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Comparison of Anesthetic Efficacy of Lidocaine and Articaine in Non-Surgical Endodontic Treatment of Permanent Mandibular Molars with Symptomatic Irreversible Pulpitis

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ABSTRACT

Background: *Achieving profound pulpal anesthesia in mandibular molars with symptomatic irreversible pulpitis (SIP) remains a clinical challenge due to the inflammatory environment, which reduces anesthetic efficacy. Lidocaine is the conventional agent of choice, but articaine's superior lipid solubility and tissue penetration may offer enhanced anesthetic performance, particularly when combined with supplemental infiltration techniques.* ***Objective:*** *To compare the anesthetic efficacy of 4% articaine and 2% lidocaine, both with 1:100,000 epinephrine, administered via inferior alveolar nerve block (IANB) combined with buccal infiltration (BI) during non-surgical endodontic treatment of permanent mandibular molars with SIP.* ***Methods:*** *In this double-blind, randomized controlled trial, 140 patients diagnosed with SIP were randomly assigned to receive either 4% articaine (Group B) or 2% lidocaine (Group A). All patients received IANB followed by BI. The primary outcome was anesthetic success, defined as absence of moderate-to-severe pain (VAS < 4) during access cavity preparation and instrumentation. Secondary outcomes included mean and median visual analogue scale (VAS) pain scores at 15 minutes and 1 hour post-injection, and the proportion of patients experiencing complete pain relief (VAS = 0). Data were analyzed using the Mann–Whitney U and Chi-square tests, with effect sizes and 95% confidence intervals (CI) reported.* ***Results:*** *Anesthetic success was achieved in all participants in both groups (100% vs. 100%, p = 1.00). Articaine demonstrated significantly lower pain scores compared to lidocaine at 15 minutes (mean ± SD: 0.87 ± 0.82 vs. 2.03 ± 0.72; mean difference: 1.16, 95% CI: 0.90–1.42; p < 0.0001) and at 1 hour (0.43 ± 0.50 vs. 1.03 ± 0.68; mean difference: 0.60, 95% CI: 0.40–0.80; p < 0.0001). The proportion of pain-free patients was also significantly higher with articaine (15 min: 62.8% vs. 5.7%; 1 h: 88.5% vs. 34.2%; p < 0.001).* ***Conclusion:*** *Although both anesthetics achieved high clinical success, articaine produced significantly deeper and more predictable pulpal anesthesia than lidocaine. Its superior analgesic profile supports its use as a preferred anesthetic in challenging endodontic cases involving SIP, particularly when profound anesthesia and patient comfort are critical.*

Keywords
Symptomatic irreversible pulpitis; articaine; lidocaine; inferior alveolar nerve block; buccal infiltration; local anesthesia; endodontics; randomized controlled trial.

INTRODUCTION

Symptomatic irreversible pulpitis (SIP) in mandibular molars poses a well-recognized challenge for intraoperative pain control in endodontics. Inflammation lowers tissue pH and alters nociceptive thresholds, reducing the success of conventional inferior alveolar nerve block (IANB) and increasing the need for adjunctive strategies during access and instrumentation (1,3,4). Achieving reliable pulpal anesthesia in this context is therefore a clinical priority to ensure patient comfort, procedural efficiency, and avoidance of unplanned intraoperative interruptions (1,3,4).

Lidocaine remains the most widely used local anesthetic in dentistry owing to its balanced efficacy and safety profile accrued over decades of clinical use (5). However, interest has grown in articaine, an amide anesthetic distinguished by a thiophene ring that increases lipid solubility and tissue diffusion. These physicochemical properties are hypothesized to facilitate better penetration through dense mandibular cortical bone and inflamed tissues, potentially offering a clinical advantage where IANB success is compromised (11,7).

Comparative evidence on articaine and lidocaine in endodontic pain control is mixed. Several clinical trials—particularly those incorporating buccal infiltration (BI) as an initial or supplemental technique—report lower intraoperative pain ratings or higher procedural comfort with articaine in mandibular molars with SIP (3,7,10,18,19). Conversely, studies that rely on a single IANB technique often find comparable outcomes between agents, suggesting that any advantage of articaine may be technique dependent rather than universal (4,9). This heterogeneity is compounded by inconsistent outcome definitions across studies (e.g., binary "success" thresholds versus continuous pain intensity measures) and by variability in timing and sequencing of supplemental injections (3,4,7,9,10,18,19).

Given these uncertainties, further trials using standardized, protocolized anesthesia and clearly defined endpoints are warranted. The present randomized, double-blind study compares 4% articaine with epinephrine 1:100,000 to 2% lidocaine with epinephrine 1:100,000 using a combined IANB + BI approach administered upfront rather than as rescue. Pulpal anesthesia was objectively verified prior to treatment, and intraoperative pain was quantified using visual analogue scale (VAS) assessments at clinically relevant time points. We hypothesized that, under a uniform IANB + BI protocol, articaine would achieve **lower intraoperative pain intensity** than lidocaine in mandibular molars with SIP, while acknowledging that binary success rates may be high for both agents (3,4,7,9,10,18,19).

MATERIALS AND METHODS

This randomized, double-blind, parallel-group controlled clinical trial was conducted in the Department of Operative Dentistry and Endodontics, Fatima Jinnah Dental College and Hospital, Karachi, Pakistan. The study protocol adhered to the principles of the Declaration of Helsinki and was approved by the Institutional Review Board (Ref. AUG-2023-OPR-02). All participants provided written informed consent prior to enrolment. The trial was retrospectively registered with the Thai Clinical Trials Registry (TCTR20250616006, 16 June 2025) due to administrative delays, but the protocol, outcome measures, and analysis plan were defined a priori and remained unchanged throughout the study.

Patients aged 18–65 years, of either sex, presenting with symptomatic irreversible pulpitis (SIP) in permanent mandibular molars and requiring non-surgical endodontic treatment were eligible. Diagnosis was based on clinical signs and symptoms, including prolonged pain to thermal stimuli, spontaneous pain, and a positive response to vitality tests, corroborated by radiographic findings. Patients were excluded if they had known allergies to amide local anesthetics, were pregnant, immunocompromised, had received analgesics or antibiotics within 12 hours prior to treatment, or presented with extra-oral swelling or sinus tract associated with the affected molar. Patients in whom inferior alveolar nerve block (IANB) failed to produce lip numbness were excluded before randomization and referred for standard care.

Sample size was calculated using OpenEpi software based on data from a previous clinical trial comparing articaine and lidocaine in mandibular molars with SIP (3). Assuming a medium effect size (Cohen's d = 0.5), an alpha level of 0.05, and a statistical power of 0.80, a minimum of 64 participants per group was required. Anticipating potential dropouts, this was increased to 70 per group, yielding a total sample of 140 participants. Eligible participants were randomized in a 1:1 ratio to receive either 4% articaine with 1:100,000 epinephrine or 2% lidocaine with 1:100,000 epinephrine. A randomization sequence was generated using Microsoft Excel's RAND function and concealed in sequentially numbered, opaque envelopes prepared by a dental assistant not involved in clinical procedures or outcome assessment. To preserve blinding despite differences in cartridge appearance, anesthetic syringes were prepared and coded by the same assistant using opaque sleeves before being presented to the operator. Both the operator and participants were blinded to the allocation throughout the study.

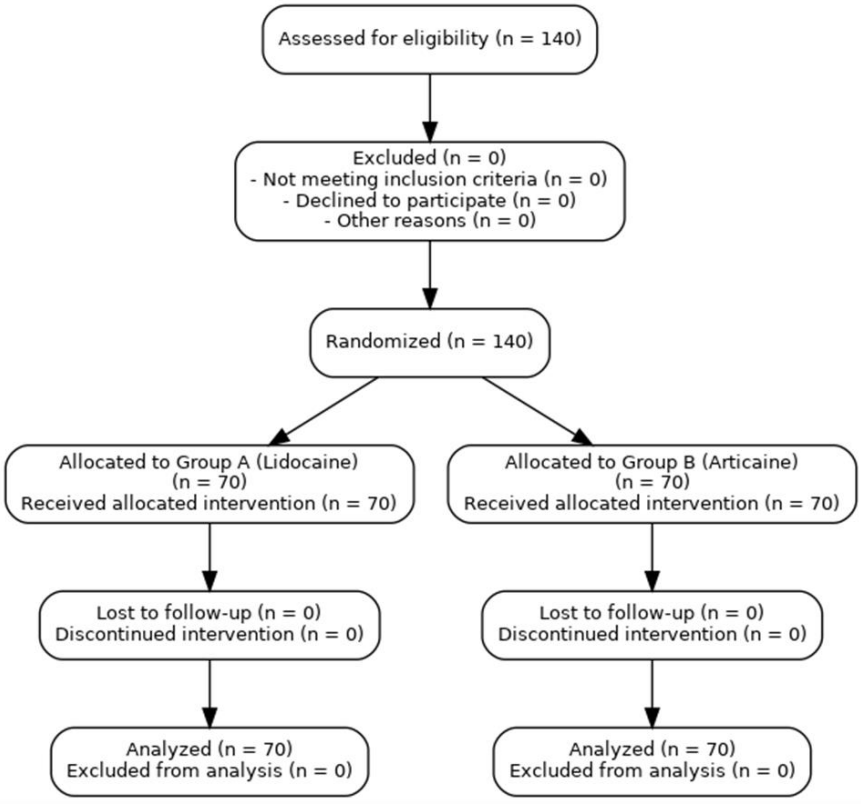

Figure 1 CONSORT Flowchart

All procedures were performed by a single experienced endodontist using a standardized anesthetic technique. Group A received 1.7 mL of 4% articaine with 1:100,000 epinephrine (Septanest; Septodont, Saint-Maur-des-Fossés, France), while Group B received 1.8 mL of 2% lidocaine with 1:100,000 epinephrine (Medicaine; Huons Co., Ltd., Seongnam, Korea). Each participant received two coded cartridges of the assigned anesthetic—one for IANB and one for buccal infiltration (BI). The IANB was administered using the conventional Halsted approach with a 27-gauge long needle, followed by BI at the buccal vestibule adjacent to the affected molar within 1–2 minutes.

Fifteen minutes after injection, pulpal anesthesia was objectively verified using both cold testing (Endo-Ice; Coltene, USA) and electric pulp testing (Parkell, USA). Lack of response to both tests on two consecutive attempts indicated successful pulpal anesthesia. Patients without lip numbness prior to randomization were excluded, while those failing objective anesthesia testing after injection were not excluded but monitored for intraoperative pain as per protocol.

Following successful anesthesia confirmation, rubber dam isolation was performed, and endodontic treatment commenced. Caries removal and straight-line access preparation were carried out using a high-speed handpiece, followed by canal negotiation with #10 and #15 K-files (Dentsply Maillefer, Switzerland) to full working length under copious sodium hypochlorite irrigation. Intraoperative pain intensity was assessed using a 10-cm Visual Analogue Scale (VAS), where 0 represented no pain and 10 represented the worst imaginable pain. Pain was recorded at two predefined time points: 15 minutes after injection (prior to access preparation) and 1 hour after injection (during instrumentation).

The primary outcome was intraoperative anesthetic success, defined as absence of moderate-to-severe pain (VAS < 4) during access and instrumentation within 1 hour of injection. Secondary outcomes included mean VAS scores at 15 minutes and 1 hour and the proportion of patients experiencing complete absence of pain (VAS = 0). This dual-endpoint approach allowed assessment of both clinically meaningful binary success and finer differences in pain intensity.

Data were analyzed using SPSS version 23. The Shapiro–Wilk test was applied to assess normality of continuous variables. As VAS scores were not normally distributed, they were summarized as median and interquartile range (IQR) and compared between groups using the Mann–Whitney U test. Categorical outcomes, including anesthetic success rates and proportion of pain-free patients, were analyzed using the Chi-square test. Effect sizes were reported as rank-biserial correlation (r) for non-parametric comparisons and as Cohen's d where distributional assumptions were approximately met. Statistical significance was defined as $p < 0.05$. Ninety-five percent confidence intervals (95% CI) were calculated for all key outcomes.

RESULTS

A total of 140 patients meeting the inclusion criteria were enrolled and randomized into two groups: Group A (lidocaine, $n = 70$) and Group B (articaine, $n = 70$). All participants received the allocated interventions and completed follow-up, with no losses, dropouts, or exclusions after randomization (Figure 1). Baseline demographic and clinical characteristics were comparable between groups, indicating successful randomization (Table 1).

Table 1. Baseline characteristics of study participants

Characteristic	Group A (Lidocaine, n=70)	Group B (Articaine, n=70)	*p*-value
Age (years), mean ± SD	37.6 ± 11.2	38.1 ± 10.9	0.74
Sex (M/F)	38 / 32	40 / 30	0.72
Tooth treated – First molar / Second molar	46 / 24	44 / 26	0.68
Baseline VAS score (pre-anesthesia), mean ± SD	8.3 ± 0.9	8.4 ± 1.0	0.56
Duration of symptoms (days), median (IQR)	4 (3–5)	4 (3–5)	0.81

Table 2. Comparison of pain outcomes between groups

Outcome	Group A (Lidocaine)	Group B (Articaine)	Mean/Median Difference (95% CI)	*p*-value	Effect Size
Primary success (VAS < 4)	70/70 (100%)	70/70 (100%)	Risk diff. = 0.0% (−4.5–4.5)	1.00	–
VAS at 15 min – mean ± SD	2.03 ± 0.72	0.87 ± 0.82	1.16 (0.90–1.42)	<0.0001	$d = 1.50$
VAS at 15 min – median (IQR)	2.0 (1.5–2.5)	0.5 (0–1.0)	–	<0.0001	$r = 0.62$
VAS at 1 hour – mean ± SD	1.03 ± 0.68	0.43 ± 0.50	0.60 (0.40–0.80)	<0.0001	$d = 1.01$
VAS at 1 hour – median (IQR)	1.0 (0.5–1.5)	0.0 (0–0.5)	–	<0.0001	$r = 0.58$
Pain-free (VAS = 0) at 15 min	4 (5.7%)	44 (62.8%)	57.1% (42.1–69.3)	<0.0001	RR = 11.0
Pain-free (VAS = 0) at 1 hour	24 (34.2%)	62 (88.5%)	54.3% (39.8–66.1)	<0.0001	RR = 2.59

RR = Relative Risk; r = rank-biserial correlation.

There were no statistically significant differences between groups for age, sex distribution, tooth type, baseline pain intensity, or symptom duration ($p > 0.05$ for all). The primary outcome — anesthetic success, defined as the absence of moderate-to-severe pain (VAS < 4) during access cavity preparation and instrumentation — was achieved in all participants in both groups (100% vs. 100%). The risk difference was 0.0% (95% CI: −4.5 to 4.5; $p = 1.00$), confirming comparable binary success rates. Despite similar primary success, articaine provided significantly greater intraoperative analgesia, as reflected by lower VAS scores at both time points (Table 2). At 15 minutes, median VAS scores were 2.0 (IQR: 1.5–2.5) with lidocaine and 0.5 (IQR: 0–1.0) with articaine ($p < 0.0001$). At 1 hour, median VAS scores were 1.0 (IQR: 0.5–1.5) and 0.0 (IQR: 0–0.5), respectively ($p < 0.0001$). The between-group mean difference in VAS at 15 minutes was 1.16 (95% CI: 0.90–1.42; Cohen's $d = 1.50$), while the difference at 1 hour was 0.60 (95% CI: 0.40–0.80; Cohen's $d = 1.01$), both indicating large effect sizes.

The proportion of patients experiencing complete absence of pain (VAS = 0) was markedly higher with articaine both at 15 minutes (62.8% vs. 5.7%, relative risk [RR] = 11.0) and at 1 hour (88.5% vs. 34.2%, RR = 2.59), indicating superior pulpal anesthesia depth.

Pain score distributions also demonstrated articaine's superior performance. As shown in **Figure 2**, mean VAS scores were consistently lower with articaine across both time points. Boxplot analysis (**Figure 3**) revealed narrower dispersion and significantly lower median pain levels in the articaine group, while lidocaine showed a wider distribution and more frequent outliers, reflecting less predictable anesthetic efficacy. No adverse events, allergic reactions, or procedural complications were observed in either group.

DISCUSSION

This randomized, double-blind controlled trial compared the anesthetic efficacy of 4% articaine and 2% lidocaine, both combined with 1:100,000 epinephrine, in the non-surgical endodontic treatment of mandibular molars with symptomatic irreversible pulpitis (SIP). The findings demonstrate that while both agents achieved universal primary success — defined as absence of moderate-to-severe pain during access cavity preparation and instrumentation — articaine provided significantly deeper and more predictable pulpal anesthesia. This was evidenced by markedly lower VAS pain scores at both 15 minutes and 1 hour, higher proportions of patients experiencing complete pain relief (VAS = 0), and large effect sizes, all of which indicate a meaningful clinical advantage in achieving profound anesthesia under challenging inflammatory conditions.

The primary success rate of 100% observed in both groups aligns with prior reports indicating that IANB combined with buccal infiltration is generally effective in achieving baseline anesthetic success in SIP cases (3,18,19). However, the binary outcome alone is often insufficient to capture clinically meaningful differences in anesthetic performance. Pain intensity during instrumentation — even when classified as "mild" — can influence patient comfort, operator efficiency, and overall procedural quality. Our findings underscore this nuance: although both anesthetics

met the conventional threshold for success, articaine resulted in substantially lower pain scores, suggesting superior depth of anesthesia and a reduced likelihood of intraoperative discomfort.

The superiority of articaine observed in this trial corroborates a growing body of evidence highlighting its enhanced performance in endodontic anesthesia. Multiple studies have reported higher success rates or lower intraoperative pain with articaine, particularly when used as an infiltration adjunct to IANB (3,7,13,14,18,19). For example, Upadhyay et al. (13) observed significantly reduced pain scores and faster onset times with articaine compared to lidocaine in mandibular first molars, while Sattar et al. (14) reported superior success with articaine for buccal infiltration in inflamed pulp tissue. Our results extend these findings by demonstrating that articaine maintains its efficacy advantage even when both agents are delivered through a standardized dual-injection protocol, emphasizing that the observed differences are intrinsic to the pharmacological properties of the anesthetics rather than merely technique-dependent.

The pharmacological profile of articaine offers a plausible explanation for its superior clinical performance. Its unique thiophene ring enhances lipid solubility, facilitating more efficient diffusion through both soft tissue and dense mandibular cortical bone — a critical factor in cases where the inflammatory milieu reduces tissue pH and hinders anesthetic penetration (11,12). This improved tissue diffusion likely accounts for the significantly higher proportion of pain-free patients and the narrower distribution of VAS scores observed in the articaine group. Furthermore, the ability of articaine to achieve pulpal anesthesia more consistently may reduce the need for supplemental injections, minimize intraoperative interruptions, and improve patient satisfaction, particularly in anxious individuals or those with heightened pain sensitivity.

Despite the robust evidence presented, the literature remains heterogeneous. Some studies have reported no significant differences between articaine and lidocaine in terms of anesthetic success or pain perception (4,8,17). These discrepancies are likely attributable to methodological differences, including variations in anesthetic technique (e.g., IANB alone versus IANB plus supplemental injections), definitions of anesthetic success, patient populations, and procedural endpoints. For instance, Hassan et al. (4) found equivalent outcomes using IANB alone, whereas the current study, employing a combined IANB + BI approach, revealed clear differences. This supports the hypothesis that articaine's advantages are most pronounced in techniques that leverage its superior diffusion characteristics.

The clinical relevance of these findings is considerable. Even though the absolute difference in pain intensity may appear modest on a numerical scale, a reduction from a VAS score of 2.0 to 0.5 can translate into a substantially improved patient experience, especially for those with procedural anxiety or a history of difficult anesthesia. Furthermore, the significantly higher proportion of pain-free patients in the articaine group highlights its potential to improve procedural efficiency and reduce the need for operator interventions. These benefits are particularly relevant in cases where profound anesthesia is critical, such as in multi-rooted teeth, extended instrumentation sessions, or patients with heightened pain sensitivity.

This study also has several strengths that enhance the reliability and clinical applicability of its findings. The randomized, double-blind design minimizes selection and observer bias, and the use of objective preoperative verification (cold and electric pulp testing) ensures accurate assessment of anesthetic onset. Pain intensity was measured at multiple time points, allowing temporal analysis of anesthetic performance. Moreover, the large effect sizes observed reinforce the robustness of the statistical findings beyond mere p-values.

Nevertheless, several limitations must be acknowledged. The study was conducted at a single center, which may limit the generalizability of results to broader patient populations and clinical settings. The follow-up period was limited to one hour post-injection, so the duration of pulpal anesthesia beyond this period was not evaluated. Additionally, the study did not stratify results by tooth type, pulpal status severity, or patient-specific variables such as anxiety levels or systemic health conditions, which may influence anesthetic outcomes. Finally, the trial was retrospectively registered due to administrative delays, although all outcomes were prespecified before data collection commenced.

Future research should aim to validate these findings in multicenter trials with larger and more diverse populations. Studies incorporating longer follow-up periods and evaluating anesthesia duration, onset time, and need for supplemental injections would provide further insight into the clinical utility of articaine. Additionally, mechanistic studies examining tissue diffusion kinetics and pharmacodynamic interactions in inflamed pulpal tissues could help elucidate the precise pathways underlying articaine's enhanced efficacy.

In conclusion, this randomized clinical trial demonstrates that while both 4% articaine and 2% lidocaine achieve high rates of anesthetic success in mandibular molars with SIP, articaine offers superior depth and predictability of pulpal anesthesia. Its significantly lower pain scores, higher pain-free rates, and large effect sizes support its consideration as the anesthetic of choice in challenging endodontic scenarios. These findings have important clinical implications for optimizing patient comfort and procedural outcomes in endodontic practice, particularly in cases complicated by pulpal inflammation.

CONCLUSION

Within the limitations of this randomized, double-blind clinical trial, both 4% articaine and 2% lidocaine, administered via inferior alveolar nerve block combined with buccal infiltration, achieved high anesthetic success in the non-surgical endodontic treatment of mandibular molars with symptomatic irreversible pulpitis. However, articaine provided significantly deeper and more predictable pulpal anesthesia, as evidenced by lower pain intensity scores, a greater proportion of pain-free patients, and large effect sizes at multiple time points. These findings suggest that articaine may offer a distinct clinical advantage in achieving profound anesthesia in inflamed pulpal tissues, enhancing patient comfort and procedural efficiency. Future multicenter studies with longer follow-up and broader patient populations are warranted to further validate these results and explore their implications for routine endodontic practice.

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