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Bone availability in the sagittal dimension of the infrazygomatic crest for miniscrew insertion: A retrospective cone-beam computed tomography study

Susana Furão,[a] Iman Bugaighis,[a,b,c] Luís Proença,[c,d] José Brito,[c] Hélder Nunes Costa,[a] François Durand Pereira,[a] and Pedro Mariano Pereira[a,c]
Caparica, Portugal, and Tripoli, Libya

Background: There is limited information available regarding the bone volume in the sagittal dimension of the infrazygomatic crest (IZC) that is safe for the insertion of a temporary skeletal anchorage device. The objective of this study was to assess the sagittal bone availability when the anterior and posterior walls of the IZC reach an inclination of 45°. **Methods:** A cross-sectional investigation was undertaken on 100 cone-beam computed tomography scans of 40 males and 60 females. A total of 20 landmarks were digitized for each IZC outline, 1 mm from the vestibular alveolar bone, and their x, y, and z coordinates were extracted. Afterward, the sagittal measurement of the IZC at which the curvature reached 45° was recorded. Symmetry of measurements was assessed using paired-samples *t* tests. In addition, these measurements were compared as a function of sex and age group (≤21 vs >21 years) using an independent-samples *t* test and the Spearman rank correlation coefficient test (P <0.05). **Results:** There were no significant differences between paired sagittal measurements of the IZC (3.5 ± 1.5 mm on the right side and 3.6 ± 1.3 mm on the left side; $P = 0.144$), except for younger patients ($P = 0.030$). In addition, no significant differences were found between corresponding male and female measurements ($P \geq 0.149$). A significant discrepancy was identified between the younger age group (3.2 ± 1.2 mm) and the older cohort (3.8 ± 1.6 mm) for the sagittal dimension of the right IZC ($P = 0.038$), with an estimated mean difference of 0.03-1.16 mm (95% confidence interval). A significant positive weak correlation was found between the sagittal dimension of the right IZC and age ($\rho = 0.201$; $P = 0.045$). **Conclusions:** Sufficient IZC bone volume is available at an angle of 45° for inserting a temporary skeletal anchorage device, with no sex or side variation, except for the significantly greater sagittal dimension of the right IZC in older patients. (Am J Orthod Dentofacial Orthop 2026;169:568-76)

Anchorage management is a critical aspect of orthodontic treatment planning,[1-3] designed to resist undesirable tooth movement.[3] Traditionally, reinforcement of anchorage has been achieved using intermaxillary elastics, extraoral forces, as well as transpalatal and lingual arches.[4] However, over the last 2 decades, the development of temporary skeletal anchorage devices (TSADs) has widened the prospects of orthodontic treatment, using effective and predetermined force application. This innovation also facilitated the development of the concept of skeletal anchorage, significantly enhancing orthodontic treatment outcomes.[5-7]

TSADs are small temporary devices used to enhance anchorage and reinforce stability. The surgical procedure for their placement is relatively simple and allows

[a]Department of Orthodontics, Egas Moniz School of Health and Science, Monte de Caparica, Caparica, Portugal.
[b]The Libyan Authority for Scientific Research, Tripoli, Libya.
[c]Egas Moniz Center for Interdisciplinary Research, Egas Moniz School of Health & Science, Caparica, Almada, Portugal.
[d]Quantitative Methods for Health Research Unit, Egas Moniz School of Health and Science, Monte de Caparica, Caparica, Portugal
All authors have completed and submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest, and none were reported.
Address correspondence to: Susana Furão, Egas Moniz School of Health and Science, CRL 2829-511 Caparica, University Campus, Quinta da Granja, Monte de Caparica, Portugal; e-mail, susana.furao@gmail.com.
Submitted, June 2025; revised and accepted, October 2025.
0889-5406

https://doi.org/10.1016/j.ajodo.2025.10.016

for immediate loading. TSADs can be positioned in various alveolar and maxillomandibular sites[6,8-10] and can serve as an anchor for various types of orthodontic tooth movements, including extrusion and intrusion, verticalization, mesialization and distalization of molars, retraction of anterior teeth, traction of impacted teeth, and indirect anchorage for space closure.[10,11]

Initially, TSADs were used only in the inter-radicular sites.[7,10,12,13] However, the limited inter-radicular distance might increase the risk of potential damage to proximal dental roots during specific dental movements.[10,12,13] Extra-alveolar sites, such as the hard palate, mandibular buccal shelf, and the infrazygomatic crest (IZC), were proposed to minimize potential iatrogenic risks during TSADs placement and the planned dentition movement, in addition to enhancing anchorage efficiency.[6,7,10,12,14,15]

The IZC position relative to maxillary posterior teeth varies with age. In younger patients, the IZC is usually located between the maxillary second premolar and the permanent first molar. The most frequent IZC location in adults is above the maxillary first molar, between the buccal roots and the buccal cortex of the maxilla.[6,14,16-18] Several investigators have reported that the IZC bone is thicker in young patients[18] and mostly longer in adults.[1] This understanding of the IZC morphologic differences across age groups is critical for optimizing TSAD placement and effectiveness.

Anatomically, the IZC has 2 cortical plates—the buccal and the maxillary sinus margin. This structural geometry enables bicortical TSAD fixation, reinforcing primary stability.[19] The maxillary sinus frequently constrains the placement of a TSAD at the IZC, leading to sinus perforation, which is considered one of the most clinically significant complications, accounting for nearly 50% of the patients evaluated. This is especially true for a more vertical insertion angle to the occlusal plane, particularly in older patients.[8] Although the literature does not report any adverse clinical signs or symptoms related to TSAD sinus perforation, a comparison between CBCT scans taken before TSAD insertion and those taken after TSAD removal showed increased sinus membrane thickness and bone resorption around the TSAD.[5,20]

A thorough understanding of the IZC anatomy and its surrounding structures is essential for avoiding iatrogenic complications and enhancing stability.[8,21]

The position and morphology of the IZC can vary among patients and populations because of genetic, environmental, craniofacial morphology, and developmental factors.[22] However, investigations assessing the IZC geometric variations among populations are scarce. Previous studies have evaluated the IZC parameter in the coronal and axial planes.[1,10,11,14,17,18,23,24] To the best of our knowledge, this is the first investigation examining the available bone in the sagittal plane when the anterior and posterior walls of the IZC reach an inclination of 45°. Therefore, the following null hypotheses were tested: (1) there are no significant differences in the mean sagittal dimensions of the IZC available for TSAD insertion between males and females when the inclination of the IZC wall reaches 45°, (2) there are no significant differences in the mean sagittal dimensions of the IZC available for TSAD insertion among age groups when the inclination of the IZC wall reaches 45°, and (3) there are no significant differences between the sagittal dimensions of the right and left IZC available for TSAD insertion when the inclination of the IZC wall reaches 45°.

MATERIAL AND METHODS

This retrospective observational study was approved by the Egas Moniz ethics committee (PT-270/23). The research protocol adhered to the European Good Practice Guidelines and the World Medical Association's Declaration of Helsinki, and followed the Strengthening the Reporting of Observational Studies in Epidemiology guidelines for observational studies.[25] Informed consent was obtained from patients before the administration of the cone-beam computed tomography (CBCT) scans.

A total of 1390 CBCT scans from male and female patients of different age groups who had visited the Egas Moniz School of Health and Science University Clinic between December 2022 and January 2024 were screened to determine the available data. Patients were excluded from the study based on the following criteria: cleft lip and palate, craniofacial deformities, systemic diseases or taking medications that might affect bone density, hypodontia or supernumerary teeth, and impacted teeth or cysts. Only high-quality CBCT scans of Portuguese patients with complete permanent dentition and without significant dentoalveolar bone loss were included in the study.

The sample size calculation was performed based on the Cohen d moderate effect size ($d = 0.6$) when analyzing the impact of age on IZC thickness. Under these conditions, considering a power of 80% and a significance level of 5%, a minimum sample of 90 participants is required. All the CBCT scans were obtained for diagnostic purposes, confined to the protocol of as low as diagnostically acceptable being indication-oriented and patient-specific.[26]

The CBCT scans were acquired in natural head position using the Planmeca Viso G7 (Planmeca, Helsinki,

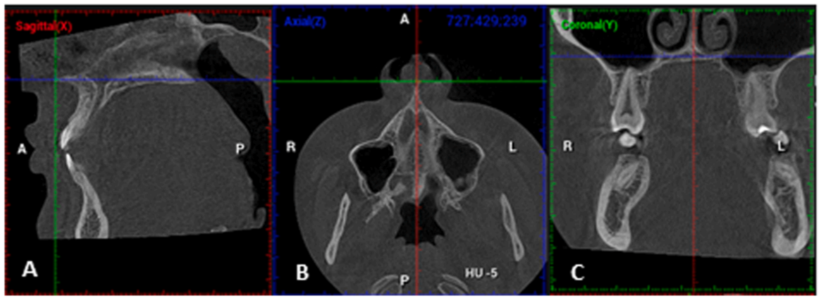

Fig 1. Image orientation: **A,** Sagittal plane; **B,** Axial plane; **C,** Coronal plane.

Finland), implementing the following settings: 120 kVp, 5 mA, large field of view (20 × 17 cm), exposure time of 30 seconds, and a segment thickness of 0.45 mm. The CBCT scans were saved in digital imaging and communications in medicine format and converted into volumetric images. These 3-dimensional (3D) images were constructed using the Planmeca Romexis Viewer (version 6.0; Helsinki, Finland).

Each participant's personal information was assigned a coded number to blind the examiner from probable bias regarding age and sex. The investigator is an orthodontist who conducted training sessions on using Plamenca Roemexis Viewer V6 software. This software features a ruler tool that is calibrated across 3 spatial planes, enabling accurate measurement of designated points in 3D.

Each image was oriented to a standardized position to ensure accurate measurements across the 3 spatial planes: sagittal, axial, and coronal. In the sagittal view, a plane joining the anterior nasal spine and the posterior nasal spine was drawn perpendicular to the vertical window frame (Fig 1, *A*). Similarly, these landmarks were used to orient the scan in the axial plane, traced parallel to the reference vertical plane (Fig 1, *B*). For the coronal plane, the center of the palatal root of the maxillary left first molar was identified. From there, a point 5 mm lateral to the midpalatal suture was established, and the midline between the nasal and the palatal cortical bones was delineated. In addition, a line was traced between the nasal and maxillary cortical bones to mitigate potential errors arising from asymmetries in bilateral bony structures or variations in bone thicknesses. This line was aligned parallel to the lower window frame (Fig 1, *C*).

A bilateral IZC assessment was performed on each oriented scan. The sagittal plane was aligned tangentially to the vestibular cortical bone, and afterward, moved 1 mm toward the vestibular direction at the level of the IZC contour. At the level of the IZC contour, the

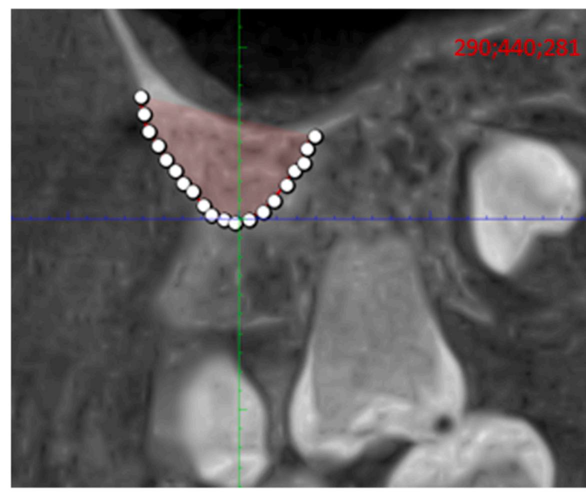

Fig 2. Marking the IZC points and their coordinates (*top right*).

IZC outline was traced using 20 landmarks on each IZC. The coordinates of the 3 planes of space were determined for each point (x, y, and z) (Fig 2). The linear distance between the point in which the curvature reached 45° on the anterior and posterior walls of the IZC (Fig 3, *A* and *B*) was determined using the formula $d = \sqrt{(x_1-x_2)^2+(y_1-y_2)^2+(z_1-z_2)^2}$.

Once the coordinate data had been extracted, the values obtained were then multiplied by the size of the corresponding voxel of each CBCT to obtain the linear computed distance in millimeters.

Statistical analysis

All measurements were saved in an MS Excel (Microsoft, Redmond, Wash) spreadsheet. SPSS (version 28.0; IBM, Armonk, NY) was used for statistical analyses. The evaluated variables were age, sex, and the coordinates of each landmark (x, y, and z).

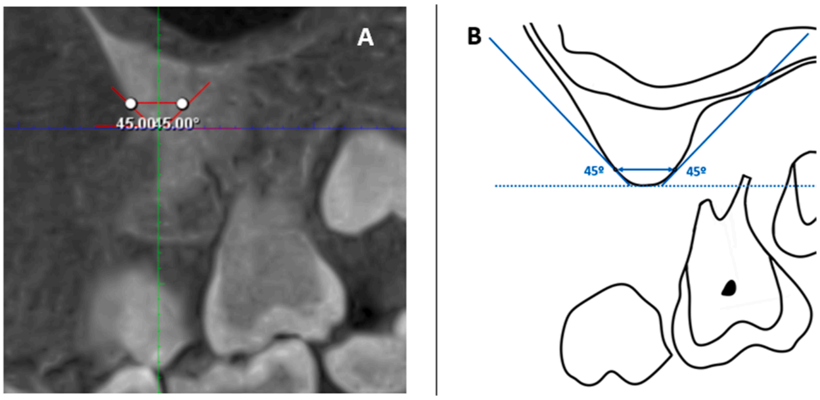

Fig 3. Sagittal view from IZC: **A,** CBCT image; **B,** Illustration.

Table I. Demographic data of the participants included in the study

Sex, n (%)	*≤21 y*	*>21 y*	*Participants*
Males	21 (52.5)	19 (47.5)	40
Females	27 (45.0)	33 (55.0)	60

Descriptive statistics included the mean, standard deviation, and minimum and maximum values. The differences in measurements between age and sex groups were performed using a paired-samples *t* test. Data adequacy to the normal distribution was evaluated using the Shapiro-Wilk test, and data homoscedasticity was assessed using the Levene test. Parametric analyses were, therefore, carried out. Paired-samples and independent-samples *t* tests were performed. The Spearman rank correlation coefficient (ρ) was used to evaluate the correlation between the sagittal measurements of the IZC and age.

One investigator (S.F.) conducted a reproducibility analysis of 10 CBCT scans selected at random, which had previously undergone measurements of the same 150 points of interest at 2-week intervals. The intraclass correlation (ICC) for agreement was employed to determine the degree of similarity between the 2 trials. The results suggest a high reproducibility between the paired measurements as follows: ICC for the right IZC = 0.99 (95% confidence interval: 0.98-0.99) and ICC for the left IZC = 0.98 (95% confidence interval: 0.93-0.99).

RESULTS

The total sample analyzed comprised 100 participants, consisting of 60 females (60%) and 40 males, aged 12-49 years. The cohort was further divided into 2 age groups: adolescents (≤21 years, comprising 21 males and 27 females) and adults (>21 years, comprising 19 males and 33 females) (Table I).

Table II. Distribution of the paired sagittal measurements of the IZC

Right		*Left*		
Mean (SD)	*Min-Max*	*Mean (SD)*	*Min-Max*	*P value*
3.5 (1.5)	0.8-8.5	3.6 (1.3)	1.1-8.1	0.144

Note. All values are in millimeters. Comparison is at a 5% significance level, using paired-samples *t* test (n = 100).
SD, standard deviation; *Min*, minimum; *Max*, maximum.

A paired-samples *t* test demonstrated comparable paired sagittal dimensions of the IZC (right side at 3.5 ± 1.5 mm and the left side at 3.6 ± 1.3 mm) at $P = 0.144$ (Table II). The independent-samples *t* test detected no significant discrepancy between the sagittal measurements of the IZC in males (right side at 3.2 ± 1.4 mm and left side at 3.4 ± 1.3 mm) and the corresponding dimensions in females (right side at 3.7 ± 1.5 mm and left side at 3.8 ± 1.4 mm) at $P \geq 0.149$ (Table III).

Considering age groups, significant differences were observed in the paired mean sagittal dimension of the IZC across the adolescent group (≤21 years: 3.2 ± 1.2 mm on the right side and 3.5 ± 1.2 mm on the left side; $P = 0.030$). The comparison between the adolescent and adult age groups revealed significantly increased sagittal measurements of the IZC in adults on the right side (>21 years: 3.8 ± 1.6 mm) (Figs 4, *A*, and 5, *A*) compared with the corresponding dimension in the younger group (≤21 years: 3.2 ± 1.2 mm) at $P = 0.038$ (Table IV; Figs 4, *B*, and 5, *B*).

Furthermore, only the right IZC dimension demonstrated a significant, though weak, positive correlation with age, suggesting greater bone availability with advancing age (Table V).

Table III. Distribution of the paired sagittal measurements of the IZC as a function of sex

		Right		Left		
Sex	*Participants*	*Mean (SD)*	*Min-Max*	*Mean (SD)*	*Min-Max*	*P value***
Males	40	3.2 (1.4)	0.8-6.2	3.4 (1.3)	1.1-6.4	0.358
Females	60	3.7 (1.5)	1.1-8.5	3.8 (1.4)	1.7-8.1	0.259
	P value*	0.152		0.149		

Note. All values are in millimeters. Comparison at a 5% significance level, using independent-samples (*) and paired-samples *t* test (n = 100).
SD, standard deviation; *Min,* minimum; *Max,* maximum.
*Independent-samples; **Paired-samples *t* test.

Table IV. Distribution of the paired sagittal measurements of the IZC as a function of age

		Right		Left		
Age	*Participants*	*Mean (SD)*	*Min-Max*	*Mean (SD)*	*Min-Max*	*P value***
≤21 years	48	3.2 (1.2)	0.8-8.1	3.5 (1.2)	1.1-7.0	**0.030**
>21 years	52	3.8 (1.6)	1.1-8.5	3.8 (1.4)	1.4-8.1	0.997
	*P value**	**0.038**		0.289		

Note. All values are in millimeters. Comparison at a 5% significance level, using independent-samples (*) and paired-samples *t* test (**); statistically significant *P* values are denoted in bold (n = 100).
SD, standard deviation; *Min,* minimum; *Max,* maximum.
*Independent-samples; **Paired-samples *t* test.

Table V. Correlation between the sagittal dimensions of the right and left IZC with age using the Spearman rank correlation coefficient (ρ)

	Right	*Left*	*Age*
Right	-	-	**0.201** (*P* = 0.045)
Left	**0.687** (*P* <0.001)	-	−0.018 (*P* = 0.860)
Age	-	-	-

Note. Statistically significant ρ values are denoted in bold (n = 100).

DISCUSSION

This study was a retrospective observational 3D radiographic investigation performed on a group of Portuguese patients stratified by age and sex. Clearly, the anatomy and variation of the IZCs are of utmost significance for determining an optimal insertion site for TSADs, therefore avoiding iatrogenic complications. Therefore, this study aimed to identify the optimal TSAD insertion site, defined as the region with the greatest sagittal dimension of the IZC when the curvature reaches 45°. Another aim was to explore the symmetry among the paired sagittal dimensions of the IZC at the possible TSAD insertion sites.

Previous studies have assessed the IZC parameters both in the coronal plane[1,10,11,14,17,18,23,24] and the axial plane.[12,27] Several investigators have concluded that the most favorable insertion site in the coronal plane is achieved at a 70° angulation in reference to the maxillary occlusal plane.[4,7,13,18] However, a 70° angulation is technically challenging to attain, as the angle between the TSAD and IZC becomes acute, thereby increasing the likelihood of damage to the adjacent roots and the risk of a possible TSAD sliding over the bone surface, potentially compromising the mucosa.[4,13,18]

The sagittal plane is equally imperative in establishing the available bone anteroposteriorly for the placement of the TSAD at the IZC. Clinically, orthodontists can visualize and palpate the mesial and distal margins of the IZC before TSAD insertion. It is particularly critical to determine the sagittal parameter when the IZC curvature reaches 45°. Beyond this angle, the IZC becomes more vertical, thereby increasing the risk of slipping the TSAD during the insertion procedure and, therefore, raising the possibility of injuring the surrounding structures. To our knowledge, none of the published investigations explored the sagittal dimension of the IZC. In the present investigation, the IZC outline was established, and the coordinates (x, y, and z) of each marked point were extracted and submitted to a mathematical formula to calculate the linear sagittal distance when the curvature reached 45°. Notably, the measurements were extracted along a straight line rather than following the curvature of the maxillary arch. It will

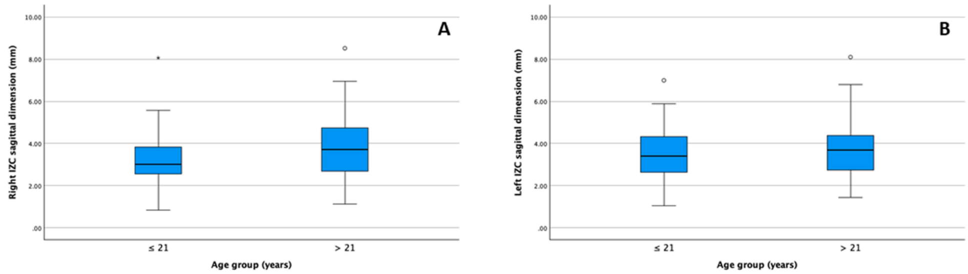

Fig 4. Box plot graphs: **A,** Right side; **B,** Left side.

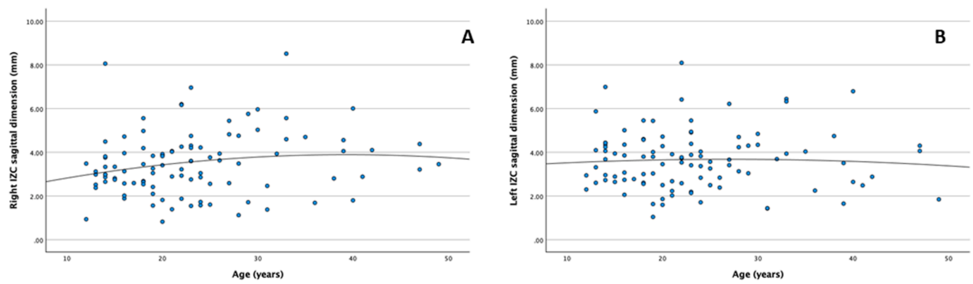

Fig 5. Scatter plot graphs: **A,** Right side; **B,** Left side.

be interesting to employ surface mapping, geometric morphometrics, and Procrustes analysis for further 3D analysis.[28]

The acquired CBCT scans were aligned to a standardized position along the 3 spatial planes to secure reproducible measurements. This standardization was performed by using landmarks proximal to the region of interest on the palatal bone. Other investigators used the infraorbital landmark,[1] and the Frankfort horizontal plane[10,14,17,29] for orientation. In our study, 2 factors influenced our decision to use maxillary landmarks for image orientation. First, to select landmarks close to the region of interest, namely, the IZC. Second, using reference landmarks implemented in previous investigations was not possible in our study because of the CBCT's restricted field of view, aligning with the protocol of as low as diagnostically acceptable being indication-oriented and patient-specific.[26] Consequently, acquiring a CBCT, including the entire maxillomandibular configuration, was unjustified.

De Clerck et al[30] suggested that the inferior margin of the maxillary zygomatic buttress is a favorable site for TSAD insertion because of its geometric configuration and position, available bone density, adequate distance from the maxillary molar roots, and the possibility of enhancing primary stability by allowing a bicortical TSAD fixation. The IZC geometry may represent a notable challenge for clinicians when planning a TSAD insertion, as the anatomic vicinity is often difficult to determine.[21]

The size of the IZC varies significantly, ranging from a well-defined protuberance to a diminutive configuration. In our study, we observed considerable variation in the mean sagittal dimensions, measuring 3.5 mm (range: 0.8-8.5 mm) on the right and 3.6 mm (range: 1.1-8.1 mm) on the left side. Notably, patients with IZC measuring smaller than 1 mm indicate inadequate bone availability, which might increase both primary and secondary TSAD failure. This factor may contribute to the reported 7% failure rate of the TSAD at the IZC.[8] Further investigation into the TSAD survival rate in relation to IZC width would be valuable in improving patient outcomes.

The IZC thickness usually ranges 2-5 mm, which, for the use of conventional TSAD of 5-7 mm, could significantly increase the risk of maxillary sinus perforation during placement.[18,31,32] Liou et al[18] noticed that bone availability in the coronal plane can range 5-9 mm when the insertion angle is set between 40° at 17 mm above the maxillary occlusal plane and 75° at 14 mm above the same plane when a TSAD of 17 mm length is placed, allowing a bicortical anchorage with greater bone availability and a lower probability of TSAD slippage during insertion.[13,18] However, no previous study has evaluated bone availability in the third dimension (sagittal) when the mesial and distal IZC margins are inclined by 45°. IZC palpation is usually performed from mesial and distal IZC boundaries in the sagittal direction, from the bottom of the vestibule to determine the sagittal width available for TSAD placement, in addition to verifying the most prominent site.

Although it could be assumed that males, being more muscular and stronger than females, would possibly have greater bone availability, our study did not reflect this assumption, as the comparable IZC dimension in both sexes indicates otherwise. Therefore, the first null hypothesis is rejected. The limited impact of sex on the sagittal measurements of the IZC has been reported in other studies.[1,11,12,16,29,33,34] Similarly, various studies have documented comparable interradicular bone thickness in both sexes.[35,36] The consistency of these findings across multiple investigations, including ours, suggests that a single protocol for the TSAD insertion at the IZC can be effectively applied to both males and females.

Our older group (>21 years) exhibited significantly increased sagittal dimensions of the right IZC compared with the younger age group (≤21 years). Fluctuating asymmetry, defined as the random deviation from perfect symmetry, is a common feature in living creatures and is observed in the craniofacial structure, including the IZC. The average magnitude of fluctuating asymmetry indicates the level of adaptation and genomic coadaptation within an individual, encompassing both anatomic and developmental stressors, or both, or even a random effect.[37,38] Therefore, there may be a genetically embedded predisposing factor to this asymmetry, exaggerated by stronger masticatory muscles in response to increased masticatory function. Consequently, a greater bone volume becomes available.[33] Because it is not known which side is preferred for chewing in each patient, establishing a relationship in this sense is not possible. Therefore, we can reject the second null hypothesis and accept the alternative one, which suggests a significant difference between the different age groups. Furthermore, only the right IZC dimension showed a significant, albeit weak, positive correlation with age, indicating increased bone availability with age.[8] The paired sagittal IZC bone availability was comparable among the group aged over 21 years. Contrarily, a significantly wider left IZC was observed in the ≤21 age group.

Our analysis revealed a symmetrical paired IZC sagittal bone availability; therefore, the third null hypothesis is accepted. This same finding was observed in different studies by Lee et al,[29] Lima et al,[12] Tavares et al,[11] and Katyal et al.[34] The exclusion of patients with pronounced asymmetry and patients with craniofacial deformities might have contributed to the lack of significant asymmetry.

Despite the relevant clinical outcome of this study, diagnostic evaluation remains critical for each patient. Accurate assessment determines the optimal miniscrew length, site, and angulation of insertion, maximizing success rates and limiting iatrogenic. Despite the significance of our findings, several limitations could be addressed. The retrospective cross-sectional study design limited control over the imaging procedure and may have introduced bias by excluding patients with insufficient clinical information. Furthermore, the examined sample comprised patients visiting a single university clinic. It is recommended that further multicenter prospective research be conducted with a larger sample size encompassing more regions in the country.

CONCLUSIONS

This study investigated the optimal TSAD insertion site, defined as the region with the greatest sagittal dimension of the IZC when the curvature reached 45°, considering age and sex, in a cohort of Portuguese participants stratified by age and sex. Within the limitations of the present investigation, we could conclude the following:

- The bone availability of the IZC in the sagittal plane when its inclination reaches 45° does not vary between sexes.
- Paired IZC showed similar bone availability in the sagittal plane when its inclination reaches 45°.
- In younger patients, there is greater bone availability in the left IZC; bone availability in the right IZC appears to be age-dependent and significantly higher in older patients.

AUTHOR CREDIT STATEMENT

Susana Furão contributed to primary investigation, data collection and ethical data interpretation, preliminary draft writing, preparing documents for ethical approval, and reviewing and editing the manuscript; Iman Bugaighis contributed to conceiving and design, supervision, data interpretation, and writing up the manuscript; Luís Proença contributed to statistical analysis and interpretation and reviewing and editing the manuscript; José Brito contributed to statistical analysis and interpretation, data curation, and reviewing the manuscript; Hélder Nunes Costa contributed to supervision, data interpretation, and revising and editing the manuscript; François Durand Pereira contributed to supervision, data interpretation, and revising and editing the manuscript; and Pedro Mariano Pereira contributed to conceiving and designing the study, supervision, and revising and editing the manuscript.

REFERENCES

1. Arango E, Plaza-Ruíz SP, Barrero I, Villegas C. Age differences in relation to bone thickness and length of the zygomatic process of the maxilla, infrazygomatic crest, and buccal shelf area. Am J Orthod Dentofacial Orthop 2022;161:510-8.e1.
2. Huang LH, Shotwell JL, Wang HL. Dental implants for orthodontic anchorage. Am J Orthod Dentofacial Orthop 2005;127:713-22.
3. Papadopoulos MA, Tarawneh F. The use of miniscrew implants for temporary skeletal anchorage in orthodontics: a comprehensive review. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2007;103:e6-15.
4. Murugesan A, Sivakumar A. Comparison of bone thickness in infrazygomatic crest area at various miniscrew insertion angles in Dravidian population—a cone beam computed tomography study. Int Orthod 2020;18:105-14.
5. Jia X, Chen X, Huang X. Influence of orthodontic mini-implant penetration of the maxillary sinus in the infrazygomatic crest region. Am J Orthod Dentofacial Orthop 2018;153:656-61.
6. Murugesan A, Jain RK. A 3D comparison of dimension of infrazygomatic crest region in different vertical skeletal patterns: a retrospective study. Int Orthod 2020;18:770-5.
7. Vargas EOA, Lopes de Lima R, Nojima LI. Mandibular buccal shelf and infrazygomatic crest thicknesses in patients with different vertical facial heights. Am J Orthod Dentofacial Orthop 2020;158:349-56.
8. Chang CH, Lin JH, Roberts WE. Success of infrazygomatic crest bone screws: patient age, insertion angle, sinus penetration, and terminal insertion torque. Am J Orthod Dentofacial Orthop 2022;161:783-90.
9. Schnelle MA, Beck FM, Jaynes RM, Huja SS. A radiographic evaluation of the availability of bone for placement of miniscrews. Angle Orthod 2004;74:832-7.
10. Tavares A, Montanha-Andrade K, Cury PR, Crusoé-Rebello I, Neves FS. Tomographic assessment of infrazygomatic crest bone depth for extra-alveolar miniscrew insertion in subjects with different vertical and sagittal skeletal patterns. Orthod Craniofac Res 2022;25:49-54.
11. Tavares A, Crusoé-Rebello IM, Neves FS. Tomographic evaluation of infrazygomatic crest for orthodontic anchorage in different vertical and sagittal skeletal patterns. J Clin Exp Dent 2020;12:e1015-20.
12. Lima A, Domingos RG, Cunha Ribeiro AN, Rino Neto J, De Paiva JB. Safe sites for orthodontic miniscrew insertion in the infrazygomatic crest area in different facial types: a tomographic study. Am J Orthod Dentofacial Orthop 2022;161:37-45.
13. Sharan J, Bajoria A, Jena AK, Sinha P, Shivakumar A, Kamal VK, et al. Assessment of bone thickness at the infra zygomatic crest region for various orthodontic miniscrew implant (OMSI) insertion angles: a cone-beam computed tomographic study. Turk J Orthod 2024;37:104-11.
14. Matias M, Flores-Mir C, de Almeida MR, Vieira BDS, Freitas KMS, Nunes DC, et al. Miniscrew insertion sites of infrazygomatic crest and mandibular buccal shelf in different vertical craniofacial patterns: a cone-beam computed tomography study. Korean J Orthod 2021;51:387-96.
15. Liu JN, He YX, Jia XT, Huang R, Zeng N, Fan XC, et al. Feasibility of mini-implant insertion between mesial and distal buccal roots of a maxillary first molar: a cone-beam computed tomography imaging study. Am J Orthod Dentofacial Orthop 2023;164:665-73.
16. Al Amri MS, Sabban HM, Alsaggaf DH, Alsulaimani FF, Al-Turki GA, Al-Zahrani MS, et al. Anatomical consideration for optimal position of orthodontic miniscrews in the maxilla: a CBCT appraisal. Ann Saudi Med 2020;40:330-7.
17. Husseini B, Younes R, Baumgaertel S, El Wak T, El Osta N, Bassil-Nassif N, et al. Assessment of infrazygomatic crest dimensions in different vertical facial growth types for miniscrew insertion: a cone-beam computed tomography study. Am J Orthod Dentofacial Orthop 2022;162:917-26.
18. Liou EJW, Chen PH, Wang Y, Lin JCY. A computed tomographic image study on the thickness of the infrazygomatic crest of the maxilla and its clinical implications for miniscrew insertion. Am J Orthod Dentofacial Orthop 2007;131:352-6.
19. Santos AR, Castellucci M, Crusoé-Rebello IM, Sobral MC. Assessing bone thickness in the infrazygomatic crest area aiming the orthodontic miniplates positioning: a tomographic study. Dent Press J Orthod 2017;22:70-6.
20. Motoyoshi M, Sanuki-Suzuki R, Uchida Y, Saiki A, Shimizu N. Maxillary sinus perforation by orthodontic anchor screws. J Oral Sci 2015;57:95-100.
21. Sanchis CR, Pérez-Varela JC, Zamora-Martínez N, García-Sanz V, Tarazona-Álvarez B, Paredes-Gallardo V. Optimal sites for mini-implant insertion into the infrazygomatic crest according to different craniofacial morphologies: a cross-sectional cone-beam computed tomography study. Am J Orthod Dentofacial Orthop 2024;167:261-72.
22. Dangal R, Shrestha RM, Dhakal J, Shrestha S, Gupta A, Shah S. Comparison of bone thickness in infrazygomatic crest area at various miniscrew insertion angles: a cone-beam computed tomographic study. Taiwan J Orthod 2022;34:185-9.
23. Baumgaertel S, Hans MG. Assessment of infrazygomatic bone depth for mini-screw insertion. Clin Oral Implants Res 2009;20:638-42.
24. Song Q, Jiang F, Zhou M, Li T, Zhang S, Liu L, et al. Optimal sites and angles for the insertion of orthodontic mini-implants at infrazygomatic crest: a cone beam computed tomography (CBCT)-based study. Am J Transl Res 2022;14:8893-902.
25. Bruggesser S, Stöckli S, Seehra J, Pandis N. The reporting adherence of observational studies published in orthodontic journals in relation to STROBE guidelines: a meta-epidemiological assessment. Eur J Orthod 2023;45:39-44.
26. Oenning AC, Jacobs R, Pauwels R, Stratis A, Hedesiu M, Salmon B, et al. Cone-beam CT in paediatric dentistry: DIMITRA project position statement. Pediatr Radiol 2018;48:308-16.
27. Liu H, Wu X, Yang L, Ding Y. Safe zones for miniscrews in maxillary dentition distalization assessed with cone-beam computed tomography. Am J Orthod Dentofacial Orthop 2017;151:500-6.
28. Mitteroecker P, Schaefer K. Thirty years of geometric morphometrics: achievements, challenges, and the ongoing quest for biological meaningfulness. Am J Biol Anthropol 2022;178:181-210.
29. Lee HS, Choi HM, Choi DS, Jang I, Cha BK. Bone thickness of the infrazygomatic crest area in skeletal class III growing patients: a computed tomographic study. Imaging Sci Dent 2013;43:261-6.
30. De Clerck H, Geerinckx V, Siciliano S. The zygoma anchorage system. J Clin Orthod 2002;36:455-9.
31. Patel B, De Rose J, Nash J, Sekula M, Gioia C, Deguchi T, et al. Variability associated with maxillary infrazygomatic crest and palatal bone width, height, and angulation in subjects with

different vertical facial growth types: a retrospective cone-beam computed tomography study. Angle Orthod 2024;94:313-9.
32. Rosa WGN, de Almeida-Pedrin RR, Oltramari PVP, De Castro Conti ACF, Poleti TMFF, Shroff B, et al. Total arch maxillary distalization using infrazygomatic crest miniscrews in the treatment of Class II malocclusion: a prospective study. Angle Orthod 2023;93:41-8.
33. Farnsworth D, Rossouw PE, Ceen RF, Buschang PH. Cortical bone thickness at common miniscrew implant placement sites. Am J Orthod Dentofacial Orthop 2011;139:495-503.
34. Katyal S, Bhatia NK, Sardana R, Singh S, Chugh A, Shamim MA, et al. Success rate and factors affecting stability of infrazygomatic miniscrew implants: a systematic review and meta-analysis. Eur J Orthod 2024;47:cjae074.
35. Lim JE, Lee SJ, Kim YJ, Lim WH, Chun YS. Comparison of cortical bone thickness and root proximity at maxillary and mandibular interradicular sites for orthodontic mini-implant placement. Orthod Craniofac Res 2009;12:299-304.
36. Sabec R, Fernandes TMF, de Lima Navarro R, Oltramari-Navarro PVP, Conti ACCF, de Almeida MR, et al. Can bone thickness and inter-radicular space affect miniscrew placement in posterior mandibular sites? J Oral Maxillofac Surg 2015;73:333-9.
37. Graham JH, Özener BB. Fluctuating asymmetry of human populations: a review. Symmetry 2016;8:154.
38. Wang Y, Metoki A, Smith DV, Medaglia JD, Zang Y, Benear S, et al. Multimodal mapping of the face connectome. Nat Hum Behav 2020;4:397-411.