



Original Article

Evaluation of Palatal Bone Thickness and Its Relationship with Palatal Vault Depth for Mini-Implant Insertion Using Cone Beam Computed Tomography Images

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Main Points

- The thickness of the palatal bone significantly decreases from anterior to posterior and also from midsagittal to lateral in patients with deep or normal palates.
- At the midsagittal, the normal palate was significantly thicker than the deep palate.
- No significant relation was found between gender and the prevalence of deep and normal palate.
- The thickness of the palatal bone was significantly more in males than females in patients with deep or normal palates.

ABSTRACT

Objective: The purpose of this study was to measure the thickness of the palatal bone using cone beam computed tomography images for placement of mini-screws and their relationship with palatal vault depth.

Methods: This study was performed on 150 maxillary cone beam computed tomography images, 50% (n = 75) had deep palate and 50% (n = 75) had normal palate and 27.3% (n = 41) were male and 72.7% (n = 109) were female. Coronal sections with a thickness of 1 mm were prepared at distances of 4 mm, 8 mm, 12 mm, 16 mm, 20 mm, and 24 mm from the posterior wall of the incisive foramen. Then, in each section, in the midsagittal line and at distances of 2 mm, 4 mm, 6 mm, 8 mm, and 10 mm from that to the lateral sides, the bone thickness was measured. The Korkhaus index was used to identify the patients with a high palatal vault.

Results: The results showed that at the posterior sections in the midsagittal and parasagittal area, a significant difference ($P < .05$) was observed between deep and normal palate, and in these points, the bone thickness in the normal palate was greater. Also, in the section of 4 mm and 8 mm, a significant difference was observed between males and females in most of these points, and those were greater in males than females.

Conclusion: The maximum thickness of the palatal bone was observed first along the midsagittal line and then the paramedian and in the anterior section. Patients with deep palate had less palatal bone thickness in the posterior sections.

Keywords: Cone beam computed tomography, mini-screw, mini-implant, palatal bone thickness, palatal depth

INTRODUCTION

In many cases, orthodontic treatment requires maximum anchorage to achieve the best results and reduce side effects; therefore, we need further extra or intraoral anchorage. The success of extraoral appliances depends on patient cooperation. For this reason, the use of intraoral anchorage devices, such as mini-screws without the need for patient cooperation, is increasingly noteworthy.¹⁻²

Hourfar et al.³ stated in their study that a correlation might be found between the availability of bone and palatal morphology. Later, it was stated that the palatal morphology and the available bone at the mini-screw insertion site in the hard palate are important factors in its primary stability and overall success, and if this primary stability is not achieved during placement, the mini-screw may fail during orthodontic treatment.³⁻⁶ Care should be taken when inserting the mini-screws to prevent penetration into the nasal cavity and incisive canal. The selection of long mini-screws increases the risk of penetration into the nasal cavity and subsequent problems. If the mini-screws is too short, the depth of penetration into the bone may not be sufficient to achieve initial stability; therefore, the clinician must recognize the midpalate and paramedian palate topography.⁷⁻¹⁰ Computer guides can help to safely insert mini-screws; however, determining the safe mini-screw insertion site through cone beam computed tomography assessments can be helpful.¹¹

Most of the patients with high palatal vault require skeletal expansion, so using mini-screws in the palatal area during orthodontic treatment is helpful. However, the results of studies are inconsistent about favorable site of mini-screw placement. Baumgaertel et al.¹² evaluated the bone depth and thickness to determine successful mini-screw placement sites. They concluded that bone depth and cortical bone thickness of the palate were most favorable around first and second premolars to place mini-screw. While, Uday et al.¹³ evaluated bone around the first premolar, second premolar, first molar, and second molar at maxillary buccal and palatal sides and mandibular buccal sides to determine safe sites for mini-screw. The results indicated that adult mandibular buccal cortical bone to be the thickest and safest. On the other hand, not many studies have evaluated the safest site for mini-screw placement in patients with a high palatal vault. This study measured the palatal bone thickness in 60 points of the palate using CBCT to determine the most suitable area to place the temporary anchorage device (TAD) and also evaluated its relationship with the palatal vault depth and gender because diagnosing the factors related to the palatal bone thickness can help clinicians to identify cases with insufficient bone thickness and design the anchorage control method accordingly.

METHODS

This retrospective analytical study was performed on 150 maxillary CBCT images consisting of 2 groups of the normal and deep palate. This study was performed after receiving approval from ethical committee of Guilan University of Medical Sciences (IR.GUMS.REC.1399.057). To determine the sample size, a formula for estimating an average in a community has been used. Considering the statistical power of 80%, error level of 0.05, standard deviation of 3.09 and $d = 1$, the minimum sample size was calculated to be 74.86 which was considered as 75:

$$n = \frac{\left(z_{1-\frac{\alpha}{2}} + z_{1-\beta} \right)^2 (\sigma^2)}{(d)^2} = \frac{(1.96 + 0.84)^2 (3.09)^2}{1^2} = 74.86 \cong 75$$

Inclusion criteria covered all patients over the age of 15 years old who have been referred to the Guilan University, Faculty of Dentistry, Department of Radiology. Exclusion criteria included the history of trauma or surgery in the study area, the presence of impacted teeth in the palate, a systemic disease affecting bone quality or quantity, pathological defects or craniofacial deformities in the maxilla and palatal area, and the presence of palatal torus. The presence of rotation or tilting in the patient's head was also examined.

Cone beam computed tomography images of all cases were taken by NewTom VGI (NewTom, Verona, Italy) with 90 kVp, 6 mA, 0.2 voxel size, and standard zoom mode. The images were then retrieved by NewTom (NNT) viewer software (NewTom, Verona, Italy).

First, the location of the incisive foramen was determined using the axial view, and then coronal sections with a thickness of 1 mm were prepared at a distance of 4 mm, 8 mm, 12 mm, 16 mm, 20 mm, and 24 mm from the posterior wall of the incisive foramen (Figure 1). Then, in each point, in the midsagittal area and at intervals of 2 mm, 4 mm, 6 mm, 8 mm, and 10 mm from that, points were identified on both sides laterally. Finally, in the designated areas, the bone thickness was measured in millimeter, which included the distance between the outer cortical layer of the nasal floor and the outer cortical layer of the oral hard palate (Figure 2).

Measurements were performed on both right and left sides of the midpalate, and their averages were used. The Korkhaus index was used to identify cases with the deep palate:¹⁴

$$\frac{\text{Palatal height} \times 100}{\text{Posterior arch width}}$$

Posterior arch width is in the section of the first molars at the level of the occlusal plane and is measured as a distance from the midpoint connecting the fissures of the first molars of 2 sides. Palatal height is measured in the midsagittal plane and as a vertical distance between that horizontal line to the palatal surface. The average of this ratio is 42%. Values above this indicate a deep palate (Figure 3).

In this study, we used archival images of patients who were referred to the Guilan University, Faculty of Dentistry, Department of Oral and Maxillofacial Radiology for reasons such as implant surgery, impacted teeth, etc. None of the patients underwent radiation for this study.

Statistical Analysis

Kolmogorov-Smirnov (KS) test was used to evaluate the normality of the groups. Independent *t*-test and Statistical Package for Social Sciences (SPSS) software (IBM Corp, Armonk, NY, USA) version 24 were used for the statistical examination of the relationship and comparison of groups if the relevant assumptions were made, otherwise Mann-Whitney *U* test was used. The significance level in all tests was considered to be $P = .05$.

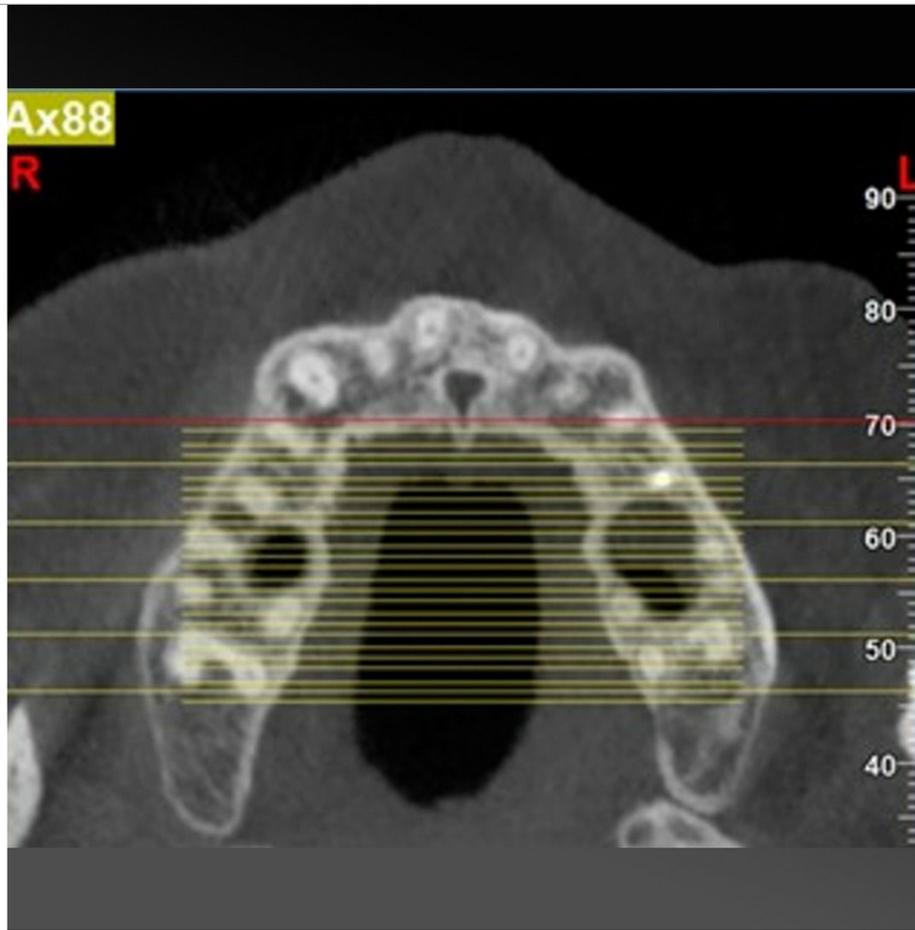


Figure 1. Reconstructed coronal cross-sections from the posterior wall of the incisive foramen

For 10 samples, measurements were repeated randomly with an interval of 2 weeks and the inter-observer agreement was evaluated by interclass correlation (ICC) calculation (ICC = 96%).

RESULTS

In this study, 50% (n = 75) of the subjects had deep palate and 50% (n = 75) had normal palate. Also, 27.3% (n = 41) were male

and 72.7% (n = 109) were female. Findings indicated 56.1% (n = 23) in men and 47.7% (n = 52) in women had deep palate. The 2 groups of deep and normal palate were homogeneous in terms of gender (P = .360).

Tables 1 and 2 show the mean and standard deviation of palatal bone thickness measurements at the distances of 4 mm, 8 mm, 12 mm, 16 mm, 20 mm, and 24 mm of posterior wall of the incisive canal and at the distance of 2 mm, 4 mm, 6 mm, 8 mm,

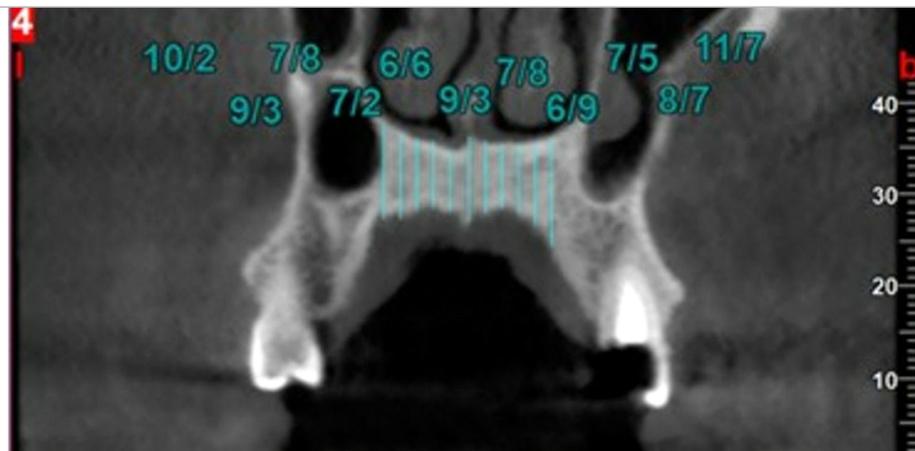


Figure 2. A sample of measurement in 1 section

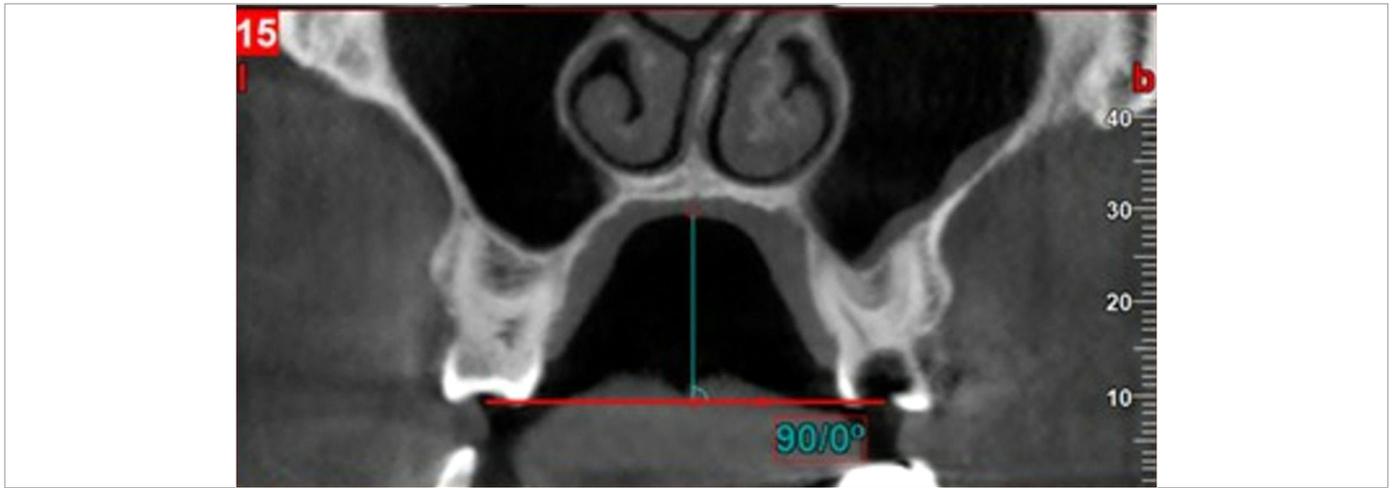


Figure 3. A sample of palatal height measurement

10 mm from the midsagittal line to the lateral sides in the normal and deep palate, respectively.

Table 3 shows a comparison of bone thickness sizes in the deep and normal palate. At the sections of 20 mm and 24 mm, a significant difference was observed in paramedian 1 (MD1), MD2, and midsagittal, and the normal palate thickness was greater in all 6 points.

Table 4 shows a comparison of bone thickness measurements by gender. Based on the obtained results in the 4 mm distance, a significant difference was observed between males and females

in all the studied areas and in all cases. It was observed that the thickness was greater in men than in women. In the sections of 8 mm in MD2, MD3, MD4, and midsagittal, a significant difference was observed. In all mentioned points, the thickness was greater in men than in women (Figure 4, 5).

DISCUSSION

One of the disadvantages of using the palatal area is the relative inadequacy of palatal bone thickness and its great variety in patients. Therefore, caution should be taken when inserting mini-screws because the selection of long mini-screws increases

Table 1. The measurements of palatal bone thickness in the normal palate

Sections	Palatal Bone Thickness					
	MD5 Mean ± SD	MD4 Mean ± SD	MD3 Mean ± SD	MD2 Mean ± SD	MD1 Mean ± SD	MM Mean ± SD
4	17.10 ± 3.45	8.0 ± 3.04	6.82 ± 2.69	6.57 ± 2.46	6.81 ± 2.11	8.95 ± 1.92
8	6.23 ± 2.43	4.42 ± 2.0	3.71 ± 1.73	4.07 ± 1.62	5.51 ± 1.67	7.64 ± 1.77
12	4.64 ± 1.80	3.13 ± 1.47	2.71 ± 1.20	3.31 ± 1.35	4.60 ± 1.55	7.22 ± 1.71
16	3.61 ± 1.47	2.40 ± 1.10	2.30 ± 1.01	3.01 ± 1.29	4.56 ± 1.60	7.39 ± 1.86
20	2.85 ± 1.30	2.0 ± 0.83	2.11 ± 0.89	2.95 ± 1.27	4.47 ± 1.73	7.74 ± 1.99
24	2.08 ± 0.77	1.79 ± 0.81	1.91 ± 0.75	2.47 ± 1.1	4.46 ± 1.55	7.68 ± 1.76

MD, mediolateral points at 10-mm, 8-mm, 6-mm, 4-mm, and 2-mm distances from the midsagittal line to the lateral; MM, midsagittal points.

Table 2. The measurements of palatal bone in the deep palate

Sections	Palatal Bone Thickness					
	MD5 Mean ± SD	MD4 Mean ± SD	MD3 Mean ± SD	MD2 Mean ± SD	MD1 Mean ± SD	MM Mean ± SD
4	10.23 ± 3.82	7.82 ± 3.16	6.48 ± 2.7	6.19 ± 2.28	6.35 ± 2.08	8.74 ± 2.07
8	6.15 ± 2.67	4.44 ± 2.05	3.60 ± 1.54	3.81 ± 1.38	4.92 ± 1.50	7.47 ± 1.72
12	4.38 ± 2.09	3.08 ± 1.52	2.59 ± 1.05	2.98 ± 1.09	4.32 ± 1.36	7.07 ± 1.75
16	3.57 ± 1.84	2.46 ± 1.24	2.15 ± 0.89	2.72 ± 1.06	4.13 ± 1.28	7.0 ± 1.64
20	2.88 ± 1.40	1.90 ± 0.91	1.86 ± 0.72	2.57 ± 0.90	4.22 ± 1.27	6.98 ± 1.57
24	2.19 ± 1.00	1.67 ± 0.70	1.71 ± 0.57	2.29 ± 0.80	4.03 ± 1.23	7.05 ± 1.54

MD, mediolateral points at 10-mm, 8-mm, 6-mm, 4-mm, and 2-mm distances from the midsagittal line to the lateral; MM, midsagittal points.

Table 3. The comparison of palatal bone thickness measurements in the deep and normal palate

Sections	MD5 P	MD4 P	MD3 P	MD2 P	MD1 P	MM P
4	.925	.735	.435	.331	.425	0.520
8	.855	.965	.695	.305	.384	0.570
12	.429	.832	.542	.104	.247	0.609
16	.889	.771	.365	.139	.074	0.174
20	.907	.507	.056	.039*	.038*	0.010*
24	.429	.332	.061	.006*	.009*	0.022*

*Statistically significant at $P < .05$.

the risk of penetration into the nasal cavity and incisive canal, and the limited palate height results in the production of short palatal mini-implants. If the mini-screws are selected too short, the depth of penetration into the bone may not be sufficient to achieve initial stability, therefore clinicians should know midpalate and paramedian palate topography.¹⁵⁻¹⁷ Determining the patient's palatal bone thickness can help the clinician prevent possible problems by determining the exact location and the size of the TAD. Also, this kind of information can help to design prefabricated devices for palatal expanders.

According to our study, when a mini-screw is needed in the palatal region, the most suitable area in terms of bone thickness to select the appropriate length of the screw is along the midsagittal line, 4 mm posterior to the incisive canal, paramedian areas, and the alveolar bone adjacent to the teeth. Along the midsagittal line, due to the presence of the nasal crest, suitable bone thickness is provided, even though insertion of the mini-screw in the non-bony sutures should be avoided due to the potential of affecting growth. In contrast to this study, Suteerapongpun et al.¹⁷ reported that the midsagittal bone thickness increased in posterior areas compared to anterior areas. Also, at the sections of 3 mm and 6 mm laterally from the posterior wall of the incisive canal, an increasing trend had been reported, which could be due to selecting shorter distances in their measurement method. The risk of penetration into the canal increases as the thickness of the bone around the incisive canal decreases. The findings of Kang¹⁶ correspond to our data in that the bone thickness decreases from the anterior to the posterior and from the midsagittal to the lateral. In another study, Ryu et al.¹⁸ reported

that the thickness of the palatal bone decreases from anterior to posterior in the paramedian regions while increases posteriorly in the midline. Inconsistencies between studies may be due to differences in bone thickness between individuals, differences in measurement methods, racial differences, and anatomy of the palate.¹⁸

The results of the current study showed that, for the insertion of the mini-screw in the anterior region of the palate, the safest location is the paramedian areas at sections of 4 mm and then 8 mm posterior to the incisive canal. In the middle and posterior areas (12 mm and more), screw insertion of more than 2 mm from the midsagittal line should be avoided. King et al.¹⁵ showed sufficient bone thickness for a 3 mm height implant in adolescents in the palatal paramedian region at a distance of 4 mm posteriorly and 3 mm laterally to the incisive foramen. In another study, Baumgaertel¹² used 30 dry skulls to assess bone thickness in the coronal sections and used dental contacts as a landmark to measure sections in the anterior-posterior dimension. He reported that bone thickness in the anterior is greatest and gradually decreases posteriorly. Also, in each coronal section, the greatest thickness was related to the parasagittal areas. When inserting the mini-screw in the anterior areas, we must consider the potential for damage to the incisive canal. Though the incisive foramen is located almost at the site of the incisive papilla, the canal extends upward and backward to about the level of the premolars (with differences in different individuals). To stay away from this sensitive area, parasagittal placement is recommended because the canal is located in the midsagittal plane.¹²

Comparing the average bone thickness between patients with deep and normal palate, the insignificant difference was observed from the sections 4-16 mm, but at 20 mm and 24 mm sections in midsagittal and parasagittal points (MD1 and MD2), the bone thickness was greater in patients with normal palate than in the deep palate. This shows the increased risk of mini-screw failure in these areas. Since the deep palate is a feature of long face patients, the difference between the 2 groups of deep and normal palate could be related to the function of the masticatory muscles, the bite force, and soft tissue function that can affect skeletal morphology. In the study by Ozdemir et al.¹⁹ it was found that the thickness of the alveolar maxillary and mandibular cortical bone was less than that of the low-angle cases, and this could lead to a higher risk of mini-screw loss in these patients. No studies were found about the relationship between the depth of the palate and the thickness of the palatal bone. Moon et al.²⁰ examined the relationship between vertical skeletal patterns and the success of mini-implants. They found that patients with a high Frankfort-mandibular angle and a low upper gonial angle had a lower odds ratio than the other facial patterns and concluded that the longer facial pattern is associated with the failure of mini-implants.

Examining the data from men and women and comparing the means showed that the greatest bone thickness is related to the midsagittal line and gradually decreases to the middle regions of the palate (MD3) and then gradually increases to the margins of the palate (MD4 and MD5). This increase is less in

Table 4. The comparison of palatal bone thickness between men and women

Sections	MD5 P	MD4 P	MD3 P	MD2 P	MD1 P	MM P
4	.026*	.008*	.004*	.010*	.003*	.002*
8	.0164*	.047*	.021*	.041*	.061*	.039*
12	.356	.229	.173	.334	.347	.399
16	.632	.623	.767	.662	.422	.730
20	.689	.644	.684	.543	.218	.131
24	.120	.875	.866	.266	.057	.056

*Statistically significant at $P < .05$.

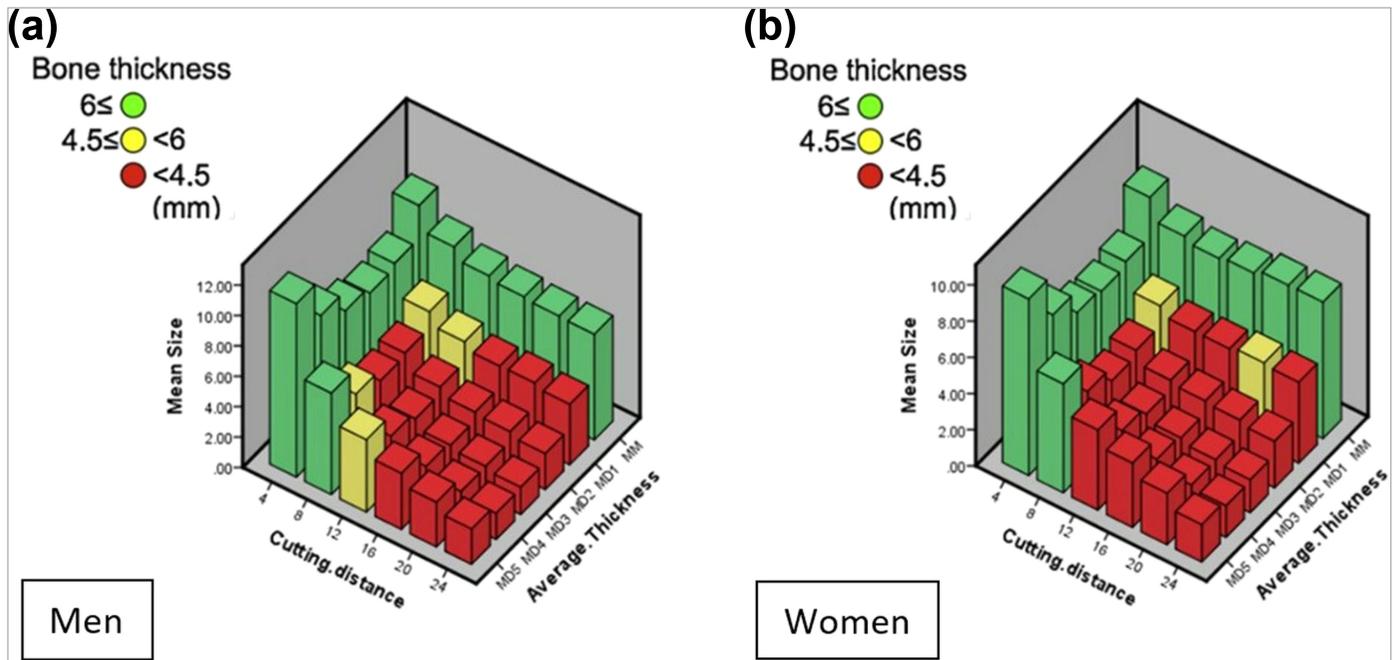


Figure 4. a, b. Thickness graph in men (a) and women (b)

the 20 mm and 24 mm sections. Also, the thickness decreases in all parts, by moving from the anterior to the posterior palate, which is more frequently observed in women. Also, by comparing males and females, it was found that the difference of palatal bone thicknesses in all points of the section of 4 mm and also in MM, MD2, MD3, MD4 points of a section of 8 mm is more in male than that in the female. So, in the anterior regions of the palate in the men, 1 mm longer mini-screws can be used. This finding was similar to Holm et al¹ who reported that, on average, bone thickness in men was 1.2 mm greater than in women. This finding was not in accordance

with the study of Wang et al.²¹ showing an insignificant difference between men and women.

One of the limitations of the current study was finding patients with deep palate. To overcome the limitation, patients from a wide age range were included in the study.

CONCLUSION

The maximum thickness of the palatal bone was observed first along the midsagittal line and then the paramedian (MD1) and

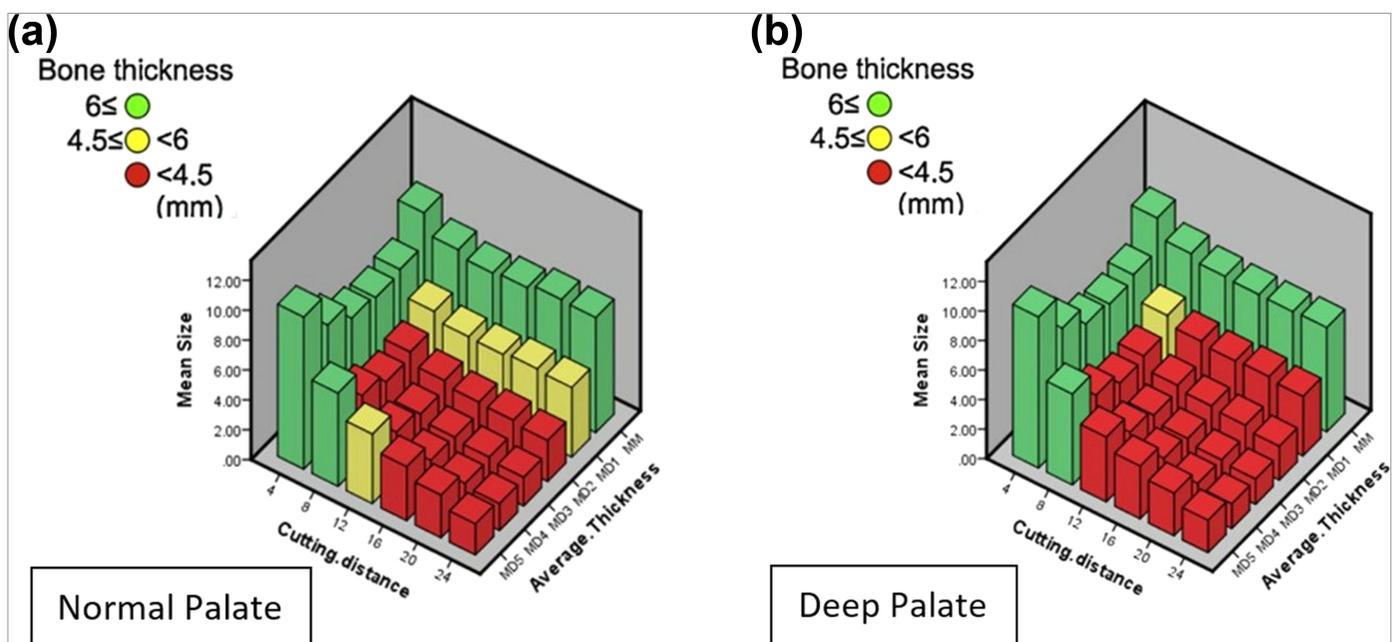


Figure 5. a, b. Thickness graph in normal (a) and deep palate (b)

anterior (4 mm distance) areas; these points could be safe areas for selecting the suitable length of the mini-screw. The thickness of the palatal bone decreases from anterior to posterior and also from midsagittal to lateral.

Patients with a deep palate at the posterior area (20 mm and 24 mm) in the midsagittal and parasagittal points had less bone thickness. Men at the sections of 4 mm and 8 mm had more bone thickness than women. When the mini-screw is to be used in the paramedian areas, it is recommended not to be inserted in the posterior areas or to use a screw with a shorter length.

There is a vast variation in the thickness of the palatal bone, and it is recommended to carefully evaluate the desired location in each patient to reduce the risk of failure of the mini-screws. This information can help clinicians to choose the best TAD location.

Ethics Committee Approval: Ethics committee approval was obtained from the Ethics Committee of Guilan University of Medical Sciences (IR.GUMS.REC.1399.057).

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