Clinical Trials (IRCT code: IRCT2015072023253N1, https://irct.ir/trial/19867). Written informed consent was obtained from all the patients.

3. Patients

Patients who attended the Department of Endodontics, School of Dentistry, Shahid Beheshti University of Medical Sciences with the following criteria were selected.

1) Systemically healthy
2) Age ≥ 18
3) Not having a known allergic reaction to anesthetic solutions
4) Not taking any medication that interferes with anesthesia
5) Not taken any analgesic medication within 6 hours before treatment
6) Not pregnant or nursing
7) Having a first or second mandibular molar diagnosed with IP requiring endodontic treatment.

To qualify for the study, patients had to have one

permanent vital mandibular first/second molar with fully formed roots without any radiographic evidence of periapical pathosis. A single investigator diagnosed IP based on the patient's response to moderate to severe (Heft-Parker visual analog scale [HP-VAS] > 54 [17]) and/or lingered pain to the cold test with EndoIce (1,1,1,2 tetrafluoroethane; DENRONIC, Aeronova GmbH & Co. KG, Germany). The exclusion criteria were necrotic molars identified upon endodontic access cavity preparation.

4. Sample size

A pilot study of 20 patients (10 patients in each group) showed a success rate of 70% for BI (7/10) and 40% for IL injection (4/10). Assuming an α error of 0.05 and a β error of 0.2, 41 patients in each group were required with an allocation ratio of 1:1. The number was increased to 50 patients per group to enable a stratified randomization procedure and account for any possible dropouts. Patients in the pilot study were not included in the final sample.

5. Recruitment

Patients were carefully instructed to rate their perceived pain on an HP-VAS diagram. The HP-VAS ruler is a 170 mm line divided into four categories: 1. no pain (< 5 mm), 2. mild pain (≥ 5 mm and ≤ 54 mm), 3. Moderate pain (> 54 mm and < 114 mm), and 4. Severe pain (≥ 114 mm) [17]. The pain scores of the participants were recorded preoperatively.

All patients received a slow conventional IANB injection [18] after obtaining negative blood aspiration, using 1.4 ml of lidocaine HCL 2% with 1: 100,000 epinephrine (Xylocaine Adrenaline, Dentsply Pharmaceutical, York, PA, USA) and 0.3 ml long buccal injection by a thumb ring syringe and a 27-gauge long needle (Septoject, Septodont, France). The patients were questioned about lip numbness every 5 min for up to 15 min; (a) if negative, they were excluded from the study and were administered another IANB and/or SIs if necessary. (b) If positive, the inflamed tooth, contralateral molar, and premolar were tested using a cold test and electric pulp test (EPT; Sybron Endo, Kerr, Italy). A cold-sprayed cotton pellet was placed on the mid-buccal surface of the crown, and the patients recorded their pain on the HP-VAS. An EPT probe was applied to the occlusal third of the buccal area of the crown. If the EPT and/or cold test results were positive, the patient was included in the study and randomly received IL or BI injections. All teeth that did not respond positively to the EPT/cold test were excluded.

6. Randomization and masking

Using a stratified permuted randomization design, patients were stratified into two strata: the first (n = 50) and second molars (n = 50). Cases in each stratum were then randomly assigned to two groups: BI (n = 25) and IL injection (n = 25) (Fig. 1). The randomization sequence was generated using Excel software (Microsoft, Redmond, WA, USA).

To conceal the allocation, an assigned nurse recorded the intervention code (1 for BI and 2 for IL group) on paper and placed it in similar opaque envelopes. Red- and blue-colored opaque envelopes were used for the first and second molar strata, respectively.

7. Intervention

Before the SIs, the investigator left the treatment room and waited outside. The nurse handed the assigned envelopes to the operator. The teeth in the IL group received 0.2 ml of 4% articaine with 1:100,000 epinephrine (Septodont, Septodont, France) in each mesial and distal portion of the tooth using a 30-gauge Xshort needle (Septoject, Septodont, France). Regular syringes were used for the injections. The needle was positioned in the proximal area from the buccal direction and inserted in the space between the root and the crestal bone at 30° to the longitudinal axis of the tooth. The anesthetic solution was injected with backpressure [15]. Patients in the BI group received an infiltration injection of 1.7 ml 4% articaine with 1:100,000 epinephrine (Septodont, France) in the buccal vestibule alongside the

Table 1. Baseline data of the participants

	BI	IL	P value
Mean age (years ± SD)	34.6 ± 9.8	34.3 ± 9.7	0.89
Gender (n)			
Male	26	23	
female	24	27	
Tooth type			
First molar	25	25	
Second molar	25	25	
Mean initial VAS			
Total (VAS ± SE)	95.88 ± 2.88	99.88 ± 2.69	0.31
First molar	97.20 ± 3.78	102.00 ± 3.99	0.39
Second molar	94.56 ± 4.41	97.76 ± 3.64	0.58
HP-VAS before the SI			
Total (VAS ± SE)	39.88 ± 2.89	38.50 ± 3.22	0.75
First molar	41.20 ± 3.82	42.08 ± 4.86	0.89
Second molar	38.56 ± 4.41	34.92 ± 4.21	0.55

BI, buccal infiltration; HP, Heft-Parker; IL, intraligamentary injection; n, number; SD, standard deviation; SE, standard error; SI, supplementary injection; VAS, visual analog scale.

targeted molar. All injections were performed by a single operator.

8. Outcome assessment

Immediately after the SI, a rubber dam was placed on the tooth to blind the investigator. Five minutes after the SI, the investigator returned to the treatment room and performed the cold test and EPT. The patients recorded their perceived pain on the HP-VAS diagrams during the SIs, access cavity preparation, and initial filing. If there was no or mild pain response to the cold test and no response with the highest EPT stimulation for two consecutive times, access cavity preparation was initiated. If such responses did not occur, the cases were considered failures. Anesthetic success was defined when access cavity preparation and initial filling were performed with no or mild pain. The data for the failed cases were documented, and treatment was continued after administering further anesthesia.

As a secondary outcome, the pulse rate was recorded before and immediately after SIs using a pulse oximeter (Contec Medical Systems, Qinhuangda, China). A single practitioner, who was an endodontist, administered all injections and performed the endodontic treatment.

9. Blinding

The investigator was blinded to the injections, the operator and investigator were blinded to the randomization process, and the statistician was unaware of the aims of the study. The patients were not informed about the technique of injection they received, and both techniques were applied using the same syringes. Therefore, the patients were blinded to the injections.

10. Statistical analysis

The normality of preoperative pain levels and demographic factors in the two groups was evaluated using the Kolmogorov–Smirnov test. The chi-squared test was used to compare the anesthetic success of the groups. An independent samples t-test was used to compare the means of the continuous variables in the groups. The Mann-Whitney U test was used to compare the pulse rates between the two groups. The significance level was defined as $P < 0.05$. The data were analyzed using SPSS 18 (SPSS Inc., Chicago, IL, USA).

RESULTS

In total, 100 patients aged 18-60 years old were

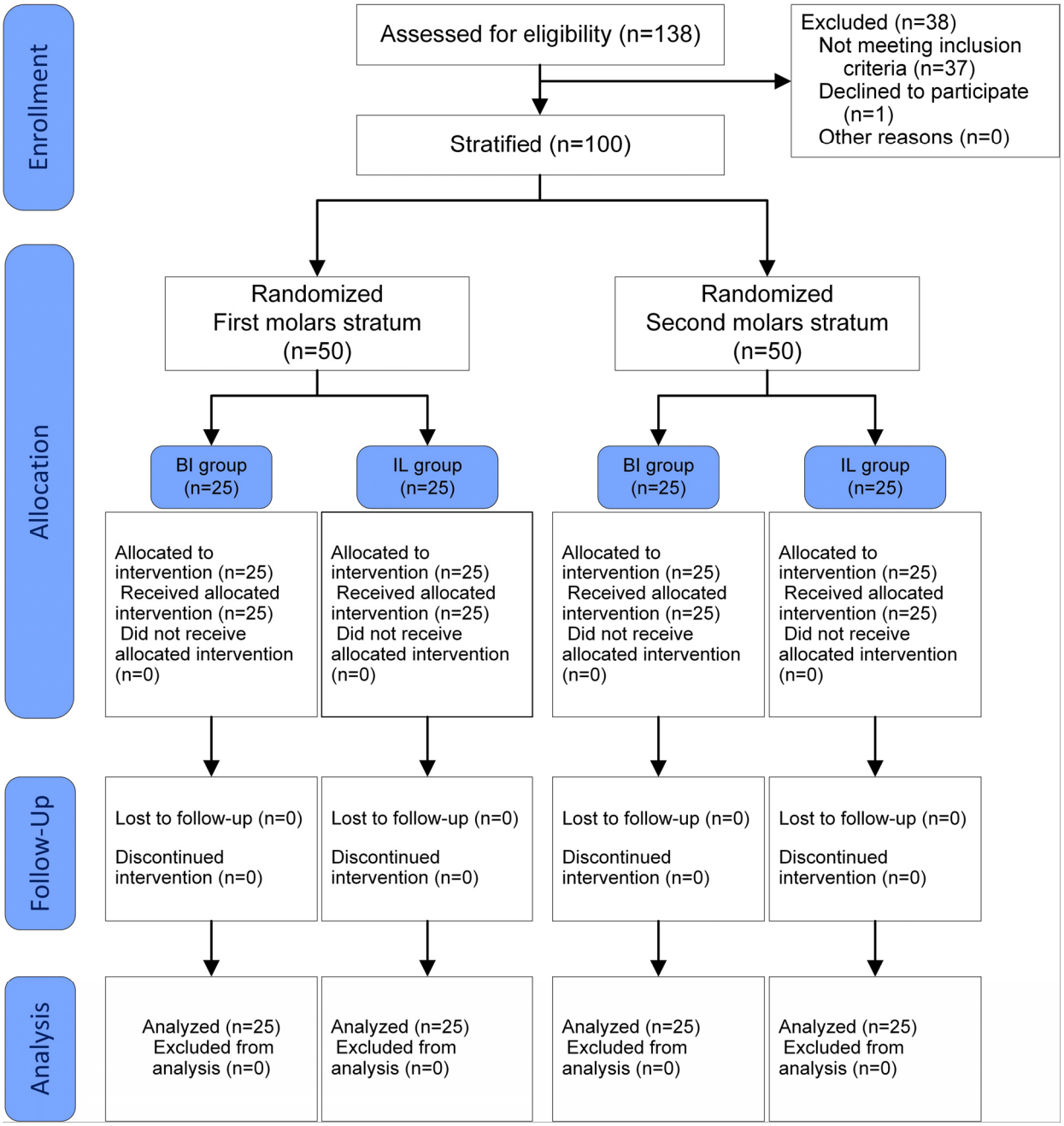

Fig. 1. The CONSORT flow diagram of the randomized clinical trial. BI, buccal infiltration; CONSORT, consolidated standards of reporting trials; IL, intraligamentary injection; n, number.

included in this study. As shown in Table 1, there was no significant difference between the two groups in terms of initial pain, pain before the SI, and demographic factors ($P > 0.05$). Fig. 1 shows the CONSORT flow diagram of this trial. The overall success rates of IL injection and BI were 80% and 74%, respectively, with no significant difference between the overall success rates of the two techniques ($P = 0.63$).

Intra-stratum analysis showed that in the first molar stratum, there was no significant difference between the two techniques ($P = 0.09$). However, in the second molar stratum, IL injection resulted in a significantly higher success rate than BI ($P = 0.017$).

Inter-stratum analysis showed that the success rates of

Table 2. Success rates for BI and IL supplemental injections in first and second mandibular molars

Goups	Success rate % (n)				
	First molar	Second molar	P value	RR† (95% CI)	Total
BI	88% (22/25)	64% (16/25)	0.047*	1.37 (0.99-1.91)	74% (37/50)
IL	68% (17/25)	92% (23/25)	0.034*	0.74 (0.55-0.99)	80% (40/50)
P value	0.088	0.017*			0.63
RR‡ (95% CI)	1.29 (0.95-1.756)	0.70 (0.51-0.95)			0.95 (0.77-1.17)

* Significant difference ($P < 0.05$)
† Success ratio for first molar/second molar
‡ Success ratio for BI/IL
BI, buccal infiltration; CI, confidence interval; IL, intraligamentary; n, number; RR, risk ratio.

Table 3. Comparison of pulse rate between the BI and IL groups

Intervention group	Immediately before the SI	After the SI	Mean HR increase
BI	85.66 ± 0.99	88.36 ± 0.95	4.70 ± 0.25
IL	86.98 ± 1.14	92.48 ± 1.08	6.50 ± 0.18
P value	0.39	0.03*	< 0.001*

*Significant difference ($P < 0.05$)
BI, buccal infiltration; HR, hazard ratio; IL, intraligamentary injection; SI, supplementary injection.

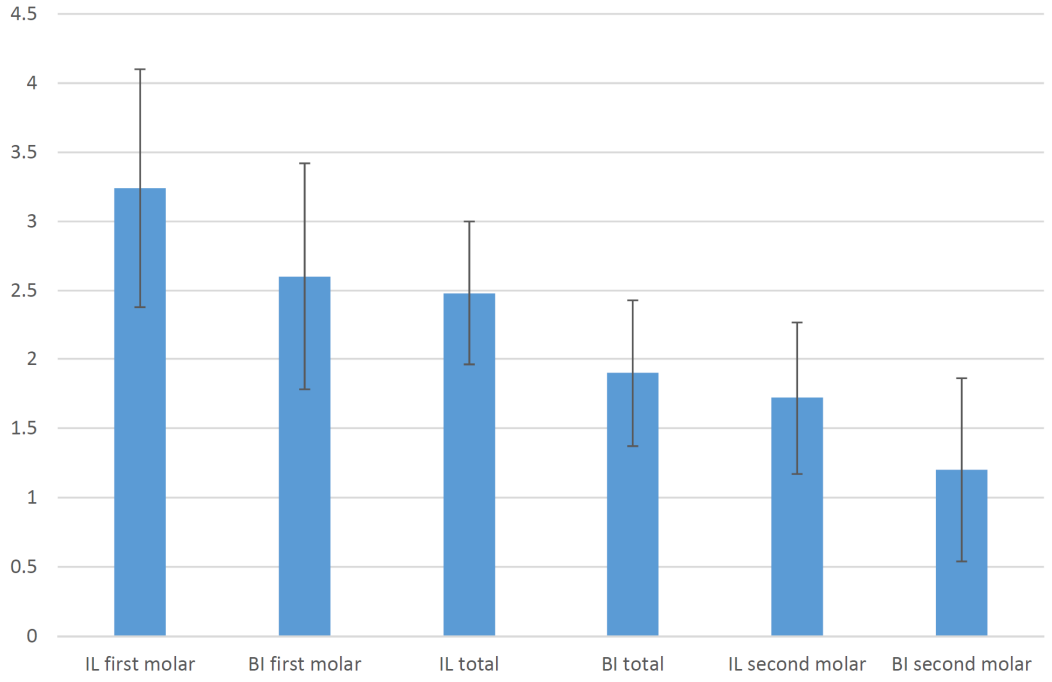

Fig. 2. Mean and standard errors of pain scores during supplemental injections, sorted largest to smallest. BI, buccal infiltration; IL, intraligamentary injection.

IL injection in the first and second mandibular molars were 68% and 92%, respectively, and the difference was significant ($P = 0.034$). The success rates of BI in the first and second mandibular molars were 88% and 64%, respectively, with a significant difference ($P = 0.047$) (Table 2).

Table 3 and Fig. 2 show the data for the secondary outcomes. As shown in Table 3, the increase in the mean pulse rate was significantly higher in the IL group than in the BI group ($P < 0.001$). Fig. 2 shows the pain scores during the SI: (1) there was no significant difference ($P = 0.86$) between the two groups; (2) in both first molar

(P = 0.59) and second molar (P = 0.55) strata, there was no significant difference between the IL and BI groups, and (3) Mann-Whitney U tests showed that there was no significant difference between the first and second molars in the IL and BI groups. No adverse effects were reported.

DISCUSSION

The present study compared the anesthetic efficacy of BI and IL injection using 4% articaine after the failure of IANB with 2% lidocaine to achieve profound anesthesia in the first and second mandibular molars. We used 4% articaine in this trial for BI and IL injections because articaine improves lipid solubility and increases diffusion through the lipid membrane of the neural sheet. In addition, the chemical structure of articaine with a thiophene ring further improves bone penetration [19]. Previous studies have shown a higher success rate for BI and IL injection of articaine than for lidocaine [20-22]. Our results showed that the both IL and BI techniques had almost similar success of 80% and 74%, respectively. Furthermore, Fan et al. reported a success rate of 81% for IL and 83% for BI injections containing 4% articaine in mandibular first molars [23]. Moreover, another study reported an 82% success rate for supplemental IL injection of 2% lidocaine with 1:80,000 epinephrine [24]. However, a recent study reported success rates of 75% for IL injection and 65% for BI with IANB in mandibular first molars with symptomatic IP. In that study, a BI containing 4% articaine (0.5 mL) was used after the failure of IANB [16], while in the current trial, a full cartridge of articaine (1.7 mL) was injected. A meta-analysis concluded that articaine has a significant advantage over lidocaine for BI after IANB, but there was no advantage for IANB alone or maxillary infiltration [25]. Therefore, in this study, articaine was used for SIs, and lidocaine was used for IANB injections.

The present study investigated the anesthetic efficacy of SIs in the first and second mandibular molars. The success rate of BI was significantly higher in the first mandibular molars than that for the second mandibular molars. Similarly, Matthew et al. reported a lower success rate for BI with articaine in the mandibular second molar [26], most probably due to the greater thickness of bone in the second molar region, resulting in a lower diffusion of articaine [27]. An anatomical study demonstrated that the mean horizontal distance of the mesial root apex to the cortical buccal plate was significantly greater in second mandibular molars than in first mandibular molars [28]. A recent study reported success rates of 60% and 63% for the BI technique with articaine in symptomatic first and second mandibular molars, respectively [11]. In that study, articaine was used for IANB, in contrast to this trial. Fowler et al. reported similar success rates of 42% and 4 8% for the BI technique in first and second mandibular molars, respectively. This controversial finding could be due to the uneven distribution of the first and second molars in the study groups and differences in clinical conditions and ethnicity [9]. Furthermore, another study showed a higher success rate of the BI technique in the second mandibular molars than in the first molars. However, they did not consider the tooth type in the randomization procedure; therefore, their samples comprised greater number of second molars in the articaine BI group [29].

Our results showed a significantly higher success rate for the IL injection containing articaine in the second mandibular molars than in the first mandibular molars. Similarly, another randomized clinical trial demonstrated 100% and 56.3% success rates for supplemental IL injection of 4% articaine in mandibular second and first molars, respectively [22]. According to the pooled quantitative analyses of a recent systematic review, supplemental IL injections could increase the overall anesthetic success rate [30]. The higher success of IL injection in second molars may be attributable to the higher porosity of the cribriform plate surrounding the mandibular second molars; the greater the porosity, the greater the potential permeability [31, 32]. Moreover, this increased permeability may improve the ability of the anesthetic to reach the adjacent nerves in the second

molars [32].

Our findings revealed that the mean pain during SI was mild, in line with the findings of Matthew et al., who reported low pain during needle insertion and injection in the BI technique [26]. Conversely, in another study, moderate and severe pain was reported in 15% and 1% of patients, respectively, for IL diffusion of the anesthetic solution [15]. In comparison, the lower pain scores in our study might be attributed to the long buccal injection that was not administered in the study by Nusstein et al. We observed a significantly higher increase in the pulse rate in the IL technique than in the BI technique. Nature of the IL injection could be similar to that of intraosseous injection; there is a transient increase in the heart rate during intraosseous injection [33]. The cancellous bone is a highly vascularized tissue that increases the absorption rate of epinephrine during the administration of the anesthetic solution. This increase could cause an increase in the pulse rate; however, it usually returns to normal after a few minutes [24].

A limitation of this study is that the individuals were not completely blinded to the injection they received. Although a slight difference between the two techniques made it impossible to completely blind the patients in a parallel, two-arm study design, the potential for bias was reduced by not disclosing the injections they received. As a strength of this study, the stratified permuted randomization method made it possible to compare both techniques and both types of teeth in the same setting, with more reliable results compared to simpler randomization techniques. However, to improve the quality and quantity of available evidence on both IL and BI techniques, further studies with different settings and anesthetic solutions are recommended.

In conclusion, after a failed IANB with 2% lidocaine, the BI technique using articaine was more successful in the first molars, and the IL technique was more successful in the second molars diagnosed with IP.

AUTHOR ORCIDs

Nazanin Zargar: https://orcid.org/0000-0002-4109-5128
Shiva Shojaeian: https://orcid.org/0000-0002-4915-6028
Mohammadreza Vatankhah: https://orcid.org/0000-0001-9988-6005
Shirin Heidaryan: https://orcid.org/0000-0003-0451-6787
Hengameh Ashraf: https://orcid.org/0000-0001-7507-4045
Alireza Akbarzadeh Baghban: https://orcid.org/0000-0002-0961-1874
Omid Dianat: https://orcid.org/0000-0001-8768-0456

AUTHOR CONTRIBUTIONS

Nazanin Zargar: Methodology, Supervision, Writing - review & editing
Shiva Shojaeian: Methodology, Supervision, Writing - review & editing
Mohammadreza Vatankhah: Formal analysis, Methodology, Visualization, Writing - original draft
Shirin Heidaryan: Investigation, Methodology
Hengameh Ashraf: Conceptualization, Methodology, Supervision
Alireza Akbarzadeh Baghban: Formal analysis, Software
Omid Dianat: Conceptualization, Methodology, Validation, Writing - review & editing

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