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Assessment of the bone thickness of the palate on cone-beam computed tomography for placement of miniscrew-assisted rapid palatal expansion appliances

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Introduction: The correction of maxillary transverse discrepancy is achieved by means of rapid maxillary expansion, which may be performed by conventional or surgically-assisted rapid maxillary expansion, and more recently, by miniscrew-assisted rapid palatal expansion (MARPE). This study assessed the bone thickness of the palate on cone-beam computed tomography (CBCT) images for placement of mini-implants and anchorage of MARPE. **Methods:** The sample consisted of 223 CBCT scans from patients of both genders (137 females and 86 males) aged ≥18 years. By using the Image Studio software (Anne Solutions, São Paulo, Brazil), measurements of the bone thickness of the palate were performed bilaterally, as follows: in the axial plane, the bone thicknesses were determined in the anterior region (distal face of the first premolars) and the posterior region (distal face of the first molars), at 3 mm and 6 mm laterally to the midpalatal suture. So in the sagittal plane, the bone thicknesses of the palate were measured in these placements from the palatal cortical to the nasal floor cortical in the anterior region at 30°, 45°, and 90°. In the posterior region, the bone thickness was determined only at 90°. The statistical tests used were the Kruskal-Wallis H test (analysis of variance on ranks) with Dunn's post-hoc test and Mann-Whitney U test ($P < 0.05$). **Results:** The bone thickness of the palate in the anterior region varied from 8.57 mm in women to 11.28 mm in men at 3 mm from the midpalatal suture and from 7.99 mm in women to 10.47 mm in men at 6 mm for 30°; from 6.35 mm in women to 9.28 mm in men at 3 mm from the midpalatal suture and from 6.20 mm in women to 8.88 mm in men at 6 mm for 45°; from 4.51 mm in women to 6.85 mm in men at 3 mm from the midpalatal suture and from 4.29 mm in women to 6.64 mm in men at 6 mm for 90°. In the posterior region, the bone thickness varied from 2.93 mm (3 mm from the suture) to 1.78 mm (6 mm from the suture) for women and from 3.24 mm (3 mm from the suture) to 1.99 mm (6 mm from the suture) for men. In general, the bone thickness of the palate is greater in the anterior region at 3 mm from the midpalatal suture at 30°. **Conclusions:** There was high variability in the bone thickness of the palate among patients and in different areas. Therefore, it is necessary to make an individualized diagnosis of the patient and manufacture the MARPE appliance carefully by performing a prior evaluation of the palatal bone thickness by means of CBCT to determine the ideal sites and inclinations for placement of mini-implants. (Am J Orthod Dentofacial Orthop 2022;161:849-57)

Posterior crossbite has a prevalence rate of 13% to 18% in deciduous and mixed dentitions and 10% in permanent dentition.[1-4] The correction of the transverse discrepancy of the maxilla is achieved with rapid maxillary expansion (RME) by means of opening the midpalatal suture, usually conducted in growing

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subjects, whereas in nongrowing patients, it is necessary to adopt surgically-assisted rapid palatal expansion (SARPE) instead.[5-7]

The clinical parameter for choosing between conventional RME and SARPE is the patient's chronological age. However, there is no consensus in the literature regarding the minimum age for pursuing SARPE. Angelieri et al[8,9] proposed a method to assess the maturation of the midpalatal suture on cone-beam computed tomography (CBCT) images to determine its maturational stage and, thus, its likelihood of a favorable response to RME.

Recently, fixed-expansion appliances anchored to miniature implants have been developed as part of a technique known as miniscrew-assisted rapid palatal expansion (MARPE), which effectively has emerged as an alternative to SARPE.[7] This maxillar expansion technique is indicated for young and adult patients leading to maximization of the skeletal effects because direct expansion forces are applied to the basal bone.[10,11] Originally developed by Lee et al[12] to avoid needing to perform 2 invasive surgical procedures at different times in a young adult patient, the MARPE appliance aimed to maximize the achievable expansion without enhancing undesired inclination of the posterior teeth and collateral periodontal effects, thus allowing for stable posttreatment results. This type of appliance has been modified to only a limited degree with the addition of a conventional Hyrax expander welded to 4 rigid helicoid connectors made of 9-mm stainless steel wire. The anterior helicoids are positioned in the region of the third palatal ridge and the 2 most posterior ones, placed in the parassutural area, in which the mini-implants (Orlus; Ortholution, Seoul, South Korea) are inserted, with a diameter of 1.8 mm and a length of 7 mm. Four orthodontic bands are then cemented on the first premolars and molars.

The stability of mini-implants during bone expansion ranges by the type of anchorage (ie, monocortical or bicortical).[13] The bicortical anchorage of mini-implants is biomechanically more adequate because it enhances their stability and orthopedic correction.[13,14] A bicortical MARPE appliance described by Carlson et al[15] shows slots welded to the expansion screw parallel to the midpalatal suture to place the 4 mini-implants inserted in a perpendicular position. The length of 11 mm for mini-implants was chosen on the basis of the height of 2 mm of the insertion slots, the space of 1-2 mm between the device and the palate surface, the gingival thickness of 1-2 mm, and the desired 5-6 mm of bone involvement. The size of the expander was chosen on the basis of the maximum size that could fit on the palatal vault and be cemented using bands on the molars.[6,7,12,14-16]

In the literature, several MARPE design[6,7,11,12] with different mini-implant lengths and insertion angles have been discussed, with reports emphasizing mainly the expansion results and lacking attention concerning how to conduct appropriate mini-implant selection with respect to the patient's anatomy. Thus, this study used CBCT images to evaluate and compare palate bone thickness in adults at 3 mm and 6 mm from the midpalatal suture and at different inclinations (30°, 45°, and 90°) for the placement of mini-implants for MARPE appliances.

MATERIAL AND METHODS

This study was approved by the Research Ethics Committee of the University of Guarulhos according to Certificate of Presentation of Ethical Appreciation no. 14942819.6.0000.5506.

CBCT scans obtained from a private clinic database from 428 patients aged ≥18 years were assessed. All examinations were conducted only for diagnosis and virtual planning of orthognathic surgeries. For the selection of relevant computed tomography (CT) images, the following inclusion criteria were adopted: aged ≥18 years and an absence of a history of surgical treatment and craniofacial abnormalities. Images not showing the maxillary first premolars or first molars or those with low quality or sharpness were excluded. Therefore, among the 428 patients, 223 were selected, including 137 women and 86 men. The sample power was 95%, with an α of 0.05 and an effect size of 0.24.

All CBCT scans were acquired with an iCAT CBCT three-dimensional imaging system (Imaging Sciences International, Hatfield, Pa). For all scans, the field of view used was 16 × 22 cm, with 110 kVp, 120-500 mA, and the scan time for 17.8 seconds with spatial resolution of 0.30 mm. Each patient remained seated erect with the Frankfort plane kept parallel to the floor during scanning.

All CBCT scans were assessed by a single examiner (S.N) who had previously been trained in using the Image Studio version 3.401 software program (Anne Solutions, São Paulo, Brazil) to perform the necessary measurements.

The vertical and horizontal reference lines of the software were manipulated considering the axial, coronal, and sagittal views to determine the best position of the head for collecting the measurements. In the coronal plane, the patient's head was positioned so that the horizontal line of the software touched the upper edges of the orbits, and the vertical line of the software was

Fig 1. Orientation of the patient's head in the coronal **(A)** and sagittal **(B)** views.

positioned in the sagittal median plane of the patient. In the sagittal view, the patient's head was repositioned so that the long axis of the palate was parallel to the software's horizontal reference line (Fig 1).

In the axial section, all landmarks of measurements of the palate were marked and are presented in Figure 2.

The determination of the necessary points in the axial section supported the generation of images in the sagittal section, in which the measurements of the bone thickness of the palate were completed, as described subsequently.

Anterior region: in the sagittal view, the measurement of palatal cortical thickness is from the software's horizontal reference line to the cortical bone of the nasal floor in parallel to the palatal plane, perpendicularly (90°) and at 45° and 30°, at 3 and 6 mm from the midpalatal suture on both sides (previously determined in the axial view). The Image Studio software's tool for angular measurement was adopted for this purpose.

Posterior region: in the sagittal view, the measurement of palatal cortical thickness is from the software's horizontal reference line to the cortical bone of the nasal floor in parallel to the palatal plane and perpendicularly (90°), at 3 and 6 mm from the midpalatal suture on both sides (Fig 3).

After 30 days, the 72 images were assessed again by the same examiner randomly to calculate the intraexaminer error. Lin's concordance correlation coefficient and the Bland-Altman method were used ($P < 0.05$).

Statistical analysis

Statistical analysis was performed using the Kruskal-Wallis H test (analysis of variance on ranks) with Dunn's post-hoc test and the Mann-Whitney U test, all at a significance level of 5%.

RESULTS

There was a high degree of agreement (0.98-0.99) between the first and second measurements. Using the Bland-Altman method, there was no proportion bias identified, thus indicating high intraexaminer agreement. The average difference between replicated measurements at 3 mm from the midpalatal suture was −0.05 (−1.38 to 1.28) and at 6 mm from the midpalatal suture was 0.01 (−1.19 to 1.21), with 95% limits of agreement. Only 2 variables showed a low intraexaminer degree of agreement in measurements, namely, at the point 45° dpmL3, distal face of the left first premolar at 3 mm from the midpalatal suture at 45° inclination, with a difference of 0.17 mm between the first and second measurements ($P = 0.035$), which might be explained by the difficulty in visualizing the bone thickness in this region, and at the point, 90° dmR3—distal face of the right first molar at 3 mm from the midpalatal suture at 90° inclination showed a difference of 0.16 mm ($P = 0.027$) because of a reduced bone thickness (Table I).

As there was no statistically significant difference between data from the right and left sides, the average was taken according to each measurement. Table II presents the measurements of palatal bone thickness and comparisons between 30°, 45°, and 90° in the anterior region and comparisons between 90° in the anterior and posterior regions, at 3 and 6 mm from the midpalatal suture for females and males.

When the inclinations of 30°, 45°, and 90° in the anterior region were compared, statistically significant differences were found in the palatal bone thickness between women and men (represented by uppercase letters [A, B, C] in Table II). The inclination of 30° showed greater bone thickness than at either of the other inclinations in the anterior region. Statistically significant differences were apparent in women and

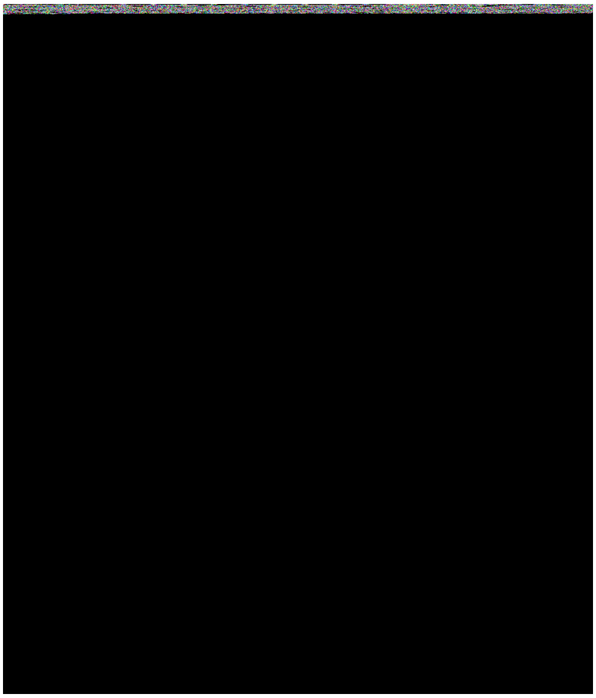

Fig 2. Landmarks of measurements of the palate. *dpmR3,* distal face of the right first premolar at 3 mm from the midpalatal suture; *dpmR6,* distal face of the right first premolar at 6 mm from the midpalatal suture; *dmR3,* distal face of the right first molar at 3 mm from the midpalatal suture; *dmR6,* distal face of the right first molar at 6 mm from the midpalatal suture; *dpmL3,* distal face of the left first premolar at 3 mm from the midpalatal suture; *dpmL6,* distal face of the left first premolar at 6 mm from the midpalatal suture; *dmL3,* distal face of the left first molar at 3 mm from the midpalatal suture; *dmL6,* distal face of the left first molar at 6 mm from the midpalatal suture.

Fig 3. Measurements of cortical bone thickness in the anterior and posterior regions of the palate in the sagittal section: **A,** 90° dmR3/90° dmL3 is the measurement from the palatal cortical bone to the nasal floor cortical bone (90°) on the distal faces of the first molars (right and left) at 3 mm from the midpalatal suture, and 90° dmR6/90° dmL6 is the measurement from the palatal cortical bone to the nasal floor cortical bone (90°) on the distal faces of the first molars (right and left) at 6 mm from the midpalatal suture; **B,** 90° dpmR3/90° dpmL3 is the measurement from the palatal cortical bone to the nasal floor cortical bone (90°) on the distal faces of the first premolars (right and left) at 3 mm from the midpalatal suture, and 90° dpmR6/90° dpmL6 is the measurement from the palatal cortical bone to the nasal floor cortical bone (90°) on the distal faces of the first premolars (right and left) at 6 mm from the midpalatal suture; **C,** 45° dpmR3/45° dpmL3 is the measurement from the palatal cortical bone to the nasal floor cortical bone (45°) on the distal faces of the first premolars (right and left) at 3 mm from the midpalatal suture, and 45° dpmR6/45° dpmL6 is the measurement from the palatal cortical bone to the nasal floor cortical bone (45°) on the distal faces of the first premolars (right and left) at 6 mm from the midpalatal suture; **D,** 30° dpmR3/30° dpmL3 is the measurement from the palatal cortical bone to the nasal floor cortical bone (30°) on the distal faces of the first premolars (right and left) at 3 mm from the midpalatal suture, and 30° dpmR6/30° dpmL6 is the measurement from the palatal cortical bone to the nasal floor cortical bone (30°) on the distal faces of the first premolars (right and left) at 6 mm from the midpalatal suture.

men at 3 and 6 mm from the midpalatal suture for the 30° inclination and at the same time for the 90° inclination in the posterior region in women and men (represented by lowercase letters [a, b] in Table II). Furthermore, the inclination of 90° was compared in the anterior and posterior regions, and it was verified that the bone thickness was greater in the anterior region, thus supporting that the bone thickness decreases in the anterior to posterior direction. Moreover, the 90° inclination in the posterior region showed a statistically significant difference at 3 and 6 mm from the midpalatal suture for both sexes.

According to Carlson et al,[15] an important factor driving the stability of the mini-implants is their bicortical involvement. Thus, 5-6 mm of bone thickness is ideal. Table III shows the frequency of patients who presented with a palatal bone thickness of >5 mm at 3-6 mm from the midpalatal suture for the inclinations of 30°, 45°, and 90°. Overall, a palatal bone thickness of >5 mm was more frequently observed in the sample at the inclination of 30° in the anterior region, whereas the bone at 6 mm from the midpalatal suture in the posterior region is not as thick.

Next, these measurements were compared between men and women, in which the palatal bone thickness

Table I. Degree of agreement between the first and second measurements (intraexaminer error)

Measurements	Pair	P value (Paired t test)	Lin's concordance (95%)
Anterior			
30°	Left3m-Left3mME	0.830	0.97 (0.95-0.98)
	Right3m-Right3mME	0.797	0.96 (0.94-0.97)
	Left6m-Left6mME	0.859	0.96 (0.94-0.98)
	Right6m-Right6mME	0.684	0.93 (0.89-0.96)
45°	Left3m-Left3mME	0.035	0.99 (0.98-0.98)
	Right3m-Right3mME	0.195	0.99 (0.98-0.99)
	Left6m-Left6mME	0.962	0.98 (0.98-0.99)
	Right6m-Right6mME	0.890	0.98 (0.98-0.99)
90°	Left3m-Left3mME	0.360	0.98 (0.96-0.99)
	Right3m-Right3mME	0.476	0.99 (0.99-0.99)
	Left6m-Left6mME	0.405	0.99 (0.99-1.00)
	Right6m-Right6mME	0.203	0.98 (0.97-0.99)
Posterior			
90°	Left3m-Left3mME	0.329	0.92 (0.87-0.95)
	Right3m-Right3mME	0.027	0.91 (0.85-0.94)
	Left6m-Left6mME	0.366	0.99 (0.98-0.99)
	Right6m-Right6mME	0.049	0.96 (0.94-0.98)

Left3mm-Left 6mm, left side of the palate 3 and 6 mm from the midpalatal suture; *Left3mmME-Left6mmME*, left side of the palate 3 and 6 mm from the midpalatal suture method error; *Right3mm-Right6mm*, right side of the palate 3 and 6 mm from the midpalatal suture; *Right3mmME-Right6mmME*, right side of the palate 3 and 6 mm from the midpalatal suture method error.

was verified to be greater in men than women for all measurements, except for in the posterior region (90°) at 6 mm, in which no statistically significant difference was apparent between the sexes (Table IV).

DISCUSSION

The efficacy of the MARPE technique has been largely described in the literature, and some factors are required for its successful performance, such as knowledge of the anatomy of the palate and an assessment of the cortical bone thickness in each patient to determine the best sites and adequate mini-implants. In this way, greater mini-implants stability may be obtained, alleviating the risk of damage during innervation.[7,16-19]

Imaging diagnosis using CBCT scans before the placement of mini-implants increases the safety and, consequently, the success of this therapy.[20,21] In our CT-based study, we measured the palatal bone thickness at points corresponding to the T-zone area of the palate to assess the safety and availability of bone for the placement of the mini-implants.[22-24] In the anterior region, we selected the area corresponding to the third palatal ridge or a line passing on the distal face of the maxillary first premolars.[12,15] The region of the third palatal ridge (or more distal transverse palatal ridge) is, clinically, a stable landmark. Previous studies have proposed that the third palatal ridge remains stable over time; therefore, it may be used as a landmark during orthodontic treatment.[25] Measurements made at 3 mm and 6 mm from the midpalatal suture were obtained in areas corresponding to the third palatal ridge on the right and left sides of the palate, respectively.[7,14,26] Meanwhile, the posterior region chosen was that corresponding to a line passing to the distal face of the maxillary first molars to apply lateral forces to the pterygoid bone, which is an important factor in determining the resistance to RME.[15]

Considering the results of our study, no statistically significant differences were apparent in terms of palatal bone thickness between the right and left sides, which corroborates with earlier findings in the literature.[27-30] Nevertheless, differences in bone thickness were verified transversally, with the vertical palate height decreasing as one moved further away from the midpalatal suture; statistically significant differences were apparent in women and men at 3 and 6 mm from the midpalatal suture for the 30° inclination as well as for the 90° inclination in the posterior region in women and men. This result corroborates with those reported by Kang et al[30] and Manjula et al.[31] In contrast, Marquezan et al[26] observed that bone thickness decreased from the suture to the paramedian region by 3 mm and then increased by 6 mm; however, their sample consisted of only 36 CT images acquired from growing and adult patients.

Moreover, the palatal bone thickness was greater at an inclination of 30°, followed by at 45° and 90° for all measurements. The smaller the evaluated angle

Table II. Measurements of palatal bone thickness and comparisons between 30°, 45°, and 90° in the anterior region and comparisons between 90° in the anterior and posterior regions, at 3 and 6 mm from the midpalatal suture for females and males

	Anterior			
Measurements	*30°*	*45°*	*90°*	*P value*
Females (n = 137)				
3 mm	8.57 (3.92)[a,A]	6.35 (3.38)[B]	4.51 (2.19)[C]	<0.001
6 mm	7.99 (3.55)[b,A]	6.20 (3.48)[B]	4.29 (2.52)[C]	<0.001
	90° (anterior)		90° (posterior)	
3 mm	4.51 (2.19)		2.93 (1.48)[a]	<0.001
6 mm	4.29 (2.52)		1.78 (0.94)[b]	<0.001
Males (n = 86)				
3 mm	11.28 (4.04)[a,A]	9.28 (4.26)[B]	6.85 (3.34)[C]	<0.001
6 mm	10.47 (3.30)[b,A]	8.88 (3.52)[B]	6.64 (3.44)[C]	<0.001
	90° (anterior)		90° (posterior)	
3 mm	6.85 (3.34)		3.24 (1.74)[a]	<0.001
6 mm	6.64 (3.44)		1.99 (1.07)[b]	<0.001

Note. Uppercase letters A, B, C show statistically significant differences found in the palatal bone thickness between the inclinations 30°, 45° and 90° for women and men; lowercase letters a, b show statistically significant differences in palatal bone thickness in women and men at 3 and 6 mm from the midpalatal suture.

Table III. Palatal bone thickness >5 mm at 3 mm and 6 mm from midpalatal suture for female and male groups

	Female (n = 137)		*Male (n = 86)*	
Angle	*3 mm*	*6 mm*	*3 mm*	*6 mm*
Anterior				
30°	78%	76%	93%	94%
45°	60%	56%	79%	82%
90°	34%	32%	66%	62%
Posterior				
90°	11%	2%	13%	1%

between the palatal plane and the long axis of the implant, the greater the availability of bone.[26,32,33] In contrast to Carlson et al,[15] who believed that placing mini-implants perpendicularly is safe, our results suggest that mini-implants inserted at inclinations of 30° and 45° enable a relatively higher percentage of benefits of the MARPE technique to be achieved by the patient because there will be a greater amount of available bone thickness in the palate. No patient in the sample showed proximity to the roots of the adjacent teeth and the incisive canal at the bone tissue measurement points.

The bone thickness showed high variability among the study participants at 3 mm and 6 mm from the midpalatal suture and different inclinations in the anterior region (30°, 45°, 90°) and the posterior region (90°). Specifically, the bone thickness of the palate in the anterior region varied from: 8.57 ± 3.92 mm in women and 11.28 ± 4.04 mm in men at 3 mm from the midpalatal suture and 7.99 ± 3.55 in women and 10.47 ± 3.30 in men at 6 mm for 30°; 6.35 ± 3.38 mm in women and 9.28 ± 4.26 mm in men at 3 mm from the midpalatal suture and 6.20 mm ± 3.48 mm in women and 8.88 ± 3.52 mm in men at 6 mm for 45°; 4.51 ± 2.19 mm in women and 6.85 ± 3.34 mm in men at 3 mm from the midpalatal suture and 4.29 ± 2.52 mm in women and 6.64 ± 3.44 mm to men at 6 mm for 90°. These variabilities of palate bone thickness among regions and inclinations show the importance of conducting CBCT evaluation before MARPE placement. It should be noted that only constricted maxillary arches were not considered an inclusion criterion in the current study. Perhaps, in constricted arches, the thickness of the palate could be less.

Corroborating with previous studies,[14,25-28,31,32,34-36] we report the existence of statistically significant differences between anterior and posterior regions, with a palatal bone thickness decreasing in the anterior to the posterior direction at the inclination of 90°. The mean values for palatal bone thickness in the anterior region ranged from 4.51 mm (3 mm from the suture) to 4.29 mm (6 mm from the suture) in women and from 6.85 mm (3 mm from the suture) to 6.64 mm (6 mm from the suture) in men; in the posterior region, from 2.93 mm (3 mm from the suture) to 1.78 mm (6 mm from the suture) in women, and from 3.24 mm (3 mm from the suture) to 1.99 mm (6 mm from the suture) in men.

Table IV. Comparison of palate bone thickness between genders.

Region	Inclination	Gender				P value
		Female (n = 137)		Male (n =86)		
3 mm						
Anterior	30°	8.57 ± 3.92	8.53 (6.44)	11.28 ± 4.04	12.02 (5.64)	<0.001
	45°	6.35 ± 3.38	5.74 (4.99)	9.28 ± 4.26	9.32 (7.39)	<0.001
	90°	4.51 ± 2.19	4.15 (2.62)	6.85 ± 3.34	6.24 (5.14)	<0.001
Posterior	90°	4.15 ± 1.48	2.60 (1.94)	3.24 ± 1.74	2.98 (2.25)	0.042
6 mm						
Anterior	30°	7.99 ± 3.55	8.58 (5.60)	10.47 ± 3.30	10.73 (3.50)	<0.001
	45°	6.20 ± 3.48	5.71 (5.71)	8.88 ± 3.52	9.48 (5.71)	<0.001
	90°	4.29 ± 2.52	3.79 (4.00)	6.64 ± 3.44	6.20 (5.27)	<0.001
Posterior	90°	1.78 ± 0.94	1.56 (0.94)	1.99 ± 1.07	1.69 (1.45)	0.120

Note. Values are mean ± standard deviation or median (interquartile range).

With regard to gender, there was a difference in the palatal bone thickness as it was typically greater in men in both the anterior and posterior regions, except for the posterior region (90°) at 6 mm, in which no statistically significant difference was found between the sexes. In accordance with our results, Holm et al[29] reported that the palatal bone thickness was, on average, 1.2 mm greater in men than in women. The findings of Chhatwani et al[35] and Yadav et al[37] also corroborated our results. In contrast, there are also studies showing that women have availability of bone equal to that of men in the posterior region of the palate.[28,30,36] Becker et al[33] discerned no difference in the palatal bone thickness to sex and age. A possible reason for this discrepancy among the abovementioned results may be due to variable measurement protocols or populations under study, with the latter involving possible ethnic differences.[35] Therefore, our results suggest that the MARPE technique may have greater limitations in women because of their reduced availability of the bone palate.

The regions for placing mini-implants for MARPE slightly differ from those for placing the palatal implants used as orthodontic accessories.[26] Nowadays, mini-implants are preferred over palatal implants because they are easier to insert and allow the placement of an immediate load and better healing after their removal.[11,26] It has been suggested that mini-implants with 5-6 mm of bone involvement are ideal for promoting greater stability.[12,15] These indications led us to assess the number of patients who had a bone thickness of >5 mm in all regions studied; overall, however, our sample included a low percentage of patients with a bone thickness of >5 mm. In the anterior region (at 90°), the percentage of patients ranged from 32% (at 6 mm for women) to 34% (at 3 mm for women), from 62% (at 6 mm for men) to 66% (at 3 mm for men) and, in the posterior region, from 2% (at 6 mm for women) to 11% (at 3 mm for women), from 1% (at 6 mm for men) to 13% (at 3 mm for men). There was also a significant difference between the distances of 3 mm and 6 mm from the midpalatal suture regarding the posterior bone thickness, with a reduced amount of bone tissue present at 6 mm.

The concern inherent with the reduced bone thickness of the palate observed in our study, which used an expressive sample (n = 223), calls attention to possible failures (eg, loss of mini-implant stability or injuries to the maxillary sinus and nasal floor) and for the need to customize the appliance according to the anatomy and bone thickness of the palate of each patient. In addition, it is necessary to point out that the appliances available in the market today do not allow the insertion of mini-implants in the anterior region with an inclination toward the anterior direction. Our study verified that many patients had insufficient bone thickness for mini-implants in the anterior region at 90° but enough for placement at 30° and 45°. The choice between 30° and 45° will depend on the bone supply of each patient. If these latter inclinations are indicated for the insertion of mini-implants, then the risk of failure will be reduced, and a substantial number of patients will benefit from the MARPE technique. A solution for dealing with the reduced bone thickness in the posterior region of the palate would be the placement of mini-implants closer to the midpalatal suture,[38-41] on which there is a greater amount of bone.

The large standard deviation values presented, in all measures, demonstrated a great degree of individual variability in the palatal depths of different patients, differently from what was recommended by the previous studies on MARPE placement. Moreover, it strengthens the importance of conducting individual evaluations of the palate depth on CBCT images before mini-implant placement of the MARPE.

CONCLUSIONS

1. Significant variability in the bone thickness of the palate in adult patients was recorded during this investigation. The bone thickness of the palate was greater in the anterior region at 3 mm from the midpalatal suture at 30°.
2. This study determined that low bone quantity was widely available for the placement of mini-implants, mainly in the posterior region. Therefore, the insertion of mini-implants closer to the midpalatal suture in the posterior region is suggested.
3. Careful and individual evaluation of the palatal bone thickness using CBCT scans is very important to determine the ideal sites and inclinations for placement of mini-implants for MARPE, reducing the number of injuries to the nasal cavity, maxillary sinus, and the risk of bone fractures in thin palates.

AUTHOR CREDIT STATEMENT

Silvia Negrisoli contributed to conceptualization, methodology, software, validation, investigation, data curation, original draft preparation, and visualization; Fernanda Angelieri contributed to conceptualization, methodology, investigation, visualization, and manuscript review and editing; João Roberto Gonçalves contributed to resources and conceptualization; Hélio Doyle Pereira da Silva contributed to validation, formal analysis, and data curation; Liliana Ávila Maltagliati contributed to visualization and manuscript review and editing; Ana Carla Raphaelli Nahás-Scocate contributed to conceptualization, methodology, validation, investigation; visualization, supervision, project administration, and manuscript review and editing.

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