Gingival Biotype and Its Relationship With the Maxillary Membrane and Lateral Wall Thickness

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The purpose of this study was to analyze the risk of the maxillary sinus lift technique and the correlation between the thickness of the gingiva, maxillary sinus membrane, and the maxillary sinus lateral wall. Cone-beam computerized tomograhy (CBCT) records of 32 adult dentate patients (10 male/22 female) were analyzed. The gingival thickness records of the dental units were compared with the thickness measurements of the membrane and lateral wall of the maxillary sinus. The gingival biotypes varied between 1.1 mm (thin) and 1.6 mm (thick), with a small association with sex. The thickness of the sinus membrane presented a small association between sexes (0.2 mm, female/0.3 mm, male) and gingival biotypes (Cohen $d = .52$). The lateral wall presented a weak association between the biotypes (1.3 mm, thin/1.1 mm, thick). There was also no correlation between the membrane and lateral wall ($r = -.22$). The volume dimension related to the graft area of the sinus was 4 mm^3 for men and 5 mm^3 for women. There was a weak correlation of gingival thickness compared with membrane thickness and lateral wall of the sinus ($r = .304/r = -.31$). Gingival thickness does not appear to be a reliable thickness predictor of the membrane or lateral wall of the maxillary sinus. The analysis of maxillary sinus anatomical structures through CBCT is the most reliable technique to identify the thickness of the membrane and lateral wall of the maxillary sinus before surgery. We believe that new studies are necessary to confirm our findings.

Key Words: cone-beam computed tomography, gingiva, maxillary sinus, membrane potentials

INTRODUCTION

The height loss of the alveolar bone crest after tooth extraction is a clinical challenge for implant-supported rehabilitation in the posterior maxilla region.[1] With posterior teeth loss, both the alveolar bone and the maxillary sinus floor intensify the tissue-remodeling process, resulting in the reabsorption of the alveolar bone and sinus pneumatization, creating inadequate conditions for implant insertion.[2]

In cases in which the residual bone height of the alveolar process is 5 mm or less, the technique of sinus lift through the lateral wall access associated with graft material deposition has been recommended for posterior dental implant insertion.[3,4] The maxillary sinus lift procedure to support the installation of dental implants is predictable and safe.[2] The average survival rate of these implants is 98%, similar to those installed in native bone, independent of the material used for grafting in the maxillary sinus lift technique.[5]

The elevation of the maxillary sinus membrane is a delicate procedure, and its perforation is still the most common risk during access through the lateral wall.[6] The direct communication between the grafted material and the contaminated sinus cavity can result in loss of graft material, suture dehiscence, chronic sinus infection, and loss of implants.[5]

Among the risk factors, the thickness of the sinus membrane interferes directly with its preservation during the surgical procedure,[3,7] and the risk of perforation increases as the thickness decreaes.[7] Another important risk factor is the thickness of the lateral wall of the maxillary sinus.[3,4] A positive correlation between sinus membrane thickness and gingival biotype was reported by Aimetti et al[8] and Yilmaz and Tozum,[9] demonstrating that gingival thickness can be used as a clinical reference during surgical access of the maxillary sinus, minimizing the risk of injury to the sinus membrane.

There are few correlative studies between the anatomical structures related to the maxillary sinus and the prevelance of its anatomical variations. The aim of this study was to investigate the correlation between gingival thickness and the thickness of the maxillary sinus membrane and lateral wall, using cone-beam computerized tomography (CBCT) analysis.

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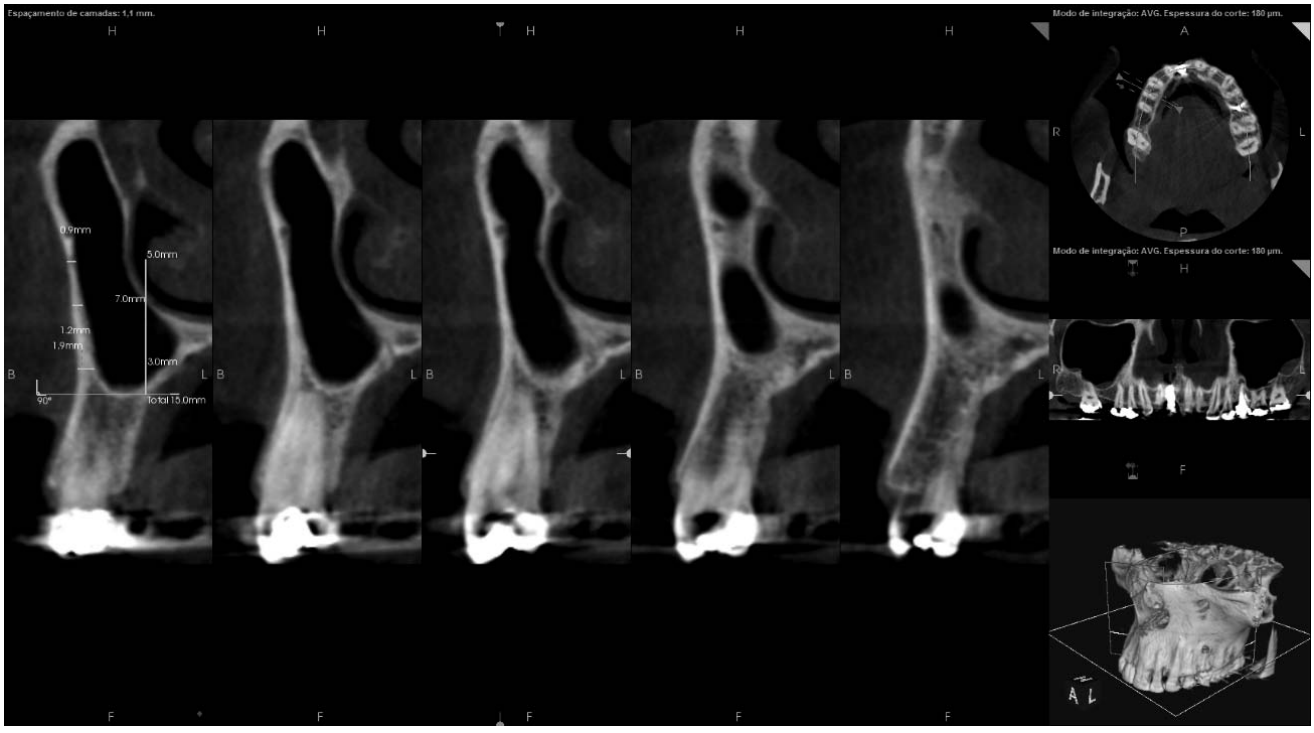

Figure 1. Tomographic image showing the identification of the maxillary sinus lateral wall measured heights (AH1, AH2, AH3).

Materials and Methods

The present cohort study was carried using CBCT analysis. Thirty-two adult patients (dentate) of both sexes (10 men/22 women) with a mean age of 36 years were examined. Ethics approval was obtained from The Bahiana Research Ethics Committee, Brazil, with the CAAE (Presentation Certificate for Ethical Appreciation) registration No. 67004617.3.0000.5544 dated July 11, 2017.

Our inclusion criteria included the presence of at least 4 teeth of the maxillary anterior region (central incisors, lateral incisors, and canines) and 3 upper premolar teeth and healthy gingiva. Exclusion criteria consisted of maxillary sinus pathologies, previous history of maxillary sinus surgery, and mucogingival or soft-tissue periodontal problems in the anterior maxillary region or premolar region. Patients were also excluded if they had clinical signs of periodontal disease (defined as a periodontal pocket >3 mm), previous orthodontic treatment, history of dental trauma or endodontic treatment, smoking, pregnancy, lactation, or use of medications that could affect gingival thickness.

Image acquisition

The CBCT images were obtained with a K9000 3D extraoral imaging system (Carestream Health). The acquisition parameters were defined according to the patient (7.0–10.0 mA, 70–76 kV), and the exposure time was 17.5 seconds. For all CBCT images, a limited 8×8 cm field of view was selected. The data were reconstructed with cuts in a range of 0.15 to 0.2 0mm for the evaluation of hard tissues and membrane and 4.9 mm for analysis of gingival tissue. The images were evaluated in a multiplanar manner in the CS 3D Imaging program, and measurements were performed by the same observer.

Gingival thickness

To evaluate patients' gingival thickness, computerized tomography images were used as described by Amid et al.[10] Soft-tissue thickness was measured at 2 mm apical, from the gingival margin, perpendicularly to the dental surface using frontal cut images and with individualization done in the midline of the same tooth in the sagittal and transverse sections. The gingival biotypes were also categorized as thin (gingival thickness <1.5 mm) and thick (gingival thickness ≥ 1.5 mm) gingival biotypes according to criteria used by Amid et al.[10]

Maxillary sinus measurements

Patients whose maxillary sinus images showed normal characteristics according to the criteria described by Shanbhag et al[11] had measurements of the maxillary sinus lateral wall and membrane thickness as well as linear measurements performed on only one side of each exam.

Maxillary sinus lateral wall

Points were chosen to measure the thickness of the maxillary sinus lateral wall: 3 height levels from the sinus floor (H1, 3 mm; H2, 10 mm; and H3, 15 mm), according to Monje et al[4]; 5.5 mm posteriorly of the maxillary sinus anterior limit (AH1, AH2, and AH3); and 5.5 mm anteriorly of its posterior limit (PH1, PH2, and PH3; Figure 1).

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TABLE 1

Mean and standard deviation of gingival thickness in the anterior and posterior regions of the maxilla according to sex and biotype

		Biotype, %			Gingiva (SD), mm		
Region	Sex	Thin	Thick	Lambda Test	Thin	Thick	Lambda Test
Anterior	Female (n = 22)	59.1	40.9	0	1.1 (0.3)	1.6 (0.1)	0
	Male (n = 10)	50	50	0	1.2 (0.1)	1.6 (0.1)	0
Posterior	Female (n = 21)	42.9	57.1	0	1.2 (0.3)	1.8 (0.3)	0
	Male (n = 9)	0	100	—	0	1.7 (0.1)	—

Maxillary sinus membrane

Measurements of the maxillary sinus membrane (Schneiderian membrane) were performed using the acquisition cut in axial images at the same points used for measurements of the lateral wall of the sinus, perpendicular to the underlying bone board.

Dimensions of maxillary sinus

The linear measurements of the sinus were made from the axial cut, constructing a connecting line between the most equidistant points in the lateral-lateral and anteroposterior directions,[12] at the level of 10-mm height from the sinus floor (AH2). The height of 10 mm was chosen considering the maxillary sinus lift limit. From the linear measurements (height, length, and width), the volume in mm^3 was calculated to estimate the amount of material needed for grafting.

Statistical analysis

The intraclass correlation coefficient (ICC) was performed to evaluate the absolute agreement for intrarater reliability using 2-way mixed effects based on a single measurement, since 2 measures were taken in time by the same observer. The interpretation of the reliability level obeyed the following classification: ICC values less than .5 were indicative of poor reliability, values between .5 and .75 indicated moderate reliability, values between .75 and .9 indicated good reliability, and values greater than .90 indicated excellent reliability. The level of significance was 5%.

For data analysis, the sample was obtained nonprobabilistically with no inferential statistics calculated. To verify the adequacy of the arithmetic mean in the sample, the symmetry, kurtosis, and variability of the distribution of values of each quantitative variable were calculated. The association of quantitative variables between groups was measured using the Cohen *d* statistic. The limits adopted for significant association effect were less than .2, no effect; from .21 to .5, small effect; from .51 to .8, moderate effect; and greater than .8, large effect. The measure of association between qualitative variables with a dependence relation was performed by asymmetric lambda statistics of Goodman-Kruskal. Pearson correlation was used to verify the degree of association between quantitative variables. Statistical analysis was carried out using statistical package R version 3.4.1. The methodology was reviewed by an independent statistician.

TABLE 2

Analysis of the gingival thickness in the anterior and posterior regions of the maxilla according to biotype and sex

Biotype, Sex	Anterior Thickness (SD), mm	Cohen *d* Test	Posterior Thickness (SD), mm	Cohen *d* Test
Thin, female/male	1.1 (0.3)	2.30	1.2 (0.3)	2.20
Thick, female/male	1.6 (0.1)		1.8 (0.2)	
Female	1.3 (0.3)	0.42	1.5 (0.4)	0.36
Male	1.4 (0.2)		1.7 (0.1)	

RESULTS

Measurement repetitions performed by the same individual were significant for sinus lateral wall (ICC = .972), sinus membrane (.998), and sinus length and width (ICC = .982/ICC = 1).

The mean gingival thickness of the anterior and posterior segment of the maxilla is shown in Table 1. The lambda test showed no association in the frequency analysis between same sex biotypes. The gingival thickness between the thin and thick biotype groups was well characterized by the Cohen's *d* test in both anterior (2.30) and posterior (2.20) segments. When comparing gingival thickness between sexes, the same test showed similarity between the groups in both the anterior (.42) and posterior (.36) regions (Table 2).

In the comparison of gingival thickness between biotypes, the Cohen *d* test showed strong distinct groups in the central incisor teeth (3.43), lateral incisor (2.10), and canine (1.81) (Table 3).

The maxillary sinus membrane thickness showed a moderate association between the sexes (male .3 mm, female .2 mm; Cohen $d = .75$) as well as between gingival biotypes (Cohen $d = .52$). In relation to the lateral wall thickness, the Cohen *d* test found only a moderate association in the comparison between gingival biotypes (thin 1.3 mm and thick 1.1 mm; Cohen $d = .76$; Table 4).

The Pearson test showed little correlation (Figures 2 and 3) between gingival thickness and maxillary sinus membrane and lateral wall thickness. As shown in Figure 4, there was a small correlation when the thicknesses of the membrane and the lateral wall of the maxillary sinus were compared.

Data on the dimensions of the maxillary sinus are shown in Table 5. The sinus volume analysis revealed a small association between the sexes (male 4 mm^3 and female 5 mm^3) using the Cohen *d* test (.77).

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Table 3

Gingival thickness (GEN) of the central incisor (CI), lateral incisor (LI), and canine (Can) teeth, according to gingival biotype

	CI (n = 31)		Cohen	LI (n = 31)		Cohen	Can (n = 31)		Cohen
Gingival biotype	Thin (n = 7)	Thick (n = 24)	*d* Test	Thin (n = 19)	Thick (n = 12)	*d* Test	Thin (n = 26)	Thick (n = 5)	*d* Test
GEN (SD), mm	0.9 (0.4)	1.7 (0.2)	3.43	1.1 (0.3)	1.6 (0.1)	2.10	1.1 (0.3)	1.6 (0.2)	1.81

Discussion

Considered the largest and most constant of the paranasal sinuses, the maxillary sinus participates in the humidification, filtration, and heating of inspired air. It has a pyramidal shape with a base facing the lateral wall of the nasal cavity and internal lining constituted by the Schneider membrane, consisting of a respiratory epithelium, pseudo-stratified columnar cilia that produces mucous secretions.[2,13]

After reaching the apex of its formation, the dimensions of the maxillary sinus range from 25 to 35 mm in width, from 36 to 45 mm in height, and from 38 to 45 mm in length and may extend anteriorly to the premolar and canine regions.[13–15] These data corroborate our findings of a mean of 27.2 mm and 29.2 mm wide and 38.3 mm and 36.6 mm long in women and men, respectively (Table 5).

The volume of the sinus can range from 12.5 to 15 cm^3, and its floor on average is located 5 to 10 mm below the nasal cavity floor.[14] In our study, the mean volume found for the sinus was 5 cm^3 in women and 4 cm^3 in men. This difference in volume in relation to that described in the literature can be explained by the way our calculations were done using the height limit of 10 mm from the sinus floor. Therefore, we believe that our findings have a more direct relationship to the real volume of graft material needed when the sinus is lifted in the edentulous maxilla (Table 5).

Surgical access through the lateral wall described by Tatum in 1977 allows a direct view of the sinus, greater distribution of graft material, and gain of bone height, being indicated in cases with minimal alveolar bone height.[4] Although the maxillary sinus enlargement through the lateral wall has good predictability, surgical complications may occur.[2]

The average membrane perforation during the sinus lift surgical procedure varies between 17.28% and 27.3%.[3,16] Studies have shown that the thickness of the membrane in perforation cases is lower than in those where it is preserved.[15,16]

Several methods for measuring sinus membrane thickness have been used. These studies found that the thickness of the sinus membrane varied between 0.8 and 1.99 mm.[9,17] Unlike the study by Anduze-Acher et al,[17] these prior studies measured the membrane in the lateral wall, above the sinus floor.

More recently, CBCT has been used to meaure the thickness of the sinus membrane. In the study by Von Arx et al,[16] the average thickness of the membrane was 2.1 ± 2.89 mm. Shanbhag et al[11] found membrane thicknesses greater than 2 mm (53.6%) and greater than 5 mm (12.9%) in the 104 studied specimens. Both studies performed sinus membrane measurement on the maxillary sinus floor area. In the study by Lin et al,[3] the mean membrane thickness located on the lateral wall of the sinus was 1.32 mm, with a variation of 0.3 to 7.9 mm.

In our study, the mean sinus membrane thickness was 0.2 (0.1) mm and 0.3 (0.1) mm for the women and men, respectively (Table 4). The lack of difference between the sexes corroborates the findings of other studies in the literature. With regard to the thickness of the membrane, our findings are closer to the studies in which the measurement occurred partially or totally in the region of the lateral wall of the maxillary sinus. Interestingly, our data corroborates those obtained through the direct measurement of the sinus membrane, as in the works by Tos and Mogensen[18] (0.3 to 0.8 mm) and Pommer et al[19] (0.35 mm). Studies also demonstrate that in the sinus floor area, the thickness of the sinus membrane is generally greater than that found on the lateral wall of the sinus. Thus, we believe that our findings better relate to the risk of membrane damage during surgical access to the sinus when it occurs through the lateral wall.

Considering the genetic influence on the determination of gingival thickness, Aimetti et al[8] analyzed the correlation between the gingival biotype and the sinus membrane thickness in 20 patients.[20] The microscopic study of membrane thickness and direct measurement of gingival thickness in the central and lateral incisor teeth and canine teeth, in both sexes, pointed to the existence of a positive correlation. Individuals with a thin gingival biotype (<1.0 mm) had a mean sinus membrane thickness of 0.61 ± 0.15 mm, whereas in individuals with a thick gingival biotype (>1.0 mm), the mean was 1.26 ± 0.14 mm. Using the CT resource, Yilmaz and Tozum[9] also observed in 44 healthy patients a positive correlation between gingival biotype and sinus membrane thickness. In the thin gingival biotype (<1.5 mm, 54.7%), the sinus membrane

Table 4

Analysis of the thickness of the membrane and lateral wall of the maxillary sinus, according to sex and gingival biotype

	Sex			Biotype		
	Female (n = 22)	Male (n = 10)	Cohen *d* Test	Thin (n = 18)	Thick (n = 14)	Cohen *d* Test
Membrane (SD), mm	0.2 (0.1)	0.3 (0.1)	0.75	0.2 (0.1)	0.3 (0.2)	0.52
Lateral wall (SD), mm	1.2 (0.3)	1.3 (0.4)	0.33	1.3 (0.3)	1.1 (0.3)	0.76

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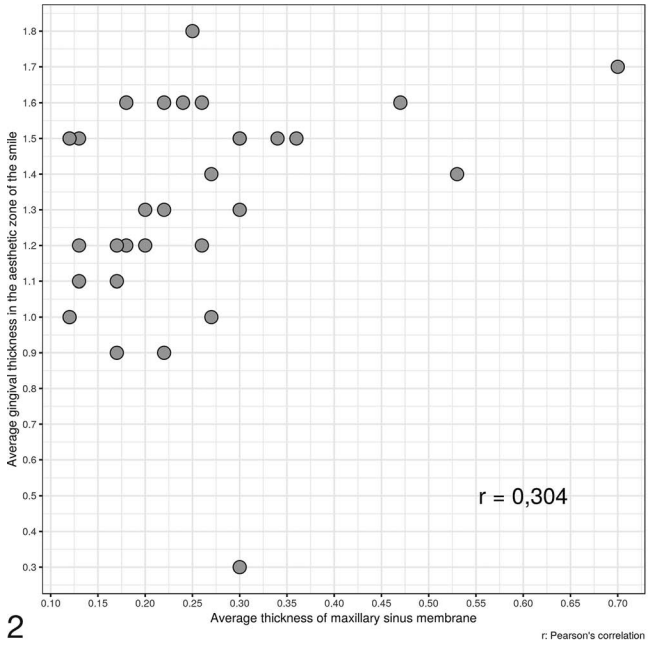

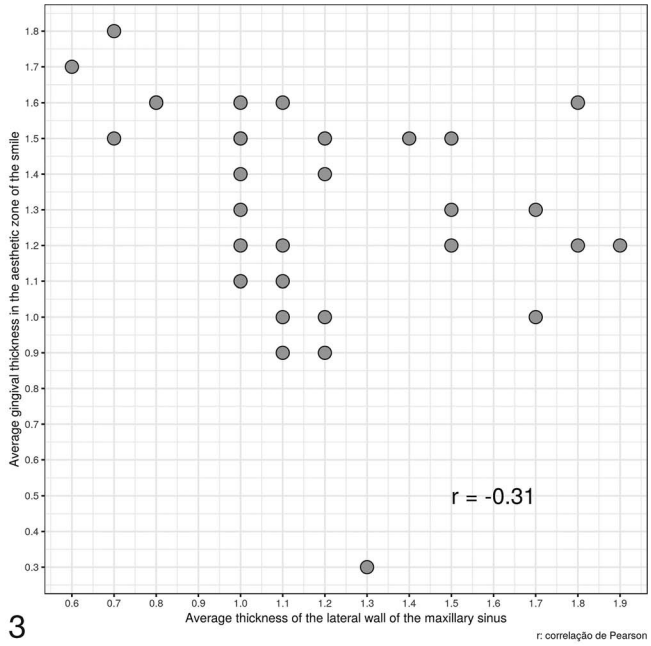

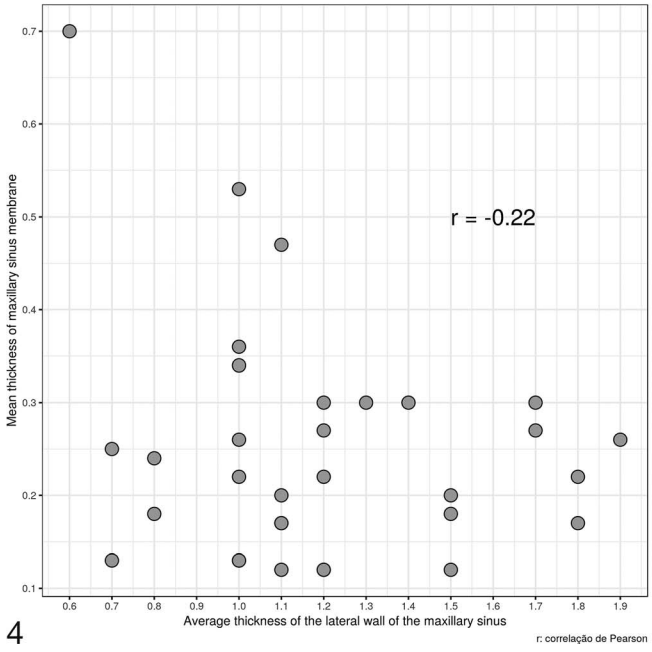

Figures 2–4. Figure 2. Correlation of the gingival thickness in the anterior region of the maxilla with the thickness of the maxillary sinus membrane. **Figure 3.** Correlation of the gingival thickness in the anterior region of the maxilla with the thickness of the maxillary sinus lateral wall. **Figure 4.** Correlation between the thickness of the membrane and the lateral wall of the maxillary sinus.

Table 5

Linear/volumetric dimensions of the maxillary sinus, according to sex

Sex	Length (SD), mm	Width (SD), mm	Volume (SD), mm^3	Cohen *d* Test
Female (n = 22)	38.3 (2.9)	27.2 (3.5)	5 (1)	.77
Male (n = 10)	36.6 (4.1)	29.2 (3.2)	4 (1.7)	

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thickness was ≤1.0 mm (46.8%), while in the thick gingival biotype (>2.0 mm, 45.3%), the thickness of the membrane was >1.0 mm (53.2%).

Although the studies of Aimetti et al[8] and Yilmaz and Tozum[9] showed a positive correlation among gingival biotype and sinus membrane thickness, the measurements method used as well as the different references of gingival biotype make it difficult to compare these data. In our study, the correlation among the sinus membrane thickness and the gingival biotype was moderate (Cohen $d = .52$), similar to the comparison between sexes (Cohen $d = .75$; Table 4). The Pearson test showed a small correlation between the thickness of the sinus membrane and the gingiva ($r = 0.304$; Figure 1).

As the gingival biotype has become a parameter of response to periodontal treatment and esthetic results in implant-supported rehabilitation, several studies started investigating their behavior pattern.[10,21] Since the introduction of CBCT, this technology has been increasingly used for visualization and measurement of gingival thickness, mainly because it is a noninvasive method.[10,21,22]

Despite the importance attributed to gingival thickness and biotype in relation to the results obtained in the various periodontal, orthodontic, and prosthetic treatments, there is still no consensus among the authors regarding gingival thickness determining exactly the type of thin or thick biotype.[23] There are reports of thin biotype ranging from less than 1 mm to less than 1.5 mm, as well as a thick biotype ranging from greater than 1 mm to greater than 2 mm.[21] In our study, using the classification adopted by Amid et al[10]—thin gingival biotype (<1.5 mm) and thick gingival biotype (≥1.5 mm)—the percentage of biotypes was shown to be balanced between the male and female sexes in the anterior region of the maxilla, 59.1%/50% thin and 40.9%/50% thick, respectively, as well as in the region of premolars in women (42.9% thin and 57.1% thick). In men, the premolar region presented only thick gingival biotypes (Table 1).

In the study by Barriviera et al,[22] the average gingival thickness found in the canine region, 2 mm below the gingival margin, was 1.97 mm. Amid et al[10] found at 2 mm below the zenith, a gingival thickness of 1.35 ± 0.29 mm (central incisors), 1.23 ± 0.29 mm (lateral incisor), and 1.15 ± 0.27 mm (canine). In this study, the authors observed a gingival thickness in the central incisor region that was significantly higher when compared with the other units. Similarly, the gingival thickness of the lateral incisor was greater than that found in the canine. In the comparison of the prevalence of gingival biotype between sexes, the authors found no difference.

In our study, the mean thicknesses of the gingiva 2 mm below the gingival margin in the midline of the central incisor, lateral incisor, and canine units in the thin and thick biotypes were 0.9 (0.4) mm/1.7 (0.2) mm, 1.1 (0.3) mm/1.6 (0.1) mm, and 1.1 (0.3) mm/1.6 (0.2) mm (Table 3). Our mean gingival thickness corroborates with the values found by Amid et al[10] and Barriviera et al,[22] whose gingival measurement height was similar. The divergence found with the work of Fu et al[21] is probably due to divergence of place for gingival measurement. In relation to the gingival biotypes, the thickness found in our study was strongly different in the 3 units, according to the Cohen d test: central incisor, 3.43; lateral incisor, 2.10; and canine, 1.81.

In the premolar region, similarly to the anterior maxilla region, we found a strong association between thin (1.2 mm) and thick (1.8 mm) gingival biotypes (Cohen $d = 2.20$), with no difference between women (1.5 mm) and men (1.7 mm; Cohen $d = .36$; Table 2). Our data for the premolar region could not be compared becuase of a lack of records in the literature regarding gingival thickness in this region. The thickness of the maxillary sinus lateral wall can directly influence the preservation of the sinus membrane during the surgical procedure of the maxillary sinus lift.[15]

In their study on atrophic maxilla, Monje et al[4] reported that the lateral wall thicknesses in completely and partially edentulous patients were 1.57 (±0.07) mm and 1.71 (±0.12) mm, respectively. No difference in thickness was found between the sexes; however, the authors observed a trend for a lower thickness of the bone wall in completely edentulous patients. The thickness of the lateral wall at 5 mm height from the maxillary sinus floor in the study by Von Arx et al[16] was 1.3 ± 0.62 mm, and the authors found no difference between sexes.

In their study of edentulous maxilla, Yang et al[24] found that the mean thicknesses of the maxillary sinus lateral wall were 1.69 ± 0.71 mm for the first premolar, 1.50 ± 0.72 mm for the second premolar, 1.77 ± 0.78 mm for the first molar, and 1.89 ± 0.85 mm for the second molar. The overall mean was 1.75 ± 0.80 mm. The authors did not find a difference between the sides, but they noted a slight tendency of greater thickness in the male sex. In the work of Neiva et al,[25] the authors found a difference between the sexes when measuring the thickness of the maxillary sinus lateral wall of the 22 Caucasian skulls (female, 1.18 mm; male, 0.75 mm).

In our study, the mean thicknesses found in the maxillary sinus lateral wall, according to sex and gingival biotype, were 1.2 mm for female, 1.3 mm for male, 1.3 mm for thin, and 1.1 mm for thick. Our study did not show differences between the sexes (Table 4), as there was no correlation between lateral wall thickness and gingival thickness in the esthetic area of the smile (Figure 3). In relation to thickness, our values were similar to those found by Von Arx et al[16] and Neiva et al.[25] Although our measurement sites corresponded in height to those chosen in the works by Monje et al[4] and Yang et al,[24] the small difference found in the thicknesses could be a result of the different ethnic groups studied. Pearson test ($r = -.22$) showed no significant correlation ($r = -.22$) between the thickness of the maxillary sinus membrane and the lateral wall (Figure 4).

Conclusions

Gingival biotype showed no significant correlation to the thickness of the maxillary sinus membrane and lateral wall, nor was there a significant correlation between the thickness of the maxillary sinus membrane and the lateral wall. Presurgical analysis of the maxillary sinus anatomical structures through CBCT is still the most reliable feature for identifying the membrane and lateral wall thickness of the maxillary sinus preoperatively. We believe that new studies are necessary to confirm our findings.

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Abbreviations

CAAE: Presentation Certificate for Ethical Appreciation
CBCT: cone-beam computerized tomography
ICC: intraclass correlation coeficient

Note

The authors do not have any financial interests, neither directly nor indirectly, in the products or information listed in the paper.

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