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Quantitative evaluation of palatal bone thickness to guide miniscrews insertion: a CBCT assessment

Avaliação quantitativa do osso palatino para orientação da inserção de mini-implantes ortodônticos: análise por TCFC

Rodrigo César Santiago[1]
Carolina de Sá Werneck[2]
Fernanda Ramos de Faria[2]
Robert Willer Farinazzo Vitral[3]
Marcio José da Silva Campos[3]

[1]Unidade Cérvico-facial, Hospital Universitário da Universidade Federal de Juiz de Fora/filial Empresa Brasileira de Serviços Hospitalares, Brasil.

[2]Pós-graduação em Odontologia, Faculdade de Odontologia, Universidade Federal de Juiz de Fora, Brasil.

[2]Departamento de Odontologia Social e Infantil, Faculdade de Odontologia, Universidade Federal de Juiz de Fora, Brasil.

✉ **Carolina Werneck**

Av. Olegário Maciel, 488, apt. 201, Santa Helena, Juiz de Fora, Minas Gerais
CEP: 36015-350
carol.werneck@yahoo.com.br

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ABSTRACT

Introduction: The use of mini-implants has become common in orthodontic practice as it has increased the possibility of skeletal anchorage. The palate constitutes a site of choice for the insertion of miniscrews purposes because it is a site with relatively safety with appropriate bone thickness and less suitability for inflammation. **Aim:** To quantitatively evaluate the thickness of the palatal bone for miniscrews insertion. **Material and Methods:** Forty-seven sets of cone beam computed tomographic (CBCT) images were selected. The sample consisted of cone beam computed tomography from 47 patients (20 male, 27 female; mean age 22.4 years old/± 3.01 years). Palatal bone thickness (PBT) was measured in millimeters (mm) with 5 regions of interest (ROIs) which were determined used the coronal reconstructions of the patatal area: 4, 6, 8 and 10 mm posterior to the incisive foramen were evaluated. A total of 940 ROIs were evaluated. **Results:** Significant differences were observed for PBT between various palatal sections ($p<.01$). The thickest area (6.31-7.03 mm) was found in the anterior part of the palate. The mean bone thicknesses in the 6, 8 and 10 mm sections were significantly less than those observed at 4 mm from the incisive foramen. **Conclusions:** The thickness of the palatal bone is progressively thinner from the palatine foramen to the posterior region. Transversally, the bone was thicker in the palatine suture than in paramedian areas, mainly in the coronal reconstructions located more laterally.

Palavras-chave: Cone-Beam Computed Tomography; Palate; Alveolar Process; Orthodontic Anchorage Procedures.

RESUMO

Introdução: O uso de mini-implantes tem se tornado comum na prática ortodôntica por aumentar a possibilidade de ancoragem esquelética. O palato constitui um local de escolha para a inserção de mini-implantes por ser um local com relativa segurança, espessura óssea adequada e menor chance para inflamação. **Objetivo:** Avaliar quantitativamente a espessura do osso palatino para inserção de mini-implantes. **Material e Métodos:** Foram selecionados 47 conjuntos de imagens de tomografia computadorizada de feixe cônico (TCFC). A amostra foi composta por 20 homens e 27 mulheres (idade média de 22 anos; ± 3 anos). A espessura óssea palatina (EOP) foi medida em milímetros (mm) em 5 regiões de interesse (ROIs) delimitadas em vistas coronais da área patatal 4, 6, 8 e 10 mm posteriores ao forame incisivo. **Resultados:** Foram avaliados 940 ROIs. Diferenças significativas foram observadas para EOP entre várias seções palatais ($p <0,01$). A área mais espessa (6,31-7,03 mm) foi encontrada na parte anterior do palato. As espessuras ósseas médias nas seções de 6, 8 e 10 mm foram significativamente menores que as observadas a 4 mm do forame incisivo. **Conclusões:** A espessura do osso palatino diminui do forame palatino para a região posterior. Transversalmente, o osso era mais espesso na sutura palatina do que nas áreas paramedianas, principalmente nas secções coronais mais laterais.

Key-words: Tomografia Computadorizada de Feixe Cônico; Palato; Processo Alveolar; Procedimentos de Ancoragem Ortodôntica.

INTRODUCTION

The use of miniscrews has become widespread and common in orthodontic practice. Their application has increased the possibility of skeletal anchorage due to their suitability for positioning in many areas of the alveolar bone. The introduction of immediately loadable miniscrew has further expanded its therapeutic potential as an effective alternative to intra and extraoral conventional anchorage.[1-5]

Although miniscrew stability allows its clinical use, they can loosen during treatment.[6] The stability of miniscrews supported by bone tissue and simple mechanical retention is reported to be lower when compared with osteointegrated implants.[7-8] Factors associated to miniscrew clinical success and stability such as age, gender, screw features, surgical procedure, inflammation, sites of insertion, and bone quality have been related on the literature.[7,9-12]

The palate constitutes a site of choice for the insertion of miniscrews for orthodontic purposes because it is a site with relatively safety with appropriate bone thickness and less suitability for inflammation.[13,14] Both bone quality and quantity play important roles in the success of miniscrews.[10] Therefore, the knowledge of bone conditions in the area of interest will allow clinicians to decide more surely regarding the miniscrew.[13]

A few studies have used conventional radiography CT for bone quantification before implant placement for orthodontic anchorage. In addition to being a reliable imaging method mainly in for linear measures,[15-23] cone beam computed tomography (CBCT) has the advantage of producing less amount of radiation to the patient.[24]

In recognition of the need for objective determinations of bone thickness to guide miniscrews placement, the aim of the present study was to evaluate variations in the bone thickness in palatal regions potentially used for miniscrew placement.

MATERIAL AND METHODS

The sample of this cross-sectional study consisted of 47 CBCT exams (20 male, 27 female; mean age 22.4 years old/± 3.01 years) from archives of Orthodontic Department of Juiz de Fora Federal University. These individuals were selected according to the following criteria: (1) absence of craniofacial malformations or syndromes; (2) no previous history of trauma or surgery in the palatal area; (3) no regular use of drugs such as steroids, barbiturates, anticonvulsants, and thyroid hormone replacements; and (4) no chronic renal failure nor hormonal disorders, particularly thyroid, parathyroid, and adrenal impairment. This study was approved by the Research Ethics Committee of Juiz de Fora Federal University (number 0115.0.180.000-11).

Data were obtained by using a CBCT system (i-CAT Cone Beam 3-D Imaging System, Hatfield, USA). The following settings were used: field of view at 22 cm, 120Kv, 47mA, exposure time of 30 seconds and slice thickness of 0.5 mm. Multiplanar reconstruction of the heads, orientation and measurements were performed via iCAT-Vision software (i-CAT Cone Beam 3-D Imaging System, Hatfield, USA).

All CBCT measurements were performed by a single orthodontist (R.C.S.), with more than 10-years of experience, who received all information from the image evaluation methodology. The first step before the selection of the regions of interest (ROIs) was positioning the maxilla according to the following orientations: (1) axial plane and sagittal plane passing through anterior nasal spine and posterior nasal spine at the sagittal and axial views, respectively (figures 1A and 1B); and (2) sagittal plane passing in the center of the suture at the coronal view (figure 1C). The second step was locating the incisive foramen up to the sagittal and axial views simultaneously. Coronal sections of three milimeters of thickness (coronal views of 3 mm thick) of the palatal region were reconstructed at 4, 6, 8, and 10 mm posterior to the distal wall of the incisive foramen (figure 2). The palatal bone thickness (PBT) was determined (in mm) in each coronal section at the median suture, 3 and 6 mm increments laterally from the midline (figure 3), totalizing 20 measurements on each CBCT image. The highest possible ROIs encompassing both the bone cortices of the palatal process and the trabecular bone were outlined. Bone thickness (in mm) was calculated using the iCAT-Vision software.

Reproducibility of the CBCT bone thickness measurements was evaluated using the intraclass correlation coefficient. The examiner evaluated 5 CBCT scans randomly selected with measurements of the same 20 ROIs obtained at 2-week intervals.

Verification of the normality and homogeneity of variables was respectively performed by the Shapiro-Wilk and Levene tests, being the distribution of the sample considered normal. There were no differences between men and women (Student t-test for independent samples) so the combined sample was used.

The one-way analysis of variance (ANOVA) was performed to analyze differences of palatal bone thickness at different areas and the Tukey multiple range test was used for multiple comparisons. The Pearson correlation test was also used to verify the relationship between patient age and the measurements of interest. Statistical analysis was performed using Statistical Package for the Social Sciences 23.0 (SPSS Inc., Chicago, USA) and significance level was established at $p<0.05$.

RESULTS

The intraclass correlation coefficient (ICC=.984) showed that reproducibility was excellent.

A total of 940 ROIs, 20 for each of the 47

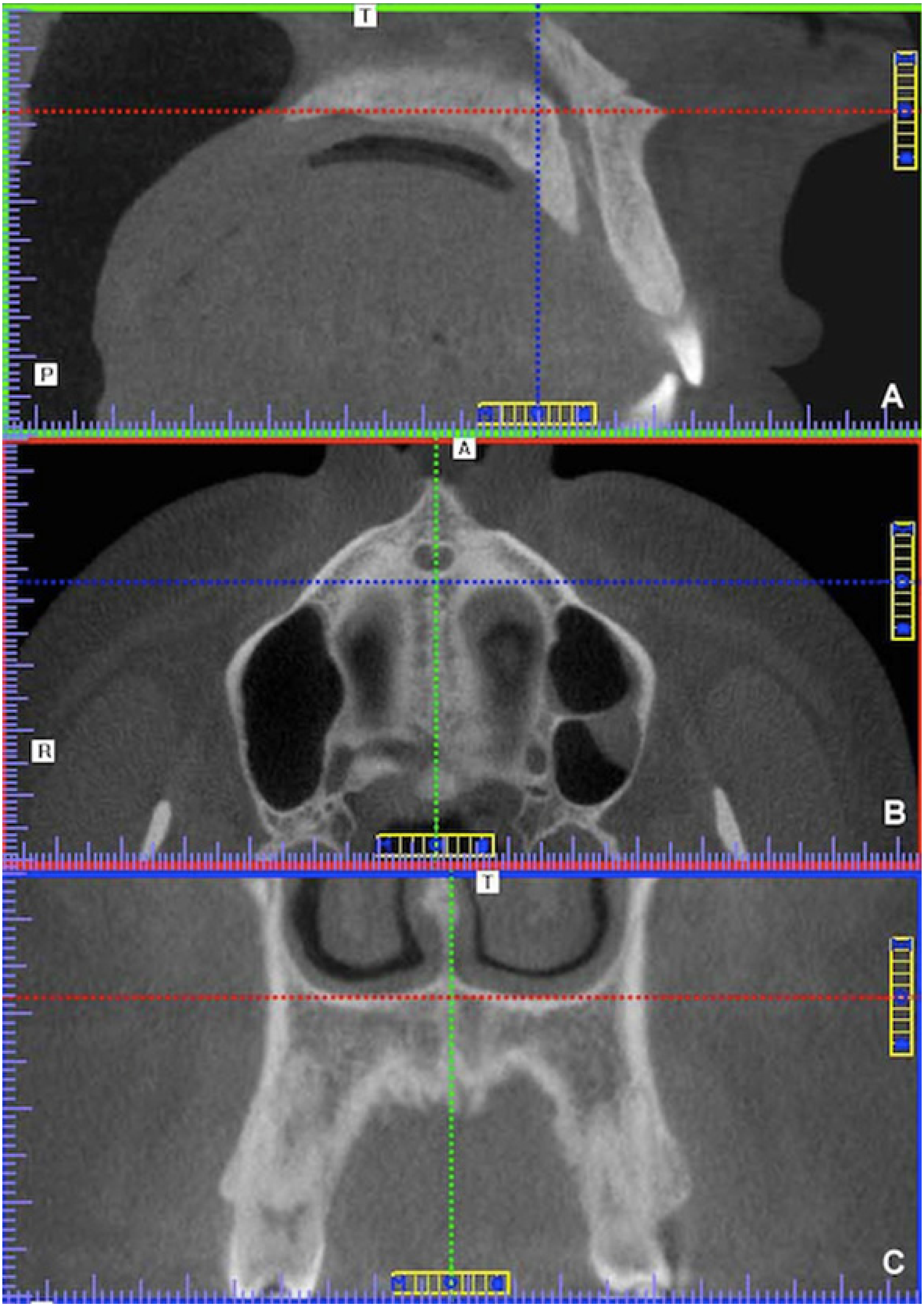

Figure 1: Sagital plane (A – red line) and axial plane (B – green line) passing through anterior nasal spine (ANS) and posterior nasal spine (PNS) at sagittal (A) and axial (B) reconstructions and sagittal plane (C – green line) passing in the center of the palatine suture at the coronal reconstruction (C).

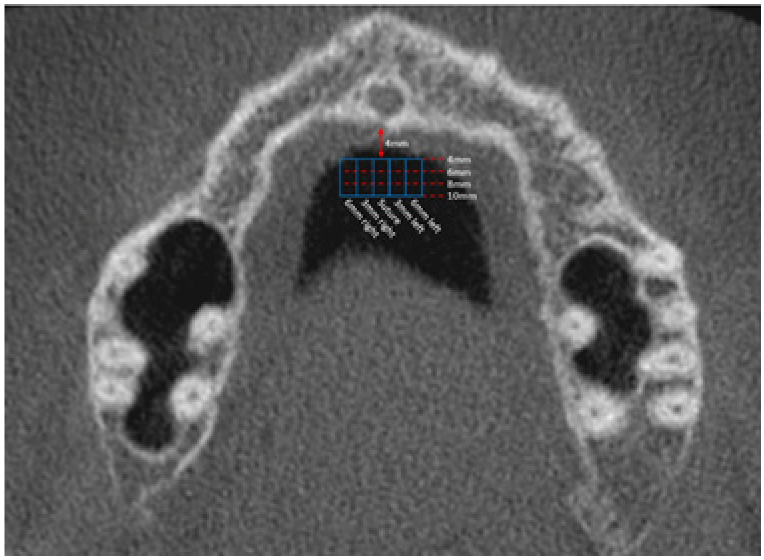

Figure 2: Coronal views of the palatal region reconstructed at 4, 6, 8 and 10 mm posterior to the distal wall of the incisive foramen.

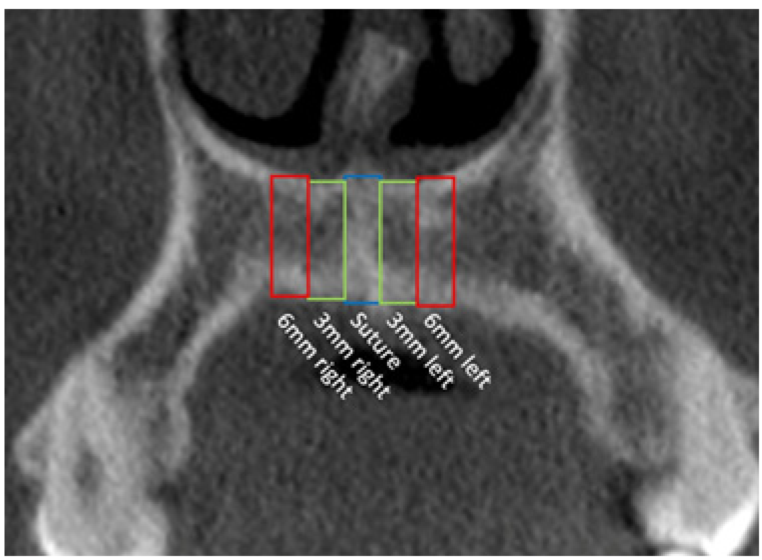

Figure 3: PBT measurements (in mm) determined in each coronal reconstruction at the palatine suture, 3 and 6 mm increments laterally from the midline.

patients, were evaluated and the PBT average values of ROIs grouped accordingly to the coronal and sagittal sections (table 1). The average values of the palatal bone thickness decreased significantly from the anterior to the posterior region comparing the coronal sections. The comparison among sagittal sections showed that the bone thickness at the suture area was significantly higher than in the lateral ROIs (p<01).

PBT average values of each ROI are shown in table 2. The average palatal bone thickness ranged from 2.78 to 7.03 mm. The average PBT in the 10 mm coronal section, at 6 mm to the right of the midline was the lowest (2.78 ± 1.44 mm) whereas the highest PBT was at 6 mm to the left side of the suture in the 4 mm coronal section. The PBT was significantly higher in the palatine suture in coronal sections of 8 and 10 mm. All in all, the palatal bone thickness decreased posteriorly in all sagittal sections (figure 4).

The palatal bone thickness showed a significant weak correlation with the age of individuals (table 3).

DISCUSSION

The stability of miniscrews is closely related to the quantity and quality of the cortical bone. The success of miniscrews can also be affected by bone density and thickness, just as the success of dental implants is influenced by bone quality.[20]

Several studies evaluated bone quantity

Table 1: Palatal bone thickness measured at each coronal (4, 6, 8 and 10 mm) and sagittal sections.

	Coronal sections (distance posterior from incisive foramen)				
	4 mm	6 mm	8 mm	10 mm	p value
PBT (mm)	6.70 ± 2.30 A	5.11 ± 1.98 B	3.97 ± 1.68 C	3.24 ± 1.53 D	<.0001

	Parasagittal reconstructions (side and distance from midline)					
	6 mm right	3 mm right	Suture	3 mm left	6 mm left	p value
PBT (mm)	4.65 ± 2.46 A	4.59 ± 2.19 A	5.43 ± 2.09 B	4.59 ± 2.23 A	4.52 ± 2.41 A	<.01

PBT - palatal bone thickness;

A,B Different letters are statistically significant by the Tukey multiple range test.

Table 2: Palatal bone thickness measured at each ROI of the palate.

Coronal Section	**Sagittal sections**					
	6 mm right (mean/SD)	3 mm right (mean/SD)	Suture (mean/SD)	3 mm left (mean/SD)	6 mm left (mean/SD)	p value
4 mm	6.88 ± 2.40 C	6.31 ± 2.16 C	6.77 ± 2.24 C	6.48 ± 2.37 C	7.03 ± 2.36 C	.557
6 mm	4.85 ± 1,96 D	4.94 ± 2.00 D	5.78 ± 2.03 C,D	4.95 ± 1.92 D	4.83 ± 1.92 D	.150
8 mm	3.73 ± 1.67 A,E,F	3.89 ± 1.68 A,E,F	4.88 ± 1.66 B,D,E	3.79 ± 1.56 A,E	3.57 ± 1.57 A,E	<.05
10 mm	2.78 ± 1.44 A,E,F	3.20 ± 1.52 A,E,F	4.27 ± 1.45 B,E	3.15 ± 1.38 A,E	2.81 ± 1.41 A,E	<.05
p value	<.05	<.05	<.05	<.05	<.05	

PBT - palatal bone thickness;

A,B Different letters are statistically significant among sagittal sections by the Tukey multiple range test.

C,D,E,F Different letters are statistically significant among coronal sections by the Tukey multiple range test.

(thickness) through conventional Computed Tomography (CT).[25,26] Quantitative computed tomography is the modality of choice to determine bone mineral density (BMD), but the X-ray dose absorbed by the patient during conventional CT scanning may limit the use of this modality for routine diagnosis in orthodontics.[25,27] According to a previous study,[26] when 3-dimensional imaging is required in orthodontic practice the CBCT should be preferred over the conventional CT one.

According to Hua et al[28], density measurements based on CBCT seemed to be inappropriate because of intensity inhomogeneity. Thus, the present study has limited itself to bone quantity assessment through bone thickness measurements.

According to Carano et al[29], in making an informed choice such as to which miniscrews to choose in terms of length and thickness, they concluded that the palate is a safety area to achieve an efficient anchorage in orthodontics. The palate allows the use of miniscrews with large diameters (2 mm or more). Therefore, according to Gracco et al[1], careful attention must be paid to the length of the miniscrew to encompass both bone cortices of the palatal process without perforating the nasal cavity. In the present study, the thickest part of the palate was the anterior 4 mm from the incisive foramen, and this finding agrees with the reports of previous studies.[1,14,30] The total thickness observed in the 4, 6, 8 and 10 coronal sections were lower than those observed on previous studies.[1,14,25] However, none of these previous researches reported that the maxillar was positioned according to specific orientations to avoid measurement bias due to palatal plane inclination in which the greater the inclination the thicker the measured area.

The results highlight that the major thicknesses of the palate are found at 6 mm to the left and the right of the suture in the anterior part of the palate (4 mm coronal section), and that the thinnest bone was at the same sagittal section in the most posterior part of the palate (10 mm coronal section). The morphology of the palate varies according to different coronal sections and in the 6, 8 and 10 mm sections, the morphology changes noticeably as the thickest bone was at the suture and thinner bone was laterally found at 6 mm. These results

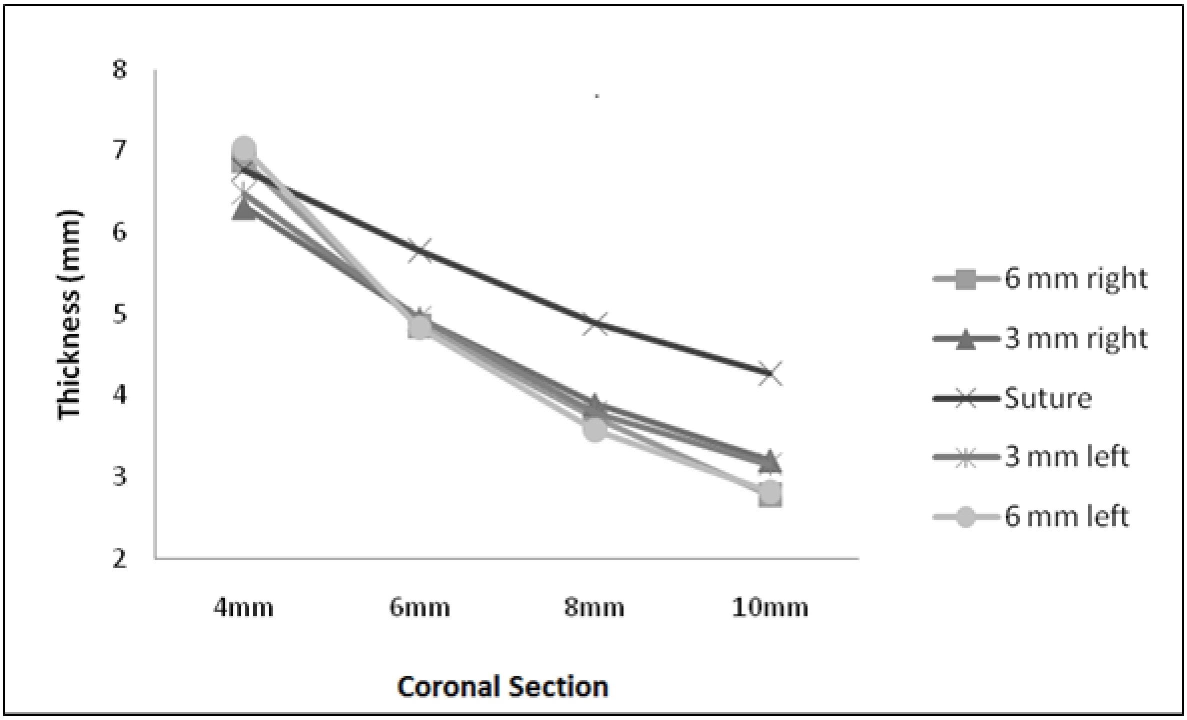

Figure 4: Average palatal bone thickness at each different coronal and parasagital reconstructions.

Table 3: Correlation between palatal bone thickness and age of individuals.

	r	p-*value**
Palatal bone thickness X Age of individuals	.106	.001

* Pearson correlation

are similar to those reported by Gracco et al.[1]

In this study, the palatal bone thickness tends to progressively decrease from the foramen toward the 10 mm coronal sections in all sagittal sections. This finding agrees with the literature, in which a few studies reported that vertical height of the palatal bone decreases toward the posterior planes.[1,14,25,30-33] Hourfar et al[33] associated the reference planes for measurement with the palatine grooves and concluded that the region of greater thickness is the anterior palate, more precisely at the level of the third palatine groove.

Considering the transversal direction, the decrease was observed in the palatal bone thickness from the suture to the 3 and 6 mm sagittal sections on the right and on the left. This variation was significant at 8 and 10 mm coronal sections. Different findings were reported by Gracco et al[1], no significant difference was observed in palatal bone thickness at the suture or at 3 and 6 mm laterally. At the 4 mm coronal section, an increase was observed from the 3 to the 6 mm sagittal sections, however, in the other coronal sections a decrease was detected from the 3 to the 6 mm. This result agrees with the one reported by Ravi et al[30] They found the 4 mm coronal section in the region of the suture thicker than in the parassagittal regions, while the opposite was evaluated in other posterior coronal sections.

Previous studies,[25,26] stated that the suitable bone height for miniscrews insertion is defined as 4 mm or more. According to this statement, the results of the present study show that 4 and 6 mm coronal sections are safe at both sutures and parasagittal areas. Regarding the other sections, only the coronal suture region showed more than 4 mm, suggesting that bone thicknesses found in the posterior region of the palate are not suitable for miniscrews placement.

Corroborating with the reports of Gracco et al[1] and Holm et al[34], no statistically significant differences were observed between the average palatal bone thickness to the left and to the right of the suture in this study. The definitive length of the miniscrews should also take into account the thickness of the mucosa, because soft-tissue measurements at the midpalatal suture area show that the thickest portion is 4 mm posterior to the incisive papillae, and that the thickness remained constant at 1 mm posterior to this point.

Further researches undertook verification of the relationship between miniscrews' success rates and the thickness of total bone and soft-tissue. Miniscrews features could elucidate the influence of these factors on stability of miniscrews and eventually justify the use of CBCT in orthodontic treatment planning when necessary.

CONCLUSION

The thickness of the palatal bone is progressively thinner from the palatine foramen to the posterior region and from the palatine suture to the paramedian areas. Bone thickness was greater than 4.8 mm in all regions until 6 mm posterior to the palatine foramen.

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