ORIGINAL ARTICLE

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Assessment of infrazygomatic crest dimensions in different vertical facial growth types for miniscrew insertion: A cone-beam computed tomography study

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Introduction: This study aimed to assess the depth and height of the infrazygomatic crest (IZC) located in the posterior maxilla at the junction with the zygomatic process in patients with different vertical facial growth types as a potential miniscrew insertion site. **Methods:** The sample consisted of cone-beam computed tomography scans of 117 patients (42 males and 75 females), with a mean age of 22.9 ± 2.7. The population was divided into 3 groups according to the measured SN-GoGn angle: Decreased facial proportions (n = 28), average facial proportions (n = 62), and increased facial proportions (n = 27).

Bone depth was assessed at 5 levels: apex, 1, 2, 3, and 4 mm vertically from the apex. The measurements were performed on the mesiobuccal and distobuccal roots of the first molar and the mesiobuccal root of the second molar. Repeated-measure analysis of variance followed by univariates analyses and Bonferroni multiple comparisons were performed to compare the mean bone thickness between groups. The IZC height was assessed through a vertical line ranging from the furcation of the maxillary first molar to the sinus floor. Analysis of variance followed by Tukey (honestly significant difference) post-hoc tests was used to compare the mean height between groups. **Results:** Mean bone depth between the 3 groups were significantly different at the mesiobuccal root region of the first molar at all the measured levels. It was smaller for average, intermediate for decreased, and elevated for increased facial proportions. No statistical difference was shown at the distobuccal root of the first molar except for the apex level and the mesiobuccal root of the second molar except for the apex and 4 mm levels. The mean bone height was significantly different between subjects with increased facial proportions and the 2 other groups. **Conclusions:** Subjects with increased facial proportions tend to present a longer and deeper IZC followed by decreased facial proportions, then average facial proportions. (Am J Orthod Dentofacial Orthop 2022;■:■-■)

The osseous anatomy of the human jaws has become increasingly important for the planning and placement orthodontic miniscrews.[1] Particularly, extraalveolar anatomic locations such as the anterior palate, the infrazygomatic crest (IZC), and the mandibular buccal shelf have become popular in recent years because of the lack of dental roots at those sites.[2] The IZC is a palpable ridge in the maxillary basal bone between the alveolar and the zygomatic processes. Its position may vary between the second maxillary

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premolar and maxillary first molar according to the patient's age.[3] Anatomically, it presents a thick layer of cortical bone favorable for the primary stability of miniscrews.[3]

Insertions at the IZC can be useful for multiple indications such as the intrusion of over erupted posterior teeth,[4] en-masse retractions, an eruption of impacted teeth,[5] and the correction of anterior open bites through posterior intrusion.[4] They can be combined with alveolar miniscrews and clear aligners in patients with posterior intrusion, thus preventing the need for orthognathic surgery.[5]

In addition, according to Borzabadi-Farahani and Zadeh,[6] orthodontic movements can help optimize dental implant sites especially in the posterior maxillary region in which bone resorption occurs at a high rate because of sinus pneumatization. Such movements become more reliable when using IZC miniscrews, particularly when it comes to extrusion and orthodontic implant site switching.

However, because of individual variation[7] and the lack of information regarding this area, failure rates tend to be higher, particularly when the depth and length of this area are limited, thus resulting in sinus perforation.[8]

It's well known that the maxillary bone tends to expand caudally and anteriorly during the growth of maxillofacial structures.[9] Such growth can differ within patients because of the numerous factors encountered during the growth phase, producing an extensive array of phenotypes.[10] In terms of vertical growth patterns, a caudal overgrowth of the maxilla may often lead to an elongated facial aspect hence an increased facial proportion (IFP) phenotype; the opposite situation is seen in the decreased facial proportion (DFP) phenotype, whereas average facial proportion (AFP) subjects remain between the 2 extremes. However, the impact of the vertical facial growth types (VFGT) on the IZC dimensions and their clinical consequences is poorly explained.

One recent study demonstrated an absence of correlation between basal bone dimensions of the anterior maxilla, tooth position, and inclination.[11] To the best of our knowledge, the latter was not investigated in the posterior maxilla making it an interesting site to explore. Analyzing the anatomic characteristics of the IZC in different VFGT might be beneficial for clinicians by providing additional information permitting successful miniscrew placement.

Therefore, this study aimed to analyze the buccal bone depth and height of the IZC in different vertical facial types to aid clinicians in the planning and placement of orthodontic miniscrews.

MATERIAL AND METHODS

This study has been reviewed and accepted by the Saint Joseph University of Beirut Institutional Review Board, reference no. USJ-2020-101.

Cone-beam computed tomography (CBCT) scans taken on 1225 patients between January 2018 and September 2019 were randomly selected from the Saint Joseph University of Beirut archives, in which patients needing general dentistry treatment signed an informed consent permitting the use of their data for scientific research. The CBCTs were all acquired identically, using a NewTom VGI CBCT scanner (QR srl, Verona, Italy) with 110 kVp; 60 mA; 0.3-mm voxel size; scan time, 18 seconds; and field view of 15 × 15 cm.

The inclusion criteria of the tested population were as follows: (1) full permanent dentition except for third molars, (2) normal craniofacial development, (3) aged ≥18 years, and (4) absence of previous orthodontic or orthognathic surgical treatment.

Patients who presented 1 of the following criteria were excluded from the study: (1) CBCT scans taken without teeth in occlusion, (2) distorting pathologies of the facial mass, (3) periodontal or endodontic diseases affecting the bone, and (4) presence of metallic artifacts in the posterior maxillary region.

Following the inclusion and exclusion criteria stated above, 1108 CBCT scans were excluded from this study, as shown in the sample selection flow chart (Fig 1). The final sample consisted of CBCT scans of 117 subjects (42 males and 75 females), with a mean age of 22.9 ± 2.7. The mean ages of males and females were 23.7 ± 3.0 years and 21.1 ± 2.4 years. The whole population was divided according to VFGT into DFP (n = 28), AFP (n = 62), and IFP (n = 27).

NNT software (version 5.6; NewTom) was used to assess the validity of the obtained images. To avoid reproducibility error, patients' head position was normalized using Frankfort Horizontal (Fig 2). Subsequently, a panoramic curve featuring a cross-sectional slice thickness of 0.3 mm was drawn.

Each subject's digital imaging and communications in medicine files were exported from the NNT software and loaded into the Blue Sky Plan software (version 4.5; Blue Sky Bio, LLC, Grayslake, Ill), in which a cephalometric approach was selected. A modified Steiner measurement package was used to measure the SN-GoGn angle (Fig 3). Three main groups were generated on the basis of the measured angle; DFP consisted of subjects with $<27°$ angle, AFP enclosed subjects with a value lying between 27° and 37°, whereas the IFP included subjects who recorded a $>37°$.[12]

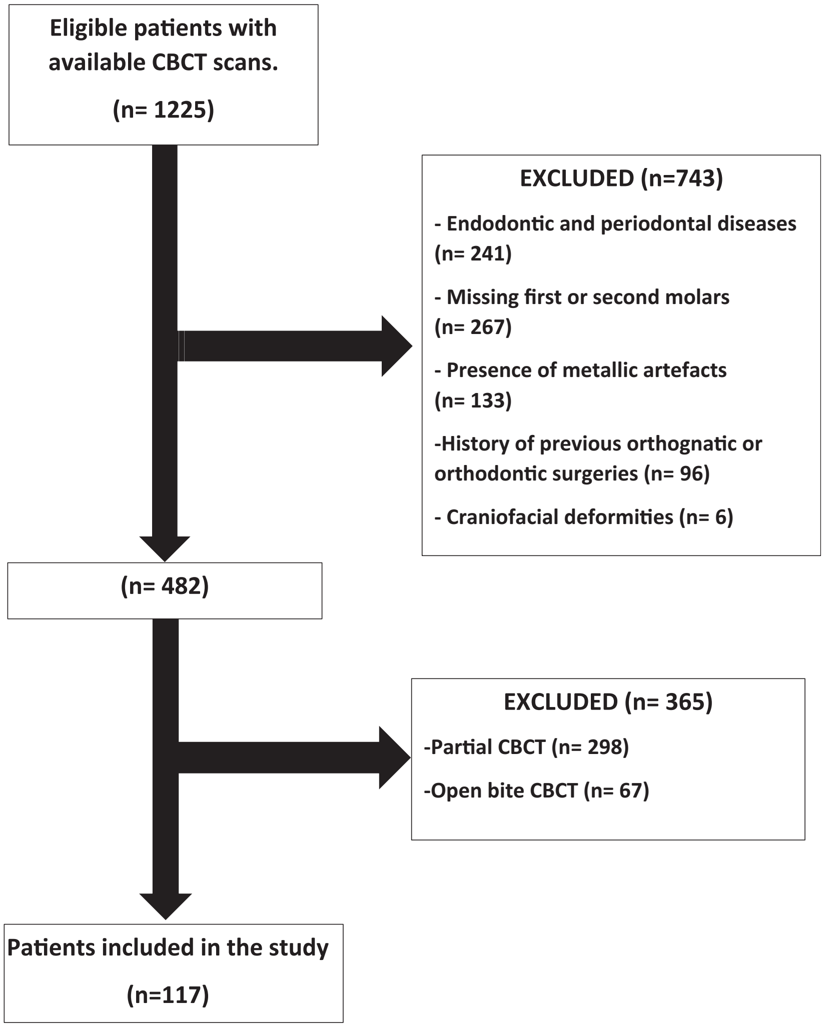

Fig 1. Flow chart of the sample selection.

The measurement method described by Baumgaertel and Hans[7] was adopted and modified to improve the accuracy of measurements, especially when encountering curved apices. The modification consisted of double-checking the location of the radiological apex of the roots in both the panoramic and axial views. All dimensions were measured twice, and the mean of the 2 measurements was reported.

First, The region between the mesiobuccal root of the first and second molars was divided into 3 zones; each zone was labeled according to the corresponding root.

Then, the section passing through the apex of the root was selected in a coronal view. The radiological apex was identified, a horizontal tangent line between the apex and the alveolar bone was drawn perpendicular to the buccal alveolar bone itself, and the distance was recorded in mm. Four measurements were assessed by retreating progressively each time 1 mm from the apex and drawing the horizontal line described above. A calibrated operator repeated those measurements in the 5 zones (Fig 4, *A*).

A slice corresponding to the center of the interradicular space clearly showing the furcation was selected and a vertical line going from the furcation to the radiological floor of the maxillary sinus; the distance was then recorded in a separate table (Fig 4, *B*).

Statistical analysis

SPSS software (version 25.0; IBM, Armonk, NY) was used for the statistical analysis of the data. The type I error was set at 0.05. Intraobserver reproducibility was evaluated using the intraclass correlation coefficient (ICC) with a 95% confidence interval; the ICC for all

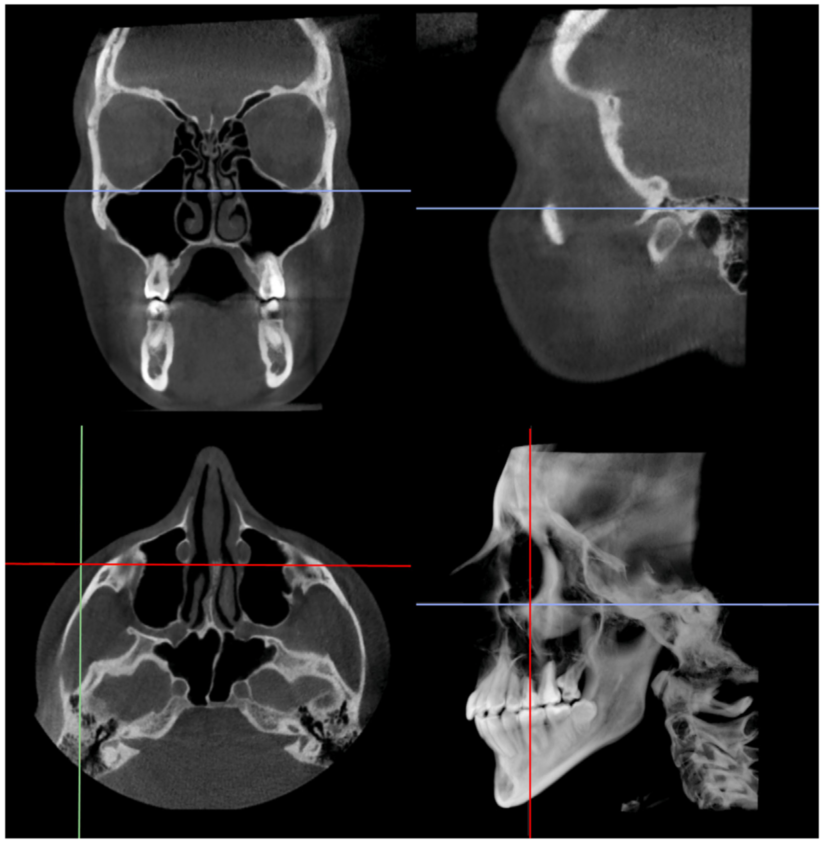

Fig 2. Patient head orientation in different CBCT views.

measurements was superior to 0.996, indicating excellent reproducibility.

Repeated-measure analyses of variance with 1 between-subjects factor (VFGT) were performed to compare the mean bone depth between participants with IFP, AFP, and DFP types within levels. These tests were followed by univariate analysis and Bonferroni multiple comparisons.

The height was also measured on the first molar and compared between subjects with IFP, AFP, and DFP. Analysis of variance was used for statistical comparisons and was followed by Tukey (honestly significant difference) post-hoc tests.

RESULTS

The mean bone depth was significantly different between VFGT groups at the apex ($P = 0.046$), at 1 mm ($P = 0.001$), 2 mm ($P = 0.004$), and 3mm ($P = 0.038$); it was smaller for AFP, intermediate for DFP and elevated for IFP. However, the mean bone depth at the 4mm level was not significantly different between different VFGTs ($P = 0.2570$) (Table 1 and Fig 5).

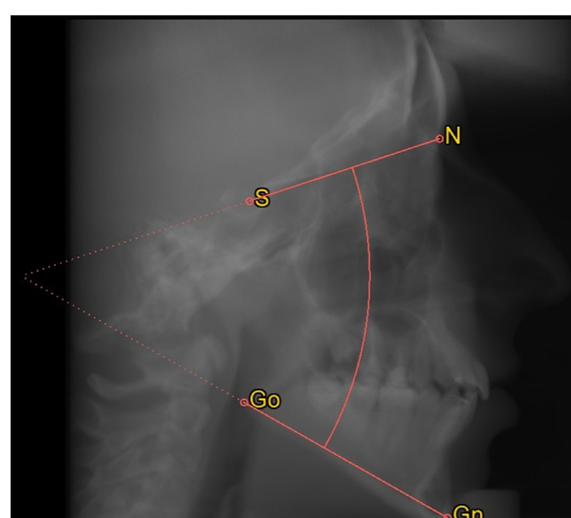

Fig 3. SN-GoGn angle measurement on a CBCT-based cephalogram.

The mean bone depth at the distal root of the first molar was not significantly different between DFP, AFP, and IFP participants at the apex level ($P =$

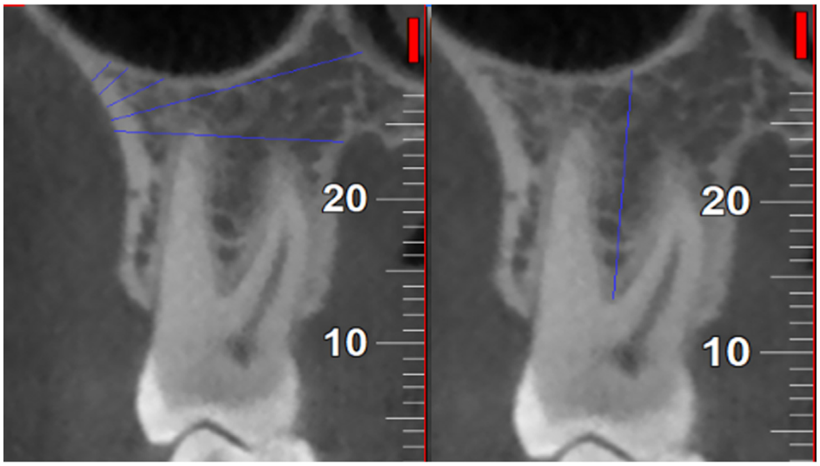

Fig 4. Linear measurement techniques used to assess depth (1) and height of the infrazygomatic crest (2). Height is measured by drawing a line between the molar furcation and the sinus floor, whereas depth corresponds to a horizontal line perpendicular to the buccal alveolar line at 5 different levels.

Table I. Bone depth at the mesial root of the first molar

Variables	*n*	*Mean, mm*	*Standard deviation*	*Minimum*	*Maximum*
First molar mesial apex					
DFP	28	6.436	4.7104	1.0	18.3
AFP	62	5.261	3.4600	0.5	16.2
IFP	27	7.644	5.1086	0.5	15.9
First molar mesial 1 mm					
DFP	28	5.336	4.9252	0.8	18.0
AFP	62	3.965	2.8691	0.5	16.0
IFP	27	7.485	5.4129	0.0	16.9
First molar mesial 2 mm					
DFP	28	4.950	5.0463	0.8	19.2
AFP	62	3.344	2.4927	0.5	14.5
IFP	27	6.304	5.0076	0.0	16.7
First molar mesial 3 mm					
DFP	28	3.725	3.5603	0.8	16.5
AFP	62	2.992	2.5350	0.5	14.7
IFP	27	4.919	4.1762	0.0	15.3
First molar mesial 4 mm					
DFP	28	3.093	3.0246	0.0	14.7
AFP	62	2.769	2.4556	0.0	14.1
IFP	27	3.881	3.6629	0.0	13.2

0.137), at 1 mm (P = 0.091), 2 mm (P = 0.067) and 3 mm (P = 0.093). However, the mean bone depth was significantly different between different VFGT at the 4 mm level (P = 0.019); it was smaller for AFP, intermediate for DFP, and elevated for IFP (Table II and Fig 6).

The mean bone depth at the mesial root of the second molar was significantly different between VFGT at the apex level (P = 0.050) and 4 mm (P = 0.045); it was smaller for AFP, and the difference was not significantly different between DFP and IFP (P = 1.000). In contrast, the mean bone depth was not significantly different between DFP, AFP, and IFP participants at 1 mm (P = 0.091), 2 mm (P = 0.076), and 3 mm (P = 0.081) (Table III and Fig 7).

The mean bone height on the first molar was significantly different between DFP, AFP, and IFP (P = 0.042); it was significantly increased in participants with IFP, but the difference was not significant between AFP and DFP (P = 0.714) (Table IV and Fig 8).

DISCUSSION

The use of miniscrews at the IZC showed promising results in molar distalization and en-masse retraction of the maxillary dentoalveolar complex when used bilaterally.[13] However, because of the complex anatomy and generally unfavorable soft tissue, the IZC is frequently avoided as an insertion site, and the reported higher failure rates here further discourage practitioners from using this insertion site.[8] According to Jia et al[8], most of these failures were related to maxillary sinus perforation because of the insufficient height and depth of the IZC.

This study aimed to analyze the bone depth and height of the IZC in different vertical facial types to guide clinicians when planning and placing orthodontic miniscrews.

This study showed a significant difference between different VFGTs in depth and height.

The IFP group scored the greater mean values in terms of depth at the apex and 1 mm, 2 mm, and 3 mm of the mesiobuccal root of the first molar.

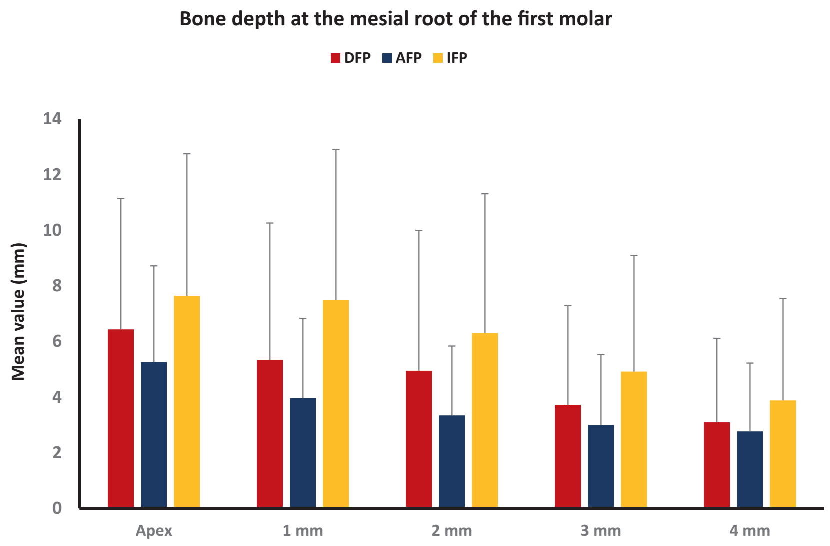

Fig 5. Comparison of bone depth measurements on the mesial root of the first molar between the different studied groups.

Table II. Bone depth at the distal root of the first molar

Variables	*n*	*Mean, mm*	*Standard deviation*	*Minimum*	*Maximum*
First molar distal apex					
DFP	28	6.732	5.0393	1.0	17.4
AFP	62	5.103	3.4324	0.5	19.0
IFP	27	6.733	5.4759	0.0	15.9
First molar distal 1 mm					
DFP	28	4.982	4.2607	0.6	15.3
AFP	62	3.950	2.3839	0.5	13.5
IFP	27	5.774	5.3243	0.0	17.3
First molar distal 2 mm					
DFP	28	4.407	4.0668	0.6	16.1
AFP	62	3.423	2.1891	0.5	13.7
IFP	27	5.278	5.0972	0.0	16.5
First molar distal 3 mm					
DFP	28	3.979	3.5304	0.6	13.2
AFP	62	3.035	2.2594	0.2	16.2
IFP	27	4.596	4.5506	0.0	16.1
First molar distal 4 mm					
DFP	28	3.861	3.7718	0.6	13.8
AFP	62	2.608	1.8375	0.2	14.5
IFP	27	4.430	4.0339	0.0	14.7

IZC depth is defined by the distance between the buccal and the palatal/sinus limits of the IZC zone without root interference. Understanding that subjects in the IFP group experienced greater vertical development than subjects in the other groups may explain that mean values here were the highest among the 3 study groups. Therefore, it is likely that the increased depth within the IFP group is due to the IZC height and probably not strictly related to the buccopalatal width (Fig 9).

The significantly increased values of depth and height at the first molar zone in the IFP group observed could be explained by Oksayan et al,[14] who reported a decrease in vertical sinus dimension and width when compared with other VFGT, and additionally by the findings of Kuitert et al[15] regarding IFP group who present a longer maxillary alveolar ridge. However, the results of the present study were in contradiction with the Costea et al[16] results. According to these authors, the IFP group tends to have a reduced distance between root apices and the sinus floor compared with the DFP.

Regarding the DFP group, the results showed higher values than the AFP but lower than IFP at the mesiobuccal root apex and 1 mm, 2 mm, and 3 mm of the first molar. The intermediate values might be explained by the undersized length compared with the IFP and the disproportionate muscular force compared with the AFP, thus, creating a thicker cortical bone as an adaptive process (Fig 9). It appears that the strong masseter muscle that inserts above the IZC might dictate the bone architecture. According to Kiliaridis et al,[17] the bone structure near areas of muscular activity tends to adapt by layered deposition, particularly when experiencing a tension stimulus above a certain threshold.

The height mean values were significantly lower than the IFP group values, but there was no difference in the AFP group. Oksayan et al[14] demonstrated greater sinus dimensions when compared with the IFP because of smaller vertical dimensions separating the roots from

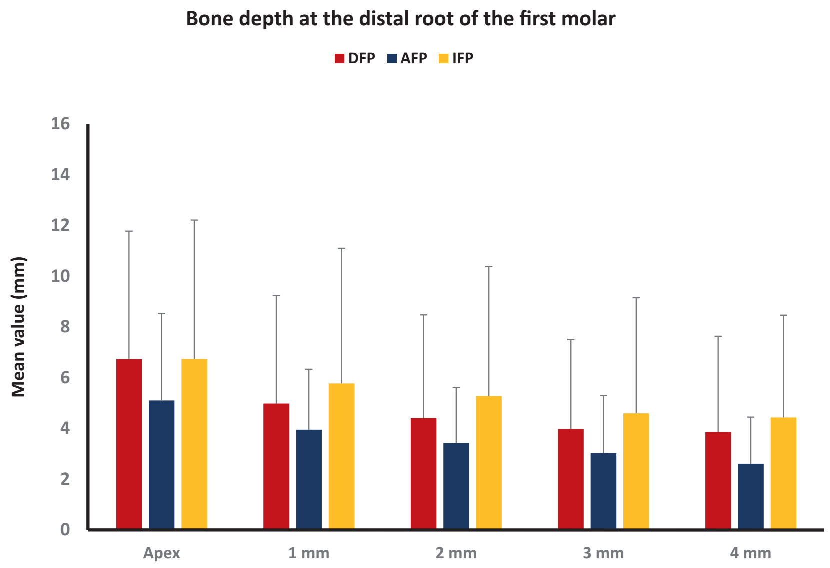

Fig 6. Comparison of bone depth on the distal root of the first molar between the different studied groups.

Table III. Bone depth at the mesial root of the second molar

Variables	*n*	*Mean, mm*	*Standard deviation*	*Minimum*	*Maximum*
Second molar mesial on the apex					
DFP	28	6.918	4.5649	1.0	18.6
AFP	62	5.665	3.0438	1.2	16.2
IFP	27	7.796	4.8869	1.2	16.2
Second molar mesial at 1 mm					
DFP	28	6.404	4.9597	1.0	18.6
AFP	62	4.790	3.1188	1.2	15.2
IFP	27	6.452	4.6407	1.2	15.6
Second molar mesial at 2 mm					
DFP	28	5.793	4.9269	1.0	18.1
AFP	62	4.227	2.9741	1.2	15.0
IFP	27	5.989	4.6238	1.2	15.2
Second molar mesial at 3 mm					
DFP	28	5.254	4.5938	1.0	16.6
AFP	62	3.765	3.1061	1.2	15.5
IFP	27	5.534	4.7025	1.2	14.8
Second molar mesial at 4 mm					
DFP	28	4.807	4.5668	1.0	16.4
AFP	62	3.234	2.8053	1.0	16.0
IFP	27	5.163	4.7454	1.2	14.4

the sinus floor. However, Costea et al[16] indicated that the roots are farther from the sinus floor.

In AFP group presented the lowest values out of the 3 VFGTs. Being an in-between entity in terms of length and muscular forces, subjects in this group may not benefit from the influence of the 2 parameters reported above for the extremes (Fig 9). The AFP roots are generally projected into the sinus, as stated by Costea et al,[16] thus explaining the low values in terms of depth and height.

The measurement variations at the distobuccal root of the first molar and the mesiobuccal root of the second molar were less significant than those observed at the mesiobuccal root of the first molar. The lack of statistical difference could be attributable to the oblique direction of the maxillary growth and the intimacy with the sinus floor. Swasty et al[18] defined a progressively increasing vertical compensatory mechanism at the mandible; hence, the posterior area showed similar depth values at different levels except at the apex level and at 4 mm. However, those levels are useless for miniscrew insertion planning. In addition, Liou et al,[3] the IZC location fluctuate between the second maxillary premolar and the first molar. Baumgaertel and Hans defined the IZC as a potential insertion site above the maxillary first molar.[7] Therefore, it appears that the bone available for miniscrew insertions diminishes toward the distal, and hence it comes as no surprise to see differences in measurements between the various groups also diminish.

Several studies investigated the IZC using different measurements without considering any anatomic or craniofacial growth patterns. Santos et al[19] measured the thickness at the distobuccal root of the first molar at 2 mm and 4 mm above the apex using a horizontal line. In contrast, Liou et al[3] probed the IZC through an angle-based method; the authors drew a vertical

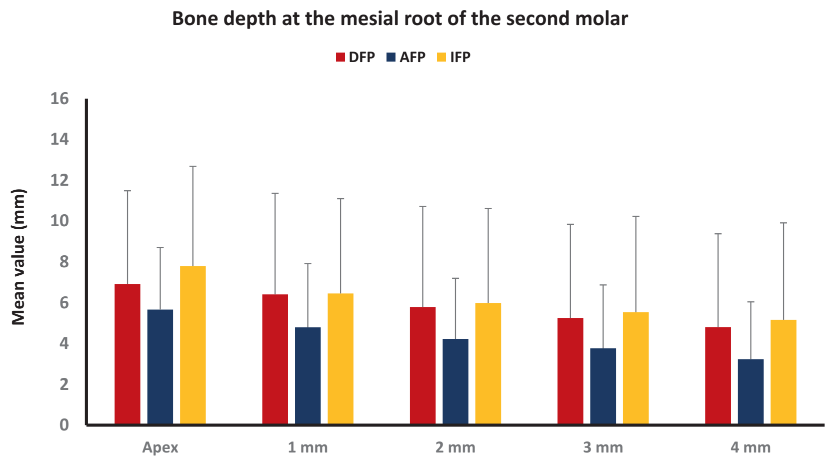

Fig 7. Comparison of bone depth on the mesial root of the second molar between the different studied groups.

Table IV. Bone length at the first molar

First Molar	*n*	*Mean (mm)*	*Standard deviation*	*Minimum*	*Maximum*
DFP	28	7.629	4.0253	1.5	18.3
AFP	62	6.877	3.5242	0.4	20.4
IFP	27	9.356	5.6325	0.0	25.3

reference line and then added 8 lines creating various angles of different grades, indicating a precise thickness value. As for Baumgaertel and Hans,[7] these authors developed the method used in this article to assess the depth of the IZC. However, they stated an important interindividual variation in terms of linear depth, which may be due to the heterogeneity of their sample.

Recently, the effect of VFGT on the IZC dimensions was investigated by a limited number of other papers.

Murugesan and Jain[20] and Paul et al[21] showed a reduced thickness of the IZC in high-angle subjects. Although Murugesan et al[20] suggested the mesiobuccal root of the second molar as the ideal insertion position, Paul et al[21] favored the space between the first and second molar. Limited sample size, anatomic variation of the IZC location, and assessment techniques might strongly influence the obtained outcomes, as seen in these studies.

Vargas et al[22] studied the IZC thickness in different vertical facial heights using the gonial angle as a reference. They measured the thickness at 2 different angle values (65 and 70 degrees) in the sagittal plane. The angles were composed of a blue line passing through the apex of the desired root and a red line tangent to the buccal cortical bone. They concluded an absence of correlation between the vertical facial height and the thickness of the IZC, which contradicts our study. This can be explained by differences in measurement techniques and clinical assumptions made on the miniscrew insertion path, which did not allow these authors to take advantage of the entire bone volume that the IZC offers. Vargas et al[22] focused on the insertion angle, whereas this study scanned the whole depth at 5 different levels allowing more detailed values, thus influencing the statistical outcomes.

The results shown may be beneficial in the orthodontic treatment of patients in which temporary anchorage devices (TADs) at the IZC can be used either for vertical corrections such as to perform unilateral or bilateral posterior intrusion or anterioposterior corrections such as retraction of the maxillary anterior segment in a first premolar extraction, or even full maxillary arch retraction.

Our findings will allow clinicians to better identify patients suitable for TADs at the IZC. Although it is clear that TADs are never fully inserted at the IZC, practitioners should still use the information laid forth in this article to select the dimensions of the TADs according to the VFGT. Although a radiological examination is always recommended before any extra alveolar TADs insertion, the results of this study demonstrated that TADs could be longer and tilted for the IFP, should be of medium length for the DFP, and need to be shorter if they are used at all, for the AFP patients. This should allow TADs use with reduced risk of interacting with adjacent anatomic structures in the increased facial proportions group, potentially leading to greater stability and better anchorage.

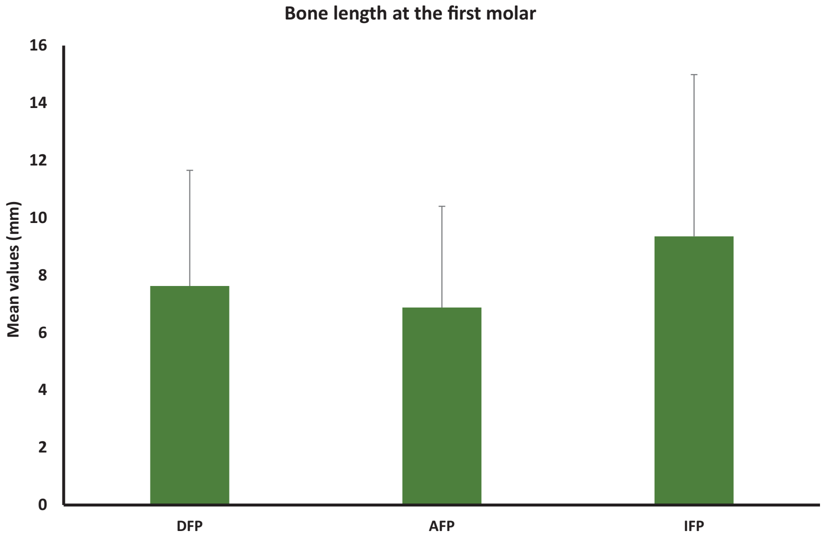

Fig 8. Comparison of bone length on the first molar between the different studied groups.

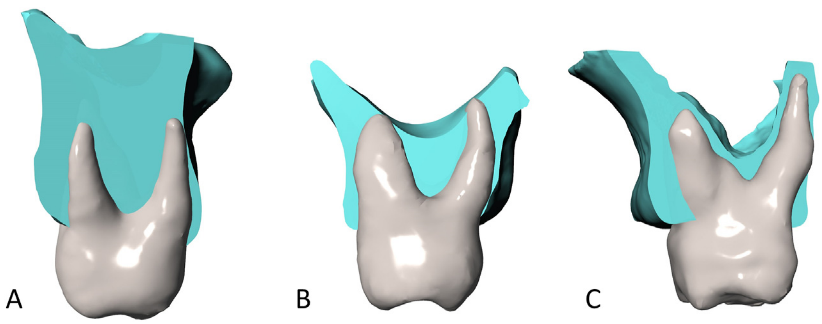

Fig 9. Three-dimensional reconstruction of the infrazygomatic region at the mesiobuccal root of the first molar: **A,** IFPs subject; **B,** AFPs subject; **C,** DFPs subject.

CONCLUSIONS

The main variations of the infrazygomatic crest depth and height, assessed in different VFGT, were located at the mesiobuccal root of the first molar. The highest values were observed in the increased facial proportions followed by DFPs, then the average facial proportions group.

AUTHOR CREDIT STATEMENT

Joseph Bouserhal contributed to conceptualization, supervision, and project administration; Ronald Younes contributed to supervision and project administration; Bachar Husseini contributed to investigation, data curation, and software management; Terry El Wak contributed to manuscript review and editing; Nad el Osta contributed to formal analysis; Nayla Bassil Nassif contributed to supervision; and Sebastian Baumgaerten contributed to methodology, validation, and supervision.

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