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Estimation of Palatal Bone Thickness to Determine Optimal Site for Mini Implant Placement- A Cone Beam Computed Tomography Study

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ABSTRACT
Aim-The aim of this study was to measure palatal bone thickness using CBCT to determine safe sites for mini implant placement as well as to check for any difference in bone thickness with respect to gender. **Materials and method-**Records of 50 patients requiring CBCT images between 14 -30 years of age were selected for the study based on the inclusion and exclusion criteria.All CBCT images were generated using Ondemand3D software. Axial section of maxilla wherein the incisive foramen is clearly visible was taken for measurement. Distances of 4,8,16 and 24 mm from midpoint of posterior border of incisive foramen were chosen and labeled as A,B,C and D . On the transverse plane, lines were marked at 0, 3 and 6 mm laterally from the median suture and were numbered as 2,1,0,1,2 .Bone thickness at these points of intersection are measured perpendicular to the bony palatal surface on the corresponding sagittal section using Ondemand3D software. The measurements are recorded at 20 sites for 50 patients by a single investigator. 15 randomly selected CBCTs were measured twice.**Results-** There was great variation in bone thickness at all locations in both males and females. The values were as large as 7.5mm at point A1 and as low as 1.2 at point D2. The highest mean bone thickness (7.484mm) was found to be at point A1 which is 4mm posterior to incisive foramen and 3mm lateral to it. Most measurements showed that the bone thickness decreased as we go more posterior and laterally.**Conclusion-**Mean palatal bone thickness for mini implant placement are highest on points A1 and A2 bilaterally. These points lie at 3mm and 6mm laterally on perpendicular from point A0 which is located at 4mm from posterior border of incisive foramen on mid palatal suture. There was no statistically significant difference between mean palatal bone thickness between males and females except at point A0,A2 and C0 which is negligible.

Key Words: CBCT; bone thickness; mid palatal suture; mini implants; TADs

I. INTRODUCTION

The key for successful orthodontic treatment is based on effective anchorage control. Mini implants are an excellent alternative to extra oral anchorage such as head gears and they offer several advantages. They require minimum patient compliance and provide a simple, convenient and cost effective method for providing absolute anchorage.[1] In addition, small dimensions, their ease of insertion and removal as well as their relatively lesser cost as compared to regular dental implants are further factors making them an effective and commonly used tool in the orthodontic practice.[2]Esthetic considerations and the growing demand for treatment methods that require minimal compliance, have led to the expansion of mini-implant usage. [3]

Bone quality and quantity plays an important role in the success of mini- implants as anchorage unit. Miniscrews in the maxilla have less stability than in the mandible because of its porous form. However, since the palate is composed of dense cortical bone, it has been determined as the best anchorage site in the maxilla.[4] Palatal mini implants have been widely used for a variety of tooth movements which includes molar protraction, intrusion of molars, distalization, MARPE (mini implant assisted rapid palatal expansion), bone anchored pendulum appliance etc.[5]

The median and paramedian areas of the palate consist of thick cortical palatal bone of good quality and quantity to support mini implants.[5] Palatal bone has the advantages of having lesser anatomical structures, such as nerves, blood vessels, or roots, that can interfere with the placement of mini-implants as compared to buccal cortical plates. Additionally, palatal area is suitable for mini-implant insertion as a result of keratinized mucosa covering the bones leading to less or no

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potential soft tissue irritations.[5] Whereas in the posterior palate there are some limiting anatomical structures, such as the increased soft tissue thickness composed mainly of adipose tissue and minor salivary glands, greater palatine arteries, veins, and nerves.[6]

Previous studies have shown that median and paramedian areas of anterior palate are suitable for mini implant placement. Some literature show that median palatal bone is most suitable as it has good level of bone due to nasal crest. However, in children and adolescents it may not be reliable as ossification of suture takes place later during adulthood. In such cases, paramedian site can be considered as an alternative.[3]Bernhart et al found a mean bone thickness of only 2.94mm at the suture and, therefore, recommended an insertion site of 3-6mm paramedian to the suture.[7]King et al advised placing screws 4mm distal to the incisive foramen and 3mm lateral to the suture.[8] On the other hand authors like kim et al showed more success rate when mini implants were placed on palatal suture.[9] Therefore it is necessary to evaluate bone thickness in different regions of palate, as stability of the palatal TADs depends on the amount of bone.

CBCT images can be helpful to evaluate bone thickness to anchor the mini implant and miniplate securely and to visualize neighboring structures for avoiding damage or complications during its placement and be useful in identifying optimal site location.CBCT technology enables us to evaluate the interradicular distance and thickness, transverse bone thickness, bone density and thickness, cortical bone dimensions and quality.

Therefore, the purpose of this study was to quantitatively evaluate the bone thickness at different standardized points in the palate to select ideal site for implant placement.

II. MATERIALS AND METHOD :

CBCT records were selected from the Department of Orthodontics &dentofacial orthopedics and Department of Oral medicine and Radiology, Rajarajeswari dental college and hospital, Bangalore. Records of 50 patients requiring full skull/maxillary CBCT between 14 - 30 years of age was selected for the study based on the inclusion and exclusion criteria. No informed consent was taken as all CBCT images had been obtained in the past.Patients with craniofacial anomalies and syndromes, suffered trauma or undergone surgery ,Palatal cysts or tumours,palatalcleft,Systemic illness affecting bone quantity or quality,Impacted teeth in palatal bone were excluded.

CBCTs was taken using SoredexScanora 3D with the following settings:

Potential – 90Kv
Current – 12.5 mA
Exposure time – 15 seconds
voxel size -0.133- 0.35mm

ONDemand3D Software was used for image processing and analysis with screen resolution of 1920×1200 pixels and 64-bit color. Measurements on scan was made using ONDemand3D SOFTWARE. Axial and sagittal views of CBCT images were used for the measurement

Figure 1: SoredexScanora 3D CBCT machine

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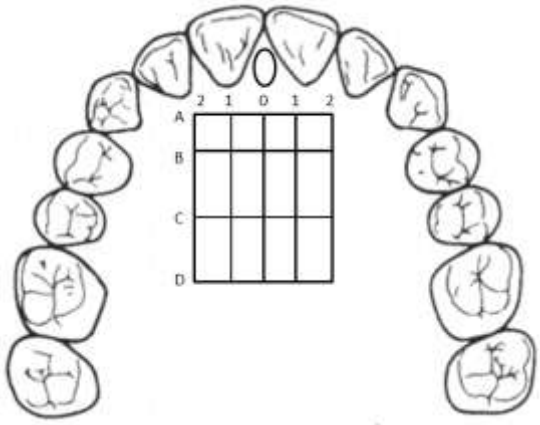

Figure 2: Reference lines for measurement of palatal bone

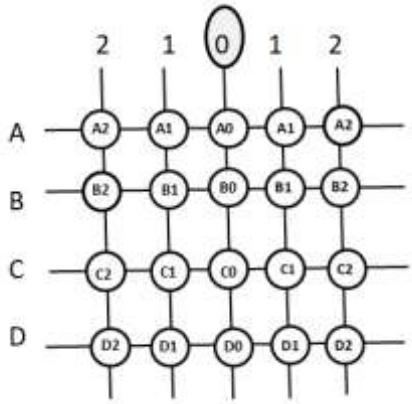

Figure 3: Measurement points on the palate

Axial section of maxilla wherein the incisive foramen is clearly visible was selected to do the measurements. Distance of 4,8,16 and 24 mm from mid point of posterior border of incisive foramen were taken and were as labeled as A,B,C and D . On the transverse plane, lines were marked at 0,3 and 6 mm laterally from the median suture and were numbered as 0,1,2 bilaterally. For example, a point 4mm on the median would be named A0 and a point 16mm posterior to incisive foramen and 3mm lateral would be named C3. 20 points which included 4 points on the median (A0,B0,C0,D0), 4 points 3mm from median (A1, B1, C1, D1) and 4 points 6mm from median (A2, B2, C2 and D2) bilaterally. (figure 2 & 3)

Figure 4: OnDemand3D software showingAxial section

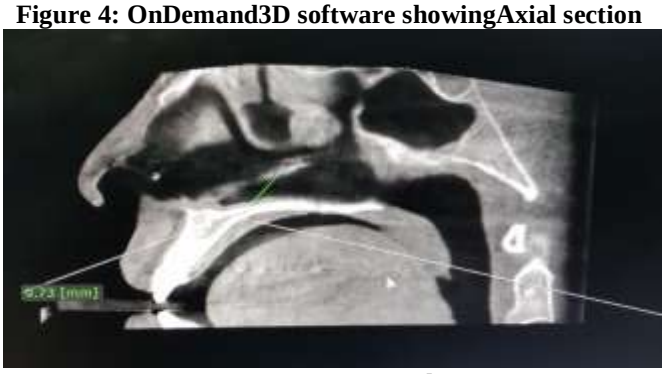

Figure 5: OnDemand3D

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Software showing Sagittal Section

Points to be measured were marked on axial section and the bone thickness at these points of intersection were measured perpendicular to the bony palatal surface on the corresponding sagittal section.(figure 4 & 5) The measurements were recorded at these 20 sites for all 50 patients by single investigator. 15 randomly selected CBCTs were measured twice to rule out any errors.

III. STASTISTICAL ANALYSIS :

Statistical Package for Social Sciences [SPSS] for Windows, Version 22.0.Released in 2013. Armonk, NY: IBM Corp., was used to perform statistical analyses.

Student Paired t test was used to compare the mean Palatal Bone thickness (in mm) between right & left sides in different regions.

Repeated Measures of ANOVA Test followed by Bonferroni's post hoc test was used to compare the mean Palatal Bone Thickness (in mm) b/w diff. points on Mid Palatal Suture at 0 mm, 3 mm & 6 mm and also the comparison of mean Palatal bone thickness b/w diff. distances from MPS at various points were performed using the same test.

Independent Student t Test was used to perform gender wise comparison of mean Palatal Bone Thickness (in mm) at different distances at different points on Mid Palatal Suture. The level of significance [P-Value] was set at $P<0.05$.

IV. RESULTS :

Table 1 :Age and Gender distribution among study subjects

Variable	Category	n	%
Age	15-20 yrs.	19	38%
	21-25 yrs.	20	40%
	26-30 yrs.	11	22%
		Mean	**SD**
	Mean	22.20	4.47
	Range	15 - 30	
Gender	Males	26	52%
	Females	24	48%

Age and gender distribution of patients is shown in table 1. In this study,20 standardized sites on the palate were measured, out of which 4 measurements were made on the median and 8 were made on paramedian sites on left and right side each. Points selected were at a distance of 4,8,16 and 24 mm from midpoint of posterior border of incisive foramen at the MPS and at 3 and 6 mm from the MPS on right and left side.

There was no statistically significant differences in palatal bone thickness on right and left side. Hence the mean measurements of right and left side were taken for statistical analysis.

The mean palatal bone thickness at point A0, B0, C0 and D0 on midpalatal suture was 5.13±1.82, 4.70±1.43, 4.35±0.96, 4.57±0.96 respectively. Comparison of mean palatal bone thickness at midpalatal suture (0mm) using repeated measures of ANOVA shows there was no statistically significant difference in Mean palatal bone thickness between different points at mid palatal suture.(Table 2A)

The mean palatal bone thickness at point A1, B1, C1 and D1 at 3mm distance from MPS was 7.484±1.575, 3.870±0.943, 2.516±0.659, 2.234±0.607 respectively. The difference in mean palatal bone thickness at 3mm from MPS was statistically significant at $P<0.001$. There was gradual reduction in mean palatal bone thickness from anterior to posterior region. (Table 2B) Similar results were shown for mean palatal bone thickness at 6mm from mid palatal suture. It was 7.153±1.575, 3.644±1.148, 1.961±0.771, 1.325±0.532 at point A2, B2, C2 and D2 respectively. The difference in mean palatal bone thickness at 6mm from MPS was statistically significant at $P<0.001$. (Table 2C).

Mean palatal bone thickness at different distances from Median at Line A,B,C and D are shown in figure 6 A, B, C and D. Mean palatal bone thickness at different distances on Line A,B, C and D – gender wise comparison is shown in Figures 7 A,B,C and D.

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2A.Comparison of mean Palatal Bone Thickness (in mm) b/w diff. points on Mid Palatal Suture at 0 mm using Repeated Measures of ANOVA Test						
Points	**N**	**Mean**	**SD**	**Min**	**Max**	**P-Value**
A0	50	5.13	1.82	2.8	9.0	0.74
B0	50	4.70	1.43	1.6	7.8	
C0	50	4.35	0.96	2.2	6.5	
D0	50	4.57	0.96	2.6	6.5	

2B.Comparison of mean Palatal Bone Thickness (in mm) b/w diff. points on Mid Palatal Suture at 0 mm using Repeated Measures of ANOVA Test						
Points	**N**	**Mean**	**SD**	**Min**	**Max**	**P-Value**
A0	50	5.13	1.82	2.8	9.0	0.74
B0	50	4.70	1.43	1.6	7.8	
C0	50	4.35	0.96	2.2	6.5	
D0	50	4.57	0.96	2.6	6.5	

2C.Comparison of mean Palatal Bone Thickness (in mm) b/w diff. points on Mid Palatal Suture at 0 mm using Repeated Measures of ANOVA Test						
Points	**N**	**Mean**	**SD**	**Min**	**Max**	**P-Value**
A0	50	5.13	1.82	2.8	9.0	0.74
B0	50	4.70	1.43	1.6	7.8	
C0	50	4.35	0.96	2.2	6.5	
D0	50	4.57	0.96	2.6	6.5	

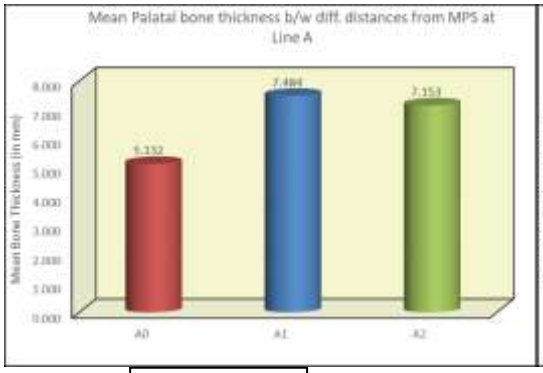

Figure 6A

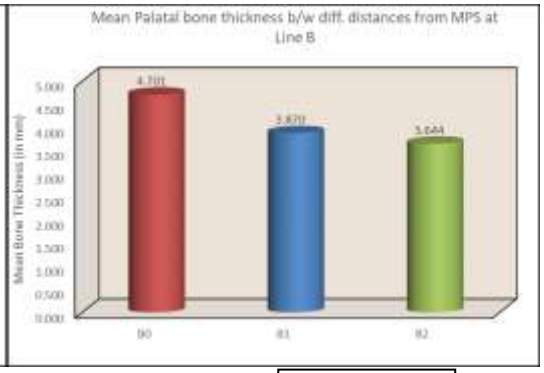

Figure 6B

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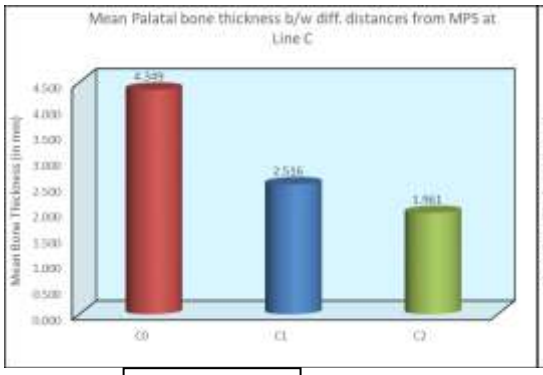

Figure 6C

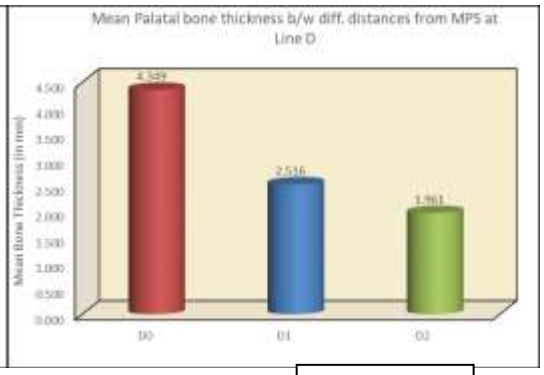

Figure 6D

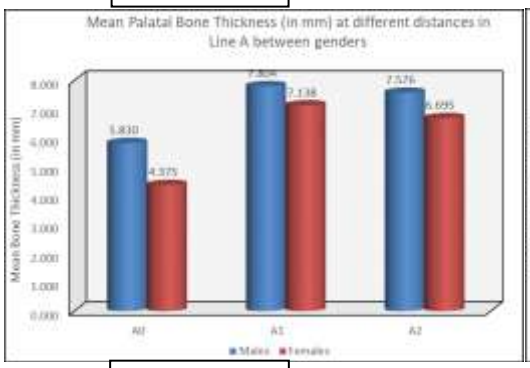

Figure 7A

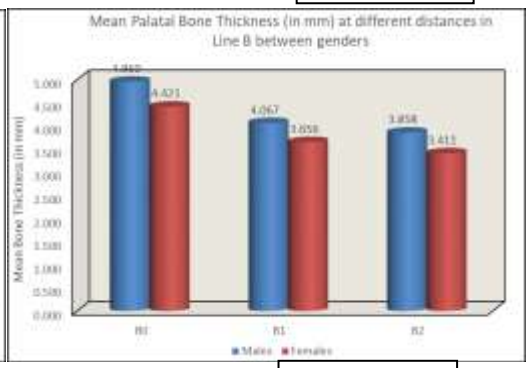

Figure 7B

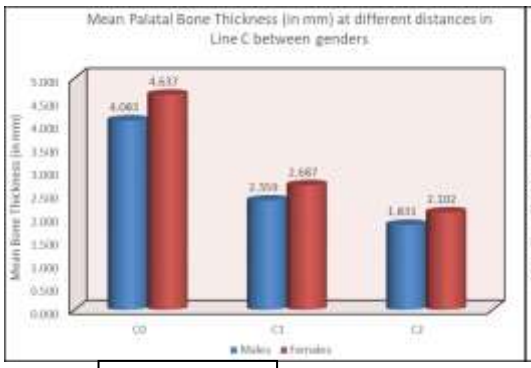

Figure 7C

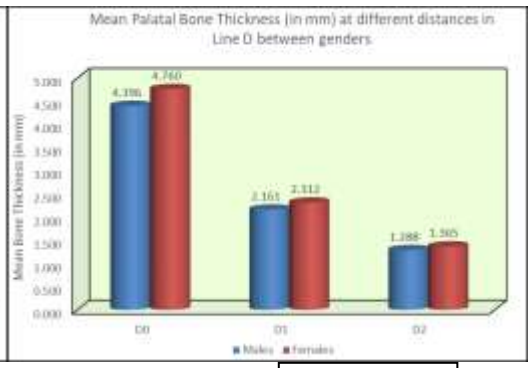

Figure 7D

V. DISCUSSION

The developing demand for orthodontic treatment with minimal patient compliance and maximum anchorage has prompted utilization of TADs. Various factors play a role in stability of mini implants, among these, anatomic location and bone thickness at implant site is known to be critical factors.[1] Inadequate bone thickness at the implant placement site can pose a risk of perforating into the maxillary sinus or the incisive canal or nasal cavity.[3] The palate has become popular site for placement of TADs due to its easy access, keratinized mucosa, lack of vital structures and reduced risk of root injury. The keratinized mucosa of palate along with adequate cortical bone have strong effect on primary stability and success of the orthodontic mini implants.

According to a study by Ludwig et al, palatal implant should be placed perpendicular to the palatal surface and angled toward the incisor roots to ensure optimal retention and effectiveness. Hence in this study bone thickness was measured perpendicular to the palatal surface.[10]

There were great variation in bone thickness at all locations among all subjects. The values were as large as 7.5mm at point A1 and low

as 1.2 at point D2. The highest mean bone thickness (7.585mm) was found to be at A1 which is 4mm posterior to incisive foramen and 3mm lateral to it. Most measurements showed that the bone thickness decreased as we go more posterior and laterally.

In the MPS the mean palatal bones thickness ranged from 5.13mm at point A0 to 4.35mm at point C0 and it was not statistically significant whereas at 3mm from MPS the mean palatal bone thickness ranged from 7.484mm at point A1 and 2.234mm at point D1 which was statistically significant. The mean palatal bone thickness decreased as we measured posteriorly from point A1 to point D1, 3mm lateral to MPS. Similarly at 6mm lateral to MPS, the mean palatal bone thickness ranged from 7.153 mm at point A2 and 1.325mm at point D2. Bone thickness was highest at line A, followed by line B, C and D at both 3mm and 6mm lateral to MPS. Line A had significantly larger mean palatal bone thickness as compared to line B, C and D. The mean palatal bone thickness at line C and D had lesser variation.King et al advised placing screws 4mm distal to the incisive foramen and 3mm lateral to the suture which is in agreement with findings of current study.[8]

At point A1, ie 4mm posterior to incisive foramen , highest mean palatal bone thickness of 7.484±1.419 is present at point A1 followed by 7.153±1.575 at A2 and least bone thickness of 5.132 at A0 (0mm). Lesser bone thickness available for placement of TADs at A0 (MPS) could be due to presence of incisive canal. Some older studies have overestimated the amount of bone thickness that is available for implants in the median hard palate. In a study by Henriksen et al, measurements have shown that an average of 8.6 +/- 1.3 mm of bone is available for the implant. However, considering the incisive canal (where only bone thickness inferior to it is measured), only 4.3 +/- 1.6 mm of bone exists. The canal itself measure about 2.5 +/- 0.6 mm in diameter.[11]

At line B. ie 8mm posterior to incisive foramen, highest mean palatal bone thickness of 4,701±1.430 at point B0 followed by 3.870±0.943 at B1 and 3.644±1.148 at B2.The mean palatal bone thickness reduces from MPS laterally. Similarly at line C, 16mm posterior to incisive foramen, the mean palatal bone thickness reduces from MPS laterally with highest bone thickness of 4.349±0.956 at MPS and lowest at C2 with bone thickness of 1.961±0.771 mm. At point D, highest mean palatal bone thickness of 4.571±0.958 was present at MPS (D0) and lowest bone thickness at D2 of 1.325±0.532. Mean palatal bone thickness reduces from MPS to 3 and 6mm laterally except in case of line A where there is higher mean palatal bone thickness on 3mm(A1) and 6mm(A2) laterally than the mid palatal suture itself (A0).

Difference in mean palatal bone thickness between male and female patients is not statistically significant except at points A0, A2 and C0 where it is statistically significant. In general the females have slightly lesser bone thickness as compared to males with exception of point D where females have relatively more bone thickness as compared to males but it is not statistically significant. Results of study done by Graccio et al also showed no sex-related differences.[12]

The results of current study partially agrees to study by Graccio et al where he measured palatal bone thickness on paracoronal views. Greatest bone thickness of 4 to 8mm was found in anterior palate (ie, 4mm and 8mm from incisive foramen). There was no significant difference in bone thickness in 16 and 24mm distance[12]. At the mid palatal suture bone thickness was higher at 4mm and 8mm distance than 16mm and 24mm which does not fully correlate with the present study where at 4mm on MPS (A0) the bone thickness was slightly lesser.

Study by Maike Holm et al showed that least mean palatal bone thickness was measured in the mid sagittal plane which increased 2mm laterally. There was significant difference between measured bone thickness, with bone thickness increasing upto 14mm posterior to CEJ in all sagittal planes. Bone thickness of females is on an average 1.23mm lesser than of male patients. His study also showed that bones thickness was on an average 6.44mm lesser in 9 to 13 year old patients as compared to 14-18 and 19-30 year old group. In the present study, the bone thickness decreased from anterior to posterior region in all sagittal planes similar to study by Holm et al, but there is no significant difference between male and female bone thickness. The bone thickness was measured perpendicular to bony surface in this study, similar to the present study.[5]

Sungmin Kang et al reported that the palatal bone thickness tends to decrease posteriorly and laterally which is in agreement to the findings of the current study.[3]The reason for this can be due to the embryonic development of the palate. Development of hard palate is by fusion of primary and secondary palate which form anterior and posterior palate.[13]The thickness of bone in posterior palate is lesser due to limited vertical thickening of secondary palate as a result of rapid development of tongue.

Success of palatal TADs depends on the quantity of bone as it relies on mechanical retention for its stability. Bone at MPS (nasal crest) is adequate and is considered to be a safe site for placement of TADs. However in adolescent patients the chances of failure is high due to inadequate ossification of the suture. Therefore in adolescent patients it is best to avoid median region to ensure stability of implants.[5] In a study done by Ryu et al, results showed that palatal bone thickness was lower in early mixed dentition patients as compared to late mixed dentition and adult patients.[14] It is found that even in adult patients there can be possibility of connective tissue interposition between bone and screw which can increases chances of implant failure.[12]

According to Gracco et al, posterior palate is also suitable for placement of TADs because of the quality of double cortical bone and the reduced mucosal thickness.[8]

The anterior palate is ideal for placement of orthodontic mini implant as it has appropriate quantity of cortical bone. Paramedian placement of TADs are more favourable as they have sufficient cortical cone thickness as well as they demand shorter force arm.[15] Knowledge of palatal morphology and the bone depth and thickness helps us place mini implants and avoid its failure. Also with the advent of CBCT in craniofacial diagnosis, it has become easier to visualize palate and surrounding structures for safe placement of mini implants.

However, drawbacks were present in the study. CBCT images of patients above 14 years were taken. Including early mixed dentition patients would facilitate comparison between growing children, adolescents and adults to evaluate the ossifying stages of MPS. The radiological reference points and lines are reproducible in CBCTs, but cannot be clearly reproducible clinically as they are bony reference points under the palatal mucosa.

VI. CONCLUSION

The following conclusions can be drawn from the present study:

1. Mean palatal bone thickness for mini implant placement are highest on points A1 and A2 bilaterally. These points lie at 3mm and 6mm laterally on perpendicular from point A0 which is located at 4mm from posterior border of incisive foramen on mid palatal suture. Orthodontic mini implants can also placed on mid palatal suture as it has sufficient bone thickness but is better avoided in mixed dentition/adolescent patients due to incomplete ossification.
2. The mean palatal bone thickness tends to decrease laterally and posteriorly except at the mid palatal suture where palatal bone thickness is sufficient at posterior area
3. There is no statistically significant differences between mean palatal bone thickness between males and females except at points A0,A2 and C0 which is negligible.

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