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Comparison of Local Anesthetic Effects of Lidocaine and Articaine at Different Buccal Cortical Bone Thicknesses during Mandibular Molar Implant Surgery

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Abstract: *Objective:* This study aims to evaluate the efficacy of local infiltration anesthesia using lidocaine and articaine during mandibular molar implant surgery with different buccal cortical bone thicknesses (1 mm, 1–2 mm, 2 mm), to provide scientific evidence for the clinical selection of anesthetic agents. *Methods:* The study subjects were 240 adult patients who underwent mandibular molar implant surgery at the Second Affiliated Hospital of Hainan Medical University between May 2023 and May 2024. The thickness of the buccal cortical bone was confirmed using cone-beam computed tomography (CBCT), and patients were randomly divided into three groups: the first group (cortical bone thickness 1 mm), study group (lidocaine, 40 patients) and control group (articaine, 40 patients); the second group (cortical bone thickness 1–2 mm), study group (lidocaine, 40 patients) and control group (articaine, 40 patients); and the third group (cortical bone thickness 2 mm), study group (lidocaine, 40 patients) and control group (articaine, 40 patients). The primary outcomes measured were onset time of anesthesia (seconds) and anesthesia efficacy rate (percentage). *Results:* In the first group, the onset time of anesthesia in the lidocaine group and articaine group was 45.2 ± 5.32 seconds and 44.80 ± 4.60 seconds, respectively, with no statistically significant difference (p = 0.720). The overall efficacy rates were 95.0% and 97.5%, respectively, with no significant difference (p = 0.556). In the second group, the onset time of anesthesia was significantly longer in the lidocaine group than in the articaine group (56.70 ± 6.05 seconds vs. 50.35 ± 5.66 seconds, $p < 0.05$), and the overall efficacy rate was lower (80.0% vs. 95.0%, $p < 0.05$). In the third group, the onset time of anesthesia was significantly prolonged in the lidocaine group (65.4 ± 6.68 seconds) compared to the articaine group (52.25 ± 5.80 seconds, $p < 0.01$), and the overall efficacy rate was significantly lower in the lidocaine group (79.0% vs. 90.0%, $p < 0.01$). *Conclusion:* There is no significant difference in anesthetic efficacy between lidocaine and articaine when the buccal cortical bone thickness is 1 mm. However, when the buccal cortical bone thickness is 1–2 mm or 2 mm, articaine demonstrates a faster onset time and higher anesthetic efficacy.
Keywords: Lidocaine; Articaine; Buccal cortical bone thickness; Local infiltration anesthesia; Implant surgery

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1. Introduction

Oral implant surgery is a commonly used treatment for restoring patients' masticatory function and improving their quality of life [1]. During this procedure, the choice of anesthetic drugs is crucial, which directly affects the patient's comfort and the smooth progress of the surgery [2]. Lidocaine is widely used in nerve block anesthesia due to its good anesthetic effect. However, local infiltration anesthesia has become a more preferred form of anesthesia due to its potential to inhibit intraoperative pain feedback and increase the risk of nerve injury [3,4]. In local infiltration anesthesia, the thickness of the lateral buccal cortical bone has a significant effect on the anesthetic effect [3]. As the buccal lateral cortical bone is usually thicker in the mandibular region [5], the diffusivity and onset time of local anesthetic drugs may be limited, affecting their anesthetic effect. Cortical bone thickness is a key factor in determining the penetration ability of anesthetic drugs, and thicker cortical bone may attenuate the diffusion of anesthetic drugs, thereby prolonging the onset time of anesthesia and decreasing the overall effective rate, which poses a challenge to clinical practice.

Lidocaine, as a classical local anesthetic drug, has a good performance in most oral surgeries [6]. However, when confronted with thicker cortical bone, the penetration of lidocaine may be insufficient, resulting in suboptimal anesthesia. In contrast, articaine possesses greater tissue permeability due to its thiophene ring structure, especially better diffusion in bone tissue [7], and is therefore considered to have superior anesthetic effects than lidocaine in thicker bone regions.

Although existing studies have shown that articaine has advantages in areas of thicker bone [7,8], there is a lack of systematic comparative studies on the effects of anesthesia between lidocaine and articaine under different buccal cortical bone thicknesses. Therefore, this study aimed to evaluate the onset of anesthesia and the effective rate of lidocaine and ativan in mandibular permanent molar implantation under different cortical bone thickness conditions, aiming to provide clinicians with a scientific basis for selecting local anesthetic drugs and optimizing the anesthetic strategy during surgery.

2. Information and methods

2.1. Study subjects and grouping methods

Two hundred and forty adult patients who underwent mandibular permanent molar implantation at the Second Affiliated Hospital of Hainan Medical University between May 2023 and May 2024 were included in this study. All patients had their buccal cortical bone thickness measured by cone-beam CT (CBCT) scanning before surgery and were divided into three groups according to their buccal cortical bone thickness: the first group consisted of patients with a buccal cortical bone thickness of 1 mm, the second group consisted of patients with a buccal cortical bone thickness of 1 to 2 mm, and the third group consisted of patients with a buccal cortical bone thickness of 2 mm. Each group was further divided into a study group (lidocaine group, 40 patients) and a control group (ativanolone group, 40 patients) using the randomized numerical table method, with 80 patients in each group, for a total of 240 patients.

The mean age of the patients in the study group was 40.65 ± 3.21 years old, and the mean age of the patients in the control group was 40.12 ± 3.14 years old, and the general data of the patients in the two groups, such as age, gender, weight, and general health status, were comparable. Inclusion criteria: (1) adult patients aged between 20 and 60 years old; (2) patients who needed to undergo mandibular permanent molar implantation; (3) buccal cortical bone thickness confirmed to meet the criteria of the study group by cone-beam CT (CBCT) measurements before the operation; (4)

patients who had not taken drugs that might affect the effect of anesthesia during the period; (5) patients who were able to cooperate with the operation and postoperative follow-up observation. Exclusion criteria: (1) patients with severe hepatic or renal dysfunction; (2) patients with acute or chronic serious infections; (3) patients with a history of allergy or contraindication to local anesthesia drugs (e.g., lidocaine or ativan); (4) pregnant or lactating females; (5) patients with severe periodontitis or other serious diseases of the oral cavity. All enrolled patients signed an informed consent form, and the informed consent procedure complied with the ethical requirements of the Declaration of Helsinki. The study was reviewed and approved by the Ethics Committee of the Second Affiliated Hospital of Hainan Medical University and was conducted in strict accordance with relevant ethical and scientific standards.

2.2. Anesthesia methods

The patients all received mandibular permanent molar implantation with local infiltration anesthesia. The study group used lidocaine injection (Suicheng Pharmaceutical Co, Ltd, National Pharmaceutical License No. H41023668, specification: 5 mL: 0.1 g), with an injection dosage of 2.0–3.0 mL, a maximum dose of no more than 5 mg/kg body weight, and an injection rate of no more than 1 mL/min. The control group used ativanine epinephrine injection (Produits Dentaires Pierre Rolland, Registration No. H20140732, Specification: 1.7 mL: Articaine Hydrochloride 68 mg with Epinephrine Tartrate 1 μg), the injection dose is 1.5–1.7 mL, the maximum dose does not exceed 5 mg/kg body weight, the injection speed does not exceed 1 mL/min.

2.3. Observation indexes

This study mainly observes the anesthesia onset time and the anesthesia effect 5 minutes after anesthesia in the two groups. The judgment standard of the anesthesia onset time is as follows: using a probe to check the patient's surgical area for pain detection, and the anesthesia is regarded as onset when the patient does not have an obvious pain response. The effect of anesthesia is divided into the following three categories: "complete effect" if the pain is eliminated and the operation can be carried out smoothly; "good effect" if there is slight pain but the operation is not affected; "poor effect" if the patient feels obvious pain and needs to tolerate it to continue the operation [9]. If the patient feels significant pain and has to tolerate it to continue the operation, it is considered as "poor effect" [9]. The total effective rate of anesthesia was calculated as: total effective rate of anesthesia = complete rate + good rate.

2.4. Statistical analysis

Data were analyzed using SPSS 20.0 statistical software. Count data were expressed as the number of cases (%], and the χ^2 test was used; measurement data were expressed as the mean ± standard deviation (SD), and *t* test was used for intergroup comparisons, and repeated-measures ANOVA was used for comparisons at multiple time points. Differences were expressed as statistically significant at $P < 0.05$.

3. Results

3.1. Anesthesia onset time

In the first group of patients, the onset time of anesthesia was 45.20 ± 5.32 seconds in the lidocaine group and 44.80 ± 4.60 seconds in the ativanine group, and the difference was not statistically significant ($p = 0.720$), indicating that there was no significant difference in the onset time of the two anesthetics in the presence of thin buccal cortical bone. In the

second group of patients, the onset of anesthesia in the lidocaine group was 56.70 ± 6.05 seconds, which was significantly longer than that in the ativanolone group, which was 50.35 ± 5.66 seconds ($p < 0.01$), suggesting that the onset of anesthesia for lidocaine was significantly prolonged as the thickness of the buccal cortical bone increased. In the third group of patients, the onset of anesthesia in the lidocaine group was further prolonged to 65.40 ± 6.68 seconds, which was significantly higher than that of 52.325 ± 5.80 seconds in the ativanolone group ($p < 0.01$), indicating that the onset of anesthesia was significantly faster for ativanolone than lidocaine in the thicker cortical bone condition (**Table 1**).

3.2. Anesthesia effect

In the first group of patients, the total effective rate of anesthesia was 95.0% in the lidocaine group and 97.5% in the ativanine group, and the difference between the two was not statistically significant ($p = 0.556$), indicating that the anesthesia effect of the two local anesthetics was similar under the condition of thin cortical bone on the buccal side. In the second group of patients, the total effective rate of anesthesia in the lidocaine group was 80.0%, which was significantly lower than that of 95.0% in the ativanolone group ($p < 0.05$), suggesting that the anesthetic effect of ativanolone was superior to that of lidocaine under conditions of moderately thick cortical bone. In the third group of patients, the total effective rate of anesthesia in the lidocaine group was 70.0%, which was significantly lower than that of 90.0% in the ativanolone group ($p < 0.05$), further indicating that as the thickness of buccal cortical bone increased, the anesthetic effect of ativanolone was significantly better than that of lidocaine (**Table 2**).

Table 1. Time to onset of anesthesia in lidocaine and ativanolone groups with different cortical bone thicknesses

Subgroup	Average (seconds)	*t*	*p*
Group I: Cortical bone thickness 1 mm			
Lidocaine	45.20 ± 5.32	0.36	0.720
Articaine	44.80 ± 4.60		
Group II: Cortical bone thickness 1–2 mm			
Lidocaine	56.70 ± 6.05	4.874	< 0.05
Articaine	50.35 ± 5.66		
Group III: Cortical bone thickness 2 mm			
Lidocaine	65.40 ± 6.68	9.400	< 0.05
Articaine	52.25 ± 5.80		

Table 2. Overall effectiveness of anesthesia in lidocaine and ativanolone groups with different **cortical bone thicknesses**

Subgroup	Total (persons)	Effective	Ineffective	χ^2	*P*
n (%)	240	211 (87.9)	29 (12.1)		
Group I: Cortical bone thickness 1 mm					
Lidocaine	40	38 (95.0)	2 (5.0)	0.346	0.556
Articaine	40	39 (97.5)	1 (2.5)		
Group II: Cortical bone thickness 1–2 mm					
Lidocaine	40	32 (80.0)	8 (20.0)	4.114	< 0.05
Articaine	40	38 (95.0)	2 (5.0)		
Group III: Cortical bone thickness 2 mm					
Lidocaine	40	28 (70.0)	12 (30.0)	5.000	< 0.05
Articaine	40	36 (90.0)	4 (10.0)		

4. Discussion

4.1. Advantages of local infiltration anesthesia

In the past, nerve block anesthesia was the mainstay in the implantation of mandibular posterior teeth, but nerve block anesthesia is complicated to operate, involves complex anatomical structures, there is a risk of injury to the nerves, and the numbness of the lips and tongue caused by the postoperative period can last for several hours, which undoubtedly affects a certain amount of eating and speech functions, and even the occurrence of biting the lip and tongue tissues [10,11]. In contrast, local infiltration anesthesia is easy to operate, with lower technical requirements, and the scope of anesthesia is limited to the surgical area, which can effectively control intraoperative pain and reduce the risk of nerve injury and infection [12,13]. Therefore, local infiltration anesthesia is not only suitable for routine surgery, but also popular in primary hospitals because of its simplicity and safety.

4.2. Comparison of the effectiveness of lidocaine and ativanacaine

The results of this study showed that there was no significant difference in the onset time of anesthesia and the total effective rate of anesthesia between lidocaine and ativanolone in the thinner (1 mm) buccal cortical bone. This suggests that both anesthetic drugs are effective under thinner bone tissue, which is consistent with previous studies [2,14]. However, as the thickness of buccal cortical bone increased (1–2 mm and 2 mm), articaine showed significant advantages in terms of onset of anesthesia and total effective rate of anesthesia. Articaine contains a thiophene ring in its molecular structure, which results in enhanced lipid solubility and more rapid penetration into thicker soft and bone tissues [6,15]. Therefore, articaine has a faster onset of action and a higher success rate of anesthesia in thicker bone and is suitable for procedures requiring deeper anesthesia.

4.3. Permeability of anesthetic drugs and the effect of formulation

The permeability of anesthetic drugs is not only determined by their molecular structure, but also related to the formulation of the drug. The formulation of articaine contains epinephrine, which prolongs the retention time of the anesthetic drug by constricting local blood vessels and reducing local blood flow, thus enhancing its concentration and permeability in the tissue. This mechanism allows articaine to exhibit enhanced anesthetic effects in areas of thicker bone, especially effective when deeper anesthesia of bone tissue is required [7,16,17]. In thicker cortical bone conditions, the anesthetic effect of lidocaine is limited by a longer onset of action, resulting in the potential need for higher intraoperative dosages or adjuncts to other anesthetic methods to maintain adequate anesthesia [18]. Therefore, there is a greater advantage of articaine in complex surgeries.

Although articaine exhibits greater penetration and anesthesia, the epinephrine in its formulation also poses cardiovascular risks, especially in patients with cardiovascular disease, where epinephrine may trigger adverse reactions such as increased heart rate and blood pressure [16,19,20]. Therefore, caution should be exercised in the use of ativan in such high-risk patients, especially in settings where primary care equipment is more limited, and enhanced monitoring is needed. In contrast, lidocaine's unique antiarrhythmic effect makes it the local anesthetic of choice for patients with ventricular arrhythmias, and its absence of adrenaline allows it to be used in patients with diabetes mellitus, hypertension, and hyperthyroidism, and, if necessary, in patients during pregnancy [16,21,22].

4.4. Clinical recommendations

In summary, ativan demonstrates a faster onset of action and better anesthetic effects in thicker cortical bone conditions,

and is especially advantageous in procedures involving deeper bone tissue. However, articaine contains epinephrine and requires strict monitoring in patients with potential risks to the cardiovascular system. In contrast, lidocaine is particularly suitable for widespread use in primary hospitals because it does not contain epinephrine, has fewer cardiovascular side effects, and is safer. Clinicians should choose anesthesia drugs reasonably according to the patient's specific situation, taking into account the bone condition, surgical complexity and the patient's cardiovascular health, to ensure the best surgical outcome and patient safety.

Disclosure statement

The author declares no conflict of interest.

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