Original Research

https://doi.org/10.36377/ET-0170

Influence of root length on the success of buccal infiltration anesthesia using 4% articaine in maxillary first molars with irreversible pulpitis undergoing root canal treatment: a clinical study

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Abstract

INTRODUCTION. Buccal infiltration using 4% articaine with epinephrine is a widely preferred anesthetic technique for maxillary molars. However, failures in achieving profound pulpal anesthesia, especially in teeth with irreversible pulpitis, remain clinically challenging. Anatomical factors such as root length may influence anesthetic diffusion but are seldom investigated.

AIM. To evaluate the effect of root length on the success rate of buccal infiltration anesthesia in maxillary first molars diagnosed with irreversible pulpitis.

MATERIALS AND METHODS. A prospective single-arm clinical trial was conducted on 60 adult patients with irreversible pulpitis in maxillary first molars. Following buccal infiltration with 1.7 ml of 4% articaine containing 1:100,000 epinephrine, pain responses during dentin removal, pulp chamber access, and canal instrumentation were recorded using the Heft-Parker Visual Analog Scale. Root lengths were measured radiographically using a standardized endodontic protocol. Anesthetic success was defined as no or mild pain at any procedural stage.

RESULTS. Overall anesthetic success was 81.1%. Success rates by root were: mesiobuccal 83.3%, distobuccal 81.7%, and palatal 78.3%. Mean root lengths were 18.8 ± 1.5 mm (mesiobuccal), 19.1 ± 1.5 mm (distobuccal), and 20.6 ± 1.7 mm (palatal). No statistically significant correlation was found between increased root length and anesthetic failure ($p > 0.05$).

CONCLUSIONS. The variations in the lengths of different roots of maxillary first molars do not significantly affect the success rate of buccal infiltration anesthesia in cases of irreversible pulpitis.

Keywords: anesthesia, dental pulp test, endodontics, articaine, pain measurement, maxillary first molar, root morphology

Article information: received – 14.11.2025; revised – 29.12.2025; accepted – 10.01.2026

Conflict of interest: The authors declare no conflict of interest.

Acknowledgements: No funding or individual acknowledgements are declared.

For citation: Patil A.H., Yadav P., Mistry L.N., Jaiswal H.C., Naik V., Sachdev S.S. Influence of root length on the success of buccal infiltration anesthesia using 4% articaine in maxillary first molars with irreversible pulpitis undergoing root canal treatment: a clinical study. *Endodontics Today*. 2026;24(1):143–150. https://doi.org/10.36377/ET-0170

Влияние длины корня на эффективность щечной инфильтрационной анестезии с 4% артикаином при верхних первых молярах с необратимым пульпитом, подвергающихся эндодонтическому лечению: клиническое исследование

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Резюме

ВВЕДЕНИЕ. Щечная инфильтрационная анестезия с использованием 4% артикаина с адреналином широко применяется для верхних моляров. Однако случаи неудачи достижения глубокой пульпарной анестезии, особенно при необратимом пульпите, представляют клиническую проблему. Анатомиче-

ские факторы, такие как длина корня, могут влиять на диффузию анестетика, однако изучены они недостаточно.
ЦЕЛЬ. Оценить влияние длины корня на успешность щечной инфильтрационной анестезии у верхних первых моляров с диагнозом необратимого пульпита.
МАТЕРИАЛЫ И МЕТОДЫ. Проведено проспективное одноплечевое клиническое исследование на 60 взрослых пациентах с необратимым пульпитом верхних первых моляров. После щечной инфильтрации 1,7 мл 4% артикаина с концентрацией адреналина 1:100 000 регистрировали болевые реакции при удалении дентина, вскрытии пульповой камеры и инструментальной обработке каналов с использованием визуальной аналоговой шкалы Heft-Parker. Длина корней измерялась рентгенологически по стандартизированному эндодонтическому протоколу. Успех анестезии определялся как отсутствие боли или л егкая боль на любом этапе процедуры.
РЕЗУЛЬТАТЫ. Общая успешность анестезии составила 81,1%. Успешность по корням: мезиобуккальный – 83,3%, дистобуккальный – 81,7%, небный – 78,3%. Средняя длина корней составила: мезиобуккальный – 18,8 ± 1,5 мм, дистобуккальный – 19,1 ± 1,5 мм, небный – 20,6 ± 1,7 мм. Статистически значимой корреляции между увеличением длины корня и неудачей анестезии не выявлено ($p > 0,05$).
ВЫВОДЫ. Вариации длины различных корней верхних первых моляров не оказывают существенного влияния на эффективность щечной инфильтрационной анестезии при необратимом пульпите.

Ключевые слова: анестезия, тестирование зубной пульпы, эндодонтия, артикаин, измерение боли, верхний первый моляр, морфология корня

Информация о статье: поступила – 14.11.2025; исправлена – 29.12.2025; принята – 10.01.2026

Конфликт интересов: Авторы сообщают об отсутствии конфликта интересов.

Благодарности: Финансирование и индивидуальные благодарности для декларирования отсутствуют.

Для цитирования: Патил А.Х., Ядав П., Мистри Л.Н., Джайсвал Х.Ч., Найк В., Сачдев С.С. Влияние длины корня на эффективность щечной инфильтрационной анестезии с 4% артикаином при верхних первых молярах с необратимым пульпитом, подвергающихся эндодонтическому лечению: клиническое исследование. *Эндодонтия Today.* 2026;24(1):143–150. https://doi.org/10.36377/ET-0170

INTRODUCTION

Pain is a multimodal unpleasant perception predominantly associated with tissue damage and can vary in intensity from mild to severe [1]. Dental pain commonly occurs when there is pulp hyperemia resulting from a pathology (typically dental caries), which leads to the development of increased pressure inside the restricted pulp chambers and canals, causing excruciating pain. Dental pain is the most common reason for patients to seek dental treatment. Dental professionals, therefore, perform endodontic procedures involving the removal of the affected pulp tissues and replacing it with an inert material to eliminate the pain and anxiety [2].

The handling of dental pulp tissue during endodontic procedures can be extremely painful, and therefore, local anesthesia is administered [3]. Experiencing pain during dental treatment affects the patient's confidence in the dentist's ability to treat them [4]. This pain may extend into the postoperative period, leading to negative feedback from the patients [5]. Furthermore, the patients may become reluctant to undergo dental treatment in the future. Therefore, a dental professional strives to minimize the pain during and after the dental treatment to instill a positive attitude in the patients towards dental treatment and the dentist [6].

To tackle this issue, numerous measures are adopted by the dentists, which most commonly comprise administration of a local anesthetic agent and prescription of pre-emptive analgesics. Among various anesthetic solutions, 4% articaine with 1:100,000 epinephrine has gained popularity due to its superior bone penetration, rapid onset, and extended duration of action [7]. These agents are injected near the periapical region of the teeth, commonly using the infiltration technique before initiating the root canal procedure. However, clinical studies report that a significant proportion of maxillary molars, especially those diagnosed with irreversible pulpitis, may not achieve complete pulpal anesthesia with buccal infiltration alone [8]. While numerous factors, including the inflammatory state of the pulp, tissue pH, and patient-specific variables such as anxiety and pain threshold, have been investigated in relation to anesthetic success, anatomical factors such as root length have not been adequately explored.

The maxillary first molar typically has three roots, mesiobuccal (MB), distobuccal (DB), and palatal (P), with the palatal root often being the longest [9]. It has been postulated that greater root length, particularly of the palatal root, may impair anesthetic diffusion from the buccal cortical plate, thereby diminishing anesthetic efficacy [10; 11]. This hypothesis is clinically relevant, especially when using buccal infiltration as the sole anesthetic technique, as longer roots may lie beyond the effective diffusion range of the local anesthetic, leading to incomplete pulpal anesthesia. While several studies have examined supplemental anesthesia techniques and anesthetic agents, the impact of root length on infiltration success remains underexplored.

Given this gap in the literature, the present clinical study was undertaken to investigate the effect of root length, specifically in the maxillary first molar, on the success rate of buccal infiltration anesthesia using 4% articaine with 1:100,000 epinephrine in patients with irreversible pulpitis. By evaluating pain response during access and instrumentation procedures, this study aims to provide valuable insights that may help clinicians anticipate anesthetic challenges and tailor pain management strategies accordingly, improving both clinical efficiency and patient outcomes in endodontic practice.

MATERIALS AND METHODS

Study design and ethical approval

this clinical study was designed as a prospective, single-arm clinical trial aimed at assessing the relationship between root length and the success rate of maxillary buccal infiltration anesthesia in patients with irreversible pulpitis. The study protocol received approval from both the Institutional Scientific Review Committee and the Institutional Ethical Committee (IEC No. 3210322, dated 16/02/2022). Additionally, the research protocol was prospectively registered with the Clinical Trials Registry of India (CTRI/2022/09/058230), and the study adhered to the Consolidated Standards of Reporting Trials (CONSORT) guidelines to ensure methodological transparency and ethical conduct [12].

Patient selection and recruitment

participants were screened and enrolled from the outpatient department of the institution between August 2022 and February 2023. Inclusion criteria required participants to be above 18 years of age and to present with a maxillary first molar clinically diagnosed with irreversible pulpitis, based on a prolonged symptomatic response to cold stimulation using Endo-Frost, which is composed of ethyl chloride and a mixture of propane and butane. Only teeth with radiographic evidence of normal periapical structures, as confirmed using an intraoral periapical radiography (IOPA), were included. Patients were excluded if they exhibited clinical signs of acute infection, such as swelling or sinus tract formation, if periapical radiolucency was evident, if they were pregnant, or if they had a known allergy to local anesthetic agents.

Eligible patients were provided with detailed verbal and written information about the study, and written informed consent was obtained prior to participation. Prior to administration of anesthesia, patients were asked to rate their baseline pain using the Heft-Parker visual analog scale (VAS), a validated 170-mm scale [13]. Pain scores were categorized as follows: no pain (0), mild pain (>0–54 mm), moderate pain (55–114 mm), and severe pain (115–170 mm).

Sample size estimation

sample size was determined using a power analysis based on the minimum clinically significant difference in VAS scores. With an expected standard deviation of 0.75, an alpha error probability of 0.05, and a power of 0.8, the calculated sample size required for the study was 60 teeth.

Treatment protocol

All endodontic procedures were performed by a single experienced operator, following a standardized protocol. The target tooth was anesthetized using a buccal infiltration technique. Before injection, topical 20% benzocaine gel (Projel-20, Septodont USA) was applied to the mucosa overlying the apices of the MB, DB and palatal roots of the maxillary first molar. A 27-gauge, 35 mm Septoject needle (Septodont, France) was used to deliver 1.7 ml of 4% articaine with 1:100,000 epinephrine into the alveolar mucosa between the buccal roots using the infiltration anesthesia technique. To ensure that anesthesia was delivered appropriately at the periapical region, the position and angulation of the needles were standardized according to the preoperative radiographs for all patients. The injected areas were massaged for 20 seconds to ensure proper dispersion of the local anesthetic agent into the tissues surrounding all three roots.

Following a latency period to allow for anesthetic onset, the tooth was isolated with a rubber dam, and endodontic access cavity preparation was initiated. At each critical treatment stage, dentin removal, pulp chamber entry, and canal instrumentation, the patient's pain perception was recorded using the Heft-Parker VAS [13]. Anesthesia was deemed successful if the patient reported no to mild pain, while moderate or severe pain was considered indicative of anesthetic failure. If failure occurred at any stage, supplemental intrapulpal anesthesia was administered to continue the treatment.

Measurement of root length and canal instrumentation

a #15 hand K-file with a rubber stopper was inserted up to the point where a proprioceptive tugback was felt. This point was discerned to be the apex of the root, and the position of the file was then confirmed radiographically using an intraoral periapical radiovisiograph. Measurements were taken from the tip of each root to the corresponding cusp tip. The file with a stopper was then removed, and the length was measured using a standard Endo-block (Dentsply Maillefer, Switzerland). For MB root having two root canals, the higher value was considered as the root length. Length of each root was recorded in a standard worksheet (MS Excel v2019, Microsoft, Redmond, USA). The preparatory and measurement steps are collectively shown in Fig. 1. The canals were negotiated and shaped using the Protaper Gold rotary instrumentation system (Dentsply Sirona, Charlotte, USA), with apical preparation tailored based on apical gauging. Irrigation was performed copiously throughout the procedure using 2.5% sodium hypochlorite by a 26-gauge needle, ensuring optimal debridement. Further instrumentation, including subsequent file systems and obturation procedures, was completed in the same visit according to standard endodontic protocols.

RESULTS

A total of 60 patients participated in this study (Fig. 2), including 34 females (56.7%) and 26 males (43.3%), with a mean age of 27.2 years. The distribution of anesthesia success did not differ significantly between male and female participants ($p > 0.05$), indicating that gender did not influence anesthetic outcomes in this sample.

Following administration of a single buccal infiltration injection of 4% articaine with 1:100,000 epinephrine, the overall success rate of anesthesia, defined as the absence of pain or only mild pain during treatment, was 81.11%. Evaluation at different procedural stages (Table 1) revealed that 93.33% of patients reported no or mild pain during dentin removal, while 90% of patients experienced successful anesthesia during pulp chamber access.

Table 1. Number and percentage of anesthesia success during various stages of the treatment

Таблица 1. Число и доля случаев успешной анестезии на разных стадиях лечения

Stage of treatment	Number of faliures	Failurerrate, %	Number of successes	Success rate, %
Dentin removal	4	6.67	56	93.33
Pulp exposure	6	10.00	54	90.00
Throughout the endodontic procedure	4	6.67	56	93.33

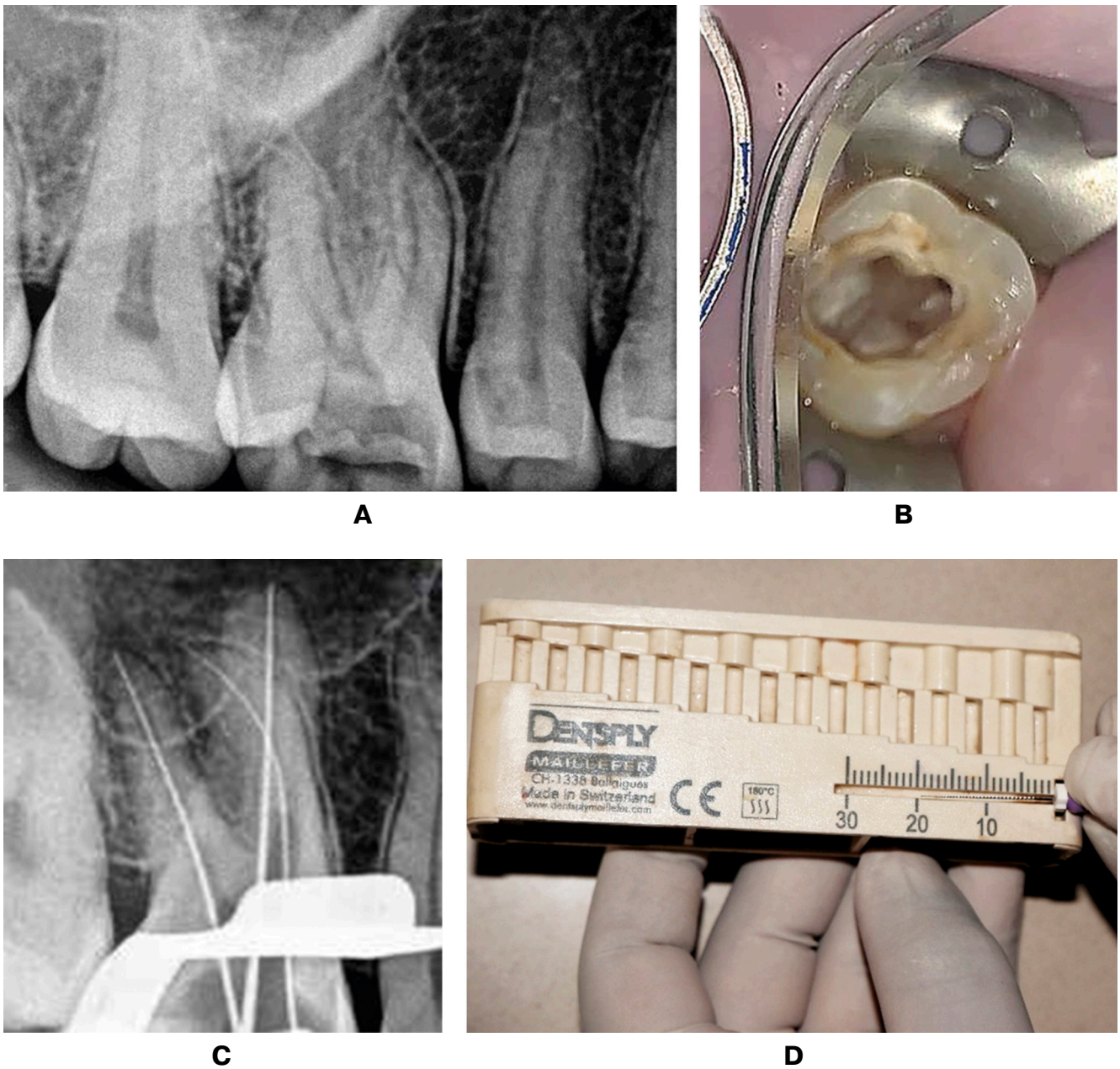

Fig. 1. Preparatory and measurement steps: (*A*) pre-operative radiograph showing maxillary first molar with occlusal caries involving enamel, dentin and pulp; (*B*) visualization of the root canals after access cavity preparation; (*C*) confirmatory radiograph showing insertion of the file up to the root apex; (*D*) Measurement of the file length using an Endo-block

Рис. 1. Этапы подготовки и измерения: (*A*) предоперационный рентгеновский снимок верхнего первого моляра с окклюзионным кариесом, поражающим эмаль, дентин и пульпу; (*B*) визуализация корневых каналов после подготовки доступа; (*C*) контрольный рентгеновский снимок, демонстрирующий введение инструмента до верхушки корня; (*D*) измерение длины инструмента с помощью эндоблока (Endo-block)

Only four patients (6.67%) experienced moderate to severe pain during dentin removal and required supplemental palatal infiltration for effective pain control. An additional six patients (10%) reported pain upon pulp exposure (Fig. 2), of which four reported pain persisting during root canal instrumentation and were successfully managed with intrapulpal anesthesia.

When analyzed by individual root (Fig. 3), the MB root exhibited the highest success rate of 83.33%, followed closely by the DB root at 81.67% and the palatal root at 78.33%. Although the palatal root showed a slightly higher rate of anesthetic failure, the point-biserial correlation test indicated no statistically significant differences in anesthesia success rates among the three roots (MB vs. DB: $p = 0.938$; MB vs. P: $p = 1.000$; DB vs. P: $p = 0.938$).

The analysis of root length revealed that the palatal roots were significantly longer than the MB and DB roots. The mean root lengths were as follows: palatal root (20.6 ± 1.7 mm), DB root (19.1 ± 1.5 mm), and MB root (18.8 ± 1.5 mm). Despite this difference in root length, no statistically significant association ($p > 0.05$) was observed between increased root length and anesthetic failure, suggesting that longer palatal roots did not compromise the efficacy of buccal infiltration anesthesia in maxillary first molars (Table 2).

These findings support the conclusion that buccal infiltration with articaine is highly effective for maxillary first molars with irreversible pulpitis and that variations in root length, particularly in the palatal root, do not significantly influence anesthetic success.

DISCUSSION

The present clinical study aimed to evaluate whether root length, particularly that of the palatal root, influences the success rate of buccal infiltration anesthesia in maxillary first molars diagnosed with irreversible pulpitis. Clinical trials offer a unique advantage by capturing real-time biological interactions and variables that laboratory-based studies may not accurately reflect. In dental anesthesia, buccal infiltration remains a widely favored technique for maxillary molars due to the porosity of the maxillary bone, which facilitates diffusion of anesthetic agents [14]. While palatal injections are known to be more painful, prior research by Aggarwal et al. indicated no significant improvement in anesthetic success when palatal injections were added to buccal infiltration for maxillary molars with irreversible pulpitis [15]. This finding supports the clinical preference to avoid palatal injections unless absolutely necessary.

In this study, a single buccal infiltration of 4% articaine with 1:100,000 epinephrine resulted in a notable 81.11% overall success rate for pulpal anesthesia. When analyzed root-wise, the MB root demonstrated the highest success rate at 83.33%, followed by the DB at 81.67%, and the palatal root at 78.33%. Despite the slightly lower success rate associated with the palatal root, statistical analysis revealed no significant correlation between increased root length and anesthetic failure. Nonetheless, the comparatively lower success rate in the palatal root warrants clinical attention, particularly because it often exhibits the greatest length and may lie beyond the effective diffusion zone of the anesthetic solution administered buccally [16].

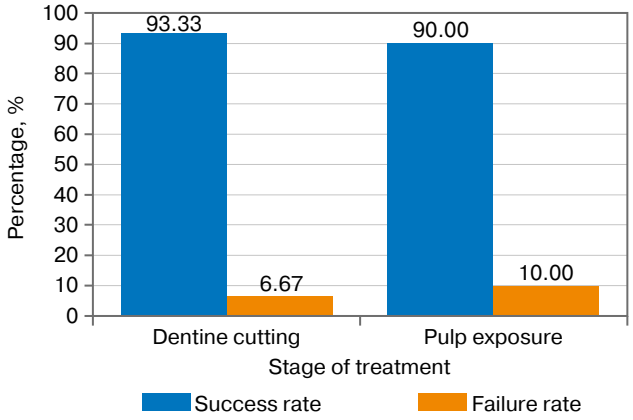

Fig. 2. Graphical representation of success and failure rates during different treatment stages

Рис. 2. Графическое отображение частоты успешного и неудачного исхода на различных стадиях лечения

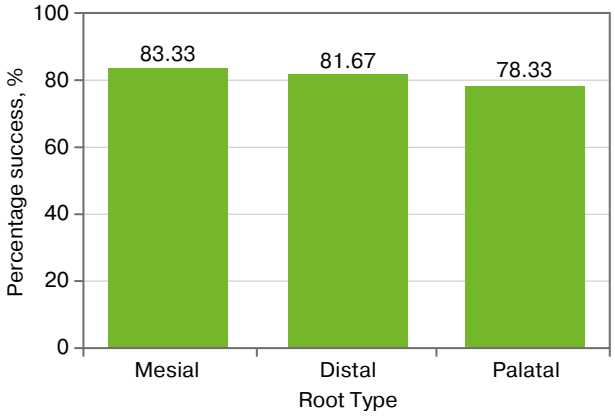

Fig. 3. Graphical representation of the success rates of anesthesia in individual roots

Рис. 3. Графическое представление уровня успешности анестезии по отдельным корням

Table 2. Failure and success rates of anesthesia according to the mean root length

Таблица 2. Частота неудач и успеха анестезии в зависимости от средней длины корня зуба

Root (Mean ± SD mm)	Failures *n* (%)	Success *n* (%)	χ^2 (df)	*p*-value (vs others)
MB (18.8 ± 1.5)	10 (16.7%)	50 (83.3%)	0.39 (2) overall	0.82 (overall)
DB (19.1 ± 1.5)	11 (18.3%)	49 (81.7%)	–	0.79 (MB vs DB)
P (20.6 ± 1.7)	13 (21.7%)	47 (78.3%)	–	0.47 (MB vs P); 0.63 (DB vs P)

These findings align with earlier literature. Evans et al., Srinivasan et al., and Woo et al. have all highlighted limitations of buccal infiltration in anesthetizing the palatal root, especially in cases of irreversible pulpitis [17–19]. Moreover, Omar et al. suggested that the anatomical proximity of the maxillary sinus to the roots of the upper molars, particularly the palatal root, may interfere with anesthetic diffusion [11]. When the sinus floor extends between the buccal and palatal roots, the sinus membrane could act as a physical barrier, thereby reducing the efficacy of the infiltration [20]. The role of adjacent hard tissue morphology, including root divergence and bone density, is increasingly recognized as a significant determinant of anesthetic success [20].

A study by Askari et al. utilized 2% lidocaine with 1:80,000 epinephrine and demonstrated a lower success rate (61%) for maxillary first molars with irreversible pulpitis [10]. They found significantly higher failure rates associated with longer palatal and DB roots [10; 15–19]. In contrast, our study found that despite palatal roots being the longest, there was no statistically significant difference in anesthesia success based on root length, possibly due to the superior diffusion characteristics of articaine. The discrepancy observed in earlier studies could be due to the fact that different lengths of roots require different positions and angulations of the anesthetic needle so that the agent is delivered to the periapical area. The standardization of these procedures constitutes a potential strength of the present study.

The higher efficacy of articaine may be explained by its molecular structure, as noted by Srinivasan et al., who reported a 100% success rate in a small sample of 10 teeth using articaine for buccal infiltration [18]. Although the present study observed a slightly lower success rate, the findings remain consistent when accounting for the larger sample size. The chemical structure of articaine, featuring a thiophene ring and high lipid solubility, facilitates enhanced membrane penetration and diffusion through bone and nerve tissues [21]. Pharmacological studies have consistently demonstrated that articaine exhibits superior permeation capabilities compared to other anesthetics, which may explain its more reliable performance in challenging clinical scenarios such as irreversible pulpitis [22].

Clinically, this study underscores two practical recommendations. First, the depth of needle insertion during buccal infiltration should ideally correspond to the estimated root length, particularly for molars with elongated or divergent roots [23]. Preoperative periapical radiographs obtained using the paralleling technique can be instrumental in estimating root length. Second, if a CBCT scan is available from previous diagnostics, it may serve as a valuable adjunct in planning anesthetic delivery by providing a three-dimensional understanding of root morphology and adjacent anatomical structures [24]. Furthermore, root divergence could delay anesthetic diffusion to the palatal root apex, particularly in widely spread roots, and may contribute to localized anesthetic failure despite overall clinical success [20].

Overall, the study affirms the effectiveness of 4% articaine in achieving profound pulpal anesthesia via buccal infiltration in the majority of maxillary first molars with irreversible pulpitis. While anatomical factors like root length and sinus proximity may influence anesthetic diffusion, they do not necessarily predict failure, especially when a potent anesthetic agent like articaine is used with proper technique and case-specific planning.

CONCLUSION

Within the limitations of this clinical study, it can be concluded that variations in root length, including the longer palatal root of the maxillary first molar, do not significantly affect the success rate of buccal infiltration anesthesia in cases of irreversible pulpitis. The findings suggest that root length alone is not a predictive factor for anesthetic success when using 4% articaine with 1:100,000 epinephrine. Hence, clinicians may not need to modify anesthetic technique solely based on root length when performing endodontic procedures on maxillary first molars.

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AUTHOR'S CONTRIBUTION

All the authors made equal contributions to the publication preparation in terms of the idea and design of the article; data collection; critical revision of the article in terms of significant intellectual content and final approval of the version of the article for publication.

ВКЛАД АВТОРОВ

Все авторы внесли равноценный вклад в подготовку публикации в части замысла и дизайна исследования; сбора данных; критического пересмотра статьи в части значимого интеллектуального содержания и окончательного одобрения варианта статьи для опубликования.