Original Article

Bone thickness and height of the buccal shelf area and the mandibular canal position for miniscrew insertion in patients with different vertical facial patterns, age, and sex

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ABSTRACT

Objectives: The objectives of this article were the following: (1) to analyze bone thickness and height (BTH) of the buccal shelf area (BS) quantitatively in four different potentially eligible sites for miniscrew insertion; (2) to compare and contrast BTH and the changes in spatial position of the inferior alveolar nerve canal (IANC); and (3) to assess differences with age among vertical facial patterns (hypodivergent, normodivergent, and hyperdivergent) and sex.

Materials and Methods: Cone-beam computed tomography scans of 205 individuals (110 women and 95 men) were divided into groups according to age, vertical facial pattern, and sex. The BTH of the BS and the BTH to the IANC were measured in the mesial and distal roots of the first and second molars.

Results: BTH progressively increased in a posterior direction ($P < .001$), while BTH to the IANC increased and decreased ($P < .001$) for thickness and height, respectively, in the same direction in all age groups, for the three different vertical facial patterns, and in both sexes. Women showed significantly less BTH to the IANC ($P < .002$). Hypodivergent patients had greater BTH ($P < .024$) and a smaller bone height to the IANC ($P < .018$) only in the first molar region. Patients over 40 years of age had lower bone height in the second molar area ($P < .003$).

Conclusions: The ideal place for BS miniscrew insertion is the region of the distal root of the second molars, regardless of facial pattern, sex, and age. The BS in women has less BTH and less BTH to the IANC. (*Angle Orthod.* 2023;93:185–194.)

KEY WORDS: Mini dental implant; Trabecular bone; Cortical bone; Mandibular canal

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INTRODUCTION

Miniscrews have been widely used to obtain temporary skeletal anchorage and to facilitate orthodontic biomechanics.[1] The overall failure rate of miniscrews was shown[2] to be 13.5%, and a failure rate of 7% has been reported[3] for extra-alveolar miniscrews. The stability of these devices is directly linked to bone density, bone thickness and height (BTH), insertion site, and proximity to roots, nerves, and vessels.[4–7]

An optimal place for installing mandibular miniscrews is the buccal shelf area (BS) because of the quantity and quality of bone available,[8–12] the high rate of stability of the devices, and the distance from the dental roots.[3] However, the best insertion site in the BS and how vertical facial pattern, age, and sex influence site suitability remain unclear given anatomic variability.[8–12]

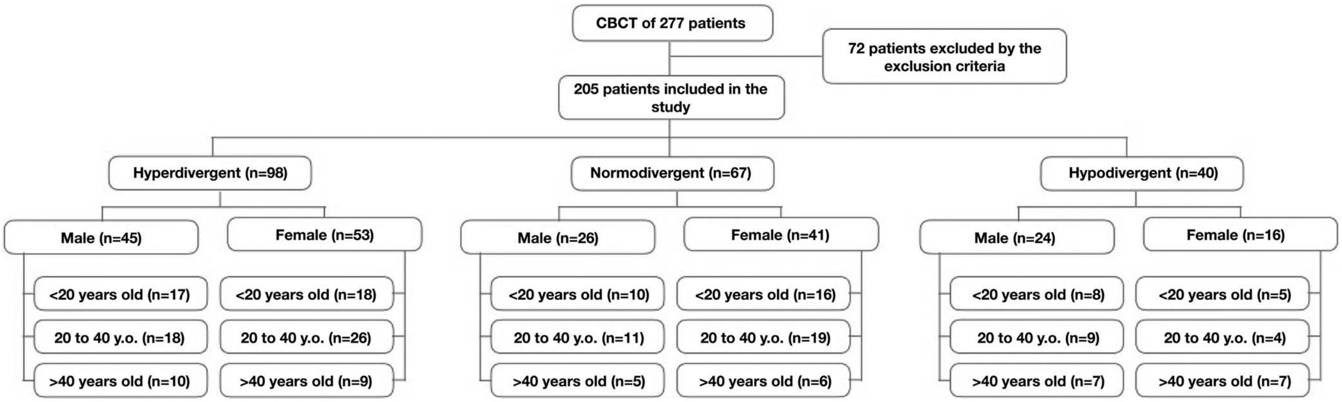

Figure 1. Sample distribution diagram.

Additionally, understanding variations in the position and course of the inferior alveolar nerve canal (IANC) is extremely important for miniscrew insertion.[13] Failure to recognize anatomic variations in the IANC can lead to peri- and postsurgical complications.[9–11,13] The shape, size, and symmetry of other structures vary according to facial type.[8,9,12] The aim of this study was to evaluate whether the vertical facial pattern, sex, and age influence these bone assessment parameters and the course of the IANC. The null hypothesis was that the BTH of the BS, as well as the BTH to the IANC, in men and women are not affected by the vertical facial pattern and age.

MATERIALS AND METHODS

This research was approved by the Ethics and Human Research Committee of Pontifical Catholic University of Minas Gerais (PUC Minas; 45064921.9.0000.5137). This retrospective cross-sectional study evaluated 205 cone-beam computed tomography (CBCT) scans of patients who were referred to the Department of Radiology at PUC Minas between 2014 and 2016. All images were deidentified prior to data access. This work followed the guidelines of the Reporting of Observational Studies in Epidemiology (STROBE)[14] for observational studies. The sample size was calculated with a confidence of 95% ($\alpha = .05$), a sample power of 80%, and a low to moderate effect size (0.30), showing that 203 patients would allow the determination of the effect of independent variables on the bone thickness of the mandibular BS.

Table 1. Characterization of Patients According to the Variables of Interest[a]

Characteristics	Distribution n	%
Sex		
Female	110	53.7
Male	95	46.3
Total	205	100.0
Age group, y		
<20	73	35.6
20–40	88	42.9
>40	44	21.5
Total	205	100.0
Vertical pattern		
Hyperdivergent	98	47.8
Normodivergent	67	32.7
Hypodivergent	40	19.5
Total	205	100.0

[a] Database: 205 patients, overall.

The sample consisted of 110 women and 95 men, 80% of whom were Caucasian (Figure 1; Table 1). The mean age was 26.6 ± 10.8 years. Exclusion criteria included individuals with (1) previous orthodontic treatment; (2) extraction of lower first or second molars; (3) implants or pontics replacing the lower first or second molars; (4) periodontal disease, history of orthognathic surgery, or presence of any genetic syndrome; (5) evident asymmetries; and (6) CBCT showing supernumerary teeth, impacted teeth, enlarged cystic follicle, or any other pathology in the area of interest. Subjects were divided into groups according to the cephalometric values (hypodivergent, normodivergent, and hyperdivergent), age (<20, 20–40, and >40 years), and sex (male and female).

CBCT scans were obtained using an i-CAT scanner (Imaging Sciences International, Hatfield, Pa), with the following acquisition parameters: 120 kV, 5 mA, 40-second acquisition time, 0.3-mm voxel size, and 18 × 20.6-cm field of view. All scans were saved in a DICOM file and analyzed using Dolphin Imaging Software 11.9 (Chatsworth, Calif).

One investigator (VE) performed all measurements and evaluations on an HP Pavilion 23 All-in-One display monitor screen (Palo Alto, Calif) under standardized ambient light and sound conditions. To minimize measurement errors produced from nonstandard head postures, all images were oriented using the following protocol: the axial plane was positioned tangentially to the most inferior portion of the furcations of the mandibular first and second molars on the left

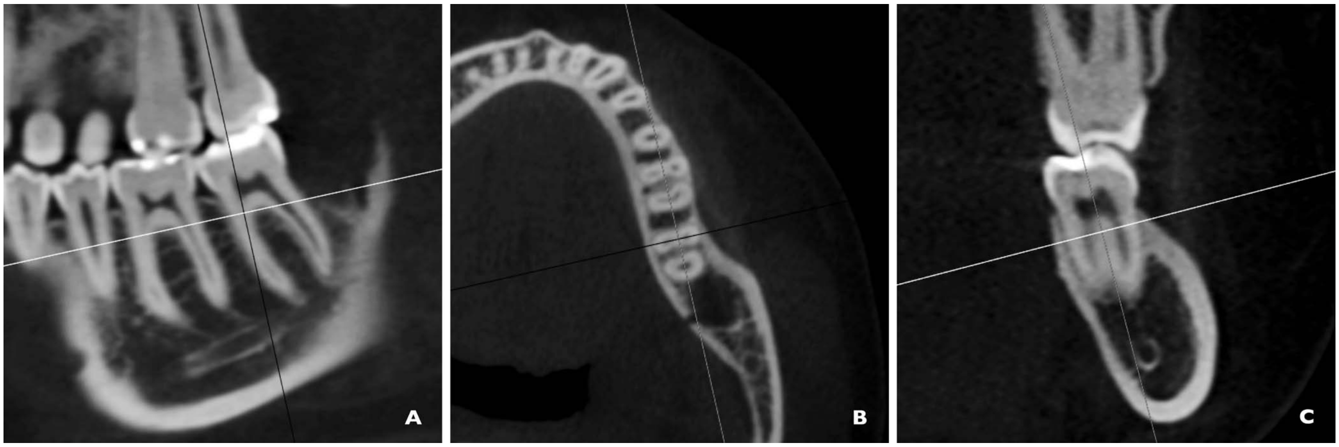

Figure 2. CBCT orientation. (A) Sagittal view. White line: axial plane; Gray line: coronal plane. (B) Axial view. White line: sagittal plane; Gray line: coronal plane. (C) Coronal View. White line: Sagittal plane; Gray line: axial plane.

side; the sagittal plane was positioned in the center of the alveolar process, parallel to the mesial roots of the lower left first molar (M6) and distal to the lower left second molar (D7); and the coronal plane was positioned parallel to the long axis of the mesial root of the lower left second molar (M7) (Figure 2). Measurements were performed in four coronal slices that were tangent to the center of the mesiobuccal and distobuccal roots of the first (M6 and D6) and second lower molars (M7 and D7), respectively. Considering that the bone thickness is similar on both sides of the mandible in patients considered symmetrical, only the left side was evaluated.[15]

To assess the buccal bone thickness, a reference line was drawn from the cemento-enamel junction (CEJ) in an apical direction, tangent to the buccal root surface. Measurements were made at 6 mm and 11 mm from a true horizontal line apical to the CEJ, starting from the tangent to the root surface to the most buccal point of the cortical bone[12] (Figure 3A). These locations were chosen because the minimum standard miniscrew length is 6 mm and extra-alveolar mini-screws are usually longer than 10 mm.[4] The bone

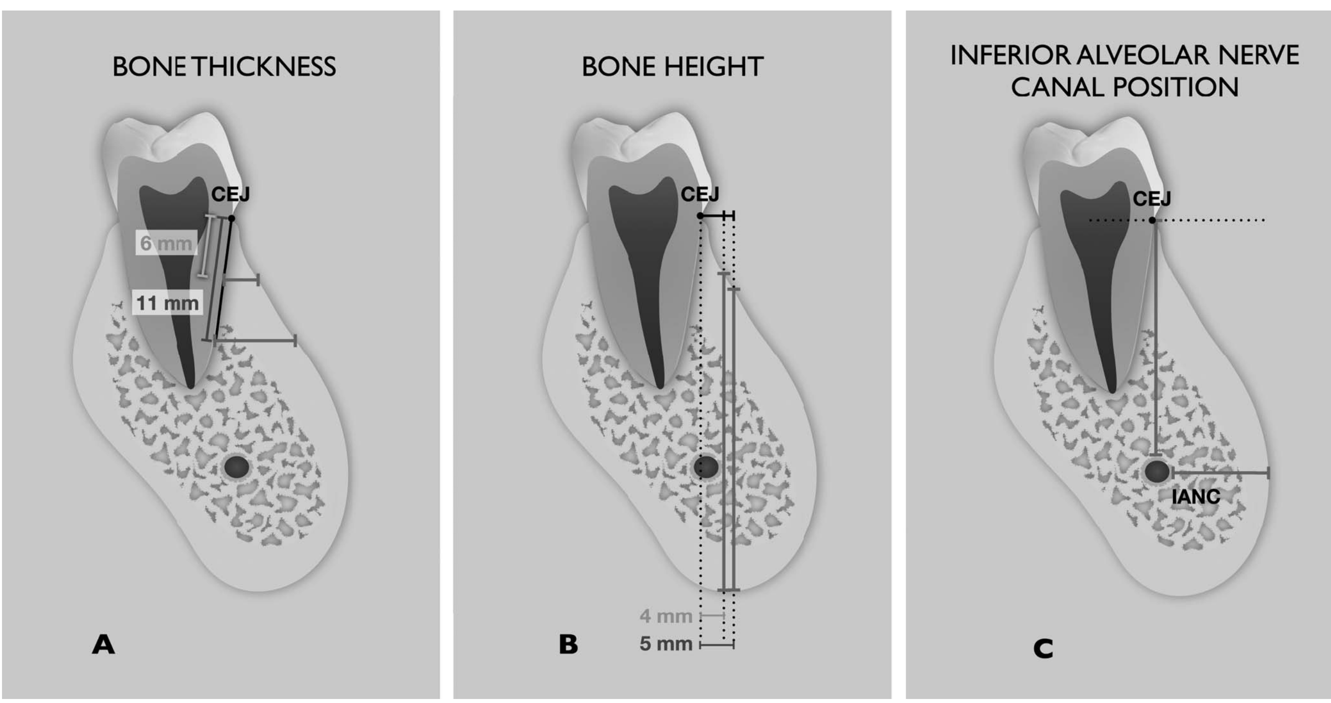

Figure 3. (A) Assessment of bone thickness at 6 mm and 11 mm from the CEJ. (B) Assessment of bone height at 4 mm and 5 mm from the CEJ. (C) Assessment of BTH to the IANC.

Table 2. Descriptive and Comparative Measures Among the Four Surfaces Evaluated in the Study by Bone Thickness (6 mm and 11 mm to the Cemeto-Enamel Junction)[a]

Assessment Point, mm	Tooth/Root	n	Descriptive Measures		P
			Mean ± SD	P_{50} (P_{25}–P_{75})	
6	M6	205	1.4 ± 0.6	1.4 (1.0–1.9)	<.001
	D6	205	2.1 ± 1.1	1.9 (1.4–2.6)	M6 < D6 < M7 < D7
	M7	205	3.2 ± 1.4	3.1 (2.2–4.0)	
	D7	205	5.0 ± 2.0	5.0 (3.5–6.2)	
11	M6	205	2.7 ± 1.0	2.7 (2.0–3.3)	<.001
	D6	205	3.4 ± 1.3	3.3 (2.6–4.2)	M6 < D6 < M7 < D7
	M7	205	5.1 ± 1.4	5.2 (4.1–5.9)	
	D7	205	6.2 ± 1.6	6.3 (4.9–7.3)	

[a] Database: 205 patients. SD indicates standard deviation; P, percentile (eg, P_{50} = 50th percentile); *P*, significance probability of analysis of variance based on a block model. Mean and SD values expressed in mm.

height of the BS was evaluated by tracing true vertical lines at 4 mm and 5 mm buccally to the CEJ,[12] which intercepted the external cortex of the mandible at two points. The distance between them was determined as the length of bone in the vertical direction (Figure 3B).

The spatial positioning of the IANC was also evaluated. The bone height was the shortest distance between a line passing through the highest point of the IANC to the true horizontal line that intercepted the CEJ (Figure 3C). The buccal bone thickness to the IANC was measured between a true horizontal line traced in the most buccal point of the IANC and the end of the buccal cortex (Figure 3C).

Statistical Analysis

Data were summarized by simple descriptive statistics. Mean, standard deviation, and percentage distributions were calculated for (1) hypodivergent, normodivergent, and hyperdivergent patients; (2) by age; and (3) for males and females. The examiner (VE) repeated the measurements for each of the outcomes after 14 days, resulting in an intraclass correlation coefficient range of 0.952 to 0.998 for intraexaminer evaluation. To evaluate the effect/influence of sex, age group, and vertical pattern on the mean of bone assessment parameters, analysis of variance was used based on a one-factor block design. To examine the normality of distribution and homogeneity, one-sample Kolmogorov-Smirnov and Levene tests were used, respectively. Software (SPSS 20.0 for Windows) was used for statistical analyses, and significance levels were set at $P < .05$.

RESULTS

Table 1 and Figure 1 show the group-specific mean and standard deviation of the subjects in their respective groups. The BS bone thickness showed a significant progressive increase ($P < .001$) in a posterior direction—M6 < D6 < M7 < D7 = 5.0–6.2 mm—in all age groups, in the three different vertical facial pattern groups, and in both sexes (Table 2; Figure 4). In the first molar region, older patients (those >40 years) had a lower bone thickness at 6 mm from the CEJ compared to the two younger groups ($P < .001$). The hypodivergent patients had greater bone thickness at 11 mm from the CEJ in the region of the first molar ($P < .01$). There were no differences between males and females with regard to bone thickness ($P > .05$).

The BS bone height showed a significant progressive increase ($P < .001$) in a posterior direction—M6 < D6 < M7 < D7 = 20–22 mm—in all age groups, in the three different vertical facial pattern groups, and in both sexes (Table 3; Figure 5). Women had a significantly lower BS bone height than did men ($P < .002$). Hypodivergent patients had greater bone height in the D6 root area ($P < .024$). There was no difference among the age groups, except in the 5-mm region of the D7 root, in which the youngest group had significantly lower values ($P < .003$).

Bone height to the IANC showed a significant progressive decrease in a posterior direction (M6 = D6 > M7 > D7 = 14.6 mm), in all age groups, in the three different vertical pattern groups, and in both sexes (Table 4; Figure 6). Female patients had significantly lower bone height to the IANC in all regions regardless of the group ($P < .01$). In addition, hyperdivergent patients showed significantly higher values in the M6 region when compared to hypodivergent and normodivergent patients ($P = .023$). In addition, 20–40-year-old patients had significantly greater distances in the M6, M7, and D6 regions when compared to other age groups ($P < .041$), regardless of sex and vertical facial pattern.

The bone thickness to the IANC showed a significant, progressive increase in a posterior direction, with M6 < D6 < M7 = D7 = 6.5 mm (Figure 6). Women

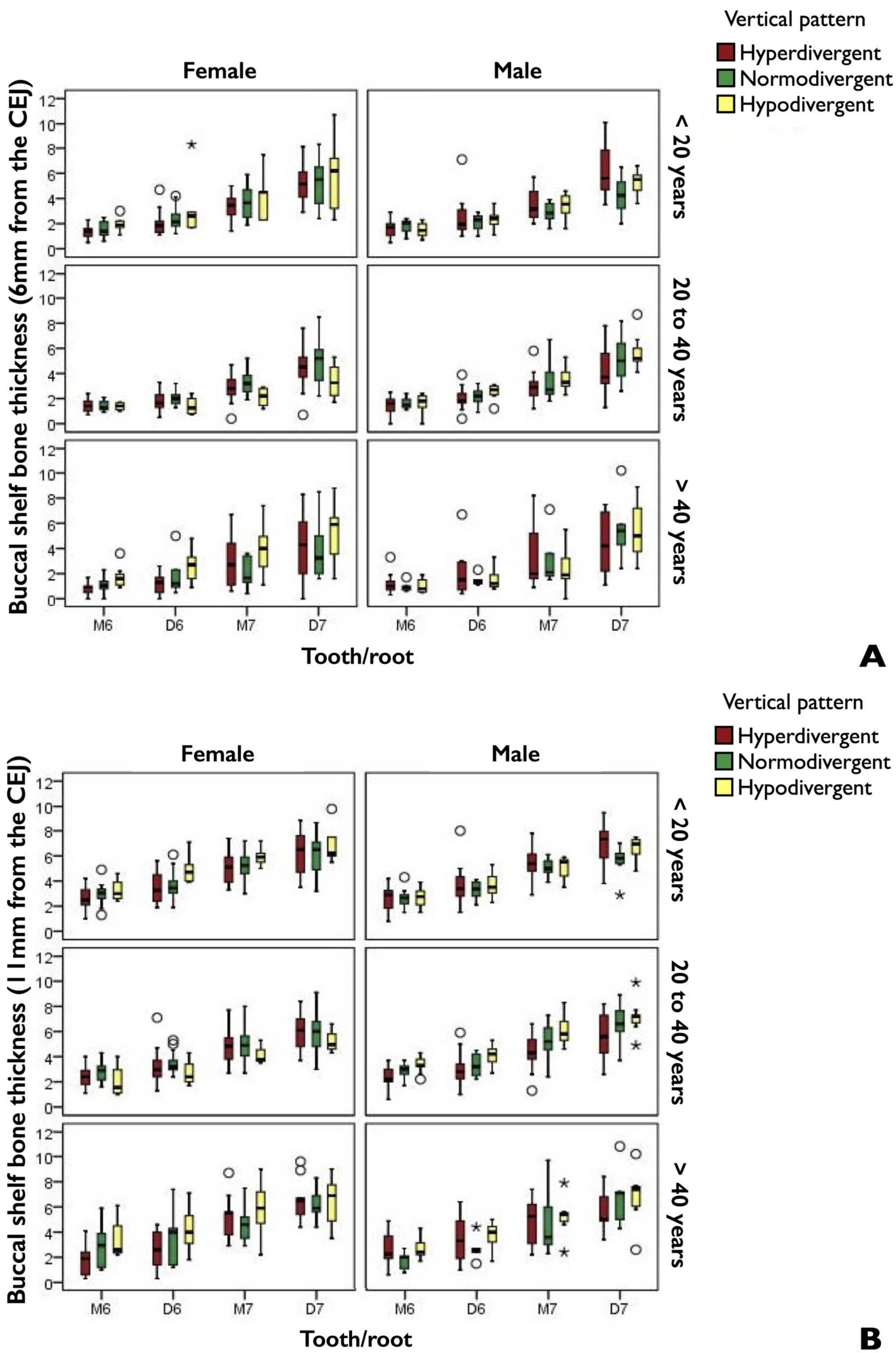

Figure 4. (A) Bone thickness at 6 mm from the CEJ. (B) Bone thickness at 11 mm from the CEJ.

Table 3. Descriptive and Comparative Measures Among the Four Surfaces Evaluated in the Study by BS Bone Height (4 mm and 5 mm to the Cemento-Enamel Junction)[a]

Assessment Point, mm	Tooth/Root	n	Descriptive Measures		*P*
			Mean ± SD	P_{50} (P_{25}–P_{75})	
4	M6	205	0.2 ± 0.5	0.0 (0.0–0.0)	<.001
	D6	205	1.2 ± 0.9	1.4 (0.0–1.9)	M6 < D6 < M7 < D7
	M7	205	1.5 ± 0.8	1.7 (1.2–2.0)	
	D7	205	2.2 ± 1.2	2.2 (2.0–2.4)	
5	M6	205	0.1 ± 0.4	0.0 (0.0–0.0)	<.001
	D6	205	0.8 ± 0.8	0.8 (0.0–1.6)	M6 < D6 < M7 < D7
	M7	205	1.2 ± 0.8	1.3 (0.0–1.8)	
	D7	205	2.0 ± 0.6	2.1 (1.8–2.4)	

[a] Database: 205 patients. SD indicates standard deviation; P, percentile (eg, $P_{50} = 50$th percentile); *P*, significance probability of analysis of variance based on a block model. Mean and SD values expressed in cm.

exhibited a smaller buccal bone thickness to the IANC (average 5.7 mm, vs 6.7 mm for men) in all regions ($P < .05$) (Table 4). No differences were found among age and vertical facial pattern groups ($P < .05$).

DISCUSSION

Knowledge of the anatomy and variability of the mandibular BS is of paramount importance for miniscrew insertion and survival. This study sought to analyze a possible association between vertical facial pattern, sex, and age and BS thickness and height. This was the first study to map the path of the inferior alveolar nerve in the BS, evaluating the BTH to the IANC, as well as to investigate possible differences due to vertical facial pattern, sex, and age. The results showed that the BTH progressively increased in a posterior direction, while the BTH to the IANC increased and decreased, for thickness and height, respectively, in the same direction in males and females in all age groups as well as in the three different vertical facial pattern groups.

Bone thickness is a determining factor for the primary stability of miniscrews, and thin bone is associated with a greater risk of failure.[16] This study revealed that alveolar bone thickness progressively increased distally ($P < .001$), regardless of sex, age, and facial pattern (Table 2), which was in agreement with the findings of previous studies.[9,15,17] The proximity of the second molar to the ramus and, consequently, the incidence of greater masticatory forces may be responsible for this greater bone dimension. Previous studies[8,9,12,15] have reported greater buccal bone thickness in hypodivergent patients, but small sample size decreases the statistical power and increases the chances of type II error in these studies. Another factor to be noted is that the bone thickness was measured only in one region of the root, without considering spatial changes of the inferior alveolar nerve. Others[9,15] did not assess the buccal bone thickness to the IANC. This study revealed that vertical facial pattern and age did not affect the region of the second molar, which is the region with the greatest bone thickness, which was in agreement with the findings of Arango et al.[17] It also showed that there was no difference between males and females, in agreement with the findings of previous studies.[4,15,17–19]

The bone height followed the same pattern as bone thickness, with a progressive increase distally ($P < .001$). D7 was the region with the highest bone level

Table 4. Descriptive and Comparative Measures Among Bone Heights and Bone Thicknesses Evaluated in the Study Relative to the Inferior Alveolar Nerve Canal[a]

Parameter	Tooth/Root	n	Descriptive Measures		*P*
			Mean ± SD	P_{50} (P_{25}–P_{75})	
Bone height	M6	205	16.8 ± 2.6	16.9 (15.4–18.4)	<.001
	D6	205	16.6 ± 2.3	16.5 (15.0–18.2)	(M6 = D6) > M7 > D7
	M7	205	15.0 ± 2.2	14.7 (13.6–16.3)	
	D7	205	14.6 ± 2.1	14.7 (13.2–16.2)	
Bone thickness	M6	205	5.3 ± 1.6	5.2 (4.4–6.1)	<.001
	D6	205	6.1 ± 1.5	6.1 (5.3–6.9)	M6 < D6 < (M7 = D7)
	M7	205	6.5 ± 1.6	6.6 (5.5–7.4)	
	D7	205	6.5 ± 1.7	6.4 (5.4–7.5)	

[a] Database: 205 patients. SD indicates standard deviation; P, percentile (eg, $P_{50} = 50$th percentile); *P*, significance probability of analysis of variance based on a block model. Mean and SD values expressed in mm.

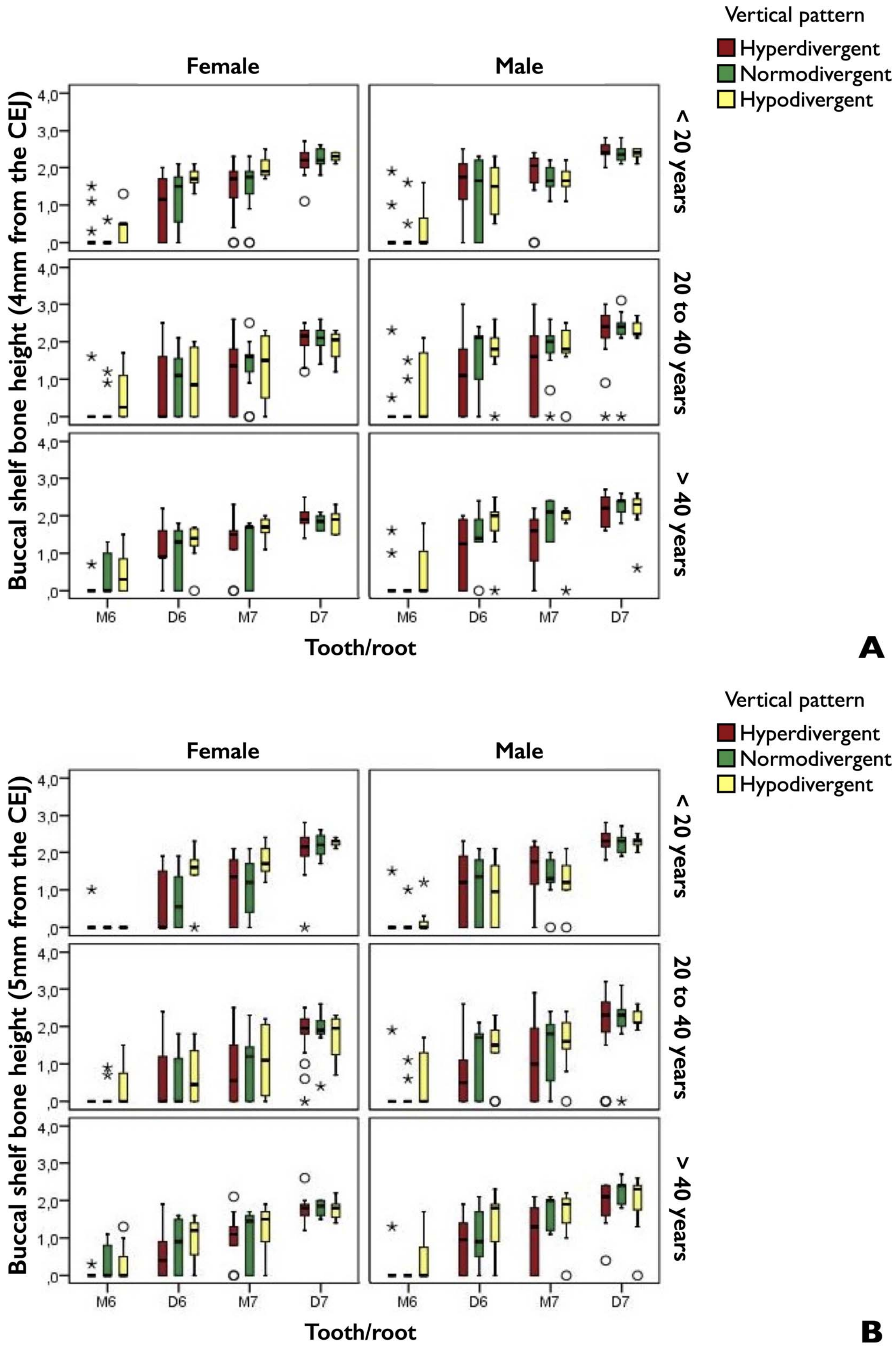

Figure 5. (A) Bone height at 4 mm from the CEJ. (B) Bone height at 5 mm from the CEJ.

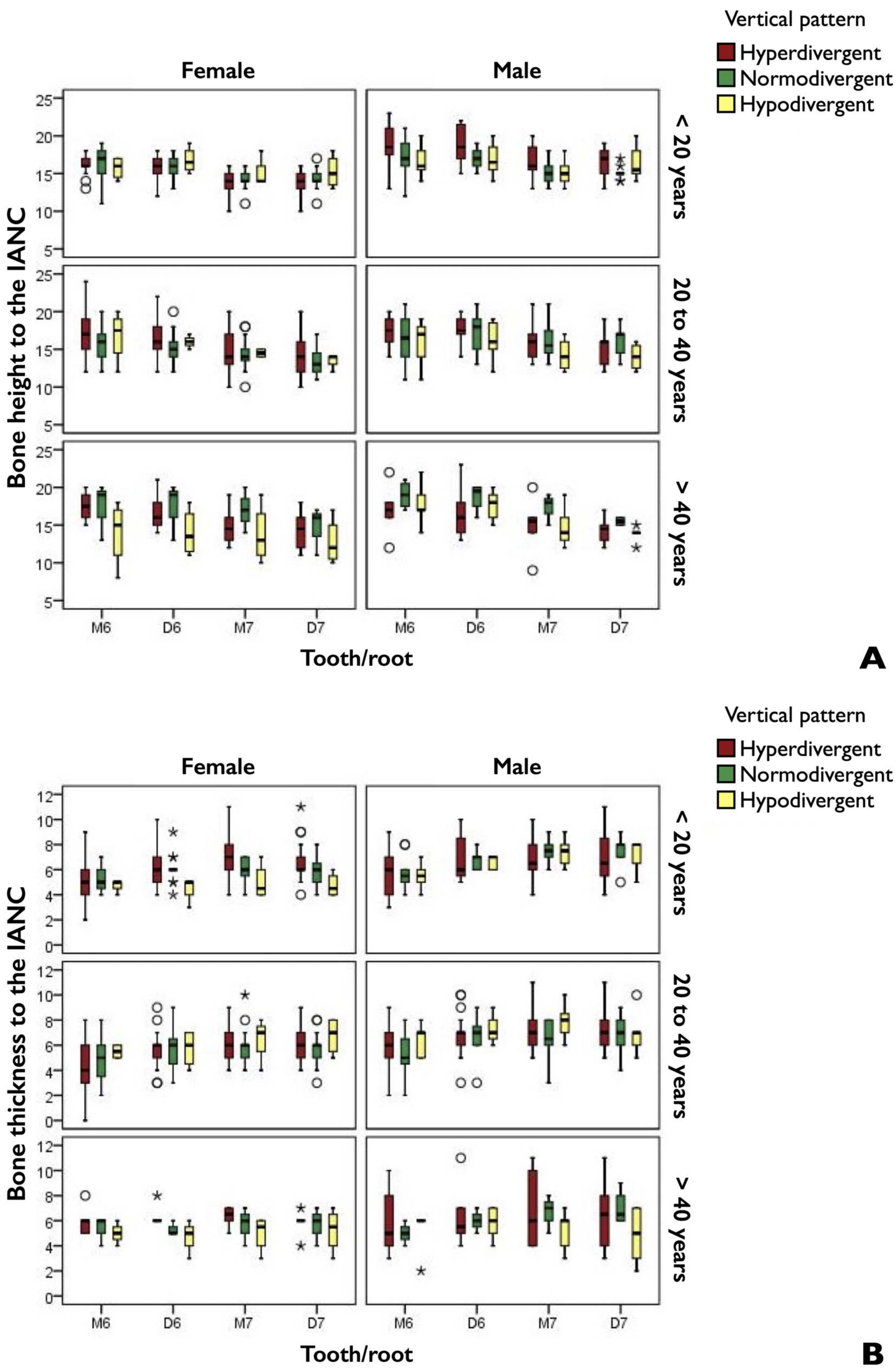

Figure 6. (A) Bone height to the IANC. (B) Bone thickness to the IANC.

(Table 3). These results contradicted the findings of Gandhi et al.,[9] who reported a gradual decrease in bone height toward the second molar. Although the authors claimed that they measured the height of the alveolar bone to the IANC, they used a line passing through the roof of the IANC and not the alveolar nerve itself, which, as shown in the current study, moves medially and may not interfere with miniscrew placement. This study also revealed that females had significantly lower alveolar height in all regions ($P < .002$), which was in agreement with previous studies.[18,19] No differences in bone height were found among vertical facial patterns in the second molar area. The current results also differed from those of previous studies[19,20] that reported greater posterior alveolar height in hypodivergent patients. These differences might be related to smaller samples, which increased the type II error, but they also might have been due to the different methodology used, since the authors measured the bone height from the alveolar crest. The youngest group had greater bone height in the 5-mm region of the D7 root, but this difference was not clinically significant.

The bone height to the IANC progressively decreased distally. However, the IANC progressively moves medially in the same direction, which can minimize the negative impact of the height reduction regardless of age, sex, and vertical pattern. The BTH to the IANC was significantly lower in females in all regions ($P < .05$), which was in agreement with the results of previous studies.[9,19,21] The bone height to the IANC was significantly higher in the hyperdivergent group only in the M6 region. This result was slightly different than the findings of Gandhi et al.,[9] who reported that bone height was greater in all of the BS in the hyperdivergent group. However, buccal bone thickness to the IANC was not assessed in that study, and the IANC may be lingually positioned and may not interfere with miniscrew insertion. The current results also contradicted those of previous studies[20,22] that reported that the posterior alveolar height was greater in hypodivergent subjects but that did not assess the location of the IANC. Oliveira et al.[23] reported that in hypodivergent and normodivergent patients, the IANC traveled along a path close to the root apices, while in hyperdivergent patients it was closer to the base of the mandible, with branches extending to the root apices. However, they did not evaluate the BTH to the IANC, reporting only whether the nerve was close to the roots or close to the mandibular base. Additionally, it was unclear how the authors oriented the jaws; inconsistencies in sample orientation could cause inconsistent measurements.

As the length of commercially available BS miniscrews varies between 10 and 14 mm, the height of the BS in the region of the D7 root (20–22 mm) seems to have the optimum BTH necessary for insertion. On average, the IANC was 6.5 mm from the buccal bone cortex and 15 mm from the CEJ, in agreement with Levine et al.[24] However, the individual variation was relatively high, as shown by the standard deviations, which suggests that three-dimensional images are very important for personalized planning in each case.

This study had some limitations. Bone density and periodontal soft tissue characteristics, both important factors for stability of miniscrews, were not evaluated. For proper selection of the insertion site, the soft tissue must be considered, because its mobility can affect long-term stability of the miniscrew.[9] Further studies should assess the influence of sagittal skeletal characteristics, different ethnicities, and clinical factors, such as the need for a pilot hole, gingival tissue thickness, and quality of life. Additionally, in this study, a 0.30-mm voxel size was used for imaging, but smaller dimensions can improve precision measurement of cortical bone thickness.

CONCLUSIONS

- The ideal location for BS miniscrew insertion is the buccal region of the distal root of the second molar, regardless of facial pattern, age, or sex.
- Bone thickness and height progressively increase distally, while the bone thickness and the bone height to the mandibular canal increase and decrease, respectively, in the same direction in all age groups, in the three different vertical facial pattern groups, and in both sexes.
- Buccal shelves in females have less bone thickness and height, with thinner bone and less bone height to the mandibular canal.

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