IEJ
Iranian Endodontic Journal

Assessing the Impact of Mandibular Molar Root Length on Success in Supplemental Intraligamentary Injection for Irreversible Pulpitis

Marzieh Kamali [a], **Masoud Parirokh** [b], **Hamed Manochehrifar** [b*], **Nouzar Nakhaei** [c]

a Department of Endodontics, School of Dentistry, Guilan University of Medical Sciences, Iran; b Endodontology Research Center, Kerman University of Medical Sciences, Kerman, Iran; c Neuroscience Research Center, Kerman University of Medical Sciences, Kerman, Iran

Article Type: **Original Article**

Received: 26 Sep 2023
Revised: 23 Nov 2023
Accepted: 05 Dec 2023
Doi: *10.22037/iej.v19i1.42660*

**Corresponding author*: Hamed Manochehrifar, Endodontology Research Center, Kerman University of Medical Sciences, Kerman, Iran.

***E-mail*:** hamed_man61@yahoo.com

Introduction: This study investigates the influence of root length in mandibular molars with irreversible pulpitis on the success of supplemental intraligamentary injection following an inferior alveolar nerve (IAN) block. Various factors, including anatomical location, tooth type, and anesthetic solution, may affect supplemental anesthesia success. **Materials and Methods:** A total of 251 patients diagnosed with irreversible pulpitis in mandibular first or second molars underwent buccal infiltration anesthesia (4% articaine with 1:100,000 epinephrine) after IAN block injection (3% prilocaine and 0.03 IU/mL of felypressin). Fifty patients experiencing pain during access cavity preparation received supplemental intraligamentary injection (0.3 mL of 2% lidocaine with 1:80,000 epinephrine) at each mesial and distal line angle. The root length of treated teeth was recorded using an apex locator. Data analysis involved independent t-tests, Chi-square tests, and logistic regression. **Results:** Successful supplemental intraligamentary injection was observed in 21 (42%) out of 50 patients. No significant correlation was found between the mean length of mesiobuccal (P=0.61), mesiolingual (P=0.34), or distal (P=0.60) canals of mandibular molars and the injection's success. Logistic regression analysis, however, revealed a significant impact of mesiolingual canal length on the success rate [OR 0.09 (0.01-0.79), P=0.030]. **Conclusion:** The root length of mandibular first and second molars does not significantly affect the success of supplemental intraligamentary injection.

Keywords: Intraligamentary Injection; Irreversible Pulpitis; Mandibular Molar; Root Length

Introduction

Local anesthesia of mandibular molars is challenging due to the high percentage of anesthesia failure. The inferior alveolar nerve (IAN) block is the commonly adopted local anesthetic technique for the mandible, which has a success rate of 40% to 60% [1]. High variation in the reported success rates is due to genetic variations, different anesthesia techniques, and inter-individual differences, among other factors [2]. Several methods have been proposed to increase the success rate of IAN block [3], such as increasing the volume of the anesthetic agent [4], decreasing the speed of injection [5], taking analgesics before anesthetic injection [6], and supplemental injections [5] like Buccal infiltration [7] or Intra-septal injection [8]. Supplemental injections include intrapulpal, intraosseous, and intraligamentary injections [6, 9].

Intraligamentary injection also known as periodontal ligament (PDL) injection [6] is an intraosseous injection through which an anesthetic agent is injected into the PDL and reaches the dental pulp through the PDL or the surrounding bone. The natural cribriform plates of the alveolar socket provide a path for the spread of anesthetic agents toward the pulpal nerve fibers [10]. A previous study showed that PDL injection is the most popular supplemental injection used by the members of the American Association of Endodontists and general dentists [11, 12]. Several studies have assessed the efficacy of PDL injection. Pulpal anesthesia is often achieved 30 sec after PDL injection [13]. The most important parameters to consider in this technique are the correct needle positioning and injection of the anesthetic agent with pressure. The clinician should feel resistance against injection during the procedure, and considerable pressure is recommended to ensure optimal success [13].

Two previous studies showed that 56% to 70% of mandibular posterior teeth with irreversible pulpitis that was still painful after the PDL injection successfully anesthetized the conventional anesthetic injection. Systematic review studies have reported that intraligamentary injection can significantly increase the success of local anesthesia of mandibular posterior teeth with irreversible pulpitis and failed IAN block [14-16]

According to the literature, the success rate of IAN block in teeth with symptomatic irreversible pulpitis is 28%, increasing to 75% by adding supplemental intraligamentary injection [17]. Also, a previous study showed that increasing the volume of lidocaine in supplemental intraligamentary injection further increased the success of anesthesia [18]. Moreover, the presence of epinephrine and increasing its concentration would further increase the success of local anesthesia [10, 19]. And also there is not any significant difference exists between lidocaine and articaine for intraligamentary injection as the supplemental anesthesia technique [1, 20].

It has been shown that the success rate of infiltration in maxillary molars is correlated with their root length, particularly the length of the palatal root. The failure rate was higher for longer roots [21, 22].

The effects of different factors on the success rate of intraligamentary injection in mandibular molars have been previously investigated in the literature. However, the effect of root length on the success of supplemental intraligamentary injection in mandibular molars has not been evaluated. Thus, this study aimed to assess the effect of mandibular molar root length on the success of intraligamentary injection.

Materials and Methods

The study population of this retrospective cohort observational study included patients presenting to the private office of an endodontist. The study protocol was approved by the ethics committee of the Kerman University of Medical Sciences (IR.KMU.REC.1399.625).

In this study, all patients that their mandibular molars need endodontic treatment, had irreversible pulpitis were treated in a private practice office limited to endodontics during a period of 3 years (April 2018 to April 2021) had been included. Dental records of 251 patients who had undergone endodontic treatment of mandibular molars were evaluated. Patients who met the following inclusion criteria were enrolled: Age over 18 years, having one mandibular first or second molar with irreversible pulpitis that required endodontic treatment, having a history of spontaneous pain, having severe, long-lasting pain in response to cold test, ASA class I or II systemic health status according to the American Society of Anesthesiologists, and being able to describe the type and severity of pain. The exclusion criteria were systemic diseases, ASA class III or IV, presence of periodontal problems, gingival recession or bone loss, deep pocket probing depth, allergy to the anesthetic agent, intake of analgesics within the past 12 h before the procedure, chronic alcohol consumption, intake of psychedelic medications, unrestorable crown, teeth under prosthetic crowns, presence of edema or sinus tract around the tooth, pregnancy or nursing, severe cuspal erosion, and loss of mesiobuccal, mesiolingual, or distobuccal cusp.

Eligible patients presenting to a private endodontic office were enrolled. The patients first received an IAN block with the standard technique by injection of one cartridge of 3% prilocaine plus 0.03 IU/mL of felypressin (Daru Pakhsh, Tehran, Iran) at the same side as the mandibular first or second molar with irreversible pulpitis. For this purpose, the anterior border of the mandible was felt, and the location of the coronoid process was identified. The needle was inserted 2 mm above the occlusal plane of mandibular molars at a hypothetical line drawn from the coronoid process to the pterygomandibular raphe. The body of the syringe was on the opposite side above the premolars. After touching the bone, the needle was slightly retracted, and the anesthetic agent was injected within 60 sec after aspiration. Ten min after IAN block injection, the patient was asked about the anesthesia of the lip corner at the side of the injection. In case of failure, the patient would be excluded from the study. Patients who reported lip anesthesia were enrolled, and then a 4% articaine cartridge plus 1:100,000 epinephrine (Artinibsa, Inibsa, Barcelona, Spain) was injected for buccal infiltration anesthesia. After 5 min, a rubber dam and clamp were placed, and a classic access cavity was prepared after caries removal. The patients were asked to raise their hand if they felt pain during caries removal, access cavity preparation and entry into the pulp chamber, and while root canal preparation. Patients who raised their hands to indicate pain were asked about the quality of pain and the need for a supplemental anesthetic injection. Patients' response was categorized as mild, moderate, or severe pain. If the patient had moderate to severe pain in each step of the treatment (access cavity preparation, pulp exposure, root canal instrumentation), it has been considered as anesthesia failure. In addition, if the patient asked for a supplemental injection, a supplemental intraligamentary injection was administered.

In addition to self-report of pain by patients, the sound eye motor (SEM) scale was used to assess pain during the procedure, from the initiation of access cavity preparation to the completion of root canal instrumentation. Accordingly, any sound made by the patient, any change in eye movements or blinking, and any head or body movement were considered signs of pausing the procedure and asking the patient about pain [23]. If the patient did not require a supplemental injection, but SEM suggested the presence of pain and discomfort, the patient would be questioned

again about the quality of pain and the need for a supplemental anesthetic injection.

Patients who received IAN block and buccal infiltration anesthesia but still had pain during access cavity preparation or dentin removal received intraligamentary injection of 2% lidocaine plus 1:80,000 epinephrine with a 27-gauge needle with 25 mm length (NOP Dental Needles, Spident, Korea) by the same operator who performed the IAN block. The injection was performed at the mesiobuccal line-angle of the tooth with pressure when the needle could no longer proceed. The needle tip had approximately a 30-degree angle relative to the tooth's longitudinal axis. For easier injection, the needle was bent in the middle. If resistance were not felt, the needle would be inserted deeper into the PDL, and the injection would be repeated. The same injection was performed at the distal of the tooth in the distobuccal line-angle [24].

The injected volume was 0.3 mL on each side of the teeth [18, 25]. The anesthesia was successful if the patient did not have pain or discomfort during the rest of the procedure after the supplemental injection. SEM findings also confirmed the absence of pain and discomfort. The root length of the teeth that received supplemental injection was recorded according to the value displayed by the apex locator (J. Morita, Kyoto, Japan). For this purpose, after access cavity preparation and negotiating the canal orifice, a #10 K-file measured the primary root canal length, and the length of each canal was separately recorded. The files were inserted into the canals, and digital radiography confirmed the root length (Carestream RVG 5200; Carestream Health Inc, Rochester, NY, USA). In case of discrepancy, the apex locator measured the root length again. Finally, the correlation of success of supplemental intraligamentary injection with root length was statistically analyzed based on tooth type (first/second molar), age, and gender. Root length was compared between the two groups of anesthesia success and failure, and the qualitative variables were also compared between the two groups by independent t-test and Chi-square test. Multivariate logistic analysis was used to identify the effect of various variables on the success of intraligamentary injection. The Hosmer-Leme show goodness-of-fit test showed a good fit (P=0.58). Statistical analysis was done using the SPSS software (SPSS Statistics version 21, IBM Corporation, Armonk, NY, USA).

Results

A total of 251 patients who required endodontic treatment of mandibular first or second molars and received IAN block and buccal infiltration anesthesia as their primary anesthetic injection was evaluated in this study. The primary anesthetic injection was successful in 150 patients (59.76%), so they did not require supplemental anesthesia. However, 101 patients required supplemental injection; 50 patients (19.92%) expressed pain during dentin preparation and received intraligamentary injection, while 51 patients (20.32%) had pain during pulpal exposure or root canal preparation and, therefore, required supplemental intrapulpal injection. Patients requiring intraligamentary injection included 27(54%) females and 23(46%) males. The injection was performed for the mandibular first molar in 27 (54%) and the mandibular second molar in 23 (46%) patients.

In the present study, intraligamentary injection was successful in 21 patients (42%) (Table 1). These patients only had pain during access cavity preparation in dentin and no longer had pain during pulpal exposure and root canal instrumentation. However, the intraligamentary injection was considered failed in patients who still had pain during pulpal exposure (n=26, 52%) and root canal preparation (n=3, 6%) and required supplemental intrapulpal injection.

As shown in Table 1, the success rate of supplemental intraligamentary injection was 48.1% in mandibular first molars and 34.8% in mandibular second molars, with no significant difference between them (P=0.34).

As demonstrated in Table 2, the mean age was 32.5 years in patients who required endodontic treatment of first molars and 40.4 years in patients who required endodontic treatment of second molars; the difference in the mean age was significant between the two groups (P=0.016).

The results showed no significant correlation between the mean length of mesiobuccal (P=0.61), mesiolingual (P=0.34), or distal (P=0.60) canal of mandibular first and second molars and success of intraligamentary injection (P>0.05). In other words, the mean root length of mandibular first and second molars had no significant effect on the success of intraligamentary injection. Table 3 presents the mean length of mesiobuccal, mesiolingual, and distal roots.

Gender had no significant effect on the success of intraligamentary injection (P=0.34). All patients were examined one week after intraligamentary injection, and none had pain, edema, infection, or any other complication.

As shown in Table 4 the only variable that showed significant effect on the success of intraligamentary injection was the mesiolingual canal length.

Discussion

This study assessed the effect of root length of mandibular molars with irreversible pulpitis on the success of intraligamentary injection following a failed IAN block. The results showed the overall success rate of supplemental

intraligamentary injection is 42% followed by an IAN block with 3% prilocaine and 1:20,000 levonordefrin and buccal infiltration anesthesia of 4% articaine with 1:100,000 epinephrine in patients who had moderate to severe pain during the procedure. Also, the root length of mandibular first and second molars had no significant effect on the success of intraligamentary injection.

A review study and meta-analysis revealed that the success of IAN block was 12% with lidocaine and 55% with prilocaine [25]. Thus, prilocaine was used for IAN block injection in the present study. Another study on the efficacy of buccal infiltration anesthesia with 4% articaine and 1:100,000 epinephrine along with IAN block with 2% lidocaine and 1:80,000 epinephrine reported a higher success rate of a combination of these two injections (91.7%) compared with an IAN block alone (55.6%). Also, they showed that buccal infiltration anesthesia with articaine was more comfortable for patients than IAN block [26].

Aggarwal *et al.* [27] revealed that adding a combination of buccal and lingual infiltration anesthesia with 2% articaine or 2% lidocaine led to a higher success rate of IAN block. Also, articaine resulted in a higher success rate (67%) than lidocaine (47%). However, none had a 100% success rate; therefore, supplemental injections are necessary. In the present study, intraligamentary injection was performed following an IAN block and buccal infiltration anesthesia.

Another meta-analysis showed the superiority of articaine to lidocaine in infiltration anesthesia and IAN block for teeth with irreversible pulpitis. However, their efficacy was not significantly different for IAN block for teeth with symptomatic irreversible pulpitis [28].

Su *et al.* [29] in a meta-analysis, reported that 4% articaine resulted in a higher success rate of anesthesia, lower pain level during injection and treatment, faster onset of anesthesia, and a lower percentage of complications compared with 2% lidocaine in teeth with irreversible pulpitis Articaine was more effective than lidocaine at providing local anesthesia in both the maxillary and mandibular regions, using both infiltration and inferior alveolar nerve block (IANB) techniques. A study found that adding lingual infiltration anesthesia with articaine to buccal infiltration anesthesia with articaine and inferior alveolar nerve block (IANB) with lidocaine did not significantly increase the success rate of anesthesia in patients with irreversible pulpitis in mandibular molars [30].

The abovementioned studies all demonstrated that buccal infiltration of articaine significantly increased the success rate of IAN block. Thus, in the present study, buccal infiltration of 4% articaine plus 1:100,000 epinephrine was used along with an IAN block.

Previous studies have confirmed that IAN block for mandibular teeth with irreversible pulpitis is among the most challenging anesthetic injections in the dentoalveolar region. Thus, the need for a supplemental injection is often higher after the IAN block of mandibular molars [1, 20]. The effects of several factors on the efficacy of intraligamentary injection have been investigated in the literature. These factors include volume of anesthetic agent (13), type of anesthetic agent (15, 22), concentration of epinephrine in the anesthetic agent (7, 14), use of medications such as dexamethasone (26), association of other supplemental injections (19), and technique of injection. The results of these studies have been mixed, with some studies showing that certain factors can improve the efficacy of intraligamentary injection, while other studies have shown no significant effect. More research is needed to determine the optimal parameters for intraligamentary injection.

Table 1. The success rate of supplemental intraligamentary injection based on tooth type

	Success		Failure		*P*-value
Mandibular 1st molar	13	48.1(%)	14	51.9(%)	0.34
Mandibular 2nd molar	8	34.8(%)	15	62.2(%)	
Total	21	42(%)	29	58(%)	

Table 2. Mean (SD) of distribution of mandibular molars based on age and gender of patients

	Mandibular 1st molar	Mandibular 2nd molar	*P*-value
Age (years)	32.5 (±11.3)	40.4 (±11.2)	0.016
Male	13 (48.1%)	10 (43.5%)	0.741
Female	14 (51.9%)	13 (56.5%)	
Number	27(54%)	23(46%)	

Table 3. Comparison of root length according to success of intraligamentary injection

Canal		N	Mean (SD)	*P*-value
Mesiobuccal	**Success**	21	20.83 (1.41)	0.61
	Failure	29	20.34 (4.25)	0.57
Mesiolingual	**Success**	21	20.47 (1.38)	0.34
	Failure	29	21.15 (1.61)	0.33
Distal	**Success**	21	20.59 (1.74)	0.60
	Failure	29	20.84 (1.55)	0.60

Table 4- The multivariate logistic regression model for the success of intraligamentary injection.

Variables		Odds ratio (95% CI)	*P*-value
Age		0.97 (0.91-1.03)	0.284
Gender	**Male**	0.62 (0.16-2.37)	0.489
	Female	---	
Tooth	**1st molar**	1.75 (0.44-6.86)	0.425
	2nd molar	---	
Mesiobuccal canal length		5.01 (0.77-32.70)	0.092
Mesiolingual canal length		0.09 (0.01-0.79)	0.030
Distal root length		1.71 (0.74-3.94)	0.208

The effects of several different parameters such as volume of the anesthetic agent [18], type of anesthetic agent [20, 27], the concentration of epinephrine in an anesthetic agent [10, 19], use of medications such as dexamethasone [31], association of other supplemental injections[24], and technique of injection on the efficacy of intraligamentary injection have been investigated in the literature. Only a few studies assessed the effect of maxillary molar root length on the success of infiltration anesthesia. They showed a significant correlation between higher palatal root length of maxillary molars and failure of infiltration anesthesia [21, 22]. However, the association of root length of mandibular molars with the success of intraligamentary injection has not been previously investigated. Thus, a question arises where such a correlation exists because in intraligamentary injection, the anesthetic agent should reach the apical foramen. However, the present results refuted this association. The mean lengths of the mesiobuccal, mesiolingual, and distal roots were very similar in the present study. This may be why there was no significant difference in length between the first and second molars.

Several methods are using for evaluating patients' pain during root canal treatment. Simple visual analogue (VAS) scale, Heft-Parker VAS, and categorized VAS have been known as VAS tools for determining patients' pain during endodontic treatment. In this study the categorized VAS have been used for evaluating patients' pain. Attar *et al.* has shown that there was no significant difference among various VAS on determining patient's pain. While it's known that pain thresholds are similar among individuals, their pain tolerances vary significantly [32, 33]. The clarity on whether VAS scores provide insight into patients' pain thresholds or tolerances remains uncertain. In this study, a categorized scale was utilized to assess patients' pain and anesthesia success, specifically determining if further anesthesia was needed. Injection success was assumed when patients experienced no or mild pain during access cavity preparation and root canal instrumentation, without requiring a supplementary injection. Besides the categorized pain scale, the treating practitioner's observations of subjective evaluation methods (SEMs) were employed to indicate pain during treatment. SEM evaluations are commonly used in studies on pain perception in children [25, 34]. Furthermore, if a patient declined the initial offer of supplementary injection but SEM observations indicated positive responses following treatment, the practitioner could discern whether the patient harbored a fear of receiving another injection or possessed low pain tolerance. The advantage of this method lies in its ability to replicate the clinical scenarios encountered by dentists during endodontic treatment.

The patients were asked whether they required a supplemental injection in the present study. In case of a positive response, the primary anesthesia would be considered a failure, and a supplemental injection would be administered. In this case, the reaction of patients to pain was assessed rather than the pain threshold [23, 25].

Aggarwal *et al.* compared the efficacy of articaine and lidocaine for a successful intraligamentary injection and found no significant difference. Thus, lidocaine was used for intraligamentary injection in the present study[1]. In a previous study success rate of 0.2 mL intraligamentary injection was reported as 64%, while 0.6 mL was 84% successful in IANB failed cases [18, 35]. However, the present study's success rate was 42% after injecting 0.3 mL of anesthetic agent at each side. Differences in the results may be due to different anesthetic agents used for supplemental injection, the technique of injection, the type and volume of anesthetic agent used for primary injection, or different eligibility criteria. Another study, however, compared different supplemental injections and reported a success rate of 48% following injection of 0.18 mL of lidocaine plus 1:80,000 epinephrine, which was close to the value in the present study [35].

Evidence shows that the thickness of cortical bone covering the mandibular first and second molar roots differs, and the cortical bone plate is thicker around the second molar [36]. In the present study, the success rate of intraligamentary injection for mandibular first and second molars was also compared, yielding a success rate of 48.1% for mandibular first molars and 34.8% for mandibular second molars, with no significant difference between them. The results were comparable to the previous studies since the present study used 2% lidocaine plus 1:80,000 epinephrine for intraligamentary injection [20]. However, they showed a significantly higher success rate for mandibular second molars than first molars when articaine was used for intraligamentary injection. They attributed the higher efficacy of articaine to its better penetration ability [20]. also, the other studies found no significant difference in the success rate of intraligamentary injection between the first and second molar when articaine was used [1].

Previous studies found no significant difference in the success rate of IAN block and buccal infiltration anesthesia of articaine following an IAN block between mandibular first and second molars [37, 38]. It has been demonstrated that intraligamentary injection is often associated with pain at the injection site and edema[39]. However, the patients had no complications one week after the procedure in the present study.

In the current study, the mean root length of teeth was highly similar, which may be responsible for the lack of a significant correlation between root length and the success of supplemental intraligamentary injection. The wide confidence interval and

insignificant odds ratio for mesiobuccal canal length in the multivariate logistic model may be due to low sample size, but the effect may be clinically relevant owing to marginally significant (*P*-value 0.092). Moreover, supplemental intraligamentary injection was only performed for patients with a failed IAN block before pulpal exposure, resulting in a small sample size. As reported in the results, 20.32% of patients required supplemental injection after pulpal exposure.

Different anesthetic agents' efficacy for IAN block has been investigated, and the superiority of other anesthetic agents to lidocaine has been previously confirmed [40]. Similarly, future studies need to assess and compare the efficacy of different anesthetic agents for supplemental intraligamentary injection. Moreover, evaluating the effect of root length and cortical bone thickness at the site of different teeth on the success of buccal infiltration anesthesia or supplemental intraligamentary injection is recommended.

One of the limitations of this study was the small sample size. Therefore, future studies should consider large sample size for evaluating the effect of root length on success rate of supplemental injections.

Conclusion

This study showed no significant correlation between the root length of mandibular first and second molars and the success rate of supplemental intraligamentary injection. The success rate of supplemental intraligamentary injection was not significantly different between mandibular first and second molars.

Acknowledgments
None.

Conflict of interest
None.

Funding support
No funding was received for this study.

Authors' contributions
Study conception and design: Masoud Parirokh. Data collection: Marzieh Kamali. Analysis and interpretation of results: Nouzar Nakhaei. Draft manuscript preparation: Hamed Manochehrifar. All authors reviewed the results and approved the final version of the manuscript

Informed consent:
Written informed consent was obtained from the patients.

References

1. Aggarwal V, Singla M, Miglani S, Kohli S. Efficacy of Articaine versus Lidocaine Administered as Supplementary Intraligamentary Injection after a Failed Inferior Alveolar Nerve Block: A Randomized Double-Blind Study. J Endod. 2019;45(1):1-5.
2. Biocanin V, Brkovic B, Milicic B, Stojic D. Efficacy and Safety of Intraseptal and Periodontal Ligament Anesthesia Achieved by Computer-Controlled Articaine+Epinephrine Delivery: A Dose-Finding Study. Clin Oral Investig. 2013;17:525-33.
3. Sakhaeimanesh V, Khazaei S, Kaviani N, Saatchi M, Shafiei M, Khademi A. Anesthetic Efficacy of Articaine and Ketamine for Inferior Alveolar Nerve Block in Symptomatic Irreversible Pulpitis: A Prospective Randomized Double-Blind Study. Iran Endod J. 2017;12(4):449.
4. Nusstein J, Reader A, Beck FM. Anesthetic Efficacy of Different Volumes of Lidocaine with Epinephrine for Inferior Alveolar Nerve Blocks. Gen Dent. 2002;50(4):372-5; quiz 6.
5. Aggarwal V, Singla M, Miglani S, Kohli S, Irfan M. 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. 2012;38(12):1578-80.
6. Parirokh M, Abbott PV. Present Status and Future Directions-Mechanisms and Management of Local Anaesthetic Failures. Int Endod J. 2022;55 Suppl 4:951-94.
7. Martin M, Nusstein J, Drum M, Reader A, Beck M. Anesthetic Efficacy of 1.8 mL versus 3.6 mL of 4% Articaine with 1:100,000 Epinephrine as a Primary Buccal Infiltration of the Mandibular First Molar. J Endod. 2011;37(5):588-92.
8. Bonar T, Nusstein J, Reader A, Drum M, Fowler S, Beck M. Anesthetic Efficacy of Articaine and Lidocaine in a Primary Intraseptal Injection: A Prospective, Randomized Double-Blind Study. Anesth Prog. 2017;64(4):203-11.
9. Mehrvarzfar P, Esnashari E, Salmanzadeh R, Fazlyab M, Fazlyab M. Effect of Dexamethasone Intraligamentary Injection on Post-Endodontic Pain in Patients with Symptomatic Irreversible Pulpitis: A Randomized Controlled Clinical Trial. Iran Endod J. 2016;11(4):261.
10. Meechan J. A Comparison of Ropivacaine and Lidocaine with Epinephrine for Intraligamentary Anesthesia. Oral Surg Oral MedOral Pathol Oral Radiol Endodo. 2002;93(4):469-73.
11. Savani GM, Sabbah W, Sedgley CM, Whitten B. Current Trends in Endodontic Treatment by General Dental Practitioners: Report of a United States National Survey. J Endod. 2014;40(5):618-24.
12. Bangerter C, Mines P, Sweet M. The Use of Intraosseous Anesthesia Among Endodontists: Results of a Questionnaire. J Endod. 2009;35(1):15-8.
13. Meechan J. Supplementary Routes to Local Anaesthesia. Int Endod J. 2002;35(11):885-96.
14. Nusstein J, Claffey E, Reader A, Beck M, Weaver J. Anesthetic Effectiveness of the Supplemental Intraligamentary Injection, Administered with a Computer-Controlled Local Anesthetic Delivery System, in Patients with Irreversible Pulpitis. J Endod. 2005;31(5):354-8.
15. Pan J, Wang Y, Qian Y, Zou J, Zhang Q. Comparison of Dental Anesthetic Efficacy Between the Periodontal Intraligamentary Anesthesia and other Infiltration Anesthesia: A Systematic Review and Meta-Analysis. Peer J. 2023;11:e15734.

16. Gupta A, Wadhwa J, Aggarwal V, Mehta N, Abraham D, Aneja K, Singh A. Anesthetic Efficacy of Supplemental Intraligamentary Injection in Human Mandibular Teeth with Irreversible Pulpitis: A Systematic Review and Meta-Analysis. J Dent Anesth Pain Med. 2022;22(1):1-10.
17. Shahi S, Rahimi S, Yavari HR, Ghasemi N, Ahmadi F. Success Rate of 3 Injection Methods with Articaine for Mandibular First Molars with Symptomatic Irreversible Pulpitis: A CONSORT Randomized Double-Blind Clinical Trial. J Endod. 2018;44(10):1462-6.
18. Aggarwal V, Singla M, Miglani S, Kohli S, Sharma V, Bhasin S. Does the Volume of Supplemental Intraligamentary Injections Affect the Anaesthetic Success Rate after a Failed Primary Inferior Alveolar Nerve Block? A Randomized-Double Blind Clinical Trial. Int Endod J. 2018;51(1):5-11.
19. Aggarwal V, Singla M, Saatchi M, Hasija M. Anaesthetic Efficacy of 2% Lidocaine with Different Concentrations of Epinephrine (1:80,000 And 1: 200,000) in Intraligamentary Injection after a Failed Primary Inferior Alveolar Nerve Block: A Randomized Double-Blind Study. Acta Odontol Scand. 2020;78(4):275-80.
20. Zargar N, Shooshtari E, Pourmusavi L, Akbarzadeh Baghban A, Ashraaf H, Parhizkar A. Anaesthetic Efficacy of 4% Articaine in Comparison with 2% Lidocaine as Intraligamentary Injections after an Ineffective Inferior Alveolar Nerve Block in Mandibular Molars With Irreversible Pulpitis: A Prospective Randomised Triple-Blind Clinical Trial. Pain Research and Management. 2021;2021:1-10.
21. Askari EM, Parirokh M, Nakhaee N, Hosseini HR, Abbott PV. The Effect of Maxillary First Molar Root Length on the Success Rate of Buccal Infiltration Anesthesia. J Endod. 2016;42(10):1462-6.
22. Hosseini HR, Parirokh M, Nakhaee N, Abbott PV, Samani S. Efficacy of Articaine and Lidocaine for Buccal Infiltration of First Maxillary Molars with Symptomatic Irreversible Pulpitis: A Randomized Double-Blinded Clinical Trial. Iran Endod J. 2016;11(2):79.
23. Parirokh M, Samadi I, Nakhaee N, Abbott P. Comparison of the Anaesthesia Success Rate in Maxillary First and Second Molars with 3% Prilocaine as the Anaesthetic Agent. Eur Endod J. 2021;6(3):254.
24. Parirokh M, Sadr S, Nakhaee N, Abbott P, Askarifard S. Efficacy of Supplementary Buccal Infiltrations and Intraligamentary Injections to Inferior Alveolar Nerve Blocks in Mandibular First Molars with Asymptomatic Irreversible Pulpitis: A Randomized Controlled Trial. Int Endod J. 2014;47(10):926-33.
25. Hameed NN, Sargod SS, Bhat SS, Hegde SK, Bava MM. Effectiveness of Precooling the Injection Site using Tetrafluorethane on Pain Perception in Children. J Indian Soc Pedod Prev Dent. 2018;36(3):296-300.
26. Kanaa MD, Whitworth JM, Corbett IP, Meechan JG. Articaine Buccal Infiltration Enhances the Effectiveness of Lidocaine Inferior Alveolar Nerve Block. Int Endod J. 2009;42(3):238-46.
27. Aggarwal V, Jain A, Kabi D. Anesthetic Efficacy of Supplemental Buccal and Lingual Infiltrations of Articaine and Lidocaine after an Inferior Alveolar Nerve Block in Patients with Irreversible Pulpitis. J Endod. 2009;35(7):925-9.
28. Brandt RG, Anderson PF, McDonald NJ, Sohn W, Peters MC. The Pulpal Anesthetic Efficacy of Articaine Versus Lidocaine in Dentistry: A Meta-Analysis. J Am Dent Assoc. 2011;142(5):493-504.
29. Su N, Li C, Wang H, Shen J, Liu W, Kou L. Efficacy and Safety of Articaine Versus Lidocaine for Irreversible Pulpitis Treatment: A Systematic Review and Meta-Analysis of Randomised Controlled Trials. Aust Endod J. 2016;42(1):4-15.
30. Dou L, Luo J, Yang D. Anaesthetic Efficacy of Supplemental Lingual Infiltration of Mandibular Molars after Inferior Alveolar Nerve Block Plus Buccal Infiltration in Patients with Irreversible Pulpitis. Int Endod J. 2013;46(7):660-5.
31. Aggarwal V, Singla M, Saatchi M, Gupta A, Hasija M, Meena B, Kumar U. Preoperative Intraligamentary Injection of Dexamethasone Can Improve the Anesthetic Success Rate of 2% Lidocaine During the Endodontic Management of Mandibular Molars with Symptomatic Irreversible Pulpitis. J Endod. 2021;47(2):161-8.
32. Dawson A, List T. Comparison of Pain Thresholds and Pain Tolerance Levels Between Middle Easterners and Swedes and Between Genders. J Oral Rehabil. 2009;36(4):271-8.
33. Attar S, Bowles WR, Baisden MK, Hodges JS, McClanahan SB. Evaluation of Pretreatment Analgesia and Endodontic Treatment for Postoperative Endodontic Pain. J Endod. 2008;34(6):652-5.
34. Aminabadi NA, Farahani RMZ. The Effect of Pre-Cooling the Injection Site on Pediatric Pain Perception During the Administration of Local Anesthesia. J Contemp Dent Pract. 2009;10(3):1-9.
35. Kanaa MD, Whitworth JM, Meechan JG. 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. 2012;38(4):421-5.
36. Jin G-C, Kim K-D, Roh B-D, Lee C-Y, Lee S-J. Buccal Bone Plate Thickness of the Asian People. J Endod. 2005;31(6):430-4.
37. Shapiro MR, McDonald NJ, Gardner RJ, Peters MC, Botero TM. Efficacy of Articaine Versus Lidocaine in Supplemental Infiltration for Mandibular First versus Second Molars with Irreversible Pulpitis: A Prospective, Randomized, Double-Blind Clinical Trial. J Endod. 2018;44(4):523-8.
38. Ashraf H, Kazem M, Dianat O, Noghrehkar F. Efficacy of Articaine versus Lidocaine in Block and Infiltration Anesthesia Administered in Teeth with Irreversible Pulpitis: A Prospective, Randomized, Double-Blind Study. J Endod. 2013;39(1):6-10.
39. Malamed SF. The Periodontal Ligament (PDL) Injection: An Alternative to Inferior Alveolar Nerve Block. Oral Surg Oral Med Oral Pathol. 1982;53(2):117-21.
40. Larocca de Geus J, Nogueira da Costa JK, Wambier LM, Maran BM, Loguercio AD, Reis A. Different Anesthetics on the Efficacy of Inferior Alveolar Nerve Block in Patients with Irreversible Pulpitis: A Network Systematic Review and Meta-Analysis. J Am Dent Assoc. 2020;151(2):87-97.e4.

Please cite this paper as: Kamali M, Parirokh M , Manochehrifar H , Nakhaei N. Assessing the Impact of Mandibular Molar Root Length on Success in Supplemental Intraligamentary Injection for Irreversible Pulpitis. Iran Endod J. 2024;19(1): 28-34. *Doi: 10.22037/iej.v19i1.42660.*