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COMPARISON OF PALATAL BONE HEIGHT IN DIFFERENT FACIAL MORPHOLOGICAL PATTERNS BY CONE BEAM COMPUTED TOMOGRAPHY – A PROSPECTIVE STUDY

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Abstract

Background:
Orthodontic mini-implants require adequate palatal bone support to achieve primary stability and successful skeletal anchorage. Variations in palatal bone height associated with different vertical facial growth patterns may influence the selection of safe and optimal insertion sites. CBCT provides a reliable three-dimensional assessment of palatal bone morphology and can aid in treatment planning.

Objective:
To evaluate the relationship between facial growth pattern and palatal bone height using CBCT and to identify regions of adequate bone availability for orthodontic mini-implant placement.

Materials and Methods:
A prospective CBCT-based study was conducted on 90 subjects (45 males and 45 females) aged 18–30 years. Participants were equally divided into three groups according to facial growth pattern: average (n=30), horizontal (n=30), and vertical (n=30). Palatal bone height was measured at standardized locations 3, 6, and 9 mm lateral to the midpalatal suture and at 4-mm intervals posteriorly from the distal margin of the incisive foramen. A total of 18 measurement points were evaluated using Carestream CS 9600 CBCT software. Statistical analysis was performed using SPSS version 26.0. Comparisons among groups were made using one-way ANOVA with post hoc testing, while gender and side-wise comparisons were analyzed using independent and paired t-tests, respectively. Statistical significance was set at $p < 0.05$.

Results:
No significant difference was observed between right and left palatal bone height measurements ($p > 0.05$). Males demonstrated significantly greater composite palatal bone height than females overall (6.89 ± 2.33 mm vs. 6.15 ± 2.21 mm; $p = 0.031$). Mean composite palatal bone height differed significantly among facial growth patterns, with the highest values observed in the horizontal group (7.31 ± 2.14 mm), followed by the vertical group (6.58 ± 2.01 mm) and the average group (5.66 ± 1.84 mm) ($p = 0.011$). Post hoc analysis revealed significant differences between average and vertical groups ($p = 0.041$) and between average and horizontal groups ($p = 0.004$). At most measurement sites, palatal bone height was greatest in the horizontal growth pattern and progressively decreased in posterior regions. Bone height increased significantly with lateral movement from 3 mm to 9 mm from the midpalatal suture in anterior and middle palatal regions ($p < 0.05$), while posterior regions demonstrated lower values and less variation.

Conclusion:
Palatal bone height is significantly influenced by facial growth pattern, with horizontal growers exhibiting the greatest bone availability and average growers the least. The anterior and paramedian regions of the palate provide the most favorable bone support for orthodontic mini-implant placement. CBCT-based individualized assessment is recommended for accurate identification of safe insertion sites and optimal screw length selection in skeletal anchorage procedures.

Introduction

By providing an accurate three-dimensional image of craniofacial anatomy with minimum distortion and superimposition, CBCT has greatly improved orthodontic diagnosis[1]. CBCT improves treatment planning and diagnostic reliability by measuring palatal bone measurements more accurately than traditional lateral cephalometry[2-3]. Orthodontic mini-implants have broadened the scope of conventional orthodontic treatment because they offer a great substitute for conventional compliance-dependent, tooth-borne anchorage techniques. Mini-implant technology has expanded due to aesthetic concerns and the increasing need for orthodontic treatment procedures that require minimal compliance, particularly by adults.[4]. Additionally, prior orthodontic mobility limits have been overcome, attributable to the micro implant. For instance, it is now feasible to manage the vertical dimension, intrude molars to fix an open bite, or shift the entire dentition in the same direction. The use of mini-implant anchors in orthodontic therapy is growing in importance.[5] Titanium miniscrews, which were first employed for bone fixation in plastic and reconstructive surgery, are now utilised in orthodontics and numerous new miniscrew designs have been developed.[6] There are numerous intraoral locations where orthodontic mini-implants for complete anchoring can be positioned. For several reasons, the palate in the median or paramedian region is likely one of the best locations. Other than the incisive foramen, there is minimal risk of harming anatomical structures, and it is covered has keratinized gingiva, making it less prone to irritation. High-quality cortical bone is seen in the palate's median region, which helps keep the mini-implants in place.[7] The growing use of temporary anchoring devices (TADs), which need adequate bone support to guarantee primary stability and long-term effectiveness, makes accurate assessment of palatal bone morphology more crucial. In essence, the mini-implant's dimensions should match the quantity of bone that is available at the site of insertion. The success of a mini-implant depends critically on the bone height that is available at the palate's mini-implant site. Inadequate bone would not only compromise the stability of the mini-implant, but it would also cause a nasal cavity hole during insertion. Short palatal mini-implants were developed due to the palate's limited bone height.[8,9] Palatal bone thickness has been quantitatively evaluated in several CBCT-based studies to determine optimal locations for mini-implant placement. Regional differences in palatal bone thickness were shown by early three-dimensional analysis, highlighting the significance of customised anatomical evaluation.[10-11] It has also been emphasised how important cortical bone thickness is in determining implant stability.[12] Age-related variations in palatal bone thickness between teenagers and adults have been documented, and evaluations of bone density have further highlighted the significance of a thorough anatomical examination before implant implantation.[13-14] Further research has established normative reference values for clinical application by examining characteristics related to palatal bone thickness in adult populations.[15] Anatomical recommendations for the safe and efficient insertion of palatal mini implants have been proposed in addition to thickness measurements. To maximise stability and minimise difficulties, certain insertion locations within the palatal region have been found[16]. Variations in bone dimensions that impact clinical decision-making have been identified through comparisons between median and paramedian regions[17]. The therapeutic usefulness of CBCT-based assessments has been further strengthened by more recent studies that assessed palatal bone thickness in connection to palatal vault depth and appliance-specific requirements.[18-20] Although these investigations have established normative palatal bone parameters, it has been demonstrated that alveolar and cortical bone qualities are influenced by craniofacial morphology. People with varying vertical face proportions have been found to exhibit differences in alveolar bone mapping.[21] There is also evidence of variations in cortical bone density among vertical face forms.[22] In untreated adults, correlations between cortical bone thickness and facial growth patterns have been found." Additionally, recent CBCT-based analyses have confirmed the influence of vertical facial type on alveolar bone thickness.[23-24] These results imply that craniofacial bone structure is significantly influenced by skeletal shape. More precisely, studies looking at the relationship between palatal bone thickness and facial morphological patterns have found quantifiable variations across different types of faces[25]. Additionally, differences between open and typical vertical skeletal layouts have been shown.[26] Therefore, it has been highlighted how crucial it is to take facial growth trends into account while planning palatal mini-implant placement[27]. Palatal bone height has received less attention as a characteristic controlled by facial shape, despite the substantial body of literature concentrating on palatal bone thickness. There has been evidence linking mid-palatal cortical thickness to face height.[28] Furthermore, variations in palatal density, thickness, and height based on facial biotype have been noted[29]. Although CBCT has been used to evaluate palatal bone height across facial morphological features, there is still no prospective data.[30]

Materials and Methods

Study Design and Sample

This prospective study was conducted in the Department of Orthodontics and Dentofacial Orthopaedics, People's University. A total of 338 patients were screened for eligibility, of which 90 subjects were selected according to predefined inclusion and exclusion criteria. Written informed consent was obtained from all participants before enrollment.

Inclusion Criteria

- Age between 18 and 30 years.
- Full complement of teeth up to second molars.
- No history of trauma or surgery in the craniofacial region.
- No previous orthodontic treatment.

Exclusion Criteria

- History of orthognathic surgery.
- Presence of prosthesis.
- Congenitally missing teeth or grossly decayed teeth (except third molars).
- Previous orthodontic treatment.
- Impacted teeth in the palatal region.

Sample Distribution

The study sample consisted of 90 subjects equally distributed among three facial growth pattern groups:

- Group A: Average growth pattern (n = 30)
- Group B: Horizontal growth pattern (n = 30)
- Group C: Vertical growth pattern (n = 30)

Each group consisted of 15 males and 15 females.

Assessment of Facial Growth Pattern

Facial growth pattern was determined using the following cephalometric parameters:

1. Gonial angle.
2. Basal plane angle.
3. Mandibular plane angle (SN-GoGn).
4. Mandibular plane angle (GoMe-FH).

These parameters were used to classify subjects into average, horizontal, and vertical growth pattern groups.

CBCT Imaging and Measurements

CBCT scans were obtained using a CS 9600 Carestream CBCT machine (Kodak Carestream

Health, Rochester, NY, USA) (Fig1)with the following parameters:

- Voxel size: 0.3 mm
- Tube voltage: 120 kVp
- Tube current: 6.3 mA
- Field of view: 12 × 10 cm

Measurements were performed using CS 3D Imaging Software (version 3.10.21).(Fig 2A,B)

The palatal bone height was measured perpendicular to a horizontal reference plane passing through the distal border of the incisive foramen and the posterior nasal spine. Measurements were obtained at:

- 3 mm, 6 mm, and 9 mm lateral to the midpalatal suture (D3, D6, D9). (Fig 3A,B)
- 4-mm intervals posterior to the distal margin of the incisive foramen (P4, P8, P12, P16, P20, and P24).

A total of 18 measurement points were evaluated bilaterally.

Statistical Analysis

Data were analyzed using SPSS version 26.0.

- Descriptive statistics were expressed as mean ± standard deviation.
- Chi-square test was used for gender distribution.
- Independent samples t-test was used for gender comparison.
- Paired t-test was used for right-left side comparison.
- One-way analysis of variance (ANOVA) was used for comparison among facial growth pattern groups.
- Post hoc analysis was performed whenever significant differences were detected.
- Repeated measures ANOVA was used to evaluate changes across lateral and posterior positions.

A p-value < 0.05 was considered statistically significant.

Fig.2 Carestream 9600 CBCT Machine

Fig 2 A. Carestream 9600 CBCT Scanner Software

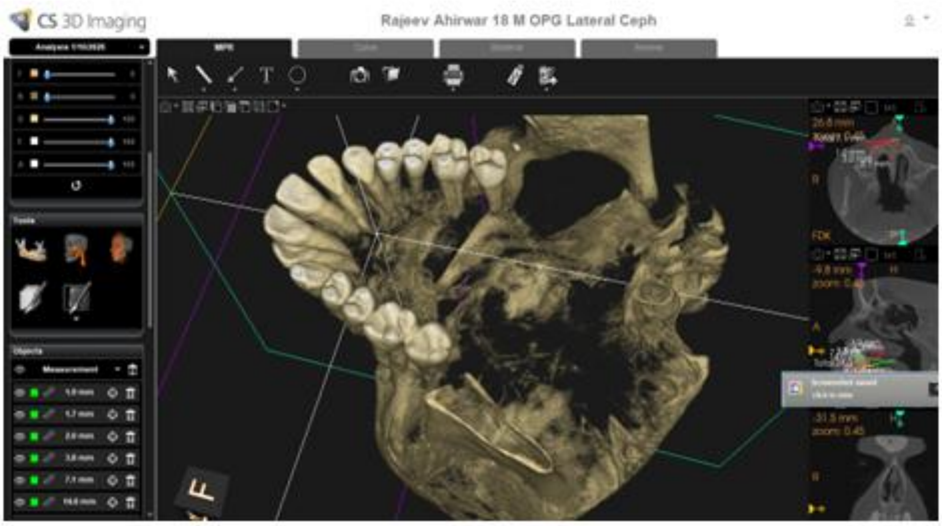


Fig 2. B Carestream 9600 CBCT Software

Fig. 3, A. Reference polylines constructed at distances of 3 mm, 6 mm, and 9 mm from the midpalatal suture, perpendicular to the midpalatal suture.

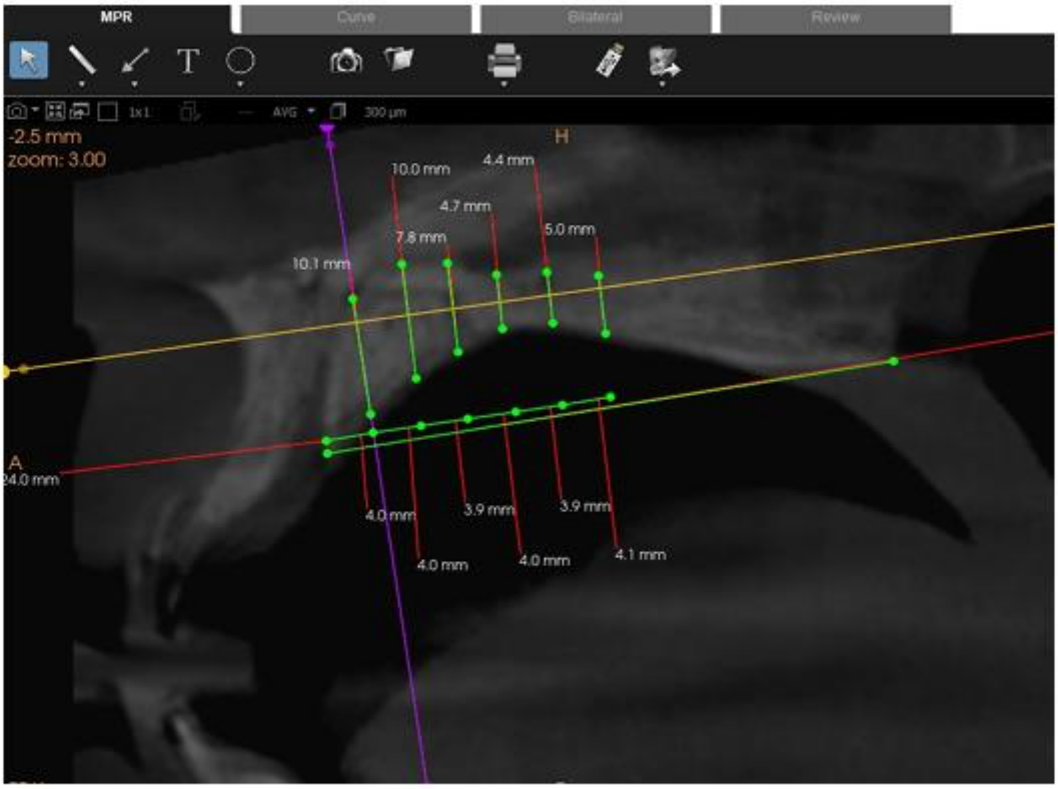


Fig. 3, B Measurements of palatal bone height

Results

Gender Distribution

The study population consisted of 45 males and 45 females. Each facial growth pattern group included 15 males and 15 females. No statistically significant difference in gender distribution was observed among groups ($p = 1.000$).

Right and Left Side Comparison

No statistically significant difference was found between right and left palatal bone height measurements in any growth pattern group.

The overall mean palatal bone height was:

- Right side: 6.49 ± 2.46 mm
- Left side: 6.55 ± 2.42 mm

($p = 0.820$)

Comparison Between Males and Females

Overall, males demonstrated significantly greater composite palatal bone height than females.

- Males: 6.89 ± 2.33 mm
- Females: 6.15 ± 2.21 mm

($p = 0.031$)

Within the horizontal growth pattern group, males showed significantly greater palatal bone height than females (7.78 ± 2.20 mm vs. 6.84 ± 2.03 mm; $p = 0.041$).

Palatal Bone Height According to Facial Growth Pattern

The mean composite palatal bone height was:

- Average growth pattern: 5.66 ± 1.84 mm
- Vertical growth pattern: 6.58 ± 2.01 mm
- Horizontal growth pattern: 7.31 ± 2.14 mm

The difference among groups was statistically significant ($F = 4.87$, $p = 0.011$).

Post hoc analysis demonstrated:

- Average vs Vertical: $p = 0.041$
- Average vs Horizontal: $p = 0.004$
- Vertical vs Horizontal: $p = 0.198$

Thus, the average growth pattern group exhibited significantly lower palatal bone height than both vertical and horizontal groups.

Site-Specific Measurements

At most measurement locations, the horizontal growth pattern group exhibited the highest palatal bone height values, followed by the vertical group and then the average group.

The highest measurements were observed in the anterior palate (P4 region), particularly at D9/P4, where values exceeded 10 mm in all groups.

Palatal bone height progressively decreased from anterior to posterior regions.

The lowest values were observed at the P24 region.

Changes with Lateral Movement

Palatal bone height generally increased from D3 to D9.

Significant increases were observed at:

- P4 ($p < 0.001$)
- P8 ($p = 0.012$)
- P12 ($p = 0.018$)
- P16 ($p = 0.041$)
- P20 ($p = 0.049$)

No significant difference was observed at P24 ($p = 0.082$).

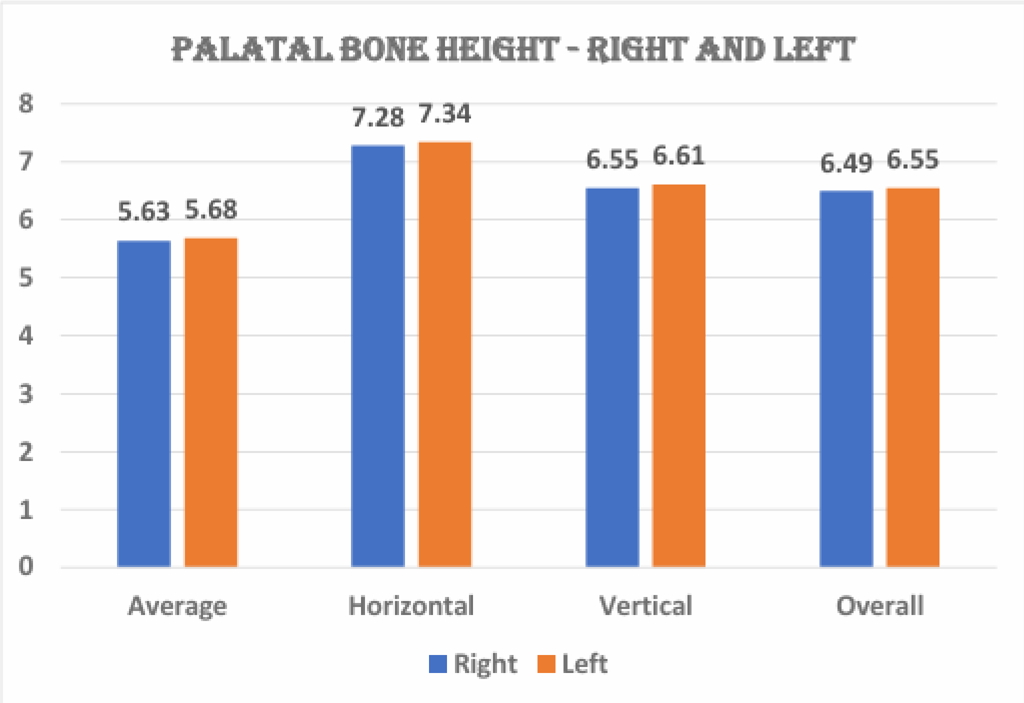
Changes with Posterior Movement

Palatal bone height decreased progressively from anterior to posterior regions.

Significant differences were observed at:

- P4 (p = 0.005)
- P8 (p = 0.017)
- P12 (p = 0.026)

No significant differences were detected at P16, P20, or P24.

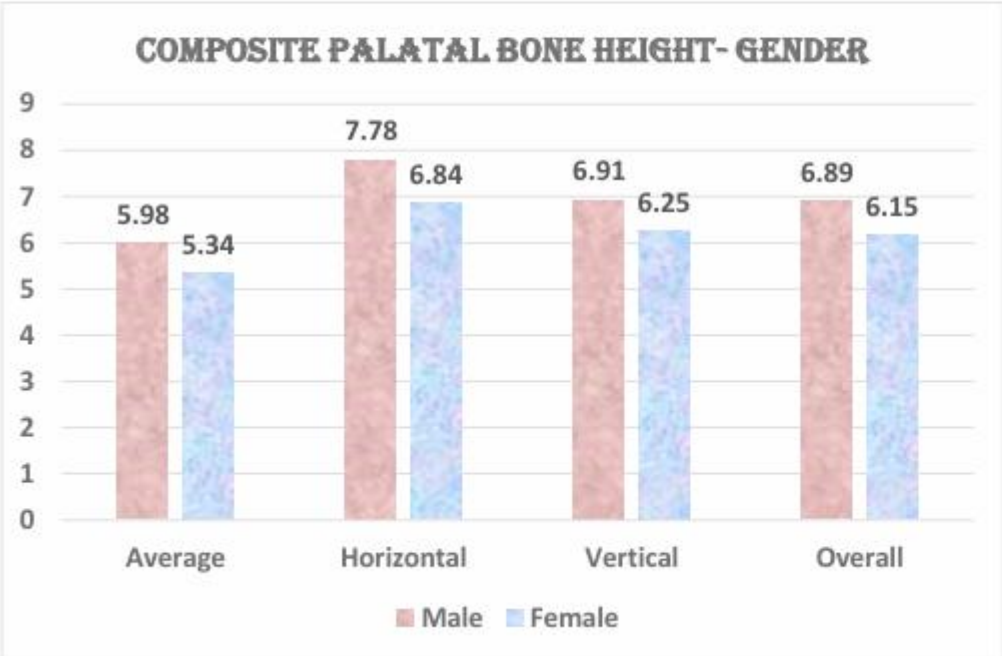


Graph 1: Comparison of composite palatal bone height between right and left sides

Group	Male		Female		t value	p value
	Mean	SD	Mean	SD		
Average	5.98	1.92	5.34	1.71	1.79	0.084 (NS)
Horizontal	7.78	2.20	6.84	2.03	2.17	0.041*
Vertical	6.91	2.11	6.25	1.88	1.68	0.103 (NS)
Overall	6.89	2.33	6.15	2.21	2.21	0.031*

NS – Not significant; *=Significant

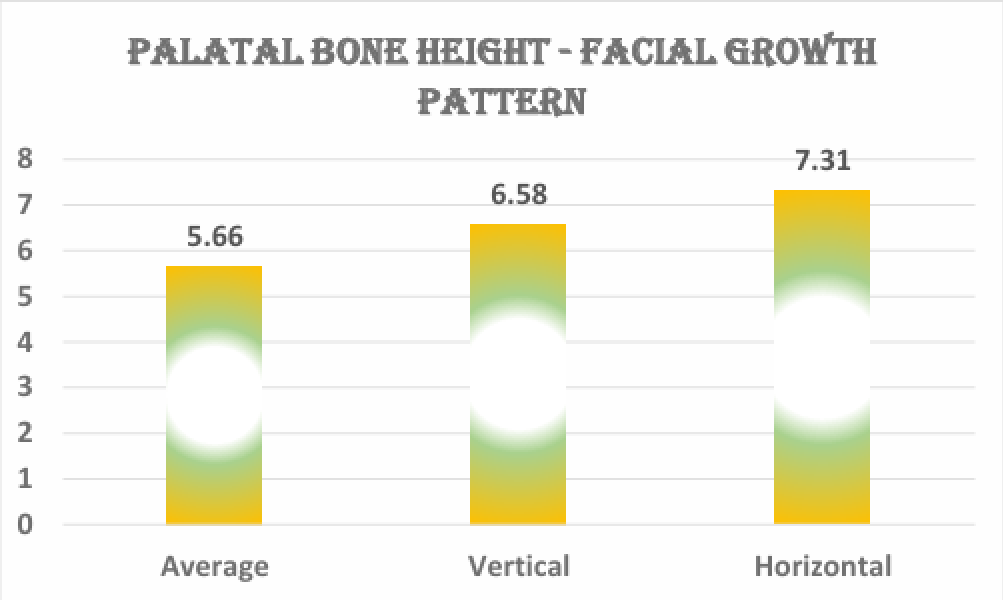
Table 1: comparison of Composite Palatal Bone Height Between Males and Females



Graph 2: Comparison of composite palatal bone height between males and females

Growth pattern	Mean (mm)	SD	F value	p value
Average	5.66	1.84	4.87	0.011*
Vertical	6.58	2.01		
Horizontal	7.31	2.14		

Table 2: Composite palatal bone height according to facial growth pattern



Graph 3: Composite palatal bone height according to facial growth pattern

Discussion

The present study investigated the relationship between facial growth pattern and palatal bone height using CBCT imaging. The findings demonstrated that facial growth pattern significantly influences palatal bone height, supporting the alternate hypothesis and rejecting the null hypothesis.

No significant difference was observed between the right and left sides, indicating bilateral symmetry of palatal bone height. This finding suggests that clinicians may expect similar bone availability on either side of the palate during mini-implant placement.

Gender-based analysis demonstrated significantly greater palatal bone height in males than females. The greater bone dimensions observed in males may be attributed to generally larger craniofacial skeletal dimensions and increased bone mass.

The horizontal growth pattern group exhibited the greatest mean palatal bone height, followed by the vertical and average growth pattern groups. These findings are consistent with studies reporting greater craniofacial bone dimensions in subjects with reduced vertical facial divergence. Increased bone availability in horizontal growers may provide more favorable conditions for primary stability of orthodontic mini-implants.

Site-specific analysis revealed that the anterior palate contained the greatest amount of available bone. Palatal bone height progressively decreased in posterior regions. These findings support previous CBCT investigations that identified the anterior and paramedian palate as the most suitable regions for skeletal anchorage.

The increase in bone height with greater lateral distance from the midpalatal suture was particularly evident in the anterior and middle palatal regions. The D9 locations consistently demonstrated higher values than D3 and D6 locations. This observation suggests that paramedian insertion sites may offer greater bone support compared with sites closer to the midpalatal suture.

The reduction in palatal bone height in the posterior palate emphasizes the need for careful treatment planning in this region. Although adequate bone was present at many posterior sites, the available height was considerably lower than that observed anteriorly.

Overall, the findings highlight the importance of individualized CBCT evaluation before mini-implant placement. Knowledge of facial growth pattern and regional bone availability can assist clinicians in selecting safe insertion sites and appropriate screw lengths, thereby improving anchorage stability and minimizing complications.

Conclusion

Within the limitations of the present prospective CBCT-based study, it can be concluded that palatal bone height is significantly influenced by facial growth pattern, anatomical location, and, to a lesser extent, gender. Individuals with a horizontal growth pattern demonstrated the greatest palatal bone height, followed by vertical and average growth patterns, indicating that skeletal morphology plays an important role in determining bone availability for orthodontic mini-implant placement. Palatal bone height was found to be greater in the anterior and paramedian regions and progressively decreased toward the posterior palate. Additionally, an increase in bone height with lateral distance from the midpalatal suture supports the clinical preference for paramedian insertion sites. No significant difference was observed between the right and left sides, indicating bilateral symmetry of palatal bone height. Based on the present findings, the most favorable region for mini-implant placement lies between 4–8 mm posterior to the incisive foramen and 3–9 mm lateral to the midpalatal suture, with an extended favorable zone up to 12 mm posteriorly in individuals with a horizontal growth pattern. These results emphasize that the selection of implant site and dimensions should be individualized according to the patient's skeletal pattern and anatomical characteristics. Overall, this study highlights the importance of CBCT-based three-dimensional assessment in enhancing the safety, accuracy, and predictability of orthodontic mini implant placement. The findings contribute to the existing body of knowledge by demonstrating that palatal bone height, in addition to thickness, is a critical parameter that must be considered in clinical decision-making.

Credit authorship contribution statement

Rajesh kumar Balani, Amitabh Kallury, Chandrika Dubey: Writing - review & editing, Supervision, Project administration, Methodology, Conceptualization. Akshay Agarwal: Material and method , Cbct measurement. Sawan Singh: Writing - original draft, Data curation. Surabhi Lata: Writing - original draft, Data curation.

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