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Comparative evaluation of 4% articaine and 2% lignocaine for maxillary premolar extractions during orthodontic treatment

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Abstract:
Effective pain control during maxillary premolar extraction requires a local anesthetic with rapid onset and adequate duration of action. Therefore, it is of interest to examine the anesthetic efficiency of 4% articaine and 2% lignocaine in 40 patients. The onset and duration of anesthesia, pain during injection, extraction and post-anesthetic complications were evaluated. Thus, data shows that articaine showed a significantly faster onset of anesthesia, prolonged anesthetic duration and obviated the need for supplemental palatal infiltration compared with lignocaine.

Keywords: Anesthetic efficacy, tooth extraction, articaine hydrochloride

Background:
Effective pain modulation is one of the fundamental requirements for successful dental treatment **[1]**. Adequate local anesthesia not only minimizes pain during dental procedures but also improves patient cooperation, reduces anxiety and enables the clinician to perform treatment efficiently **[2]**. The ideal local anesthetic should exhibit a prompt onset of action, profound anesthesia, acceptable duration and a favorable safety profile with minimal adverse effects **[3]**. Consequently, the search for local anesthetic agents that can provide superior clinical performance continues to be an important area of research in dentistry **[4]**. Lignocaine (lidocaine), introduced into clinical practice in the late 1940s, has remained the gold standard local anesthetic in dentistry because of its proven efficacy, predictable clinical performance and excellent safety record **[5]**. It is widely used for a variety of dental procedures and has showed consistent anesthetic success over several decades **[6]**. However, lignocaine may occasionally require supplemental injections and may exhibit variable onset and period of anesthesia, prompting the evaluation of newer local anesthetic agents **[7, 8]**. Articaine is a relatively newer amide local anesthetic that varies structurally from conventional agents by the presence of a thiophene ring and a supplementary ester group **[9]**. The thiophene ring increases lipid solubility, enhancing diffusion through both soft tissues and cortical bone, while the ester group allows partial metabolism in the plasma, reducing systemic exposure **[10]**. These pharmacological properties have been associated with a faster onset of action, improved tissue penetration, prolonged anesthetic effect and effective pain control **[11]**. Owing to these advantages, articaine has gained widespread acceptance in many countries and has become one of the utmost frequently used local anesthetics in contemporary practice **[12]**. Therefore, it is of interest to report the efficacy of 4% articaine hydrochloride formulated with 1:100,000 adrenaline relative to 2% lignocaine hydrochloride formulated with 1:80,000 adrenaline during maxillary bicuspid extractions.

Materials and Methods:
Study design:
This prospective parallel-group randomized clinical trial was conducted to assess the anesthetic efficiency of 4% articaine hydrochloride with 1:100,000 adrenaline and 2% lignocaine hydrochloride with 1:80,000 adrenalines during maxillary bicuspid extractions.

Patient selection:
A total of 40 patients requiring maxillary premolar extraction under local anesthesia were recruited from the outpatient department. Healthy participants aged 15–30 years, belonging to American Society of Anesthesiologists (ASA) Physical Status I and willing to participate in the study were included. Participants with a known allergy to amide local anesthetics or adrenaline, systemic diseases contraindicating routine dental extraction, acute infection or inflammation at the injection site, pregnancy or lactation, or those receiving medications that could influence pain perception or anesthetic efficacy were excluded from the study.

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Randomization:
Following enrolment, subjects were assigned into two equal groups (n = 20 each) using a pre-generated random number table. Group A received 4% articaine hydrochloride with 1:100,000 adrenaline (Septanest, Septodont Inc), whereas Group B received 2% lignocaine hydrochloride with 1:80,000 adrenaline (Lignospan Special). A single clinician performed all procedures using a uniform clinical protocol to ensure procedural consistency.

Clinical procedure:
A detailed medical and dental history was obtained from each participant, followed by a comprehensive clinical examination. After confirmation of eligibility, local anesthesia was administered using a standard aspirating dental syringe with a sterile short needle under aseptic conditions. In Group A, 0.5 mL of 4% articaine hydrochloride with 1:100,000 adrenaline was administered as a buccal vestibular (submucosal) infiltration adjacent to the maxillary premolar. Following a latency period of 5 minutes, the onset of anesthesia was assessed by evaluating objective signs on both the buccal and palatal aspects. If adequate palatal anesthesia was achieved, the extraction was performed without administering an additional palatal injection. In Group B, 0.5 mL of 2% lignocaine hydrochloride with 1:80,000 adrenalines was administered by buccal vestibular (submucosal) infiltration. After a 5-minute latency period, anesthesia was similarly assessed on both the buccal and palatal sides. As profound palatal anesthesia was not consistently achieved, an additional palatal infiltration of 0.2 mL of 2% lignocaine with 1:80,000 adrenalines was administered before tooth extraction. All extractions were performed by the same operator using a standardized extraction technique to minimize procedural variability.

Outcome measures:
The main outcome variables included the onset and duration of anesthesia, pain experienced during injection and extraction and the occurrence of post-anesthetic complications. The onset of anesthesia was demarcated as the time interval between completion of anesthetic administration and the first subjective sensation of numbness, confirmed clinically by the absence of pain on gentle probing of the surrounding soft tissues. The onset time was recorded in seconds using a stopwatch. Anesthetic duration was recorded as the period extending from the onset of profound anesthesia to the patient's perception of normal sensory recovery. The duration was recorded in minutes. Following delivery of the local anesthetic solution, participants were asked to quantify the pain associated with the injection using a 10-cm Visual Analog Scale (VAS). Scores ranged from 0 (no pain experienced) to 10 (maximum imaginable pain). Similarly, pain during extraction was recorded immediately after completion of the extraction using the same VAS. Patients were monitored throughout the procedure and during the post-operative period for the occurrence of post-anesthetic complications, including prolonged soft tissue numbness, hematoma, swelling, trismus, allergic reactions, or any other adverse events.

Statistical analysis:
Data were analysed using SPSS version 24 (IBM Corp., NY and USA). Continuous data (mean ± SD) were assessed by independent t-test and categorical data using the Chi-square test.

Results:
Forty patients were recruited for the investigation, with 20 participants each in the articaine and lignocaine groups. The mean age of participants was 19.85 ± 2.41 years in the articaine group and 20.15 ± 2.63 years in the lignocaine group. The gender distribution was also comparable between the groups, with males accounting for 45% and 50% and females accounting for 55% and 50% in the articaine and lignocaine groups, respectively. Baseline demographic characteristics were comparable between the two groups ($P > 0.05$) **(Table 1)**. The mean onset of anesthesia was notably shorter in the articaine group (68.33 ± 7.15 seconds) than in the lignocaine group (98.10 ± 6.16 seconds) ($P < 0.001$). Likewise, the duration of anesthesia was significantly longer with articaine (176.53 ± 8.74 minutes) compared with lignocaine (123.80 ± 15.62 minutes) **(Table 2)**. The mean pain score during buccal infiltration showed similar values between the articaine (1.85 ± 0.67) and lignocaine (1.92 ± 0.73) groups ($P = 0.746$). Pain experienced during tooth extraction was comparable in both groups, with mean VAS scores of 0.75 ± 0.55 for articaine and 0.88 ± 0.61 for lignocaine and the variation did not achieve statistical significance **(Table 3)**. Supplementary palatal anesthesia was not required in the articaine group, whereas all participants in the lignocaine group required palatal infiltration prior to extraction, demonstrating a highly significant difference between the groups. No post-anesthetic complications were observed in either group throughout the study.

Table 1: Demographic characteristics of the study participants

Characteristic	Articaine Group (n = 20)	Lignocaine Group (n = 20)	P value
Age (years) Mean ± SD	19.85 ± 2.41	20.15 ± 2.63	> 0.05
Gender n (%)			
Male	9 (45%)	10 (50%)	> 0.05
Female	11 (55%)	10 (50%)	

Table 2: Comparison of onset and duration of anesthesia

Parameter	Articaine	Lignocaine	*t* value	P value
Onset of Anesthesia (Seconds)	68.33 ± 7.15	98.10 ± 6.16	14.11	< 0.001*
Duration of Anesthesia (Minutes)	176.53 ± 8.74	123.80 ± 15.62	13.17	< 0.001*

Data are expressed as mean ± SD and analyzed using the independent t-test (P < 0.05).

Table 3: Comparison of pain during injection and extraction

Parameter	Articaine	Lignocaine	*t* value	P value
Buccal Injection pain (VAS)	1.85 ± 0.67	1.92 ± 0.73	0.316	0.746
Extraction pain (VAS)	0.75 ± 0.55	0.88 ± 0.61	0.708	0.481

Values are expressed as mean ± standard deviation (SD) and were analyzed using the independent t-test.

Discussion:

Effective pain control is essential for the success of dental procedures and the selection of an appropriate local anesthetic significantly influences both patient comfort and clinical outcomes **[13]**. Although lignocaine remains the gold standard in dental anesthesia because of its well-established efficacy and safety profile, articaine has gained considerable attention owing to its superior tissue diffusion and favorable pharmacological characteristics **[14]**. The present prospective, randomized clinical research evaluated the anesthetic efficiency of 4% articaine and 2% lignocaine during maxillary premolar extractions by evaluating the onset and duration of anesthesia, pain during injection and extraction and post-anesthetic complications. The results of the present study reported that articaine produced an earlier onset of anesthesia than lignocaine. This finding is consistent with the observations presented by Singh and Koul and Arali and P **[15, 16]**, who also reported a shorter onset time with articaine during inferior alveolar nerve block. One possible explanation for the faster onset of articaine is its relatively low pKa (7.8). At physiological pH, local anesthetics with lower pKa values exhibit a greater proportion of non-ionized molecules, facilitating more rapid diffusion across nerve membranes. In addition to pKa and lipid solubility, the protein-binding capacity of the anesthetic may also influence its clinical effectiveness. Higher protein binding increases the affinity of the drug for nerve membrane proteins, facilitating sodium channel blockade, although it's principal effect is on the duration rather than the onset of anesthesia **[17]**. The enhanced efficacy of articaine may be accredited to its distinctive chemical structure, which contains a thiophene ring that enhances lipid solubility and facilitates rapid diffusion through soft tissues and cortical bone, thereby enabling a more rapid onset of anesthesia. Improved tissue penetration allows the anesthetic to reach the nerve fibers more efficiently, resulting in an earlier onset of action **[18]**. The anesthetic effect was also suggestively extended in the articaine group than in the lignocaine group. A prolonged anesthetic effect is advantageous in oral surgical procedures because it provides sustained pain control throughout the procedure and may reduce the need for supplemental anesthetic administration. The greater protein-binding capacity of articaine has been suggested as one of the factors responsible for its extended duration of action. The present findings are in accordance with those of Ram and Amir, who documented that articaine, produced a longer duration of soft tissue anesthesia than lignocaine **[19]**. In contrast, Arali and P observed a shorter duration of action with articaine compared with lignocaine **[16]**. One of the most clinically relevant findings of the current research was that none of the patients receiving articaine required an additional palatal injection, whereas all patients in the lignocaine group required supplemental palatal infiltration before extraction. This may be attributed to the superior diffusion of articaine through the maxillary cortical bone, enabling effective palatal anesthesia following buccal infiltration alone. Eliminating the need for a palatal injection is a significant clinical advantage, as it reduces patient discomfort, anxiety and the overall complexity of the procedure. Similar findings have been reported by Hassan *et al.* and Bansal *et al.* **[1, 10],** who also showed that articaine provided adequate palatal anesthesia after buccal infiltration without the need for a supplemental palatal injection. Pain during buccal infiltration and tooth extraction was comparable between the articaine and lignocaine groups, indicating that both agents provided effective intraoperative analgesia. No post-anesthetic complications, including prolonged soft tissue numbness, hematoma, swelling, trismus, or allergic reactions, were noted in either group, suggestive of favourable risk-free profile and good tolerability of both anesthetic agents under the conditions of the present study. The findings of the present study are in agreement with those of Krishna et al., who reported that 4% articaine provided superior anesthetic efficacy and greater pain reduction than 2% lignocaine during orthodontic maxillary premolar extractions. Their findings support the superior clinical performance of articaine observed in the present study **[20]**. The outcome of current research has important clinical inferences. The ability of articaine to achieve effective palatal anesthesia following buccal infiltration alone can reduce the need for additional injections, thereby improving patient acceptance and comfort during extraction procedures. Furthermore, its rapid onset and prolonged duration may enhance clinical efficiency by shortening the waiting period before treatment while providing sustained anesthesia throughout the procedure **[21-25]**. Further studies involving more diverse populations are needed to confirm the present findings. Future multicenter trials involving larger and more diverse populations are warranted to further validate the clinical advantages and safety profile of articaine in different dental procedures.

Conclusion:

We show that 4% articaine provided a quicker onset, extended duration of anesthesia and eliminated the need for an additional palatal injection compared with 2% lignocaine. Both anesthetic agents provided comparable pain control during extraction without any post-anesthetic complications. Thus, 4% articaine can be considered a safe and effective alternative to lignocaine for maxillary premolar extractions.

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