

Palatal height, thickness and density according to facial biotype in Peruvian adults: a tomographic study

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ABSTRACT

Micro-screw stability requires adequate bone quantity and quality. Micro-screws are often placed in the hard palate, in which anatomy may vary according to vertical growth. **Aim:** To compare the height, width and density of the palate according to facial biotype using cone beam computed tomography (CBCT). **Materials and Method:** Observational cross-sectional study on a sample of 39 CBCT scans of adults aged 18 to 50 years (19 females and 20 males) assigned to facial biotypes according to SN-GoGn. The height (mm), cortical width (mm) and density in Hounsfield units (HU) were measured at 20 coordinates on the left side of the palate coordinates corresponding to the combinations of four points medial to the suture (3, 5, 7 and 9 mm) and five points posterior to the incisive foramen (3, 6, 9, 12 and 15 mm). ANOVA and Kruskal-Wallis tests were used for statistical analysis at a significance level of $p < 0.05$. **Results:** Values were: hypodivergent (height: 2.16 - 6.32 mm; width: 1.61 - 2.02 mm; density: 1117.28 - 1182.83 HU), normodivergent (height: 2.71 - 9.21 mm; width: 1.67 - 2.08 mm; density: 1106.53 - 1177.86 HU) and hyperdivergent (height: 2.37 - 12.32 mm; width: 1.62 - 2.07 mm; density: 1088.2 - 1156.7 HU). Compared to hyperdivergent subjects, in hypodivergent individuals 60% of the measurement points had lower heights and 15% of measurement points showed thinner, denser cortices, with significant differences ($p < 0.05$). **Conclusion:** Facial biotypes were found to be associated with palate bone characteristics, with greater cortical heights and widths in hyperdivergent subjects and greater densities in hypodivergent subjects.

Keywords: hard palate - bone density - cortical bone - cone beam computed tomography

Altura, grosor, y densidad del paladar según biotipo facial en adultos peruanos: un estudio tomográfico

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RESUMEN

Los microtornillos necesitan disponer de un hueso adecuado en cantidad y calidad para su estabilidad. El paladar duro es un área de colocación común de microtornillos que podría tener variaciones anatómicas debido al crecimiento vertical. **Objetivo:** Comparar la altura, el grosor y la densidad del paladar según el biotipo facial mediante tomografías computarizadas cone beam (TCCB). **Materiales y Método:** Estudio observacional transversal realizado una muestra de 39 TCCB de adultos de 18 a 50 años (19 mujeres y 20 varones) distribuidos en biotipos faciales según SN-GoGn. La altura (mm), grosor cortical (mm) y densidad en unidades Hounsfield (UH) se midieron en 20 coordenadas del lado izquierdo del paladar correspondientes a las combinaciones de cuatro puntos mediales a la sutura palatina (3, 5, 7, y 9 mm) y cinco puntos posteriores al agujero incisivo (3, 6, 9, 12, y 15 mm). Pruebas de Anova y Kruskal-Wallis fueron usadas para el análisis estadístico de la data a un nivel de significancia de $p < 0,05$. **Resultados:** Los valores fueron: hipodivergente (altura: 2,16 - 6,32 mm; grosor: 1,61 - 2,02 mm; densidad: 1117,28 - 1182,83 UH), normodivergente (altura: 2,71 - 9,21 mm; grosor: 1,67 - 2,08 mm; densidad: 1106,53 - 1177,86 UH) e hiperdivergente (altura: 2,37 - 12,32 mm; grosor: 1,62 - 2,07 mm; densidad: 1088,2 - 1156,7 UH). Los hipodivergentes en comparación a los hiperdivergentes tuvieron un 60% de puntos de medición con alturas inferiores y un 15% de puntos de medición con corticales adelgazadas y mayor densidad, con diferencias significativas ($p < 0,05$). **Conclusión:** Los biotipos faciales se encontraron asociados a las características óseas del paladar mostrando mayores alturas y grosores corticales en hiperdivergentes y mayores densidades en hipodivergentes.

Palabras clave: paladar duro - densidad ósea - cortical ósea - tomografía computarizada de haz cónico.



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INTRODUCTION

Temporary anchorage devices (TADs) are absolute anchorage systems used in orthodontics and as an alternative to maxillofacial surgery. TADs are cost-effective and require little patient collaboration^{1,2}. Among others, the palatal region is frequently used for TAD insertion, with the paramedian and medial-anterior regions having the greatest potential due to the absence of critical neurovascular bundles³.

Maximum anchorage prevents the anchored teeth from moving⁴. Successful TAD placement in the palate to ensure primary stability depends largely on the amount of surrounding bone⁵. Therefore, before placing a TAD, it is essential to assess palatal morphology, including bone quantity and quality, in order to select the appropriate micro-screw diameter and length, and avoid the risk of penetrating and/or perforating any adjacent structures⁶.

To ensure micro-screw stability, a palate must have bone height $\geq 4\text{mm}$ ⁷, cortical width $\geq 1\text{mm}$ ⁸, and be sufficiently dense to prevent loosening^{9,10}. These characteristics may differ depending on measurement towards the midline or in the anteroposterior direction, as well as other characteristics such as patient ethnicity, gender and age^{11,12}. This leads to the need for further studies to determine the most adequate areas for TAD insertion in each population¹³.

Vertical facial growth is often evaluated for orthodontic purposes using cephalometric measurements^{10,11,14}, and is closely related to morphological changes related to genetics and childhood respiratory function, with cortical bone thickness varying among different facial biotypes¹⁵⁻¹⁷. Therefore, the type of vertical growth should be considered when planning a palatal TAD insertion procedure^{10,17}.

Six previous cone beam computed tomography (CBCT) studies from Brazil¹⁸, China¹⁹, Iran²⁰, Korea²¹, Peru²² and the United States²³ compared facial biotypes and palate bone characteristics, determining parameters of bone height^{18,19,22,23}, cortical width^{20,22} and bone density^{21,22}. Sexual dimorphism was observed, with greater palatal height in males¹⁸ and greater cortical width in females²¹. An association between facial biotype and palatal height^{19,22,23} and cortical width^{20,22} has also been found.

CBCTs are conventionally used in the orthodontic clinical setting and are useful for micro-screw

planning^{24,25}. The palatal bone needs to be evaluated in order to determine the safest areas for insertion. The purpose of this study was to compare the height, width and density of the palate according to facial biotype using CBCT in Peruvian individuals. The null hypothesis was that there are no differences in the measurements between the different biotypes.

MATERIALS AND METHOD

Study design and ethics

This was a cross-sectional, analytical study developed according to the STROBE checklist. It was approved by the Institutional Research Ethics Committee of the Universidad Científica del Sur (Lima-Peru) with registration No. 189-CIEI-CIENTÍFICA-2023.

Study sample

The sample consisted of CBCTs from 39 adults (19 females and 20 males) aged 18 to 50 years (mean age 37.38 ± 9.54), performed at a private radiology center in Lima between 2020 and 2022. Inclusion criteria were CBCT records of patients at maximum intercuspitation, without systemic disease, genetic or congenital malformations, or long-term medication that could affect bone metabolism. CBCTs of the upper jaws showing impacted teeth, dental implants, or signs of disjunction or expansion were excluded.

Scan selection

The data evaluated were from previous CBCT scans of patients acquired with AXR Eagle 3D equipment (Dabi Atlante, Brazil) at a UHD setting with 129 kv; 3.2–8 mA; voxel size 0.15 mm; field of view 9 cm x 9 cm; and exposure time 25 s. The CBCT images were transferred to Digital Imaging and Communication in Medicine (DICOM) format for viewing on a 14" monitor and Core i5 computer. Image segmentation was performed with OnDemand3D™ software without filters, using tools for brightness and contrast adjustment, and enlargement.

Groups according to facial biotype

The records of the selected images included patient sex and age. The facial biotype was assessed according to Steiner's vertical cephalometric measurements with respect to the mandibular plane angle (SN-GoGn), which resulted in an average

of 32.68 ± 4.05 . The sample was selected at convenience to include 13 individuals in each group of: normodivergent ($29^\circ - 36^\circ$), hypodivergent ($< 29^\circ$) and hyperdivergent ($> 36^\circ$)²⁶.

Pilot study and calibration

An orthodontic resident (MERR) received theoretical and practical training from a specialist in orthodontics (CITF) and calibration from an expert radiologist with more than five years' professional experience in the specialty (National Registry of Specialists N°199) for software handling and palate measurement. From a pilot study on 12 CBCTs (excluded sample), we determined intra-examiner (two weeks post-revision) and inter-examiner calibration statistics with the intraclass correlation coefficient (ICC), which were excellent for measurements of palate height (ICC: intra-examiner ≥ 0.999 ; inter-examiner ≥ 0.989), cortical width (ICC: intra-examiner ≥ 0.998 ; inter-examiner ≥ 0.763), and density (ICC: intra-examiner ≥ 0.985 ; inter-examiner ≥ 0.982).

Palatal height, width and density

All images were evaluated by the calibrated observer, who made up to six CBCT observations per day on frontal, sagittal and coronal slices. The

height (H), width (W) and density (D) values of 20 measurement points were measured. These points were established according to the anatomical structures: incisive foramen (IF), and posterior and anterior nasal spine. Palatal height was plotted between the lower and upper part of the hard palate vault (Fig. 1A). The cortical width of the palate considered only the lower area of the hard palate as the area responsible for primary stability (Fig. 1B). Palate density was measured according to the attenuation seen with the Hounsfield units (HU) indicated by the software (Fig. 1C).

Measurement points

The initial point was located on the palatal bone adjacent to the IF, from which a perpendicular line was drawn to the horizontal plane passing through the median suture to the posterior nasal spine. A total 20 measurement points were plotted on a 4 x 5 grid on the left side of the middle of the hard palate. The intervals were marked lateral to the palatine raphe (PR) at 3, 5, 7 and 9 mm medial (M) (Fig. 1D) and at the back of the IF at 3, 6-, 9-, 12- and 15-mm posterior (P) (Fig. 1E).

Statistical analysis

Descriptive statistics included mean and standard

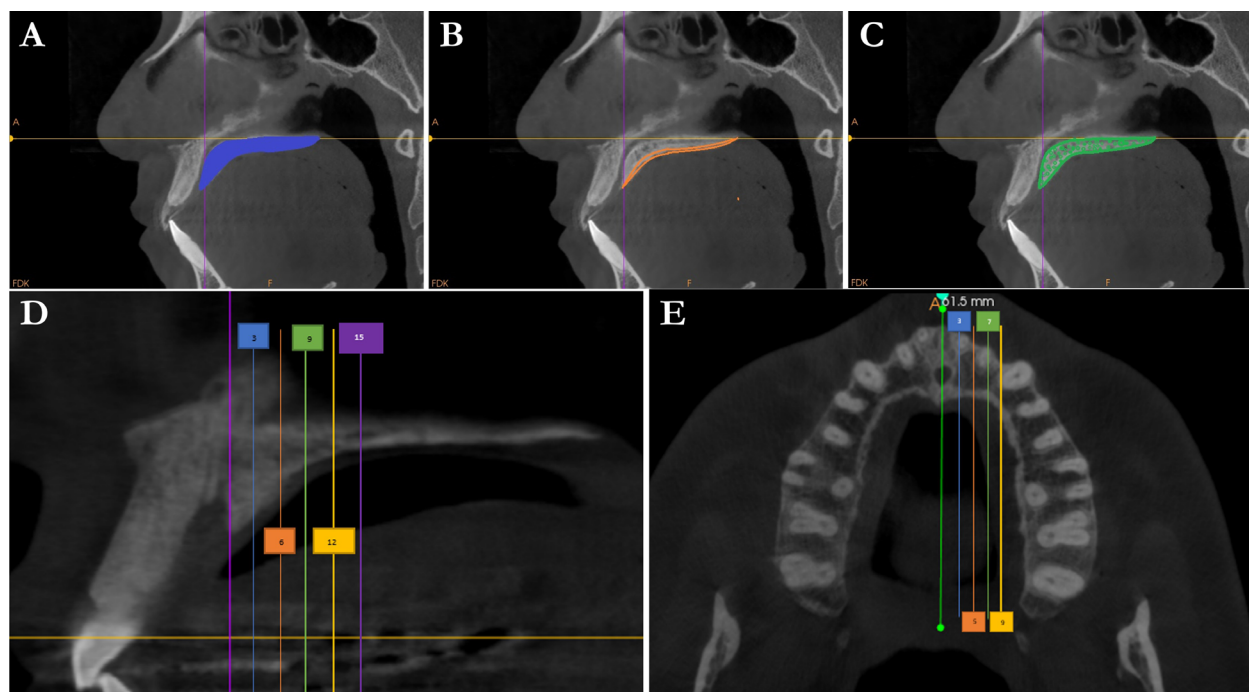


Fig. 1. Evaluation of the palatal bone in CBCT: A) height, B) cortical thickness, and C) density at the measurement points in D) cross-sectional view at 3, 6, 9, 12, and 15 mm, and E) sagittal view at 3, 5, 7, and 9 mm.

deviation (SD). Inferential ANOVA tests with Tukey's post-hoc analysis, Student's t-test for independent samples and Pearson's correlation were used when normal distribution was corroborated with the Shapiro-Wilk test. In case of non-normality, data were analyzed with the Kruskal-Wallis and Mann-Whitney U tests. Correlation was assessed as: very low (0 – 0.2), low (> 0.2 – 0.4), moderate (> 0.4 – 0.6), high (> 0.6 – 0.8) or very high (> 0.8 – 1). IBM SPSS statistical software v.26 (IBM Chicago INC) was used considering a significance level of $p < 0.05$.

RESULTS

A total 2340 measurements were taken of three palatal bone characteristics (height, cortical width and density) at 20 coordinates (combinations of four medial points and five posterior points) on CBCT images of 39 patients (13 for each facial biotype). The overall mean palate height was 5.64 ± 3.00 mm (range: 2.41 to 10.27 mm) (Table 1), palate cortical width was 2.00 ± 0.00 mm (range: 1.64 to 2.06 mm) (Table 2) and palate density was 1153.64 ± 32.13 HU (range: 1122.01 to 1158.78 HU) (Table 3).

Medial measurement of palatal height was $M3 > M5 < M7 < M9$ and in posterior measurement it was $P3 > P6 > P9 > P12 > P15$. Greater heights were found in M3/9 in P3 (8.91 to 10.27 mm), while values < 6 mm were found in M5/7 in P6/9/12/15 and M3/9 in P9/12/15 (2.41 to 5.70 mm). Height was not associated with sex or age in 90% of MP ($p < 0.05$), but a significant high positive correlation with SN-GoGn ($r = 0.607$ to 0.830 ; $p < 0.05$) was found in 70% of MP (M3/M5 at P3/6 and M7P3). The hypodivergent biotype had significantly lower heights ($p < 0.05$) compared to the hyperdivergent in 60% of MP (M3/5/7 in P3/6/9 and M9 in P6/9/12) and to the normodivergent in 40% of MP (M3P3, M5/7 in P3/6/9 and M9P6) (Table 1).

Palatal bone cortical width decreased consecutively towards the lateral and posterior areas. The cortical bone was thickest at M3P3 (2.06 ± 0.10 mm) and thinnest at M9P15 (1.64 ± 0.15 mm). Width was not associated with sex and age in $\geq 90\%$ of the MP ($p < 0.05$), but was low-moderately positively correlated with SN-GoGn ($r = 0.324$ to 0.459 ; $p < 0.05$) in 30% of the MP (M3 in P3/6/12/15 and M5 in P3/9). The hyperdivergent biotype had significantly ($p < 0.05$) greater cortical width than the hypodivergent biotype at M3P15 and M5 at P3/15 and the normodivergent

biotype at M3P15 and M9P6 (Table 2).

Palate density decreased in medial to lateral direction and in the posterior direction at P15. Density was highest at M9P12 and M3P3 (1172.46 and 1158.78 HU, respectively) and lowest at M9P15 (1122.01 HU). Density was not related to sex or age in 90% of MP ($p < 0.05$) but correlated negatively low/highly significant with SN-GoGn ($r = -0.607$ to -0.337 ; $p < 0.05$) in 20% of the MP (M3/5 in P3 and M3P6). The hyperdivergent biotype had lower densities ($p < 0.05$) than the hypodivergent biotype at M3/5 in P3 and the normodivergent biotype at M3/5/9 in P3 (Table 3).

Figure 2 shows the comparison of biotypes according to heights (Fig. 2A), thicknesses (Fig. 2B), and densities (Fig. 2C) in the anterior-medial (M3P3 to M5P6), anterior-lateral (M7P3 to M9P6), middle-medial (M3P9 to M5P15), and middle-lateral (M7P9 to M9P15) areas of the palatal bone. The heights in all palatal areas and the thicknesses in the medial palate area were significantly greater in hyperdivergent (height: 4.27 - 9.86 mm, thickness: 1.89 - 1.99 mm) compared to hypodivergent (height: 2.91 - 6.23 mm, thickness: 1.82-1.91 mm) individuals ($p < 0.001$ and $p \leq 0.006$, respectively). Densities in the medial and medio-lateral areas of the palate were significantly higher in hypodivergents (1143.04 - 1159.23 HU) compared to hyperdivergents (1119.0 - 1135.44 HU) ($p \leq 0.049$).

DISCUSSION

Treatment using micro-screws has an adequate cost-benefit ratio¹⁻³. The palate is an area of interest for micro-screw insertion, although factors related to primary stability need to be studied¹⁰⁻¹². Facial biotype is a biological factor related to bone growth and development, and could influence the decision-making process for deciding on the best placement site or selecting micro-screw length^{4,27}. The results of this study show that palate bone characteristics are associated with facial biotype but not related to sex.

In the present study, palatal height correlated positively with SN-GoGn in 70% of the MP, with greater heights observed in hyperdivergent compared to hypodivergent subjects. This agrees with a previous study on posterior palate in American subjects²², but differs from studies on Chinese¹⁹ and Peruvians subjects²², in which hypodivergent patients had higher anterior^{19,23} or posterior^{19,22} palate

Table 1. Palatal height at the different measurement points (mm) according to age, sex, and facial biotype.

Parameter	Total	Age†	Male	Female	<i>p</i> value‡	SN- GoGn†	Hypodivergent	Normodivergent	Hyperdivergent	<i>p</i> value¥
	Mean ± SD	rho (p value)	Mean ± SD	Mean ± SD		rho (p value)	Mean ± SD	Mean ± SD	Mean ± SD	
M3P3	8.91 ± 3.04	-0.016 (0.923)	9.24 ± 3.25	8.55 ± 2.85	0.488	0.830 (<0.001)*	5.62 ± 1.61c	8.77 ± 1.21b	12.32 ± 0.96a	<0.001*
M3P6	6.69 ± 2.73	-.095 (0.566)	7.01 ± 2.94	6.35 ± 2.53	0.652	0.623 (<0.001)*	4.46 ± 1.68b	6.38 ± 1.28ab	9.22 ± 2.59a	<0.001*
M3P9	4.97 ± 2.11	-0.149 (0.365)	5.04 ± 2.53	4.89 ± 1.61	0.632	0.495 (0.001)*	3.57 ± 1.59b	4.56 ± 1.62ab	6.59 ± 2.06a	0.002*
M3P12	4.11 ± 1.85	-0.248 (0.128)	4.09 ± 2.28	4.14 ± 1.33	0.938	0.264 (0.105)	3.65 ± 1.53	3.59 ± 1.67	5.10 ± 2.03	0.059
M3P15	3.73 ± 1.51	-0.184 (0.262)	3.50 ± 1.82	3.96 ± 1.10	0.341	0.193 (0.239)	3.45 ± 1.65	3.62 ± 1.49	4.11 ± 1.42	0.417
M5P3	8.24 ± 2.93	0.149 (0.367)	8.39 ± 2.84	8.09 ± 3.08	0.761	0.748 (<0.001)*	5.25 ± 2.31C	8.53 ± 1.20B	10.95 ± 1.60A	<0.001*
M5P6	5.44 ± 1.99	0.025 (0.878)	5.72 ± 2.25	5.15 ± 1.68	0.380	0.607 (<0.001)*	3.55 ± 1.18B	5.85 ± 1.33A	6.93 ± 1.69A	<0.001*
M5P9	3.75 ± 1.35	-0.142 (0.388)	4.04 ± 1.52	3.45 ± 1.09	0.366	0.392 (0.014)*	2.78 ± 0.71b	4.28 ± 1.13a	4.20 ± 1.55a	0.001*
M5P12	2.93 ± 1.19	-0.391 (0.014)*	3.05 ± 1.40	2.81 ± 0.93	0.536	0.024 (0.883)	2.56 ± 0.62	3.34 ± 1.16	2.90 ± 1.55	0.085
M5P15	2.64 ± 1.22	-0.199 (0.225)	2.57 ± 1.55	2.72 ± 0.79	0.194	0.096 (0.563)	2.34 ± 1.09	2.89 ± 1.07	2.70 ± 1.50	0.480
M7P3	8.86 ± 2.85	0.139 (0.399)	9.06 ± 3.38	8.64 ± 2.24	0.642	0.627 (<0.001)*	6.32 ± 1.96b	9.21 ± 2.63a	11.05 ± 1.64a	<0.001*
M7P6	5.70 ± 1.71	0.177 (0.281)	5.85 ± 1.91	5.55 ± 1.51	0.594	0.482 (0.002)*	4.26 ± 1.38b	6.30 ± 1.16a	6.54 ± 1.62a	<0.001*
M7P9	3.84 ± 1.29	-0.039 (0.813)	3.84 ± 1.45	3.85 ± 1.13	0.986	0.400 (0.012)*	2.93 ± 0.78B	4.20 ± 1.18A	4.40 ± 1.36A	0.004*
M712	2.88 ± 1.10	-0.330 (0.040)*	3.01 ± 1.29	2.75 ± 0.88	0.390	0.097 (0.555)	2.52 ± 0.62	3.01 ± 1.05	3.13 ± 1.36	0.306
M7P15	2.41 ± 1.07	-0.086 (0.604)	2.42 ± 1.28	2.41 ± 0.82	0.413	0.019 (0.907)	2.16 ± 0.92	2.71 ± 1.00	2.37 ± 1.26	0.283
M9P3	10.27 ± 3.44	0.191 (0.243)	9.66 ± 4.44	10.92 ± 1.81	0.517	0.434 (0.006)*	8.62 ± 3.24	10.78 ± 4.31	11.42 ± 1.92	0.091
M9P6	7.45 ± 2.43	0.165 (0.315)	7.42 ± 2.94	7.47 ± 1.82	0.800	0.510 (0.001)*	5.70 ± 2.15B	7.92 ± 1.98A	8.72 ± 2.08A	0.002*
M9P9	5.12 ± 1.98	0.050 (0.762)	5.25 ± 2.45	4.97 ± 1.37	0.593	0.430 (0.006)*	3.87 ± 1.50B	5.36 ± 1.96AB	6.12 ± 1.86A	0.009*
M9P12	4.19 ± 1.79	0.009 (0.956)	4.30 ± 2.17	4.08 ± 1.33	0.712	0.387 (0.015)*	3.12 ± 0.97B	5.28 ± 1.61AB	5.18 ± 2.08A	0.010*
M9P15	3.78 ± 1.91	-0.039 (0.812)	3.96 ± 2.53	3.59 ± 0.92	0.546	0.350 (0.029)*	2.85 ± 1.15	3.98 ± 1.98	4.51 ± 2.18	0.075

SD: standard deviation. †Pearson Correlation Test. ‡Independent samples Student's T-test or Mann-Whitney U test. ¥ ANOVA test with Tukey post-hoc or Kruskal-Wallis test. **p* < 0.05

heights close to the PR compared to other biotypes, while another study on Brazilian subjects¹⁸ found no differences. The measurement of heights in distant areas using the perpendicular to the palatal plane as a reference may not be representative due to the domed shape of the palate^{4,27}.

The insertion of mini-screws requires a palatal

height of ≥ 4 mm⁷. In this study, this required palatal height was observed from anterolateral up to 9 mm posterolateral in hyperdivergent (4.2 - 12.3 mm) and normodivergent subjects (4.2 - 10.8 mm) and up to 6 mm posterolateral (except M5P6) in hypodivergent subjects (4.3 - 8.6 mm). Clinical comparison with previous studies showed similar results in

Table 2. Palatal cortical thickness (mm) at the different measurement points according to age, sex, and facial biotype.

Parameter	Total Mean ± SD	Age† r (p valor)	Male Mean ± SD	Female Mean ± SD	p value‡	SN-GoGn† r (p value)	Hypodivergent Mean ± SD	Normodivergent Mean ± SD	Hyperdivergent Mean ± SD	p value¥
M3P3	2.06 ± 0.10	0.155 (0.346)	2.06 ± 0.12	2.05 ± 0.04	0.042*	0.367 (0.021)*	2.02 ± 0.04	2.08 ± 0.13	2.07 ± 0.08	0.076
M3P6	1.96 ± 0.10	-0.110 (0.504)	1.95 ± 0.11	1.97 ± 0.09	0.209	0.324 (0.044)*	1.94 ± 0.09	1.95 ± 0.09	1.99 ± 0.11	0.117
M3P9	1.95 ± 0.08	-0.095 (0.566)	1.95 ± 0.09	1.95 ± 0.08	0.868	0.273 (0.093)	1.93 ± 0.06	1.94 ± 0.10	1.98 ± 0.09	0.093
M3P12	1.89 ± 0.09	-0.119 (0.469)	1.88 ± 0.10	1.91 ± 0.08	0.360	0.444 (0.005)*	1.86 ± 0.06	1.88 ± 0.11	1.94 ± 0.08	0.052
M3P15	1.85 ± 0.09	-0.078 (0.635)	1.84 ± 0.09	1.87 ± 0.08	0.253	0.394 (0.013)*	1.82 ± 0.05b	1.81 ± 0.07b	1.91 ± 0.10a	0.005*
M5P3	1.90 ± 0.13	-0.119 (0.471)	1.90 ± 0.13	1.91 ± 0.14	0.774	0.459 (0.003)*	1.82 ± 0.13b	1.89 ± 0.10ab	1.99 ± 0.12a	0.007*
M5P6	1.88 ± 0.12	-0.317 (0.049)*	1.89 ± 0.11	1.86 ± 0.12	0.181	0.023 (0.888)	1.86 ± 0.13	1.86 ± 0.09	1.90 ± 0.13	0.774
M5P9	1.84 ± 0.11	-0.165 (0.315)	1.84 ± 0.12	1.85 ± 0.09	0.892	0.374 (0.019)*	1.80 ± 0.14	1.85 ± 0.08	1.88 ± 0.08	0.054
M5P12	1.83 ± 0.12	0.125 (0.448)	1.83 ± 0.14	1.82 ± 0.10	0.582	0.298 (0.066)	1.77 ± 0.14	1.84 ± 0.06	1.87 ± 0.13	0.109
M5P15	1.79 ± 0.08	0.141 (0.392)	1.78 ± 0.09	1.79 ± 0.07	0.556	0.013 (0.937)	1.75 ± 0.10B	1.83 ± 0.08A	1.78 ± 0.05AB	0.044*
M7P3	1.84 ± 0.10	-0.161 (0.328)	1.86 ± 0.10	1.81 ± 0.09	0.330	-0.076 (0.645)	1.85 ± 0.10	1.85 ± 0.11	1.82 ± 0.08	0.941
M7P6	1.79 ± 0.11	0.186 (0.258)	1.81 ± 0.09	1.76 ± 0.13	0.414	-0.266 (0.102)	1.83 ± 0.10	1.78 ± 0.12	1.75 ± 0.10	0.201
M7P9	1.74 ± 0.12	0.280 (0.084)	1.79 ± 0.11	1.69 ± 0.10	0.030*	-0.198 (0.226)	1.76 ± 0.14	1.75 ± 0.09	1.71 ± 0.11	0.520
M7P12	1.73 ± 0.09	0.206 (0.209)	1.74 ± 0.10	1.72 ± 0.07	0.398	-0.251 (0.123)	1.74 ± 0.12	1.74 ± 0.07	1.71 ± 0.06	0.550
M7P15	1.70 ± 0.09	-0.129 (0.435)	1.73 ± 0.07	1.68 ± 0.10	0.220	-0.169 (0.305)	1.72 ± 0.10	1.69 ± 0.08	1.70 ± 0.08	0.396
M9P3	1.86 ± 0.12	-0.214 (0.191)	1.87 ± 0.13	1.85 ± 0.12	0.630	-0.044 (0.793)	1.87 ± 0.13	1.83 ± 0.11	1.89 ± 0.13	0.369
M9P6	1.75 ± 0.07	-0.175 (0.286)	1.75 ± 0.05	1.74 ± 0.08	0.282	0.005 (0.977)	1.75 ± 0.06ab	1.71 ± 0.05b	1.78 ± 0.07a	0.033*
M9P9	1.69 ± 0.09	-0.096 (0.561)	1.70 ± 0.07	1.67 ± 0.11	0.227	0.132 (0.422)	1.68 ± 0.08	1.70 ± 0.08	1.68 ± 0.11	0.863
M9P12	1.70 ± 0.06	-0.167 (0.311)	1.71 ± 0.06	1.69 ± 0.07	0.398	-0.214 (0.192)	1.71 ± 0.05	1.71 ± 0.06	1.67 ± 0.07	0.157
M9P15	1.64 ± 0.15	0.148 (0.370)	1.66 ± 0.09	1.61 ± 0.19	0.683	0.140 (0.395)	1.61 ± 0.12	1.67 ± 0.10	1.62 ± 0.21	0.678

SD: standard deviation. †Pearson Correlation Test. ‡Independent samples Student's T-test or Mann-Whitney U test. ¥ ANOVA test with Tukey post-hoc or Kruskal-Wallis test. *p < 0.05

hyperdivergent individuals (China¹⁹: 4.4 - 7.5 mm; Peru²²: 7 - 12 mm; Brazil¹⁸: 6.2 - 12.8 mm), but with variations with respect to normodivergent (≈China¹⁹: 4.9 - 8.6 mm; ≈Peru²²: 5.8 - 10.1 mm; ↑Brazil¹⁸: 6.8 - 13 mm) and hypodivergent subjects (≈China¹⁹: 4.8 - 9.4 mm; ↑Peru²²: 8 - 11.8 mm; ↑Brazil¹⁸: 6.5 -

12 mm). It was of note that, as in the present study, some of the previous studies^{19,22} did not control for open bite, which according to studies from Brazil¹⁸ and Thailand²⁷, influences palatal height, possibly due to a dentoalveolar compensatory effect in the long-face pattern⁴.

Table 3. Palatal density (HU) at the different measurement points according to age, sex, and facial biotype.

Parameter	Total	Age†	Male	Female	p value‡	SN-GoGn†	Hypodivergent	Normodivergent	Hyperdivergent	p value¥
	Mean ± SD	r (p value)	Mean ± SD	Mean ± SD		r (p value)	Mean ± SD	Mean ± SD	Mean ± SD	
M3P3	1158.78 ± 64.17	0.337 (0.036)*	1162.15 ± 62.72	1155.22 ± 67.19	0.741	-0.337 (0.036)*	1182.01 ± 83.85	1148.41 ± 58.78	1145.91 ± 40.92	0.193
M3P6	1130.02 ± 55.75	0.025 (0.881)	1136.17 ± 40.97	1123.54 ± 68.58	0.725	-0.607 (<0.001)*	1164.13 ± 36.87A	1137.72 ± 58.52A	1088.20 ± 42.89B	0.001*
M3P9	1143.57 ± 67.13	0.257 (0.114)	1125.30 ± 66.65	1162.81 ± 63.74	0.081	-0.158 (0.336)	1160.78 ± 55.73	1127.40 ± 90.27	1142.53 ± 49.10	0.533
M3P12	1126.13 ± 52.47	0.015 (0.929)	1111.03 ± 62.21	1142.03 ± 34.73	0.063	-0.269 (0.098)	1145.16 ± 47.63	1112.88 ± 58.49	1120.36 ± 49.09	0.266
M3P15	1145.63 ± 48.96	0.276 (0.089)	1132.64 ± 49.66	1159.30 ± 45.52	0.014	-0.029 (0.860)	1137.12 ± 46.80	1160.63 ± 42.95	1139.13 ± 56.45	0.405
M5P3	1138.69 ± 51.94	-0.064 (0.698)	1128.29 ± 42.45	1149.65 ± 59.56	0.203	-0.377 (0.018)*	1151.03 ± 43.73a	1163.65 ± 37.95a	1101.40 ± 53.34b	0.005*
M5P6	1141.84 ± 44.20	0.172 (0.295)	1137.16 ± 47.46	1146.76 ± 41.18	0.877	-0.048 (0.772)	1139.77 ± 39.14	1145.25 ± 57.38	1140.49 ± 36.62	0.945
M5P9	1135.06 ± 48.54	0.139 (0.400)	1126.52 ± 52.27	1144.06 ± 43.86	0.265	0.004 (0.980)	1117.46 ± 42.25B	1162.05 ± 50.62A	1125.68 ± 43.53AB	0.040*
M5P12	1132.86 ± 65.03	-0.114 (0.489)	1121.62 ± 57.50	1144.69 ± 71.76	0.332	-0.278 (0.086)	1161.79 ± 67.74	1135.35 ± 62.32	1101.43 ± 54.17	0.056
M5P15	1129.96 ± 62.63	-0.158 (0.336)	1134.08 ± 71.73	1125.61 ± 53.02	0.704	-0.126 (0.444)	1135.96 ± 74.25	1134.78 ± 69.23	1119.14 ± 43.87	0.538
M7P3	1133.99 ± 55.53	-0.104 (0.530)	1139.36 ± 53.55	1128.34 ± 58.45	0.543	-0.024 (0.883)	1122.00 ± 56.54	1135.56 ± 50.14	1144.41 ± 61.46	0.891
M7P6	1134.15 ± 39.95	0.211 (0.196)	1139.41 ± 41.92	1128.62 ± 38.09	0.406	0.080 (0.630)	1135.80 ± 36.68	1119.55 ± 37.16	1147.10 ± 43.73	0.213
M7P9	1146.45 ± 54.46	-0.231 (0.158)	1151.94 ± 63.65	1140.67 ± 43.78	0.482	-0.265 (0.103)	1164.12 ± 65.57	1126.40 ± 51.50	1148.82 ± 40.61	0.210
M7P12	1136.37 ± 49.32	-0.394 (0.013)*	1134.49 ± 50.12	1138.34 ± 49.76	0.978	-0.155 (0.348)	1142.11 ± 29.86	1131.24 ± 57.48	1135.74 ± 58.68	0.349
M7P15	1132.23 ± 51.09	0.109 (0.510)	1135.08 ± 47.08	1129.22 ± 56.14	0.725	-0.077 (0.641)	1137.29 ± 49.92	1120.62 ± 63.26	1138.77 ± 39.38	0.615
M9P3	1128.38 ± 59.73	-0.055 (0.741)	1108.97 ± 52.86	1148.81 ± 61.03	0.099	-0.103 (0.532)	1117.28 ± 44.96ab	1172.74 ± 58.19a	1095.12 ± 49.28b	0.010*
M9P6	1127.87 ± 50.82	0.071 (0.669)	1127.56 ± 62.68	1128.20 ± 36.12	0.969	-0.213 (0.193)	1133.12 ± 40.05	1139.79 ± 44.04	1110.71 ± 64.28	0.245
M9P9	1128.39 ± 45.73	0.002 (0.990)	1122.55 ± 31.30	1134.54 ± 57.46	0.421	-0.030 (0.858)	1124.35 ± 55.19	1139.35 ± 47.10	1121.47 ± 34.01	0.576
M912	1172.46 ± 52.30	-0.140 (0.395)	1158.54 ± 48.10	1187.12 ± 53.76	0.088	-0.177 (0.280)	1182.83 ± 50.18	1177.86 ± 57.05	1156.70 ± 49.72	0.411
M9P15	1122.01 ± 48.26	-0.173 (0.292)	1131.66 ± 37.23	1111.85 ± 56.94	0.054	-0.316 (0.050)*	1148.37 ± 35.28	1106.53 ± 44.99	1111.13 ± 54.47	0.050

SD: standard deviation. †Pearson Correlation Test. ‡Independent samples Student's T-test or Mann-Whitney U test. ¥ANOVA test with Tukey post-hoc or Kruskal-Wallis test. *p < 0.05

In the current study, palatal cortical width correlated positively with SN-GoGn in 30% of the MP with greater width in hyperdivergent compared to hypodivergent subjects. This result contradicts findings by Iranian²⁰ and Peruvian studies²² in which the width was greater in hypodivergent > hyperdivergent > normodivergent subjects in lateral

areas close to the PR. Our study supports differences with the previous studies in the mapping of palate measurement towards the posterior of the IF, which showed greater distance in mm between each lateral and posterior MP (4 - 3 - 4, respectively)^{20,22}, as opposed to the present study (3 - 2 - 3, respectively). Cortical widths ≥1 mm, which provide better

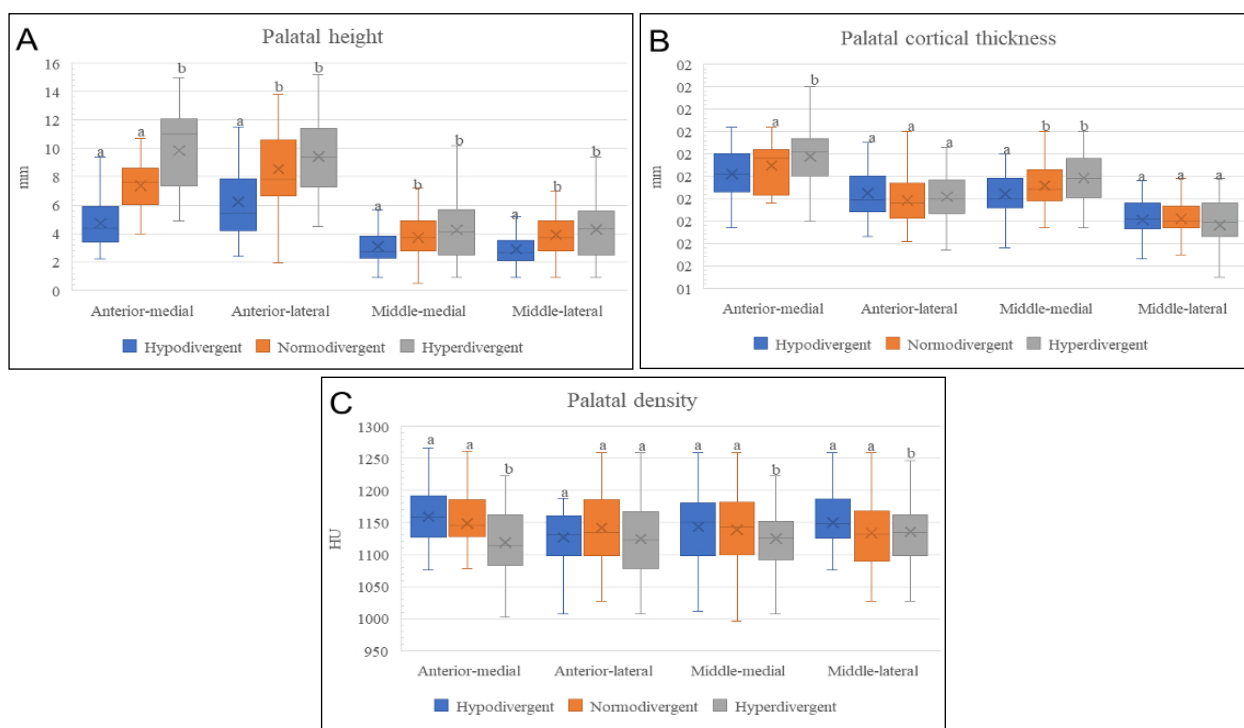


Fig. 2. Comparison of the palatal bone areas for: A) height, B) cortical thickness and C) density according to biotype. Different letters indicate significant differences with Kruskal-Wallis test. $p < 0.05$.

micro-screw anchorage⁸, were found in the total measurements of all three biotypes (1.6 to 2.1 mm). However, more areas of the palate had greater heights in the hyperdivergent and normodivergent biotypes, at 5 mm lateral and 12 mm posterior, than in the hypodivergent biotypes, at 3 mm lateral and 12 mm posterior. There were clinical differences with a study reporting a smaller width in Iranians²⁰ (0.7 - 1.7 mm), being greater in hypodivergent and normodivergent (up to 1.6 mm) than hyperdivergent biotypes (up to 1.4 mm) at 3 mm lateral and 16 mm posterior, while another study on Peruvians²² reported greater width (1.1 - 3.0 mm) in hypodivergent (up to 3.0 mm), followed by hyperdivergent (up to 2.6 mm) and normodivergent subjects (up to 2.2 mm). These data are of interest in the mechanics of the micro-screws for selecting the most adequate thread types according to increased cortical width²⁸. Palate density in this study correlated negatively with SN-GoGn in 20% of the MP, being higher in hypodivergent and normodivergent than in hyperdivergent biotypes. Differences in densities could be influenced by masticatory muscle development and masticatory functional load^{12,23}. However, other studies on Korean²¹ and Peruvian²² populations found no differences between facial

biotypes. Although Hounsfield units are often used to assess bone quality for micro-screw placement, there are no clinically established cut-off points²⁹. There are various methodological differences between the current study and previous ones, such as: (a) inclusion of other ethnicities^{18-21,23}, b) non-proportional distribution by sex^{20,22} or facial biotype¹⁸⁻²⁰, c) younger subject ages including youths aged 10 to ≤ 21 years²¹, adults aged 18 to ≤ 35 years^{19,22,23} or age not reported^{18,20}, d) CBCT with voxel size $> 0.3 - 0.6$ mm^{18-20,22,23} or not reported²¹, e) different biotype analysis with SN-GoMe^{19,20,22}, facial height index²² and mandibular plane angle^{21,23}, f) different reference MP based on teeth,^{18,23} and g) different bone density analysis with attenuation coefficients.²²

This study evaluated three palatal bone features that are clinically relevant for determining adequate micro-screw placement, including a sample with evenly distributed sex and biotype, and analyzed a large area of palate with small voxel CBCT. However, the sample size was limited, so the results must be interpreted with caution. Studies with a larger sample size are recommended to increase the possibility of generalizing the results.

CONCLUSION

Within the limitations of this study, it was concluded that the facial biotype assessed with the SN-GoGn angle is associated with palate bone characteristics, regardless of sex or age. Hyperdivergent patients

had greater heights in the anterior area and thicker cortices in the paramedial area, while hypodivergent patients had greater densities in the anteromedial area of the palate.

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CONFLICT OF INTERESTS

The authors declare no potential conflicts of interest regarding the research, authorship, and/or publication of this article.

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