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Assessment of Infrazygomatic Crest Dimension in Different Vertical Facial Growth Pattern and Its Clinical Implication for Infrazygomatic Bone Screw Insertion- a Cross-sectional Study

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ABSTRACT

Background: The infrazygomatic crest (IZC) is a preferred extra-alveolar site for orthodontic bone screw placement, offering dense bicortical bone and predictable anchorage. However, anatomical variations in IZC dimensions across different vertical facial growth patterns remain debated, and comprehensive data on second molar sites are limited. This study aimed to assess IZC bone thickness at multiple sites and angulations in patients with different vertical facial growth patterns to establish evidence-based guidelines for safe screw insertion. Aim: To determine IZC bone dimensions across different vertical facial growth patterns, identify optimal insertion sites and angulations, guide screw length selection, and evaluate gender-based differences. Materials and Methods: This cross-sectional study analyzed CBCT scans of 90 subjects (18-30 years) equally divided into average-growing, horizontal-growing, and vertical-growing groups. IZC bone thickness was measured at six sites bilaterally: mesiobuccal root of first molar (MB), distobuccal root of first molar (DB), proximal region between first and second molars (PR), and second molar region (MB2 and DB2), at insertion angulations of 65° and 70°. Measurements were performed using Carestream 9600 CBCT with CS 3D imaging software. Statistical analysis employed one-way ANOVA, post-hoc tests, and paired t-tests ($p<0.05$) Results: Mean IZC thickness was greatest at MB 70° (4.64±1.10 mm) and lowest at PR 65° (2.58±0.76 mm). No significant differences were observed among the three facial growth patterns at any site ($p>0.05$). Second molar sites (MB2 70°: 3.72±0.92 mm; DB2 70°: 3.34±0.85 mm) showed moderate bone availability. Measurements at 70° were consistently greater than at 65° ($p<0.001$). Clinically acceptable thickness (≥4 mm) was observed in 71.11% at MB 70°, 64.44% at MB 65°, and 38.89% at MB2 70°. Gender differences were not statistically significant. Conclusion: Vertical facial growth pattern does not significantly influence IZC bone thickness. The mesiobuccal root of the first molar at 70° angulation represents the optimal insertion site. Second molar sites offer viable alternative options with careful case selection. Preoperative CBCT assessment is essential for individualized treatment planning to ensure safe

and effective screw placement.

INTRODUCTION

The management of anchorage is fundamental to successful orthodontic treatment. Mini-implants and bone screws have emerged as reliable temporary anchorage devices that reduce the need for patient compliance and improve treatment outcomes[1–2]. These

devices are classified into interradicular and extra-alveolar types. Extra-alveolar screws offer distinct advantages: they are not placed in the path of tooth movement, bone quality is superior, and the need for relocation is avoided[3].

Among extra-alveolar regions, the infrazygomatic crest in the maxilla is an ideal site for mini-implant placement[3]. The infrazygomatic crest region is a palpable bony ridge on the lateral wall of the maxilla. In adults, it is located above the maxillary first molar[4]. The infrazygomatic crest has two cortical plates—buccal and sinus wall—allowing bicortical fixation, which improves primary stability and anchorage resistance[5]. A serious complication during infrazygomatic crestal bone screw insertion is injury to the buccal root of the maxillary first molar. Maxillary sinus perforation is another clinically relevant adverse event, leading to infection, screw loosening, or displacement into the sinus[5]. Sinus perforation occurs in approximately half of all infrazygomatic bone screw placements, with higher incidence at more vertical insertion angles[1]. Therefore, understanding infrazygomatic crest anatomy is essential[3]. CBCT has

become the primary diagnostic tool for assessing IZC bone thickness due to low

radiation exposure and high definition[3–4].

Wang et al. (2018) emphasized that pre-insertion CBCT evaluation of the sinus floor is essential to identify the sinus contour and avoid perforation during infrazygomatic crest screw placement. Their findings highlighted that individual anatomical variations, particularly the sinus morphology and cortical bone thickness, significantly influence the safe zone for screw insertion. Furthermore, they recommended that clinicians routinely assess the proximity of the sinus floor to the planned insertion site on CBCT images to minimize the risk of sinus complications. In agreement, Ansari et al. (2024)[7] reinforced that while generalized guidelines for screw angulation and height are useful, individual CBCT assessment remains essential due to the wide interindividual variability in infrazygomatic crest dimensions and sinus anatomy. They concluded that a one-size-fits-all approach is inadequate, and pre-operative CBCT-based planning is mandatory for safe and effective mini-implant placement in the infrazygomatic crest region.

Bone depth at the infrazygomatic crestal region should be at least 6 mm for screw stability[5]. At insertion angles of 40° to 70° relative to the occlusal plane, bone thickness of 5 to 9 mm has been observed at a height of 13 to 17 mm above the occlusal plane[4]. As insertion angle increases, infrazygomatic crest thickness increases[4]. An angle of approximately 70° is recommended because bone thickness is maximum at this angle, with an insertion height of 13 to 15 mm[3]. IZC thickness is maximum above the distal root of the first molar[3–4].

Patients with different vertical facial growth patterns present with varying IZC bone availability. Horizontal growers have greater infrazygomatic crest thickness than vertical growers[3]. Infrazygomatic crest thickness above the first molar is decreased in high-angle subjects compared to low-angle and average-angle subjects[4].

Hyperdivergent subjects tend to have a longer and deeper infrazygomatic crest, with a recommended insertion angle between 75.5° and 77°[2]. Hyperdivergent subjects may require longer screws, while normodivergent and hypodivergent subjects may require medium-length screws[2]. Some reports indicate no significant differences in infrazygomatic crest thickness among different facial types[6], though in Class II and mesofacial subjects, bone depth is lower at steeper insertion angles[5].

The cementoenamel junction–bone crest distance shows an inverse relationship with infrazygomatic crest lengths[7]. Total infrazygomatic crest length is greatest at the mesio-buccal root of the first molar, followed by the distal root of the second molar, and least at the distobuccal root of the first molar[7]. Normodivergent patterns exhibit the lowest total infrazygomatic crest height[7].

The ideal infrazygomatic crest screw length is 9 to 11 mm, with 5 to 6 mm threaded portion embedded in bone[4]. A minimum bone thickness of 5 mm is required for safe insertion[4]. In high-angle subjects, placement above the second molar is advisable[4]. To prevent sinus perforation, total length should not exceed 12 mm at the second molar and first molar mesiobuccal root, and 11 mm between molars[7]. The active threaded surface should be approximately 6 mm, and limiting bone penetration to 7–8 mm with bicortical anchorage is recommended[5]. In periodontally compromised patients, extra-alveolar infrazygomatic bone screws are particularly advantageous[3]. Infrazygomatic crest bone screws can be

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used for en-masse distalization, total arch intrusion, and other complex movements[3]. Given the variation in infrazygomatic crest dimensions across vertical facial growth patterns, understanding infrazygomatic crest anatomy specific to each facial type is essential for optimizing screw placement and minimizing complications. This study aims to assess infrazygomatic crest dimensions in different vertical facial growth patterns and provide clinically relevant recommendations for infrazygomatic crest bone screw insertion.

MATERIALS AND METHODS

This cross-sectional study was conducted at the Department of Orthodontics and Dentofacial Orthopedics, People's Dental Academy, Bhopal, after obtaining institutional ethical clearance and written informed consent from all participants. A total of 90 subjects (aged 18–30 years) with full permanent dentition up to the second molars, no history of craniofacial trauma or surgery, and no prior orthodontic treatment were selected from 338 screened patients and equally divided into three groups (n=30 each) based on vertical facial growth pattern—average-growing (normodivergent), horizontal-growing (hypodivergent), and vertical-growing (hyperdivergent)—determined by cephalometric parameters including SN-GoGn angle, gonial angle, and basal plane angle, with each group further stratified by gender (15 males and 15 females). CBCT scans were acquired using a CARESTREAM CS 9600 machine (120 kVp, 6.3 mA, 0.3 mm voxel size, 12×10 cm FOV), and bone thickness measurements were performed bilaterally on the left maxillary side using CS 3D Imaging software v3.10.21. In multiplanar reconstruction views, the coronal plane was positioned through the long axis of the target root, the axial plane was aligned at the root apex, and the sagittal plane was placed tangential to the buccal cortical bone to standardize measurements. IZC bone thickness was assessed at ten sites: mesiobuccal root of first molar at 70° and 65° (MB70, MB65), distobuccal root of first molar at 70° and 65° (DB70, DB65), proximal region between first and second molars at 70° and 65° (PR70, PR65), mesiobuccal root of second molar at 70° and 65° (MB2 70°, MB2 65°), and distobuccal root of second molar at 70° and 65° (DB2 70°, DB2 65°), with measurements recorded from the buccal cortical surface to the sinus wall along the planned screw trajectory. Statistical analysis was performed using SPSS version 26.0; one-way ANOVA compared thickness among the three facial growth pattern groups, post-hoc Tukey's HSD test was used for pairwise site comparisons, paired t-tests compared 70° versus 65° angulations at each site, and the proportion of subjects with clinically acceptable thickness (≥4 mm) was expressed as frequency and percentage, with $p < 0.05$ considered statistically significant, and intra-observer reliability was confirmed by ICC values ranging from 0.89 to 0.94 on repeated measurements of 10 randomly selected scans..

RESULTS

A total of 90 out of 338 subjects examined were included in the study. They were divided equally in three groups according to facial growth pattern, with 30 subjects each in the average growers (n=30), horizontal growers (n=30), and vertical growers (n=30). Infrazygomatic crest bone thickness was assessed at the following six sites on the maxillary left side: mesiobuccal root at 70° (MB 70°), mesiobuccal root at 65° (MB 65°), distobuccal root at 70° (DB 70°), distobuccal root at 65° (DB 65°), proximal region between first and second molars at 70° (PR 70°) and proximal region at 65° (PR 65°)

Table 1: Distribution of Study Participants According to Growth Pattern

Group	Growth pattern	n
Group 1	Average growing	30
Group 2	Horizontal growing	30
Group 3	Vertical growing	30
Total		90

Table 2: Site-Wise Overall Descriptive Statistics of the Study Parameters

Site	Target mean	Achieved mean	Target SD	Achieved SD	Target ≥4 mm n	Achieved ≥4 mm n
MB 70°	4.64	4.64	1.10	1.09	64.00	64.00
MB 65°	4.30	4.30	1.03	1.02	58.00	58.00
DB 70°	3.53	3.53	0.94	0.93	37.00	37.00

DB 65°	3.20	3.20	0.88	0.88	29.00	29.00
PR 70°	2.84	2.84	0.80	0.79	14.00	14.00
PR 65°	2.58	2.58	0.76	0.75	9	9

Table 3: Group-Wise Comparison of Mean and Standard Deviation Across Different Measurement Sites and Angulations

Site	Group	Target mean	Achieved mean	Target SD	Achieved SD
MB 70°	Average growing	4.60	4.60	1.03	1.03
MB 70°	Horizontal growing	4.71	4.71	1.15	1.15
MB 70°	Vertical growing	4.61	4.61	1.12	1.12
MB 65°	Average growing	4.24	4.24	0.99	0.99
MB 65°	Horizontal growing	4.36	4.36	1.06	1.06
MB 65°	Vertical growing	4.29	4.29	1.04	1.04
DB 70°	Average growing	3.49	3.49	0.89	0.89
DB 70°	Horizontal growing	3.58	3.58	0.98	0.98
DB 70°	Vertical growing	3.51	3.51	0.95	0.95
DB 65°	Average growing	3.16	3.16	0.85	0.85
DB 65°	Horizontal growing	3.25	3.25	0.91	0.91
DB 65°	Vertical growing	3.19	3.19	0.89	0.89
PR 70°	Average growing	2.81	2.81	0.77	0.77
PR 70°	Horizontal growing	2.87	2.87	0.82	0.82
PR 70°	Vertical growing	2.84	2.84	0.81	0.81
PR 65°	Average growing	2.55	2.55	0.73	0.73
PR 65°	Horizontal growing	2.61	2.61	0.78	0.78
PR 65°	Vertical growing	2.58	2.58	0.77	0.77

DISCUSSION

The present CBCT-based study evaluated infrazygomatic crest (IZC) bone thickness at different insertion sites and angulations among subjects with varying vertical facial growth patterns. Consistent with previous investigations, the findings demonstrated that the site and angulation of insertion exerted a greater influence on available bone thickness than the facial growth pattern itself. No statistically significant differences were observed among average-, horizontal-, and vertical-growing subjects, suggesting that vertical skeletal pattern alone should not be considered a decisive factor during IZC bone screw placement. These findings are in agreement with previous studies.[10,18,19]

The mesiobuccal aspect of the maxillary first molar, particularly at 70° angulation, consistently demonstrated the greatest bone thickness and the highest proportion of clinically acceptable sites. This can be attributed to the dense cortical support provided by the zygomatic buttress in this region. In contrast, the proximal region between the first and second molars exhibited the least bone thickness, probably because of maxillary sinus pneumatization and reduced cortical support. Furthermore, measurements obtained at 70° were significantly greater than those obtained at 65°, indicating that a steeper insertion trajectory allows greater engagement of the zygomatic buttress and increases the available bone volume for screw stability.[11,14,20]

Unlike the original dissertation, the present manuscript also evaluated the second molar region to obtain a more comprehensive understanding of posterior IZC anatomy. Although the second molar demonstrated clinically usable bone thickness in selected subjects, its values were generally lower and more variable than those recorded adjacent to the first molar. This variability is likely related to individual differences in maxillary sinus extension, posterior alveolar morphology, and zygomatic buttress anatomy. Consequently, the second molar region cannot be recommended as a routine insertion site but may serve as an alternative in carefully selected cases, particularly when the first molar region is unavailable because of previous mini-implant placement, root proximity, or planned orthodontic tooth movement.[13,17]

The inclusion of second molar measurements also emphasizes the importance of patient-specific CBCT evaluation rather than relying solely on generalized anatomical guidelines. Even when average bone thickness appears adequate, considerable inter-individual variation exists, making preoperative CBCT indispensable for identifying the safest insertion trajectory while minimizing the risk of root contact and maxillary sinus perforation. Therefore, selection of the insertion site should be based not only on average anatomical values but also on the three-dimensional morphology of each patient's IZC region.[8,9,15]

Overall, the findings suggest that the mesiobuccal region of the maxillary first molar at approximately 70° remains the most predictable and clinically favorable site for IZC bone screw placement. The additional assessment of the second molar region expands the available anatomical information and provides clinicians with an alternative site when indicated; however, its use should be guided by individualized CBCT analysis because of greater anatomical variability and the closer relationship with the maxillary sinus.[12,16]

CONCLUSION

CBCT-based cross-sectional investigation of infrazygomatic crest bone dimensions across different vertical facial growth patterns establishes that facial skeletal morphology, whether average-growing, horizontal-growing, or vertical-growing, does not exert a significant influence on bone availability in the IZC region, thereby permitting clinicians to apply standardized placement guidelines irrespective of the patient's vertical facial type. The mesiobuccal root of the maxillary first molar, particularly when approached at a 70° angulation, emerges as the most favorable insertion site, offering the maximum mean bone thickness and the greatest likelihood of achieving clinically adequate bone support, while the distobuccal root region demands judicious case selection and the interradicular area between the molars should be avoided altogether due to insufficient thickness and heightened susceptibility to sinus complications. Notably, the second molar region, specifically its mesiobuccal root at 70°, presents a practical alternative when the first molar site is precluded by anatomical constraints, with acceptable bone dimensions in a substantial proportion of cases, thereby expanding the therapeutic options available to orthodontists. A steeper insertion angulation of 70° consistently provides superior bone engagement compared to 65°, reinforcing the recommendation for more oblique screw trajectories to optimize primary stability while maintaining an adequate safety buffer from the sinus floor. Despite these generalizable guidelines, the considerable interindividual variability observed across all measurement parameters underscores the indispensable role of preoperative CBCT evaluation, as individual anatomical assessment remains the cornerstone of safe and predictable screw placement, enabling accurate site selection, appropriate angulation determination, optimal screw length prescription, and effective avoidance of iatrogenic injury to adjacent roots and the maxillary sinus. The clinical protocol derived from this evidence advocates for preferential placement at the mesiobuccal root of the first molar at 70°, with second molar sites reserved for carefully vetted cases, employing 9–11 mm screws with 5–6 mm of threaded engagement and maintaining a minimum 2 mm clearance from vital structures, all contingent upon thorough radiographic assessment. Future investigations incorporating prospective clinical correlation with actual placement outcomes and long-term stability assessments would further strengthen the evidence base and extend the applicability of these findings across diverse populations. Ultimately, while the mesiobuccal root of the maxillary first molar at 70° constitutes the optimal IZC screw insertion site and the second molar provides a viable fallback option, the imperative for individualized CBCT-based planning cannot be overstated, as it remains the definitive safeguard against complications in this anatomically complex region.

Figure 1. CARESTREAM CS 9600 CBCT MACHINE

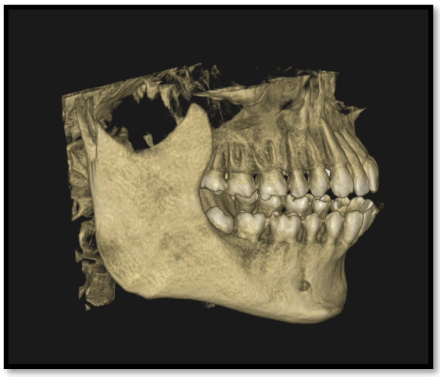

Figure 2. CBCT view

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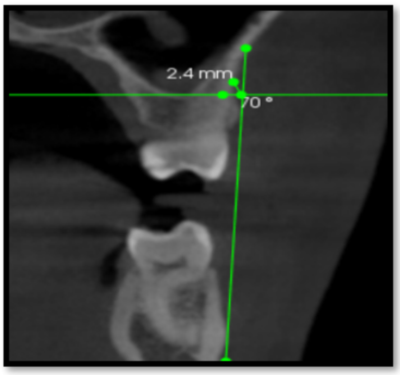

Figure 3. Bone thickness in the IC was evaluated at 700 angulation, at the site where both green lines met.

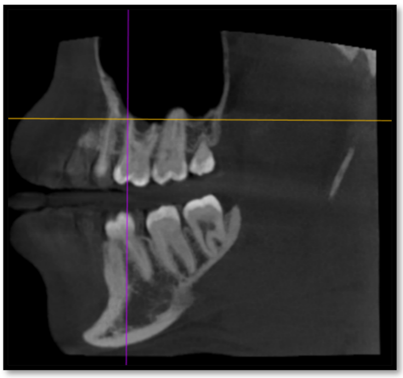

Figure 4. Orange line at the apex of the mesiobuccal root

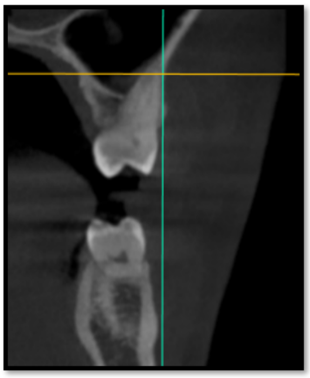

Figure 5. Green line tangent to the buccal cortical bone

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