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# Pattern of buccal and palatal bone density in the maxillary premolar region: an anatomical basis of anterior-middle superior alveolar (AMSA) anesthetic technique

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**Background:** The anterior-middle superior alveolar (AMSA) anesthetic technique has been reported to be a less traumatic alternative to several conventional nerve blocks and local infiltration for anesthesia of the maxillary teeth, their periodontium, and the palate. However, its anatomic basis remains controversial. The present study aimed to determine if the pattern of cortical and cancellous bone density in the maxillary premolar region can provide a rationale for the success of the AMSA anesthetic technique.
**Method:** Cone-beam computed tomography scans of 66 maxillary quadrants from 34 patients (16 men and 18 women) were evaluated using a volumetric imaging software for cortical and cancellous bone densities in three interdental regions between the canine and first molar. Bone density was measured in Hounsfield units (HU) separately for the buccal cortical, palatal cortical, buccal cancellous, and palatal cancellous bones. Mean HU values were compared using the Mann-Whitney U test and one-way ANOVA with post-hoc analysis.
**Results:** Cancellous bone density was significantly lower ($P \leq 0.001$) in the palatal half than in the buccal half across all three interdental regions. However, there was no significant difference ($P = 0.106$) between the buccal and palatal cortical bone densities at the site of AMSA injection. No significant difference was observed between the two genders for any of the evaluated parameters.
**Conclusions:** The palatal half of the cancellous bone had a significantly lower density than the buccal half, which could be a reason for the effective diffusion of the anesthetic solution following a palatal injection during the AMSA anesthetic technique.

**Keywords:** Bone Density; Cone-Beam Computed Tomography; Local Anesthesia; Maxilla; Palate.



## INTRODUCTION

The anterior-middle superior alveolar (AMSA) injection is a relatively recent local anesthetic technique for dental procedures in the maxilla. It offers an alternative to multiple injections required for similar purposes, such as nasopalatine, greater palatine, and infraorbital nerve blocks as well as supraperiosteal infiltrations in the buccal vestibule. The AMSA technique involves a field block injection administered from the palatal aspect, resulting in overall trauma that is lower than that caused by the conventional injections it replaces [1]. Introduced by Friedman and Hochman in

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1997, this injection targets the subneural dental plexus, also known as the superior dental plexus, located near the apices of premolars [2]. This plexus is formed by the confluence of the posterior, middle, and anterior superior alveolar nerves; therefore, AMSA injection anesthetizes the areas supplied by them [3]. As the site of needle penetration lies on the hard palate between the first and second premolars, halfway between the mid-palatine raphe and the free gingival margin, the local anesthetic (LA) solution also diffuses underneath the mucoperiosteum to reach the branches of the greater palatine as well as the nasopalatine nerves, anesthetizing most of the palatal tissues [4].

The amount of diffusion of the LA solution around the subneural dental plexus determines the effectiveness of the injection. Cetkovic et al. investigated the anatomic features of the palatal cortex that could affect the diffusion of LA solution [5]. They found that despite the thickness, the palatal cortex had higher porosity and better pore connectivity than the buccal cortex. Their analysis also revealed that the palatal cortex had a greater mean width and number of nutrient canals that traversed the whole thickness of the cortical plates than did the buccal cortex. Apart from the pore sizes and widths of the nutrient canals, the overall density of the palatal cortical and cancellous bones might also play a role in the diffusion of LA solution to the subneural dental plexus. However, existing data are inadequate to support this assumption.

The Hounsfield unit (HU) is a reliable parameter for radiographic assessment of bone density from cone-beam computed tomography (CBCT). It is directly related to the tissue attenuation coefficients [6,7]. The alveolar bone density in the mandible and maxilla is commonly measured using this parameter to assess bone quality apart from the quantitative analysis and treatment planning for dental implants [8]. In a systematic review, Guerra et al. concluded that the CBCT-derived radiographic density is accurate enough to be a promising tool for screening patients with low bone mineral density [9]. The density of the facial and palatal cortices has been compared in various studies, while many others have compared the density of cancellous bone between different regions of the maxilla and mandible using HU on CBCT scans. However, no previous study has compared the cancellous bone's overall density in the facial half with that in the palatal half of the maxillary alveolar process. Considering this gap in the existing knowledge, the densities of both the palatal and buccal aspects of cortical and cancellous bone in the region of AMSA injection must be explored. The present study aimed to determine if the pattern of cortical and cancellous bone density in the maxillary premolar region provides any anatomical basis for the success of AMSA anesthetic injection.

## METHODS

### 1. Study design

A retrospective observational study was conducted in April and May 2020 after approval from the institutional ethics committee of the Faculty of Medicine, Aligarh Muslim University, Aligarh, India (D. No. 2041/FM, dated 26th February 2020). The patients' data were handled according to the Declaration of Helsinki's requirements and recommendations, as revised in 2013. The inclusion criteria were as follows: (1) CBCT scans of adult male or female patients aged 20 to 45 years, and (2) presence of maxillary canine, both premolars, and the first molar without any radiographic evidence of periapical pathology or osseous defects involving the interdental septum. Scans with suspected craniofacial dysmorphology, lack of clarity, or any artifact in the area of interest were excluded. A distance of more than 3 mm between the interdental alveolar crest and cementoenamel junction (CEJ) of adjacent teeth in the area of interest was also an exclusion criterion.

### 2. Sample size estimation

Sample size estimation was performed using the formula $n = (Z_{\alpha}+Z_{\beta})^2\ \sigma^2/d^2$. Assuming a pooled standard deviation of 250 units, to achieve a power of 80% and

confidence interval of 95% for detecting a minimum difference in mean density between the buccal and palatal cortical bone of 150 units, we calculated the minimum sample size to be 44 quadrants.

### 3. Sample selection

Out of a total of 85 CBCT scans used previously for treatment planning or follow-up of implant surgery in various edentulous spaces were screened to fulfill the inclusion criteria, 34 scans were selected. All scans belonged to patients without any history of metabolic disorders or medications affecting bone density. In two scans, one of the maxillary quadrants had severe bone loss and a periapical pathology around the premolars, while the other quadrant was normal. The right and left maxillary bones in each scan were counted as separate entities, and 66 maxillary quadrants from 34 patients were analyzed.

### 4. Assessment of CBCT scans and data collection

All measurements were made by a single examiner using a volumetric imaging software (Carestream Dental, France). To ensure intra-examiner reliability, measurements were repeated on five randomly selected scans at an interval of 1 week. The intra-examiner reproducibility coefficient was found to be 0.96 and 0.92 for the measurement of HU in cortical and cancellous bone, respectively. The alveolar bone density was measured in three interdental areas: Region 1, between the canine and first premolar; Region 2, between first and second premolars; and Region 3, between the second premolar and first molar. The selection of the appropriate slice in the coronal section was confirmed in the corresponding axial section. The first measurements were taken at the height of 2 mm from the midpoint of the alveolar crest.

For the evaluation of cortical bone density, the midpoint of the cortical thickness was selected. An imaginary line was drawn to equally divide the cancellous bone into the buccal and palatal halves. The cancellous bone density was measured at the midpoint between the imaginary line and the inner margin of the cortical bone

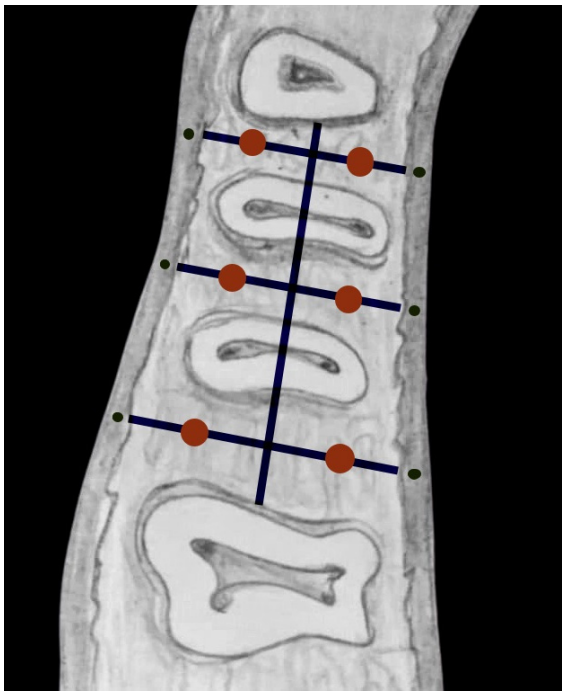

Fig. 1. Schematic diagram showing the mid-point (black dots) of the cortical thickness selected for cortical bone density evaluation. A line is drawn dividing the cancellous bone into buccal and palatal halves so that cancellous bone density is measured at the midpoint (brown circles) between the line and inner margin of cortices.

on both buccal and palatal sides (Fig. 1). Each measurement in the coronal section was repeated after an increment of 1 mm in the apical direction until the height of 10 mm was reached from the midpoint of the alveolar crest (Fig. 2). Thus, nine values were recorded for each of the four parameters (buccal cortical, palatal cortical, buccal cancellous, and palatal cancellous) in all three interdental areas. The average of these nine values was calculated and used for statistical analysis. Furthermore, the average of the first three values (2 mm, 3 mm, and 4 mm) was considered as the mean bone density in the cervical third, the next three values (5 mm, 6 mm, and 7 mm) as the middle third, and the last three values (8 mm, 9 mm, and 10 mm) as the apical third.

### 5. Statistical analysis

All statistical analysis were performed using SPSS version 20.0. The mean and standard deviation values of all four parameters were calculated for each of the 66 samples. A comparison was made between the buccal and

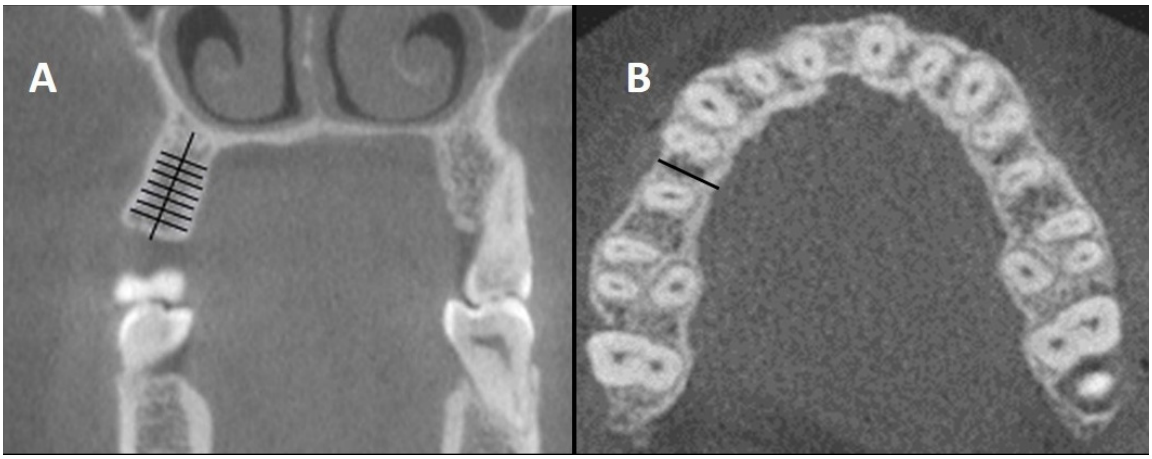


Fig. 2. Bone density evaluation between premolars in (A) coronal and (B) axial CBCT images. It may be noted that the midpoint on the alveolar crest refers to the point lying on the interdental septum, midway between the buccal cortex and the lingual cortex, as seen in the coronal section. It also coincides with the starting point of the imaginary line, which divides the cancellous bone into buccal and palatal halves.

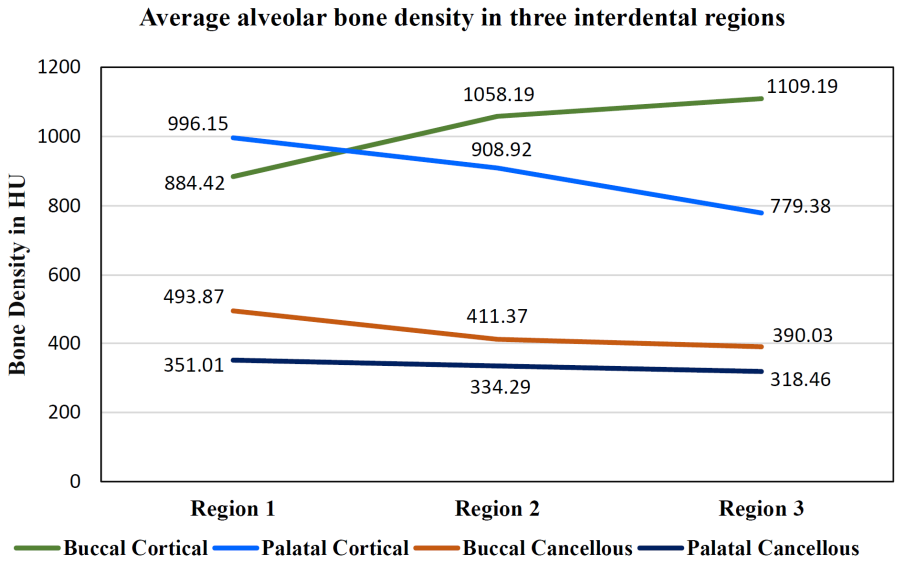


Fig. 3. Average alveolar bone density in three interdental regions. Region 1: between canine and first premolar, Region 2: between first and second premolars, and Region 3: between the second premolar and first molar.

palatal halves for cortical and cancellous bone density using the Mann-Whitney U test. For the comparison of cervical, middle, and apical thirds, one-way ANOVA was used, followed by post-hoc analysis using the Tukey HSD test. The mean values of each parameter between male and female patients were also compared. All comparisons were made separately for each of the three regions. Further, an inter-region comparison was also performed for all four parameters using one-way ANOVA and Tukey HSD test. Differences with a P-value $< 0.05$ were considered statistically significant.

## RESULTS

The alveolar processes in 66 maxillary quadrants from 34 patients (18 women and 16 men) were evaluated for cortical and cancellous bone density. The mean age of the patients was 33.97±7.47 (range; 23–44) years.

Cancellous bone density was significantly higher in the buccal half than in the palatal half across all three regions. However, the pattern of cortical bone density was different (Fig. 3). The density of buccal cortical bone was significantly lower in region 1 but significantly higher

**Table 1.** Comparison of average bone density (in HU ± SD) across different interdental regions and between buccal and palatal halves of each region

| Regions | Cortical alveolar bone | | | Cancellous alveolar bone | | |
|---|---|---|---|---|---|---|
| | Buccal | Palatal | P-value | Buccal | Palatal | P-value |
| Region 1 | 884.42 ± 126.91 | 996.15 ± 178.55 | < 0.001† | 493.87 ± 167.25 | 351.01 ± 104.51 | < 0.001† |
| Region 2 | 1058.19 ± 269.54 | 908.92 ± 161.71 | 0.106 | 411.37 ± 77.45 | 334.29 ± 82.77 | < 0.001† |
| Region 3 | 1109.19 ± 115.83 | 779.38 ± 74.08 | < 0.001† | 390.03 ± 116.09 | 318.46 ± 53.08 | 0.001† |
| P-value | < 0.001 | < 0.001 | | < 0.001 | 0.081 | |
| Significant pair-wise differences | 2 > 1*<br>3 > 1* | 1 > 2*<br>1 > 3*<br>2 > 3* | | 1 > 2*<br>1 > 3* | NS | |

*Significant inter-group difference between the regions, calculated by one-way ANOVA and post-hoc Tukey HSD test. NS, Not Significant.
†Significant difference between the buccal and palatal values, calculated by the Mann-Whitney U test.

**Table 2.** Comparison of cortical and cancellous alveolar bone density (mean values in HU ± SD) between male and female patients

| Regions | Buccal | | | Palatal | | |
|---|---|---|---|---|---|---|
| | Male (n = 31) | Female (n = 35) | P-value | Male (n = 31) | Female (n = 35) | P-value |
| | | | Cortical alveolar bone | | | |
| Region 1 | 888.65 ± 132.99 | 880.67 ± 123.09 | 0.843 | 1010.49 ± 191.18 | 983.44 ± 168.36 | 0.741 |
| Region 2 | 1118.82 ± 282.54 | 1004.49 ± 249.28 | 0.115 | 917.04 ± 177.24 | 902.79 ± 141.12 | 0.641 |
| Region 3 | 1132.03 ± 71.69 | 1088.97 ± 142.19 | 0.496 | 784.56 ± 64.92 | 774.79 ± 82.01 | 0.537 |
| | | | Cancellous alveolar bone | | | |
| Region 1 | 501.47 ± 169.06 | 487.14 ± 167.81 | 0.608 | 364.92 ± 117.62 | 338.69 ± 91.33 | 0.548 |
| Region 2 | 422.40 ± 75.35 | 406.02 ± 81.76 | 0.444 | 342.09 ± 88.56 | 327.39 ± 77.93 | 0.630 |
| Region 3 | 402.14 ± 131.86 | 379.30 ± 100.86 | 0.928 | 321.48 ± 61.96 | 315.78 ± 44.53 | 0.097 |

None of the compared values were statistically significant, as calculated by the Mann-Whitney U test.

**Table 3.** Comparison of the bone density (in HU) among the apical, middle, and cervical third of the alveolar bone, in each region

| | | Cortical alveolar bone | | | | Cancellous alveolar bone | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Buccal | P-value (Significant difference) | Palatal | P-value (Significant difference) | Buccal | P-value (Significant difference) | Palatal | P-value (Significant difference) |
| Region 1 | Apical | 1015.94±171.62 | <0.001* (A>M A>C M>C) | 1009±136.16 | 0.678 (NS) | 521.70±220.23 | 0.151 (NS) | 273.72±54.89 | <0.001* (C>A C>M) |
| | Middle | 914.46±233.78 | | 979.21±236.88 | | 458.99±151.59 | | 333.35±97.74 | |
| | Cervical | 722.86±195.79 | | 999.49±219.04 | | 500.91±185.03 | | 447.97±228.59 | |
| Region 2 | Apical | 1132.49±266.69 | 0.002* (A>C M>C) | 964.69±205.94 | 0.003* (A>C) | 428.73±129.28 | 0.335 (NS) | 332.61±84.54 | <0.001* (A>M C>M C>A) |
| | Middle | 1085.49±278.47 | | 907.47±149.10 | | 400.21±96.72 | | 279.38±128.74 | |
| | Cervical | 956.58±319.85 | | 854.61±194.49 | | 405.17±125.52 | | 390.91±105.35 | |
| Region 3 | Apical | 1186.97±172.53 | <0.001* (A>M A>C M>C) | 751.46±101.33 | 0.140 (NS) | 320.93±176.96 | <0.001* (M>A C>A) | 325.23±113.54 | <0.001* (A>M C>M) |
| | Middle | 1111.66±141.79 | | 732.49±103.91 | | 440.46±247.23 | | 257.69±128.26 | |
| | Cervical | 946.53±191.91 | | 767.59±98.72 | | 490±212.50 | | 349.71±167.19 | |

*Statistically significant. A, apical; M, middle; C, cervical; NS, non-significant. The comparison was made by one-way ANOVA and post-hoc Tukey HSD test.

in region 3 compared to that of the palatal cortical bone. This difference was not significant in region 2 (Table 1). As we moved from region 1 to region 3, a significant increase was observed in the buccal cortical bone density, while a significant decrease was observed for palatal cortical as well as buccal cancellous bone density. The decreasing trend of palatal cancellous bone density from regions 1 to 3 was statistically non-significant (Table 1).

The HU values were comparable, and no significant difference was observed between male and female patients for the cortical or cancellous bone density in all three regions (Table 2). Pair-wise comparison between the apical, middle, and cervical thirds is presented in Table 3. The apical and middle thirds showed

significantly higher buccal cortical bone density than the coronal third in all three regions. However, a reverse trend was observed for the palatal cancellous bone. The pair-wise difference was mostly non-significant in the case of the palatal cortical and buccal cancellous bone. The apical third of the buccal cortex in region 3 and the cervical third of the buccal cortex in region 1 showed the maximum (1186.97 ± 172.53) and minimum (722.86 ± 195.79) average cortical bone density, respectively. On the other hand, the apical third of the buccal aspect in region 1 and the middle third of the palatal aspect in the region 3 showed maximum (521.70 ± 220.23) and minimum (257.69 ± 128.26) average cancellous bone density, respectively (Table 3).

## DISCUSSION

The present study aimed to understand the anatomical basis of AMSA anesthetic injection. Although this technique has been reported to be effective in many clinical studies [10-13], others have questioned its predictability [14,15]. Some authors have questioned the rationale of this technique, as the anatomic basis explained by Friedman and Hochman was deemed controversial [4,10]. Iwanga and Tubbs termed this technique an unnecessary anesthetic blockade based on erroneous morphology. However, a recent comprehensive review of seven published articles in which the AMSA technique was used for various periodontal procedures concluded that this technique offers significant advantages over conventional techniques despite having several limitations [16]. It was found to anesthetize the palatal hard and soft tissues consistently and was recommended to be considered as the first line of anesthesia for periodontal procedures in the maxilla [13,16]. Its advantages include but are not limited to the reduced cumulative number of injections and the total amount of vasoconstrictor delivered as well as maintenance of upper lip movement allowing the continuous evaluation of gingival contours unaffected by lip drooping. This technique could also provide an alternative option whenever local anesthesia cannot be administered successfully through the buccal aspect, such as the presence of a large abscess or a neoplastic lesion in the buccal vestibule or reduced mouth opening due to various reasons.

The success of the AMSA technique depends on the delivery and diffusion of the LA solution around the subneural dental plexus, which is located in the alveolar process of the maxilla, anterior to the anteroinferior border of the maxillary sinus [17]. Its location clinically corresponds to the apical region of the premolars [2]. The posterior part of the plexus is formed by the posterior and middle superior alveolar nerves, while the anterior part is formed by numerous twigs from the anterior superior alveolar nerve. However, numerous variations have been reported in previous cadaver-based studies, with the middle superior alveolar nerve absent in 28% to 54% of the cases [18,19]. As far as the hard tissue structure in the AMSA injection region is concerned, very few attempts have been made to explore this issue. The present study focused on determining the overall density of the cortical and cancellous bones in the region of AMSA injection, which might also play a role in the diffusion of LA solution to the subneural dental plexus.

Cetkovic et al. reported their anatomical findings based on the micro-CT based evaluation of 20 human skulls from a Serbian museum [5]. Their observations were based on the microstructure of the palatal cortex, such as higher porosity, the interconnectivity of the pores, and the number of canals traversing the whole cortical thickness, as compared to the buccal cortex in the area of AMSA injection. The average width of the canals was also significantly higher in the palatal cortex. These characteristics provided a reasonable anatomic basis for the diffusion of LA solution and the success of AMSA injection. However, they did not evaluate the possible variations in the cancellous bone.

Many studies have compared the thickness and the density of buccal and palatal cortices using CBCT-based analysis, although for a different purpose [20,21]. It has

been reported that the density of the palatal cortex tends to decrease, while the buccal cortex tends to increase as we move from the incisor region towards the maxillary tuberosity. The present study confirms this finding as the density of the buccal cortex was maximum in the premolar-molar region (region 3), followed by the premolar region (region 2) and the canine-premolar region (region 1). At the same time, a reverse trend was observed in the palatal cortex. No significant difference has been reported between the buccal and palatal cortices in the premolar region, similar to our findings [20,21]. The cancellous bone density showed a decreasing trend from the canine through the first molar region, both in the buccal and palatal halves. This pattern is widely known, as the cancellous bone is denser and coarsely woven in the anterior region and is delicately woven in the posterior region [22].

The novel finding in our study is the significantly lower density of the cancellous bone in the palatal half than in the buccal half, consistently in all three interdental areas. Our observations, along with those of Cetkovic et al., can reliably explain the anatomical basis of AMSA injection [5]. Since the palatal cortex is more porous and has wider nutrient canals, the LA solution can easily reach the cancellous bone from the site of injection. After that, the lower density of the palatal half of the cancellous bone would facilitate diffusion until the subneural dental plexus.

Although we could not find any gender-related differences in bone density, some parameters have been reported to differ between male and female patients. Ozdemir et al. reported that female subjects generally have a denser palatal cortex than male subjects in the same region [20]. Cetkovic et al. reported that female subjects had a significantly greater mean diameter of the nutrient canal than male subjects; however, there was no significant difference in the number of nutrient canals. They also reported that most of the nutrient canals were located in the palatal process of maxilla in female subjects, while in male subjects, the majority of canals were located in the border zone between the palatal and alveolar processes. They suggested that the appropriate site for AMSA injection may differ between male and female patients based on this variation [5]. However, we could not validate their findings as we focused only on the alveolar bone and not the basal bone. We observed that the pattern of variation between the apical, middle, and coronal third was mostly inconsistent except for the average density of the palatal cortical bone, which was highest in the apical third, and palatal cancellous bone, which was highest in the cervical third in all three regions. However, this evidence was not significant enough to suggest any change in the site of AMSA injection.

Limitations of the current study included the limited sample size and selection of patients from a single geographical region. In addition, the CBCT images are influenced by the device, cone angle, and imaging parameters, which cannot be standardized in a retrospective evaluation of available data. Future prospective studies may standardize these parameters or use potentially more precise techniques like multi-slice CT, which is associated with less scattering and artifact production and better accuracy for HU values in assessing alveolar bone density [23]. Another limitation of the present study could be the criteria for determining the cervical, middle, and apical thirds, that is, each with a fixed height of 3 mm. It could have been marked based on the root length of adjacent teeth, which is variable. However, this was necessary in order to standardize the data for comparison.

Within the limitations of the present study, there appears to be a sufficient anatomic basis for the AMSA anesthetic technique. A significantly lower density of the cancellous bone in the palatal half than in the corresponding buccal half in the area of the subneural dental plexus could favor the infiltration of LA solution from the palatal aspect. However, anatomic variations in the nerve supply are common and should be considered if this technique fails to achieve the desired results in any particular individual. To enhance the understanding of the mechanism involved, more investigations with larger samples are necessary to explore the nerve supply

of the maxillary dentoalveolar complex. Exploring different anesthetic agents along with latest equipments may also ensure better predictability of this technique in the future.


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## AUTHOR CONTRIBUTIONS

**Abdul Ahad:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Resources, Software, Supervision, Validation, Writing - original draft, Writing - review & editing
**Ekramul Haque:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Resources, Software, Validation, Writing - original draft, Writing - review & editing
**Sabiha Naaz:** Conceptualization, Investigation, Methodology, Software, Writing - original draft
**Afshan Bey:** Conceptualization, Data curation, Investigation, Methodology, Supervision, Validation, Writing - review & editing
**Sajjad Abdur Rahman:** Data curation, Formal analysis, Supervision, Validation, Writing - review & editing

**CONFLICT OF INTEREST:** There are no conflicts of interest to declare.

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