Efficacy of QuickSleeper Intraosseous Injection of 4% Articaine in Mandibular First Molars With Symptomatic Irreversible Pulpitis: A Randomized Controlled Trial

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Objective: To evaluate the anesthetic efficacy of 4% articaine with 1:100,000 epinephrine via primary intraosseous (IO) injection with the QuickSleeper device vs inferior alveolar nerve block (IANB) for mandibular first molars diagnosed with symptomatic irreversible pulpitis (SIP).

Methods: Sixty-four patients with a first mandibular molar with SIP were randomly divided into 2 groups: IO (n = 32) and IANB (n = 32). Each received either an IO injection with the 5th generation QuickSleeper device or a conventional IANB with 1.7 mL 4% articaine with 1:100,000 epinephrine. Success was defined as no/mild pain upon the access cavity preparation and initial filing. Injection pain, anesthetic onset, heart rate (HR) change, HR recovery time, and duration of anesthesia were also recorded and analyzed.

Results: The success rates were 40.6% for IANB and 81.2% for IO ($P < .001$). IO exhibited a significantly lower injection pain ($P = .027$), a shorter onset of action ($P < .001$), a greater heart rate increase ($P < .001$), a faster heart rate recovery time ($P < .001$), and a shorter duration of action ($P < .001$) vs IANB.

Conclusion: Primary IO anesthesia using the fifth generation of the QuickSleeper device was more successful than IANB when using 4% articaine with 1:100,000 epinephrine to anesthetize mandibular first molars with SIP. The QuickSleeper device appeared to be a viable alternative to IANB for mandibular anesthesia.

Key Words: Articaine; Dental anesthesia; Inferior alveolar nerve block; Intraosseous; Irreversible pulpitis.

Profound anesthesia is an essential component of effective endodontic treatment. However, failure to provide apt anesthesia, especially in mandibular molars, is common, owing to physiologic, anatomic, and psychological factors as well as operator and technical aspects.[1]

Delivering profound anesthesia in molars with symptomatic irreversible pulpitis (SIP) and/or symptomatic apical periodontitis can be challenging.[2] The success rate of inferior alveolar nerve block (IANB) for ensuring adequate pulpal anesthesia in mandibular molars with SIP is low.[3] Furthermore, IANB induces a prolonged soft-tissue numbness that lasts far longer than pulpal anesthesia, which may disrupt the patient's normal daily activities.[4] Besides, in up to 89% of patients presenting with SIP, IANB causes moderate to severe pain during needle insertion, placement, and solution deposition.[5] Therefore, seeking an alternative to IANB has been a topic of interest throughout the years.

Several supplemental and primary techniques, such as buccal infiltration and intraligamentary, periodontal ligament, intrapulpal, and intraosseous (IO) injections, have been developed to improve the anesthetic success rate in mandibular

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molars with SIP. IO injection was first introduced as a primary technique[6]; it permits the direct injection of local anesthetic solution into the trabecular bone next to the periapical region after perforating the cortical plate.[7] Several systems have been introduced to the dental market to deliver IO anesthesia: Stabident (Fairfax Dental),[8] X-Tip (X-Tip Technologies),[9] IntraFlow (Intra Vantage),[10] and QuickSleeper (DHT).[11] The QuickSleeper system is a computer-controlled device with various injection methods, including osteocentral/transcortical IO injection and intraligamentary injection. The asymmetric triple bevel of its needle tip results in a less painful and easy perforation into the bone.[12,13] A previous study showed an 82.5% anesthetic success in impacted third molar surgeries for this IO system as compared to the 35% success of IANB.[14]

Although several studies investigated the success of the IO technique with other systems,[9,15] to date and to the best of our knowledge, this is the first randomized clinical trial studying IO injection of 4% articaine with 1:100,000 epinephrine using the QuickSleeper system in mandibular molars diagnosed with SIP. The primary objective of this study was to compare the success rates of the IO technique with IANB, and the secondary objectives were the comparison between the 2 techniques regarding injection pain, anesthetic onset, heart rate change, and duration.

METHODS AND MATERIALS

The protocol of this prospective, parallel-designed, 2-arm, randomized, controlled trial was approved by the Ethics Committee of Shahid Beheshti University of Medical Sciences (IR.SBMU.RIDS.REC.1394.137) and was in line with the Declaration of Helsinki 1975 and its later amendments. The protocol was registered and approved by the Iranian Registry of Clinical Trials (IRCT20180930041187N1, https://irct.ir/trial/34186) and conformed to the CONSORT statement's recommendations. Informed consent was obtained from all participants before the commencement of the trial. The participants were made up of patients referred to the Department of Endodontics, School of Dentistry, Shahid Beheshti University of Medical Sciences, Tehran, Iran.

The inclusion criteria for participants consisted of the following: 18 to 65 years of age; American Society of Anesthesiologists (ASA)-1 physical status; having a mandibular first molar diagnosed with SIP without evidence of periapical radiolucency on digital periapical radiographs; ability to read, comprehend, and sign informed consent; absence of hypertension stage I or II; absence of pregnancy or nursing; absence of any known allergies to anesthetics or materials used in the endodontic treatment; and no use of analgesic medications up to 6 hours before the endodontic therapy.

The exclusion criteria were as follows: absence of bleeding from root canals after the access cavity preparation; moderate to severe preoperative anxiety via the visual analog scale for anxiety (VSA-A; score $>$ 5 cm)[16]; and the presence of infection at the site of the needle perforation.

The investigator assessed the inclusion/exclusion criteria for each patient. Recruited patients completed a consent form in which the interventions and the potential risks/benefits were outlined in full. The investigator instructed the participants to mark their pain levels on 170-mm Heft-Parker visual analog scales (HP-VAS).[17] They also recorded their preoperative anxiety on a 10-cm VAS-A.[18] The investigator confirmed the diagnosis of irreversible pulpitis of a mandibular first molar by lingering or moderate to severe response to cold test using Endo-Ice (1,1,1,2 tetrafluoroethane; Hygenic Corp), moderate or higher pain scores on the HP-VAS,[9] and a positive response to preoperative electric pulp tester (EPT; Gentle Pulse, Parkell). A matching healthy contralateral tooth was also tested as a control. Participants were asked to mark their perceived pain upon the preoperative cold test using the HP-VAS.

Figure depicts the flow diagram of the present study. Using the stratified permutated randomization method, 64 patients were divided into 2 strata of men (n = 32) and women (n = 32). Each stratum was then randomly divided into 2 groups: IO (n = 16) and IANB (n = 16). The statistician generated random digits to assign patients in each stratum to IO/IANB group using Excel software (Microsoft Corporation). A nurse inserted the HP-VAS diagrams and a paper designating the intervention (1 for IANB or 2 for IO) into identical opaque envelopes.

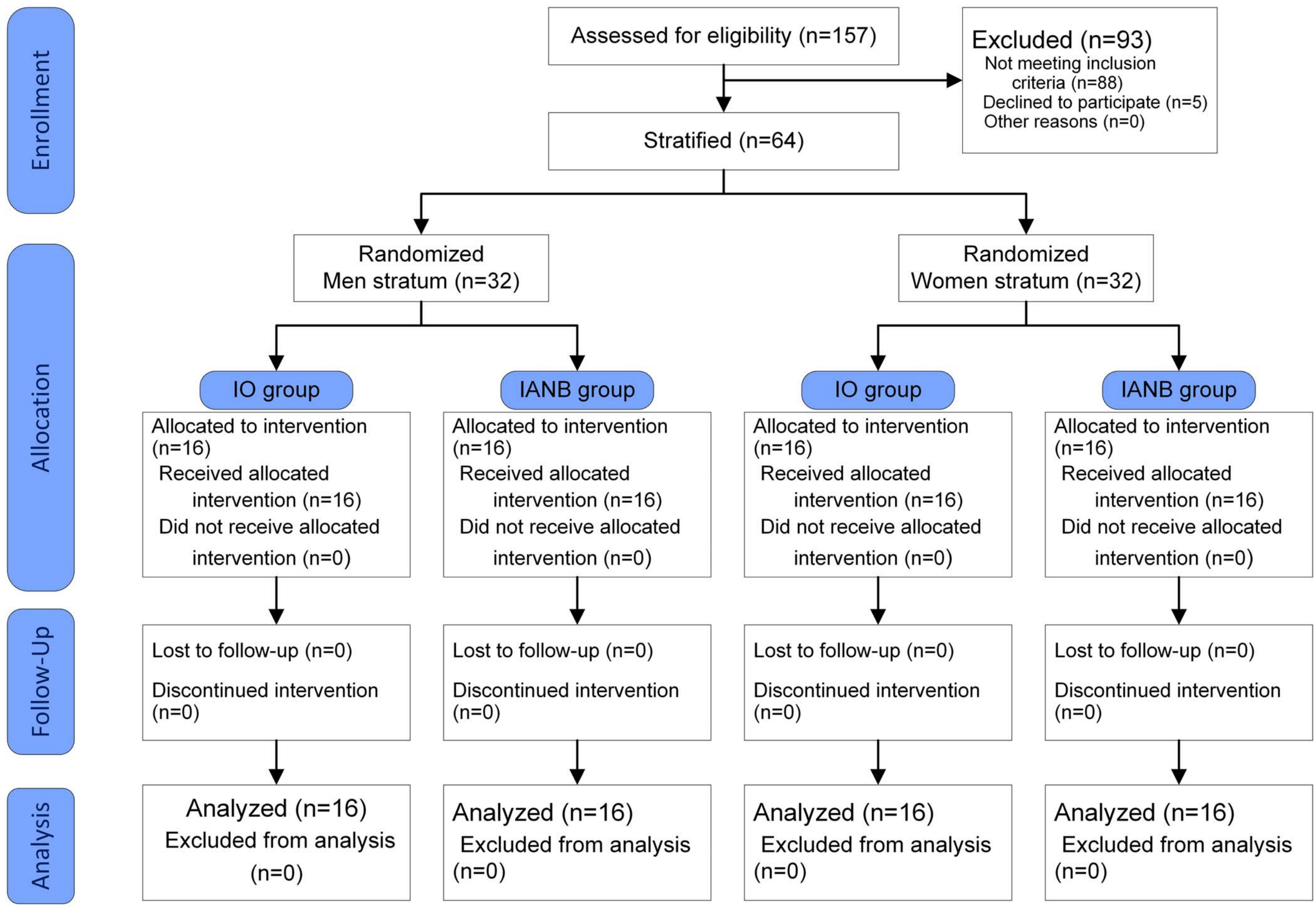
The investigator was unaware of the coding details. The investigator and the practitioner were both unaware of the randomization procedure. Moreover, a rubber dam was placed on the tooth to render the investigator blind. An appropriate clamp was chosen to rest only on the tooth structure without impinging gingival structure. The statistician was blinded to the study objectives. However, complete blinding of the participants and the practitioner was not applicable in this 2-arm study due to inherent clinical differences between the 2 injections.

Injection Protocols

After evaluating the inclusion and exclusion criteria, the investigator left the treatment room for blinding purposes. The practitioner then received the envelopes from the nurse, entered the treatment room, and opened the envelope just before the injection.

For IO injection, the QuickSleeper system was used following the 3-step procedure described by the manufacturer.[11] The injection site was roughly 2 mm below the intersection of 2 lines in the attached gingiva: (i) a horizontal line passing

Figure. Overview of Study Design



The CONSORT flow diagram for the stratified randomization method used in this study. IANB, inferior alveolar nerve block; IO, intraosseous.

the buccal gingival margins of the first and second molars, and (ii) a vertical line passing through the center of the distal papilla of the targeted tooth. Possible root proximity at the injection site was evaluated with a periapical radiograph. The needle was inserted into the subcrestal area with a slight angle to the bone surface to inject approximately 0.3 mL of 4% articaine with 1:100,000 epinephrine (Septocaine, Septodont) into the supraperiosteal region (12 mg articaine and 3 mcg epinephrine). Afterward, the cortical bone was perforated with rotation of the needle, and ¾ of the needle length was advanced deeply at a 15° to 30° angle to the root axis in order to approach the apex. After perforating the cortical bone, approximately 1.4 mL of the same local anesthetic was injected with a 16 mm 30-gauge needle into the osteocentral region (56 mg articaine and 14 mcg epinephrine). Injections were administered without any extra force using the device's automatic speed configuration set at a 1 mL/min, and if any extra resistance was observed during the injection, the needle was replaced and the injection repeated.

For conventional IANB, self-aspirating syringes (Novocol) and 27-gauge long needles were used to inject approximately 1.6 mL of 4% articaine with 1:100,000 epinephrine.[19] The rest of the solution (∼0.1 mL) was employed to anesthetize the buccal nerve. Patients without lip numbness to the midline 15 minutes after IANB were excluded from the study, received supplementary anesthesia and further endodontic treatment.

Outcome Assessment

Following completion of the local anesthetic injection, the investigator returned to the treatment room and carried out both the cold test and EPT every 2 minutes. Pain levels were recorded using the HP-VAS for the injections and upon access cavity preparation and initial filing. The access cavity preparation started when the patient reported no response with the highest EPT stimulation 2 consecutive times and had no or mild pain (HP-VAS ≤54) with a cold test using Endo-Ice. If this observation was not achieved

Table 1. Group Demographics and Preoperative Factors

	IANB (n = 32)	IO (n = 32)	P value
Gender, No. (%)			
Male	16 (50)	16 (50)	.99
Female	16 (50)	16 (50)	
Age, mean (SE), y	32.47 (1.73)	36.13 (1.99)	.171
Preop pain, mean (SE), mm	83.18 (3.07)	76.28 (3.54)	.073
Preop pain response to cold test, mean (SE), mm	109.81 (5.57)	102.72 (26.77)	.336
Preop HR, mean (SE), bpm	83.97 (1.58)	80.22 (1.76)	.119
Preop anxiety, mean (SE), cm	2.84 (0.25)	3.00 (0.24)	.492

Abbreviations: IANB, inferior alveolar nerve block; IO, intraosseous; SE, standard error; Preop, preoperative; bpm, beats/min; HR, heart rate.

up to 16 minutes, they received additional anesthesia, had their treatment completed, and were considered failed cases. The onset of pulpal anesthesia was defined as the "time after the injection to the first of two consecutive times of no response to the highest EPT stimulation."

Furthermore, patients' heart rate (HR) was monitored with a pulp oximeter before and after each injection. Baseline HR (mean HR of the 2-minute period before the treatment with 30-second intervals) and postinjection HRs (maximum HR recorded immediately and 15, 30, 45, and 60 seconds after the injection) were recorded. Moreover, HR was assessed at 30-second intervals up to 10 minutes after the injection to identify the recovery time to the preinjection HR level.

Anesthetic success was defined as no or mild pain during access cavity preparation and initial filing. Patients without bleeding after the access cavity preparation were excluded from the study. The anesthetic duration was further measured as the time from anesthetic onset to when the patient reported moderate to severe pain. Cases with worn off anesthesia received other anesthetic techniques, and their treatment was continued.

Statistical Analyses and Sample Size

The normality of preoperative anxiety levels and demographic factors in the 2 groups were evaluated using the Kolmogorov–Smirnov test. Mann–Whitney U test was used to compare preoperative anxiety between the 2 groups. Moreover, age, preoperative pain, preoperative pain response to the cold test, injection pain, and HR were compared between the 2 groups using the independent 2 samples T test. The binary logistic regression model was used to assess the effect of different variables on the anesthetic success. A significance level of 5% was assumed for interpreting the statistical tests. SPSS 18 (SPSS, Inc) was used for the analyses.

Based on a pilot study involving 16 participants (8 in each group), the initial success rate was 37.5% (3/8) for IANB and 75% (6/8) for IO. An a priori power analysis was performed to calculate the sample size using G*Power software (Version 3.1.9.7, Heinrich-Heine) with a type I error of .05, a power of 80%, and an effect size of OR = 0.2. A minimum sample size of 31 patients per group was computed, which was subsequently increased to 32 participants per group to enable the stratified randomization process. Participants in the pilot study were not included in the final samples.

RESULTS

A total of 157 possible participants were assessed for eligibility, and a total of 64 participants comprising 32 men and 32 women ultimately participated in this trial (Figure). The demographic factors of the participants are shown in Table 1. There were no significant differences between the IANB and IO groups regarding age, preoperative pain, preoperative anxiety, HR, or pain response to the cold test ($P > .05$).

The final success rate was 40.62% for IANB and 81.25% for IO ($P < .001$). As shown in Table 2, 8 participants in the IANB group and 1 participant in the IO group did not receive access cavity preparation due to responding to EPT stimulation or cold testing and were therefore considered failed cases. Their data were analyzed for all the outcomes except for the onset of action and anesthetic duration. Logistic regression analysis showed that the injection technique was the sole significant predictor of success ($P = .003$; OR = 0.169, 95% CI = 0.053–0.539). However, gender ($P = .635$; OR = 1.376, 95% CI = 0.376–4.970), age ($P = .352$; OR = 0.971, 95% CI = 0.911–1.034),

Table 2. Anesthesia Outcomes for the IANB and IO Groups

	IANB (n = 32)	IO (n = 32)	P value
Success, No. (%)	13 (40.6)	26 (81.2)	<.001
Failure, No. (%)			
Before access cavity preparation[a]	8 (25)	1 (3.1)	.012
After access cavity preparation[b]	11 (34.4)	5 (15.6)	.018

Abbreviations: IANB, inferior alveolar nerve block; IO, intraosseous.

[a] No two consecutive EPT readings with 80 or moderate to severe pain to cold test after the anesthesia.

[b] Moderate to severe pain during the access cavity preparation or initial filing.

Table 3. Secondary Study Outcomes

	IANB (n = 32)	*IO (n = 32)*	*P value*
Injection pain, mean (95% CI), mm per HP-VAS	86.63 (74.30–98.95)	18.56 (9.94–27.19)	.027
Onset of action, mean (95% CI), min[c]	9.54 (8.09–10.99)	5.26 (4.53–6.00)	<.001
HR increase, mean (95% CI), bpm	5.56 (5.01–6.11)	9.06 (7.49–10.63)	<.001
HR recovery time, mean (95% CI), min	4.92 (4.21–5.64)	2.53 (1.89–3.16)	<.001
Duration of action, mean (95% CI), min[c]	54.92 (51.42–58.42)	41.62 (39.64–43.62)	<.001

Abbreviations: CI, confidence interval; IANB, inferior alveolar nerve block; IO, intraosseous.
[c] Data for 24 participants in the IANB group and 31 patients in the IO group.

preoperative anxiety ($P = .108$; Exp(B) = 1.368), preoperative pain ($P = .860$; Exp(B) = 0.998), and preoperative pain response to the cold test ($P = .270$; Exp(B) = 1.010) were not identified as predictors of success.

Table 3 summarizes the secondary outcome findings. Mean pain scores during the injections were significantly higher for the IANB group (86.63 mm) than for the IO group (18.56 mm; $P = .027$). IO injection had a significantly shorter mean onset of action than IANB injection by more than 4 minutes ($P < .001$). The mean HR increase was significantly larger in the IO group (9.06 bpm) compared with the IANB group (5.56 bpm; $P < .001$). Nonetheless, the mean recovery time was significantly faster for the IO group (2.53 min) than for the IANB group (4.92 min; $P < .001$). The mean anesthetic duration was significantly longer for the IANB group (54.92 min) compared with the IO group (41.62 min; $P < .001$). No notable side effects were observed in either of the groups.

DISCUSSION

This study investigated the anesthetic efficacy of IO injection of 4% articaine with 1:100,000 epinephrine using the QuickSleeper device for mandibular first molars diagnosed with SIP. Our findings showed an 81.2% success rate for this technique. IO was associated with a higher success rate, shorter onset and anesthetic duration, lesser injection pain, higher HR increase, and faster HR recovery as compared with IANB.

A relatively high success rate (~90%) for supplemental IO injection in teeth with SIP has been reported.[20–23] However, supplemental injections do not prevent some of the unwanted effects of IANB. Some authors have suggested the primary use of IO injection as a successful technique for patients with irreversible pulpitis.[9,10,15,24] A previous study found a significantly higher success rate for the primary X-tip IO injection of 3% mepivacaine (56.7%) than for IANB with 2% lidocaine (23.3%) in SIP cases.[15] In another study, however, the difference between the success rates of the X-tip IO injection of 2% lidocaine (85%) and IANB (70%) was not statistically significant.[9] Pereira et al[24] found a 96.8% anesthetic success in cases with SIP for primary X-tip IO injection of 4% articaine with 1:100,000 epinephrine. Moreover, Remmers et al[10] reported success rates of 87% for the IntraFlow IO injection of lidocaine 2% and 60% for the IANB. The IO success rate of 81.2% in the present study was within the range of the mentioned studies. The success rate of 40.6% for IANB with 1.6 mL 4% articaine in this study was comparable with the 47% success rate with 1.4 mL 4% articaine reported by Ashraf et al.[3] Other authors, however, reported different success rates ranging from 24%[19] to 69.2%.[25]

The reason behind this relatively wide range could be attributed to differences in inclusion and exclusion criteria and the amount of the anesthetic administered. Moreover, the 40% higher success rate for IO compared with IANB was more notable in this study than in previous studies on the X-tip/IntraFlow injection systems. Varying results could arise from the differences in the studies' settings as follows: (i) eligibility criteria: preoperative pain level can affect the anesthetic success as emergency cases have lower rates of anesthetic success when compared to asymptomatic cases[2]; (ii) anesthetic solution: 4% articaine has a greater diffusion rate through the epineurium and bone[26,27] compared with 3% mepivacaine and 2% lidocaine; and (iii) IO delivery systems: using different systems such as X-tip, IntraFlow, or QuickSleeper could affect the success rate.

As a strategy for pain management during endodontic treatment, the approach with the least injection pain level is preferred.[28] Our findings indicated that compared with the IANB, employing the QuickSleeper resulted in lower injection pain levels. QuickSleeper's electronic needle rotation prevents tissue heating during perforation, and its electronic solution release mechanism assures a gradual anesthetic injection; both result in lower pain levels.[29] In a previous study, 53.7% of the patients reported no discomfort during injection via the QuickSleeper.[29] Another study showed that 96.6% of the patients receiving IO injections with X-tip reported no/mild pain.[30] However, other studies have shown a relatively high incidence of moderate/severe pain associated with IO injections that were as high as 48%.[31–34] Differences between studies could attributed to the samples' different characteristics as well as the IO devices employed.[29]

Following local anesthetic injection, adequate time should be given for the solution to penetrate the tissues adequately. The onset of action for IO was significantly shorter than for IANB. IO injection deposits the anesthetic solution directly into the cancellous bone near the apex of the target tooth. Hence, the diffusion in IO injections could be more rapid than conventional block techniques which require added movement through the soft tissue layers. The IO injection also does not cause complete lip numbness which may be a disadvantage for the IANB.[35]

The time for a complete endodontic debridement averaged 20 to 35 minutes in previous studies.[32,33] Noting more than 40 minutes duration for the IO technique in this study, it seems that IO injection could provide adequate anesthesia for the debridement appointment. Furthermore, our results showed that the anesthetic duration for the IO technique was significantly lower than IANB, consistent with previous findings.[10] This difference could be due to the vascularity of the cancellous bone into which the anesthetic is injected in the IO technique as compared to the IANB.[36]

A transient HR increase associated with IO techniques was reported in the literature.[30,31,37] A previous study on the anesthetic efficacy of the X-tip system using 2% lidocaine with 1:80,000 epinephrine in patients with irreversible pulpitis after IANB reported a mean HR increase of 18.93 bpm from baseline during the IO solution deposition.[30] Our findings, however, showed a smaller mean HR increase of 9.06 bpm, similar to another study using an X-tip injection with 2% lidocaine with 1:100,000 epinephrine.[22] This difference could stem from the different epinephrine concentrations in the studies. Furthermore, we found that the increase in HR associated with IO recovered to baseline in less than 3 minutes. It was in line with the 4-minute range reported in the previous studies.[30]

A meta-analysis on 6 clinical trials showed no significant difference in anesthetic efficacy between articaine and lidocaine for IANB.[38] Although there have been reports of a higher incidence of nerve damage associated with articaine vs lidocaine,[39] a recent systematic review concluded that there was no difference between articaine and lidocaine regarding nerve damage.[40] Moreover, a previous in vitro study showed that articaine did not damage neural cells more than lidocaine.[41] Therefore, and to eliminate the possible confounding effect of different anesthetics, we used articaine 4% in both the IO and IANB arms of this study.

A limitation of this study was that there was no complete blinding of the participants/practitioner due to notable differences in the 2 techniques. As a strength, the possible confounding effect of gender on the outcomes was stalled using the stratified randomization method. Noting favorable results of the QuickSleeper system in this study, we recommend that future studies try to employ different amounts of anesthetic solution and use the QuickSleeper IO injection as a supplement to failed IANB.

CONCLUSION

Our findings indicated that primary IO injection of 4% articaine with 1:100,000 epinephrine using the fifth generation of the QuickSleeper device provided more successful anesthesia in mandibular first molars diagnosed with SIP than IANB with the same local anesthetic. IO injection was associated with a significantly lower injection pain, a shorter onset of action, and a shorter anesthetic duration. IO also resulted in a significantly higher increase in HR but that normalized faster than IANB. Altogether, QuickSleeper IO was a viable alternative to IANB in cases of mandibular molars with SIP.

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