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Optimal sites for mini-implant insertion into the infrazygomatic crest according to different craniofacial morphologies: A cross-sectional cone-beam computed tomography study

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Introduction: The infrazygomatic bone crest and other extraalveolar regions represent a viable option for the placement of temporary anchorage devices when distalizing the maxillary arch. This approach allows for the movement of the dentition without concern for potential collisions among dental structures. Nevertheless, it is of the utmost importance to conduct a thorough examination of the anatomy of this region before the placement of mini-implants to prevent potential injuries, such as maxillary sinus perforations. The objective of this study was to quantify the depth of the infrazygomatic crest and evaluate its correlations with age, gender, skeletal classification, and vertical pattern. **Methods:** The study sample of this cross-sectional, retrospective study consisted of 201 cone-beam computed tomography scans collected from patients treated at the master's program in orthodontics at the University of Valencia and at a private dental clinic. The cone-beam computed tomography scans were collected for 5 years, from January 2017 to May 2022. The total and intraalveolar lengths were defined and measured at 3 points: the distal roots of the maxillary second molars, the distal roots of the maxillary first molars, and the mesial roots of the maxillary first molars. These measurements were taken on both the right and left sides using the Carestream 3D Imaging System (Atlanta, Ga). **Results:** The total length (TL) at the mesiobuccal level of the first molars was found to be significantly longer on both sides ($P = 0.001$). The intraalveolar length exhibited statistically significant differences between the right and left sides, with those of the left side exhibiting greater length ($P < 0.001$). The normodivergent patterns demonstrated lower TL values than hypodivergent ($P = 0.006$) and hyperdivergent patterns ($P = 0.033$). **Conclusions:** A statistically significant inverse relationship was observed between the distance from the cementoenamel junction to the vestibular bone crest and the total and intraalveolar lengths in the studied regions. The TL was greatest in the region of the mesiobuccal root of the maxillary first molars, followed by the region of the distal root of the second molars, and finally, the region of the distobuccal root of the maxillary first molars. Patients with normodivergent patterns exhibited the lowest total infrazygomatic ridge height. (Am J Orthod Dentofacial Orthop 2024;■:■-■)

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The datasets used and analyzed in the current study are available from the corresponding author upon reasonable request.
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The concept of skeletal anchorage in the zygomatic buttress of the maxilla was initially proposed for patients in which there was inadequate or absent dental support in the posterior segments of the maxilla, rendering conventional anchorage techniques infeasible.[1] This was due to the fact that the buttress is a solid and versatile site, thereby allowing the use of mini-plates in the area.[2] Moreover, this approach has been used when patients exhibited an increased overjet, and implant placement was not initially contemplated as part of the treatment plan because of either anatomic or osseous limitations or, in most patients, for economic reasons.[3]

In contrast to interradicular locations, the search for insertion points in extraalveolar regions (maxillary tuberosity, palatal suture, infrazygomatic region, and buccal shelf)[4-6] allows for the movement of the dentition through the application of an immediate and direct force on the dental arch, thereby avoiding potential collisions during orthodontic distalization of the dental structures. These sites include insertion points with a high availability of cortical bone, which facilitates the application of more appropriate biomechanical force vectors.[7-9]

However, among other factors,[10-13] the insertion of miniscrews into the infrazygomatic ridge is often limited by the presence of the maxillary sinus.[5,14] In fact, perforation of the sinus is one of the most clinically relevant adverse events. In their analysis of patients, some authors have reported perforations in approximately half of the patients examined. They have also observed that the incidence of sinus perforation increased with a more vertical angle of insertion of the miniscrew and that this incidence was greater in older adult patients.[15] Consequently, a preinsertion evaluation of the anatomic structures using 3-dimensional technologies, such as cone-beam computed tomography (CBCT), is an indispensable component of the diagnostic process to prevent injury during microscrew placement.[16-18]

Anatomically, the infrazygomatic crest (IZC) is a protuberance located on the zygomatic ridge that extends between the alveolar crest and the zygomatic process of the maxilla.[19] Although the definition is clear, there is no consensus regarding the anatomic structures that should be used as reference landmarks to delineate this area. The studies published to date demonstrate a considerable degree of methodological heterogeneity, with a wide range of anatomic structures identified as reference points. These include the cementoenamel junction (CEJ),[20-22] the root apex,[23,24] the mesiobuccal (MB) region of the roots,[7,21], and the alveolar crest.[25]

According to Liu et al,[25] the region between the first and second molars represents the optimal and secure zone for the placement of miniscrews in the buccal alveolar bone within the IZC region for maxillary dentition distalization. However, intrinsic factors, such as the age of the patient, have been described as influencing the anatomic characteristics of this region. In light of the fact that young patients often display greater bone thickness between the maxillary second premolars and first molars, some authors, such as Liou et al,[7] advocate a more anterior position in closer proximity to the MB root of the maxillary first molars. It should be noted that although the bone is typically thicker in growing patients,[20,26] some authors have reported that the height of the infrazygomatic ridge is greater in adult patients.[20]

It is also possible that other factors may exert an influence on the anatomic characteristics of the IZC. Although recent studies have incorporated some of these factors into their analyses, there is no consensus among authors regarding the vertical pattern.[21-24]

The necessity for further research in this area is supported by 3 key factors: the importance of characterizing the bone anatomy in the infrazygomatic area for temporary skeletal anchorage device (TSAD) placement, the wide variability of results among studies, and the limited number of studies evaluating how skeletal classification and vertical pattern may affect these data.

Accordingly, the objective of this study was to quantify the depth of the IZC at the level of the maxillary first and second molars and to evaluate potential correlations with age, gender, skeletal classification, and vertical pattern.

MATERIAL AND METHODS

This observational, cross-sectional, descriptive study received approval from the Human Research Ethics Committee of the University of Valencia (No. 1867515) and was conducted in accordance with the World Medical Organization's Declaration of Helsinki and the Strengthening the Reporting of Observational Studies in Epidemiology guidelines for observational studies.[27] Before treatment, patients signed an informed consent and commitment to data confidentiality for scientific purposes.

This work aimed to answer the research question: Which are the optimal locations in the maxilla for the insertion of infrazygomatic miniscrews in adult patients, according to their age, gender, facial pattern, and skeletal classification?

A total of 201 CBCT scans were collected between January 2017 and May 2022 from patients treated at the master's program in orthodontics at the University of Valencia and at a private dental clinic. The CBCT scans were part of the patients' initial records and were taken for reasons unrelated to the current study.

The inclusion criteria for image selection were as follows: adult patients aged 20-40 years of white ethnicity with no history of orthodontic treatment; no significant root resorption in the maxillary first and second molars; no caries in the maxillary first and second molars; no missing teeth in the maxillary second premolars, first

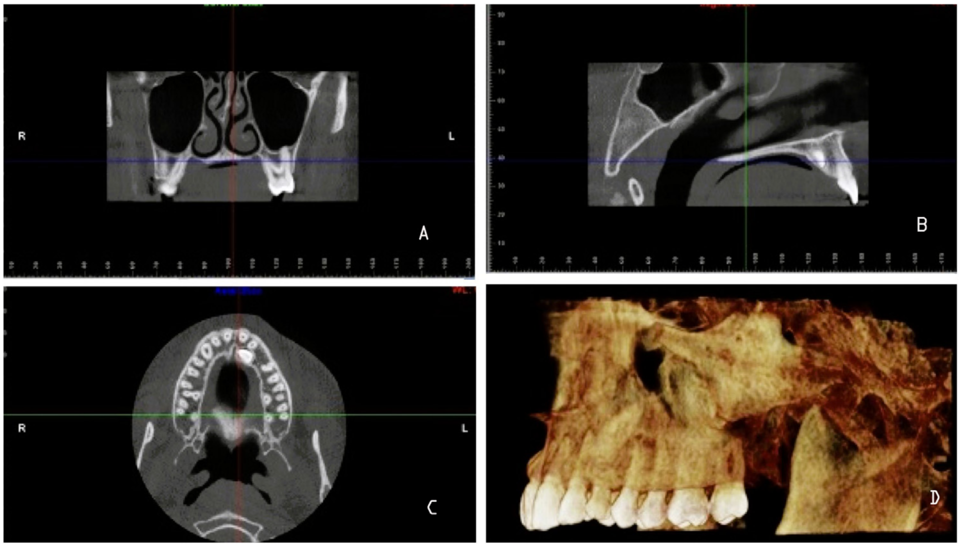

Fig 1. Location of the slices in the Carestream 3D Imaging software (Atlanta, Ga) for measuring the DB root area of the maxillary second left molar: **A,** Location of the coronal slice, with a complete view of the root being studied; **B,** Sagittal section, which enables locating the posterior region of the maxilla; **C,** The axial plane, which offers a view of the root canal of the root to be studied; **D,** Three-dimensional reconstruction of the CBCT.

and second molars; good periodontal health; and a distance of <3 mm from the CEJ to the vestibular bone crest. Patients may have maxillary third molars, but if they were extracted, it must have been at least 12 months before the performance of the CBCT scan. The exclusion criteria included the presence of deciduous teeth in the maxillary first and second molar area; smoking status; medication use that could impact bone health; dental implants in the maxillary first and second molars; endodontic or prosthetic dental restorations that could distort imaging; patients with maxillary sinus-related pathologies during the time of the tomographic image; and those whose maxillary first and second molars measure less than 45° in relation to both the occlusal plane and the longitudinal axis of the molar passing through the furcation.

CBCT images were taken in a natural head position using an i-CAT Classic unit (Imaging Sciences International, Hatfield, Pa) The CBCT imaging protocol involved 120 kVp, 8 mA, with a field of view of 5 × 5 cm, voxel size of 0.20 mm, and a scan time of 20 seconds. All teleradiographs were captured using the same digital cephalostat with a standardized method (18 × 24 cm lateral image, fast scan mode).

CBCT data were saved in digital imaging and communications in medicine format and converted to a volumetric image. The digital imaging and communications in medicine files were processed using Carestream 3D Imaging software (Atlanta, Ga). This software includes a ruler tool calibrated in the 3 planes of space, which enables the precise measurement of the field of study's length and width.

The lateral skull radiographs were imported into Dolphin Imaging software (Dolphin Imaging and Management Solutions, Chatsworth, Calif) to conduct cephalometric measurements on patients and classify them based on vertical facial-type patterns (hypodivergent, hyperdivergent, and normodivergent) and sagittal skeletal classifications (Class I, II, and III). The classification of the sample included categorizations based on Steiner's cephalometric measurements (ANB),[28] Ricketts' cephalometric measurements (facial convexity, facial axis, mandibular plane angle, and facial taper),[29] and Jacobson's cephalometric measurements (Wits).[30]

To properly locate the slice in which the measurements were to be taken, the coronal view of each side was used (Fig 1, *A*). This view was adjusted using the sagittal view of the posterior region of the maxilla (Fig 1, *B*). From there, the mesial or distobuccal (DB) root of the molar to be studied was located in the axial plane (Fig 1, *C*). The 3D CBCT reconstruction provides an overview of the region of interest (Fig 1, *D*).

Subsequently, after correctly orienting the coronal plane, the section was moved until the entire root of the studied molar was longitudinally observed.

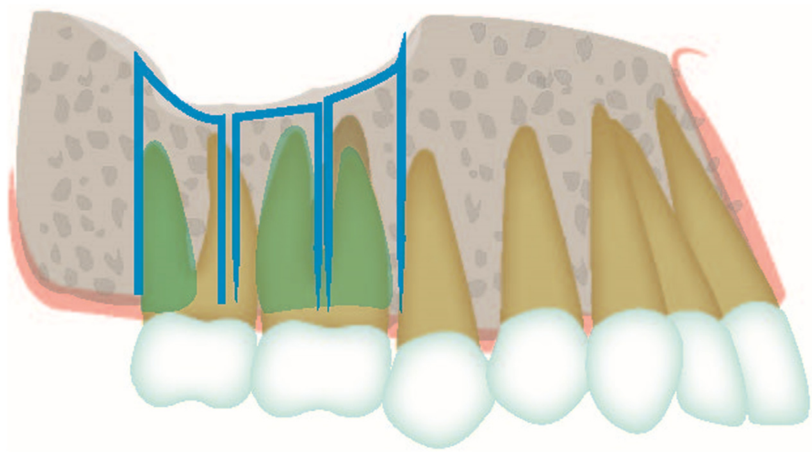

Fig 2. Three regions of study (areas between *blue* lines): region of the MB root of the first permanent molar (*blue*), region of the DB root of the first permanent molar (*blue*), and region of the distal root of the second permanent molar (*blue*).

Three anatomic structures on the right side and 3 anatomic structures on the left side of the maxilla were taken as a reference (Fig 2).

1. The MB root of the maxillary first permanent molar (1.6 MB and 2.6 MB), in the case of analyzing the mesial bone level of the same tooth.
2. The DB root of the maxillary first permanent molar, which is equivalent to the mesial region of the maxillary second permanent molar (1.6 DB and 2.6 DB), in the case of analyzing the distal bone level of the maxillary first permanent molar.
3. The DB root of the maxillary second permanent molar (1.7 DB and 2.7 DB), in the case of analyzing the bone level of the same tooth.

To carry out the measurements on each side, 3 linear measurements were defined and measured:

1. CEJ-bone crest distance (Fig 3) was defined as the distance from the CEJ to the edge of the bone crest of the targeted molar and seen from the coronal view. To standardize the measurement protocol and avoid the risk of bias in the following 2 measurements, the eligibility criteria took into consideration that no periodontal bone loss was occurring. Therefore, this distance did not exceed 3 mm in all patients.
2. The total length (TL) of the infrazygomatic ridge (Fig 4) was defined as the distance from the level of the CEJ to the floor of the maxillary sinus, in which both hard and soft tissues are found. To be able to measure this distance, an angle simulating the insertion process of the microscrew at 50° in the maxillary second molars and 60° in the maxillary first molars was configured, according to the recommendations followed by various authors.[17,19,20] A line was then drawn at the desired angle, from the line that passes through the CEJ up to the line that passes through the floor of the maxillary sinus (*green*).
3. Intraalveolar length (IL) of the infrazygomatic ridge (Fig 5): It was defined as the length of hard tissue that exists at the intraalveolar level, from the external bone surface up to the floor of the maxillary

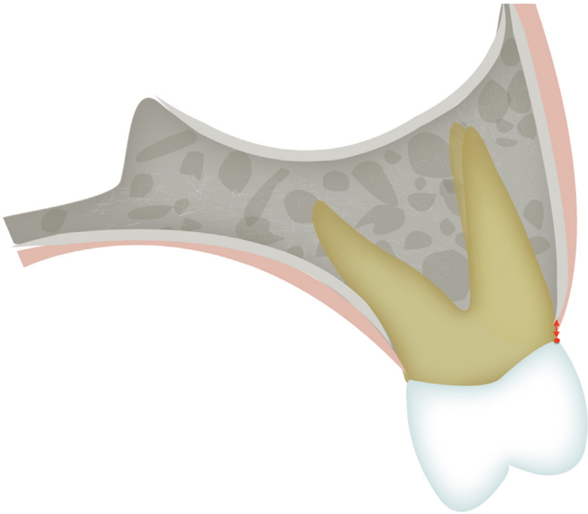

Fig 3. Location of the CEJ (*dot*) and its distance to the alveolar bone crest (*line*).

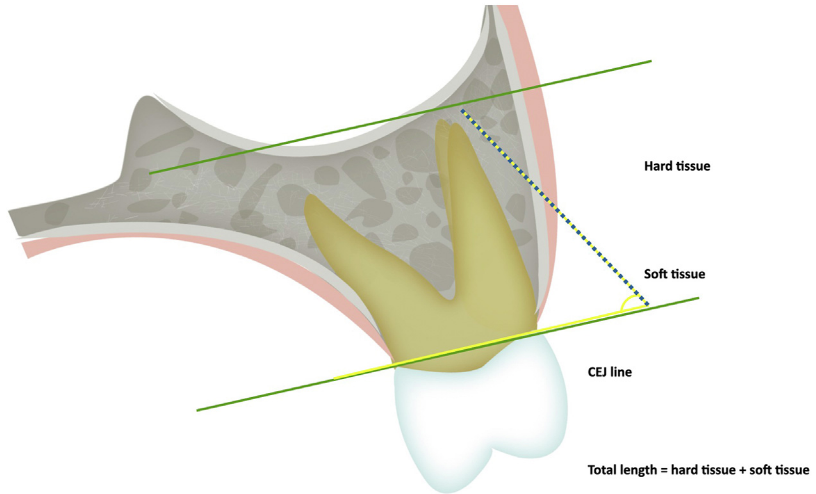

Fig 4. TL of the infrazygomatic ridge (dashed *green*). In *yellow*, the angle simulating the insertion process of the miniscrew between the line that passes through the CEJ and the line that goes up to the floor of the maxillary sinus. In *green*, 2 parallel lines pass through the CEJ and the floor of the maxillary sinus.

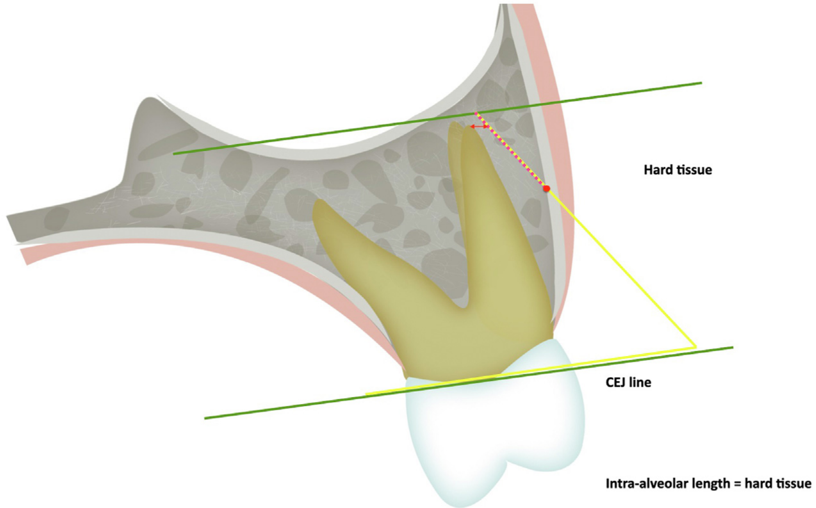

Fig 5. IL of the infrazygomatic ridge (*red*). The angle between the line that passes through the CEJ and the line that goes up to the floor of the maxillary sinus (*yellow*). Parallel lines pass through the CEJ and the floor of the maxillary sinus (*green*).

sinus (*red*), using the same line at 50° or 60° that was used for the measurement of the TL.

The following variables were recorded: sex, age, facial pattern, skeletal classification, CEJ-buccal bone crest distance, TL in millimeters (1.6 MB, 2.6 MB, 1.6 DB, 2.6 DB, 1.7 DB, and 2.7 DB), IL in millimeters (1.6 MB, 2.6 MB, 1.6 DB, 2.6 DB, 1.7 DB, and 2.7 DB).

To determine the sample size, a pilot study was carried out. According to the study by Tavares et al, in 2022,[21] an estimate of the standard deviation (SD) was obtained in the range of 2.7-3.4 mm for different angulations and distances from the CEJ on first molars. So, an SD $\pm$ 3 could be assumed as a reference for the following calculations.

Initially, the necessary sample size was calculated so that the estimate of the length value of the mean IZC of the study does not differ from the population by more than a certain margin of error. For example, to have a margin of error $<$0.5 mm, n = 139 patients are necessary.

Another approach for calculating the sample size was based on the comparison of the IZC measurement in first and second molars: that is, the calculation of the necessary sample size so that certain difference in the average IZC of both positions was detected as significant with sufficient statistical power.

The sample size required for accurately detecting significant mean values of 7.5 mm (first molars) and 8.0 mm (second molars) was calculated to be 199 patients. For a confidence level of 95%, an effect size of f = 0.2 (medium-small), an SD of ± 3 mm, and an 80% of power (paired *t* test).

A reproducibility analysis was carried out to estimate the intraclass correlation coefficient. To accomplish this, a second measurement of the dimensions involving a subsample of 25 patients was performed by a researcher (C.R.S.) to evaluate for intraexaminer error.

To evaluate the interexaminer error, a second reproducibility analysis was conducted on a subset of 30 patients using the difference in means between measurements from both observers (C.R.S. and B.T.A.).

Statistical analysis

All measurement data were recorded for each patient by entering them into an Excel document. The parameters that were measured include age, sex, skeletal classification, vertical pattern, and the performed measurements.

A descriptive analysis was conducted using mean, SD, minimum, maximum, median, and quartiles for all continuous parameters.

The normal distribution of the sample was evaluated using a Kolmogorov-Smirnov test within the statistical analysis. To compare means in 2 independent groups based on sex, an independent samples *t* test was performed. One-way analysis of variance was used to compare means among >2 independent groups (patterns and age), and multiple comparisons were adjusted using Bonferroni. This study used the Spearman correlation coefficient to evaluate the strength of the linear relationship between dimensions and age. A significance level of 5% ($\alpha = 0.05$) was employed in the analyses.

RESULTS

After applying the inclusion and exclusion criteria, 47 CBCT scans were excluded (19%), resulting in a sample size of 201 CBCT scans, comprising 89 males (44.3%) and 112 females (55.7%) participants. The mean age of the participants was 29.2 ± 5.7 years, with a range of 20-40 years, and 2 age groups: 20-30 years (n = 102) and 31-40 years (n = 99). The sample was distributed according to skeletal classification and vertical pattern. Skeletal classification was divided into Class I (n = 71), Class II (n = 61), and Class III (n = 69). The vertical pattern distribution of the sample was as follows: normodivergent (n = 60), hypodivergent (n = 55), and hyperdivergent (n = 86).

Regarding the intraobserver and interobserver reproducibility, the results indicated strong reliability both among operators, with most evaluated parameters showing intraclass correlation coefficient values ≥6 0.90.

Table I describes the TL at the first and second molar positions (1.7 DB, 2.7 DB, 1.6 DB, 2.6 DB, 1.6 MB, and 2.6 MB). On average, the TL of the infrazygomatic ridge measured 12.27 ± 2.78 mm on the right side and 12.2 ± 2.74 mm on the left side in the DB root of the maxillary second molars; 11.84 ± 2.7 mm on the right side and 11.85 ± 2.23 mm on the left side, in the DB root of the maxillary first molars, and 12.92 ± 2.86 mm on the right side and 12.9 ± 2.79 mm on the left side, in the MB root of the first molars.

Regarding the differences observed among anatomic regions (Table II), the results indicated that the TL of 1.7 DB was significantly greater than the TL of 1.6 DB ($P = 0.023$), with comparable findings on the opposite side (2.7 DB vs 2.6 DB) ($P = 0.046$). However, the TL of 1.7 DB was found to be significantly smaller than that of 1.6 MB ($P = 0.001$), and the same result was obtained when comparing the opposite side (2.7 DB vs 2.6 MB) ($P < 0.001$). No statistically significant differences were found among the homologous anatomic regions of both sides, and their symmetrical nature was accepted.

No significant differences were found in the measurement of TL depending on age and skeletal classification, but there were differences with respect to facial pattern (1.7 DB, $P < 0.005$; 1.6 MB, $P < 0.001$) and gender (1.7 DB, $P < 0.001$; 1.6 MB, $P < 0.006$; 2.6 MB, $P < 0.006$) (Table III). The results of the Bonferroni multiple comparison test indicated that normodivergent patterns exhibited lower values than hypodivergent patterns ($P = 0.006$) and hyperdivergent patterns ($P = 0.033$). Nevertheless, the values obtained between hypodivergent and hyperdivergent patterns were not significantly different ($P = 1.000$).

Table I presents the descriptive measurements of the IL in the first and second molar positions (1.7 DB, 2.7 DB, 1.6 DB, 2.6 DB, 1.6 MB, and 2.6 MB). The IL of the infrazygomatic ridge in the DB root of the maxillary second molars was 5.98 ± 2.07 mm (right side) and 6.53 ± 2.18 mm (left side); in the DB root of the maxillary first molars was 5.84 ± 1.8 mm (right side) and 6.33 ± 1.99 mm (left side); and in the MB root of the maxillary first molars was 5.98 ± 2.38 mm (right side) and 6.4 ± 2.53 mm (left side).

As shown in Table II, not enough statistical evidence was found between the various anatomic regions of the

Table I. CEJ-bone crest distance, TL, and IL

Variables	*n*	*Mean ± SD*	*Minimum*	*Maximum*	*25th percentile*	*Median*	*75th percentile*	*95% IC*
CEJ-bone crest distance, mm								
CEJ 1.7 DB	201	1.97 ± 0.44	1.14	3.02	1.60	1.90	2.20	1.91- 2.03
CEJ 2.7 DB	201	1.93 ± 0.43	1.05	3.02	1.62	1.90	2.19	1.87-1.99
CEJ 1.6 DB	201	2.03 ± 0.41	1.14	3.02	1.71	2.00	2.29	1.98-2.09
CEJ 2.6 DB	201	2.06 ± 0.40	1.14	3.12	1.80	2.00	2.21	2.00-2.12
CEJ 1.6 MB	201	2.04 ± 0.37	1.14	2.90	1.80	2.00	2.30	1.99-2.10
CEJ 2.6 MB	201	2.06 ± 0.40	1.14	3.12	1.80	2.00	2.30	2.01-2.12
TL, mm								
TL 1.7 DB	201	12.27 ± 2.78	6.24	21.01	10.30	12.48	13.90	11.88-11.65
TL 2.7 DB	201	12.20 ± 2.74	5.57	20.38	10.20	12.40	14.10	11.82-12.58
TL 1.6 DB	201	11.84 ± 2.70	5.71	19.50	10.00	11.90	13.60	11.47-12.22
TL 2.6 DB	201	11.85 ± 2.23	6.54	21.00	10.27	11.80	13.44	11.54-12.16
TL 1.6 MB	201	12.92 ± 2.86	5.16	22.00	10.87	13.09	14.90	12.52-13.31
TL 2.6 MB	201	12.90 ± 2.79	5.76	21.70	10.94	13.44	14.70	12.51-13.28
IL, mm								
IL 1.7 DB	201	5.98 ± 2.07	2.40	12.58	4.47	5.76	7.10	5.69-6.27
IL 2.7 DB	201	6.53 ± 2.18	2.00	12.60	4.89	6.43	7.80	6.22-6.82
IL 1.6 DB	201	5.84 ± 1.80	2.40	10.00	4.50	5.86	7.01	5.59-6.09
IL 2.6 DB	201	6.33 ± 1.99	2.40	11.00	4.80	6.34	7.68	6.05-6.61
IL 1.6 MB	201	5.98 ± 2.38	2.40	14.00	4.00	5.66	7.58	5.65-6.32
IL 2.6 MB	201	6.40 ± 2.53	2.30	13.40	4.51	6.00	8.20	6.05-6.75

IC, interval coefficients.

same arch. However, statistically significant differences were found between sides, concluding that the average dimensions of the left side were significantly larger than those of the right side ($P < 0.001$).

No significant differences were found in the IL measurement depending on age (Table III). Regarding skeletal classification, a statistically significant difference was found only in the mesial region of the maxillary left first molar with greater bone height in patients with skeletal Class II malocclusion ($P < 0.001$).

Statistically significant sexual dimorphism was observed between genders, with a slight increase in length found in males when compared with females, in the region of the DB root of the second molars ($P < 0.001$) and the region of the MB root of the first molars ($P < 0.006$).

A final study was made to calculate how the distance between the CEJ and vestibular bone crest influenced the measurements of TL and IL in the first and second molar regions. Table I displays the CEJ-bone crest distance in millimeters for each anatomic region. The Pearson correlation index calculation, as shown in Table IV and Figure 6, *A-F*, of all the regions studied, revealed a statistically significant inverse correlation between the CEJ-bone crest distance and the total and IL values in all regions ($P < 0.001$), except for the region of the DB root of the maxillary left first molar (2.6 DB) ($P = 0.189$). In other words, the shorter the distance between the CEJ and the crest, the longer the total and IL values. Finally, a weak to moderate correlation was found between the total and IL, which was also significant. The correlation was found to be direct, meaning that the greater the TL of the region, the greater the IL of the same region.

DISCUSSION

The morphology of the IZC is a challenging structure for the clinician when planning the insertion of TSADs because its surrounding structures and anatomic boundaries are often difficult to define and distinguish. Moreover, certain features may be determinant indicators of the bone anatomy of the IZC. Therefore, this study aimed to quantify the height of the IZC and evaluate its correlations with characteristics such as age, gender, facial pattern, or the skeletal classification of the patient.

In this study, CBCT was used because it is the method of choice in the analysis of the bone characteristics of the IZC[9,20,22,24,25] thanks to its low invasiveness and radiation exposure, high resolution, and great versatility.[31,32] Some other studies, though, were performed using computed tomography[7,21,23] technology with higher radiation risks.

Only patients with an age range of 20-40 years were included in this work because the scientific evidence shows that after 50 years old, tooth loss in the molar region is more common than in the anterior regions.[33] In contrast, it has been reported that patients aged <20 years may have bone and maxillary sinus immaturity, especially males.[9,19,20]

Table II. Mean difference, IC, and *P* values between anatomic regions and sides of TL and IL

Variables	*Mean difference*	*95% IC*	P *value*
TL			
Anatomic region			
TL 1.7 DB − LT 1.6 DB	0.42	0.06-0.79	0.023*
TL 1.7 DB − LT 1.6 MB	−0.65	−1.03 to −0.26	0.001**
TL 2.7 DB − LT 2.6 DB	0.35	0.01-0.69	0.046*
TL 2.7 DB − LT 2.6 MB	−0.70	−1.08 to −0.31	<0.001***
Side			
TL 1.7 DB − LT 2.7 DB	0.07	−0.19 to 0.32	0.609
TL 1.6 DB − LT 2.6 DB	−0.01	−0.28 to 0.26	0.936
TL 1.6 MB − LT 2.6 MB	0.02	−0.20 to 0.24	0.857
IL			
Anatomic region			
IL 1.7 DB − LI 1.6 DB	0.14	−0.11 to 0.39	0.266
IL 1.7 DB − LI 1.6 MB	0.00	−0.32 to 0.32	0.981
IL 2.7 DB − LI 2.6 DB	0.20	−0.08 to 0.47	0.161
IL 2.7 DB − LI 2.6 MB	0.13	−0.25 to 0.50	0.510
Side			
IL 1.7 DB − LI 2.7 DB	−0.54	−0.76 to −0.33	<0.001***
IL 1.6 DB − LI 2.6 DB	−0.49	−0.68 to −0.30	<0.001***
IL 1.6 MB − LI 2.6 MB	−0.41	−0.64 to −0.19	<0.001***

IC, interval coefficients.
*P <0.05; **P <0.01; ***P <0.001.

Table III. Mean values of TL and IL according to region, gender, age, skeletal classification, and facial pattern

Region	*Gender*	*Age*	*Skeletal classification*	*Facial pattern*
TL				
1.7 DB	0.111 (*t*)	0.744 (*t*)	0.711 (*F*)	0.005** (*F*)
2.7 DB	0.292 (*t*)	0.775 (*t*)	0.808 (*F*)	0.309 (*F*)
1.6 DB	0.204 (*t*)	0.565 (*t*)	0.933 (*F*)	0.021* (*F*)
2.6 DB	0.094 (*t*)	0.085 (*t*)	0.986 (*F*)	0.766 (*F*)
1.6 MB	0.643 (*t*)	0.624 (*t*)	0.131 (*F*)	0.001** (*F*)
2.6 MB	0.640 (*t*)	0.686 (*t*)	0.193 (*F*)	0.029* (*F*)
IL				
1.7 DB	<0.001** (*t*)	0.058 (*t*)	0.797 (*F*)	0.321 (*F*)
2.7 DB	0.025* (*t*)	0.602 (*t*)	0.505 (*F*)	0.721 (*F*)
1.6 DB	0.149 (*t*)	0.185 (*t*)	0.139 (*F*)	0.237 (*F*)
2.6 DB	0.379 (*t*)	0.588 (*t*)	0.907 (*F*)	0.861 (*F*)
1.6 MB	0.006** (*t*)	0.177 (*t*)	0.142 (*F*)	0.004** (*F*)
2.6 MB	0.006** (*t*)	0.346 (*t*)	0.001** (*F*)	0.052 (*F*)

t, independent *t* test; *F*, 1-way analysis of variance *F* test.
*P <0.05; **P <0.01.

Similar to our study, some other studies[20-22] used the CEJ as an anatomic reference point. The reason for doing so is that it can be very accurately located in CBCT as there is a change in density in the enamel-root transition zone. Other reference points taken by different authors, such as the root apex,[23,24] the MB region of the roots,[7,21] or the alveolar crest,[25] were discarded in this study because of their considerable interindividual variability and susceptibility to physiological or pathologic alveolar bone loss. The fact that the anatomic reference points used to calculate distances and perform measurements were disparate between the studies has led to the impossibility of data homogenization to obtain meta-analytical data.

Regarding the CEJ-buccal bone crest distance, local factors such as buccally positioned teeth,[34] orthodontic movements,[35] vertical tooth fractures,[36] or periodontal pathology[37] may alter the normal biological width. To avoid bias in the measurement of this distance, it was decided to exclude patients with a history of orthodontic treatment or who had maxillary molars with an angulation of <45°. In addition, because current evidence

Table IV. Correlation between CEJ-bone crest distance with TL and IL

Variables	TL	IL
1.7 DB		
CEJ-bone crest distance	$r = -0.38$	$r = -0.30$
	P <0.001***	P <0.001***
IL	$r = 0.41$	
	P <0.001***	
2.7 DB		
CEJ-bone crest distance	$r = -0.35$	$r = -0.24$
	P <0.001***	$P = 0.001$**
IL	$r = 0.26$	
	P <0.001***	
1.6 DB		
CEJ-bone crest distance	$r = -0.09$	$r = -0.33$
	$P = 0.197$	P <0.001***
IL	$r = 0.43$	
	P <0.001***	
2.6 DB		
CEJ-bone crest distance	$r = -0.09$	$r = -0.18$
	$P = 0.189$	$P = 0.012$*
IL	$r = 0.40$	
	P <0.001***	
1.6 MB		
CEJ-bone crest distance	$r = -0.23$	$r = -0.44$
	$P = 0.001$**	P <0.001***
IL	$r = 0.63$	
	P <0.001***	
2.6 MB		
CEJ-bone crest distance	$r = -0.17$	$r = -0.35$
	$P = 0.013$*	P <0.001***
IL	$r = 0.58$	
	P <0.001***	

*P <0.05; **P <0.01; ***P <0.001.

shows significant dimensional bone changes at molar extraction sites during the first year after tooth extraction,[38,39] the inclusion criterion was to include only patients in which the extraction of the maxillary third molars had been at least 12 months before the CBCT scan.

To facilitate the measurements, an angle of 50º in the maxillary second molars and 60º in the maxillary first molars was configured to simulate the insertion of the microscrew based on the angles previously recommended by various authors.[17,19,20]

Regarding the measurement of the TL, the results of this investigation showed that the highest values were found in the region of the MB root of the maxillary first molars (12.92 ± 2.86 mm right and 12.9 ± 2.79 mm left), followed by the region of the DB root of the second molars (12.27 ± 2.78 mm right and 12.2 ± 2.74 mm left), and finally the region of the DB root of the maxillary first molars (11.84 ± 2.7 mm right and 11.85 ± 2.23 mm left), with statistically significant differences between them. However, in contrast with our results, some authors[25,40] recommended the placement of the microscrews between the maxillary first and second molars, at the level of the mesial root of the maxillary second molar, because they found greater bone thickness and, therefore, greater bone consistency for mechanical loading in those areas.

In relation to the measurement of the IL, the average values found in this study ranged from 5.84 ± 1.8 mm in the region of the DB root of the maxillary first molars on the right side to 6.53 ± 2.18 mm in the region of the distal root of the maxillary second molars on the left side.

The values of the IL found in our work are lower than those of many dimensions of active threading surfaces of microscrews available on the market. Ideally, the threaded surface of the temporary anchoring device should be anchored to the bone region, with the smooth, polished transmucosal neck remaining in the soft-tissue area. Therefore, during the insertion process of TSADs, it is recommended to stop inserting the microscrew as soon as the smooth neck has reached the periosteum. Over-insertion may increase the torsional stress on the neck of the microscrew, leading to loosening of the microscrew and excessive soft-tissue growth. In addition, the threaded surface in soft tissue promotes plaque buildup and worsens the prognosis of the temporary anchoring device.[6]

In this section, a certain asymmetry was observed between both sides, with statistical significance being observed with larger dimensions on the left side than on the right side of the patient. After an exhaustive analysis, this statistical finding would have no clinical value, considering the average difference was 0.41-0.54 mm.

In terms of the correlations between the total and ILs and the features, this study found that the normodivergent patterns had significantly lower TLs than the hypodivergent and hyperdivergent patterns in all areas, especially in the region of the DB root of the second molars and the region of the MB root of the first molars. Our results agreed with the conclusions of Husseini et al,[24] whose main variations in height and depth were located in the MB root of the maxillary first molars in the hyperdivergent group. This fact could be explained by the circumstance that in hyperdivergent patterns, there is usually a decrease in the dimension and width of the maxillary sinus in the vertical direction compared with other facial patterns,[41,42] and a larger maxillary alveolar ridge.[43] However, the results of this study contradict the results of Costea et al,[44] who found that the hyperdivergent group tended to have a reduced distance between the root apices and the floor of the maxillary sinus compared with the hypodivergent group.

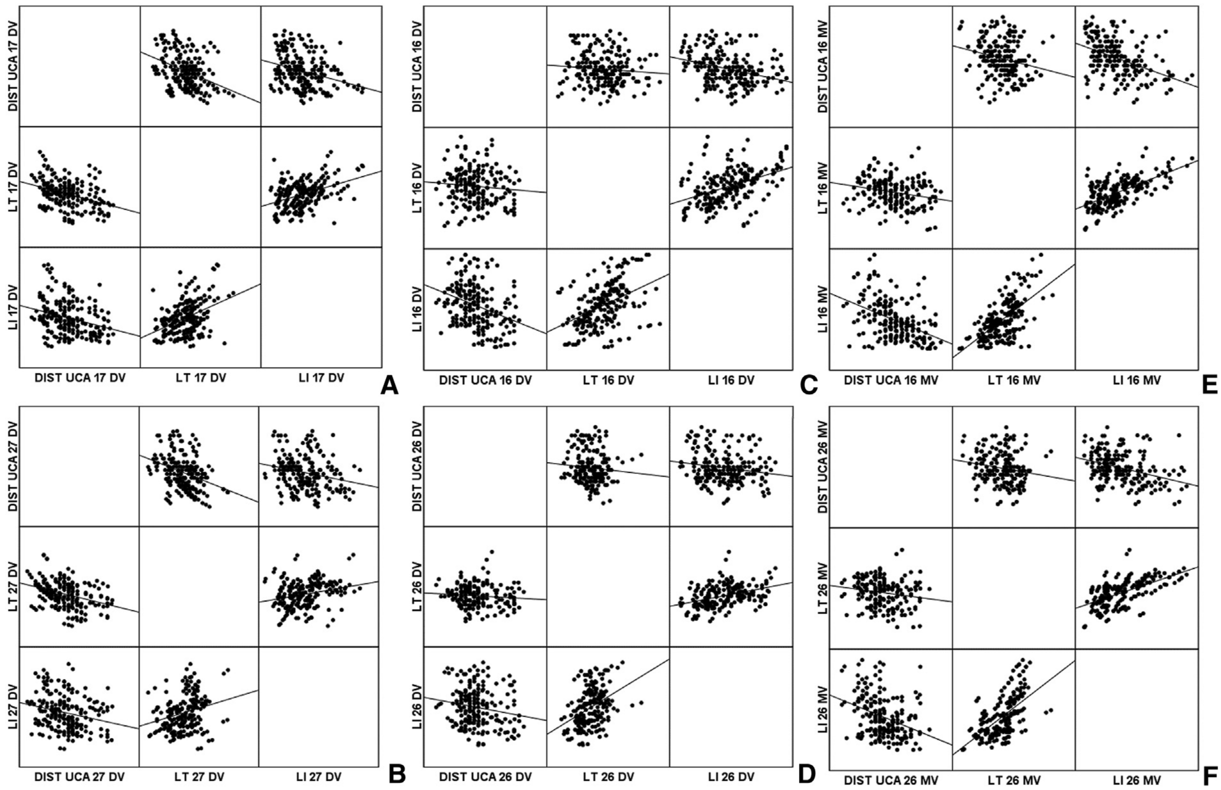

Fig 6. Regression graphs of the correlation between the CEJ-bone crest distance and the total and ILs of all the regions studied: **A,** Region of the distal root of the maxillary right second permanent molar (1.7 DB); **B,** Region of the distal root of the maxillary left second permanent molar (2.7 DB); **C,** Region of the DB root of the maxillary right first permanent molar (1.6 DB and 2.6 DB); **D,** Region of the DB root of the maxillary left first permanent molar (2.6 DB); **E,** Region of the MB root of the maxillary right first permanent molar (1.6 MB); **F,** Region of the MB root of the maxillary left first permanent molar (2.6 MB). *DIST UCA*, CEJ to bone crest distance.

According to the skeletal classification, a statistically significant difference was found only in the region of the MB root of the maxillary left first molars, with greater bone height in patients with skeletal Class II malocclusion. Only the work of Tavares et al[21] included the skeletal classification comparison in their sample. They only found significant differences in bone depth at different bone levels and insertion angulations in Class II and mesofacial patients. However, those results cannot be directly compared with our study because their study was aimed to compare different screw insertion distances and insertion angles.

In this work, significant differences were found in the intraalveolar measurements between the first and second molars in relation to the sex of the subjects, with larger values in males. As in our study, Arango et al[16] found a greater length of the IZC in the mesial root of the maxillary first molars in males.

In contrast to other studies,[7,20,26] no statistically significant differences were observed with respect to age. These differences may be explained by the fact that many of these studies included adolescent patients in their samples,[20,26] whereas this study included only adult subjects.

One of the key points of this investigation was to determine the influence that the CEJ-buccal bone crest distance may have on the total or IL of the infrazygomatic ridge. Although several studies have used the CEJ as an anatomic reference point,[20-22] no research work was found that examined this possible relationship.

The results confirmed the presence of an inverse and statistically significant correlation between the CEJ-buccal bone crest distance and the total and ILs in all the regions studied, except for the region of the DB root of the maxillary first molars. It can be stated that the shorter the CEJ-bone crest distance, the greater the total and ILs. This measurement can be indicative and used as a reference when characterizing the anatomy of the infrazygomatic ridge because a simple and quick measurement of the distance from the CEJ to the buccal bone crest can reveal relevant bone characteristics of the area.

The main limitation of the present research was the use of a population seeking orthodontic consultation as inclusion criteria. The authors consider it of great interest that more prospective, long-term, controlled studies with a wider age range are conducted to strengthen the evidence for these findings.

Considering the results obtained in this study, it is generally recommended not to exceed a TL of 12 mm in the region of the DB root of the maxillary second molars and the region of the MB root of the maxillary first molars and up to 11 mm between the first and second molars, because, according to some authors, microscrews of 12 mm length have a 48% probability of perforating the maxillary sinus.[11]

As for the active threading surface of the microscrew, an average of approximately 6 mm could be suitable as the active length of the device, with the remaining millimeters up to the TL being the appropriate dimension for the smooth, transmucosal neck that rests on the soft tissue.

Making a correct choice of the length of the transmucosal neck can help us select the ideal length of the microscrew in the selected anatomic region.

Our results would be in line with the ideas of Tavares et al,[21] who recommended limiting the length of the active part of the microscrew in the bone to 7-8 mm. They also advocated a bicortical anchorage insertion and a maximum penetration of the maxillary sinus of 1 mm.[21]

CONCLUSIONS

TL was greatest in the region of the MB root of the maxillary first molars, followed by the region of the DB root of the second molars, and finally, the region of the DB root of the maxillary first molars, with statistically significant differences among them. Patients with normodivergent patterns had the lowest total infrazygomatic ridge height. From a clinical perspective, the results found in this study emphasize the need to individualize each single patient and select the most adequate dimension that meets the anatomic requirements of each patient.

A statistically significant inverse relationship was observed between the CEJ-vestibular bone crest distance and the total and ILs in the regions studied, except for the DB region of the maxillary first molars. The proposed measurement protocol would assist the clinician in selecting the appropriate length of temporary anchorage devices for each region.

AUTHOR CREDIT STATEMENT

Carolina Rojo Sanchis contributed to conceptualization, methodology, data curation, and original draft preparation; Juan Carlos Pérez-Varela contributed to data curation, supervision, validation, and manuscript review and editing; Natalia Zamora-Martínez contributed to data curation, analysis of results, original draft preparation, and manuscript review and editing; Verónica García-Sanz contributed to conceptualization, visualization, investigation, and validation; Beatriz Tarazona-Álvarez contributed to investigation, validation, and supervision; and Vanessa Paredes-Gallardo contributed to supervision, validation, and manuscript review and editing.

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