VOLUME - 11, ISSUE - 03, MARCH - 2022 • PRINT ISSN No. 2277 - 8160 • DOI : 10.36106/gjra

Original Research Paper

Dentistry

ASSESSMENT OF CORTICAL BONE THICKNESS AT BUCCAL AND LINGUAL INTER RADICULAR SITES IN MAXILLA AND MANDIBLE: A CBCT STUDY

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ABSTRACT

Introduction: The two major factors which has bearing on success of mini-implants are cortical bone thickness and inter radicular distance. Hence, clinician must be aware of any differences in cortical bone thickness within jaws for safe placement of MSI. **Aim and objectives:** To assess cortical bone thickness and inter radicular distance at different heights from CEJ to determine optimal site for implant placement in maxilla and mandible, respectively. **Method:** Computed Tomographic scans of 32 maxilla and 31 mandible were taken and Galileos Implant V1.9, was used for the purpose of both measurements. For each inter radicular space, buccal and lingual cortical bone thickness along with mesiodistal distance between roots were measured at level of 2, 4 ,6 mm from CEJ between lateral incisor, canines, 1st -2^{nd} premolar, 2^{nd} premolar-1^{st} molar, 1^{st}-2^{nd} molar. **Results:** There were significant difference in bone thickness within the jaws. Cortical bone and mesiodistal distance between 2^{nd} premolar-1^{st} molar, 1^{st}-2^{nd} premolar was greater than 1^{st}-2^{nd} molar, lateral incisor–canine. Cortical bone in posterior region was thicker than in anterior mandibular regions and thickness of buccal cortex was more in mandible than in maxilla. **Conclusion:** There were differences in cortical bone thickness within the jaws at different heights from CEJ with greatest cortical bone thickness observed at 6mm from CEJ. The optimal sites of implant placement in maxilla were between 2^{nd} premolar and 1^{st} molar and between 1^{st}-2^{nd} molar in the mandible on account of adequate bone thickness along with inter radicular distance observed in these regions.

KEYWORDS : Temporary anchorage devices, Cortical Bone Thickness and CBCT.

INTRODUCTION:

Mini implants have been objects of study and research in the recent times due to its escalating popularity in the orthodontic practice. The most popular sites for placement of implants are buccal cortical plate of maxilla and mandible, palate, the lingual aspect of the maxillary alveolar process and the retromolar area in the mandible, but the loosening and failure of mini-implants are major limitations for their use. The two vital factors that clinicians should consider for micro-implant placement are safety and stability. Safety is related to avoiding root damage during miniscrew insertion in bone. On the other hand, initial stability is obtained by placing micro implants in alveolar bone with sufficient quantity. Hence, the cortical bone thickness and the inter-radicular distance are predominant factors affecting the stability of implants.

According to Costa et al[1] and Wilmes et al[2], bone quantity is a major factor associated with primary stability of mini-implants, probably because stability is achieved by mechanical retention rather than osseointegration. Motoyoshi et al[3], also recommended that cortical bone thickness of 1mm or more is a prerequisite for success of mini screw implantation. Liou et al[4], enumerated the limitations of mini-implants with risk of damage to blood vessels, nerves, and dental roots as TAD'S can shift up to 1.5 mm under orthodontic forces, therefore a clearance of 2.0 mm between the mini implant and the dental root is imperative for safety. Kuroda et al[5], also considered root proximity as a major factor for mini implant failure.

To achieve precise and safe placement of miniscrews to inter-radicular sites, Cone beam computed tomography has been selected as imaging modality for the purpose of conducting measurements in this study.

In past, most of studies have been limited to the posterior part of jaws. Another demerit of previous studies was that almost half of them have been carried out either on dry skulls or non-orthodontic patients without any malocclusion.

This study has been designed to determine the optimal sites of mini-implant placement in maxilla and mandible based on mapping of the dimensions of the inter-radicular spaces and cortical bone thickness at different distances from CEJ with aid of Cone Beam Computed Tomographic images.

MATERIAL AND METHODS:

The sample comprised of Cone Beam computed tomographic scans (Galileos Comfort X-ray system form Sirona, Germany) of 32 subjects (18 females, 16 males) within age range of 17-26 years taken at Subharti Dental College, Meerut. The scans were rejected on basis of following exclusion criteria (1) Pregnant female (2) any medical history of bone disease (3) generalized bone loss (4) subjects younger than 17 years.

Galileos Implant V1.9, a 3D viewer software a product of Sirona Dental System GmbH, Bensheim, Germany was used for assessment of the cortical bone thickness and the inter radicular distance between (1) lateral incisor and canine (2-3), 1^{st} and 2^{nd} premolar (4-5), 2^{nd} premolar and 1^{st} molar (5-6) and 1^{st} -2^{nd} molar (5-6) (Fig 1, Fig 2).

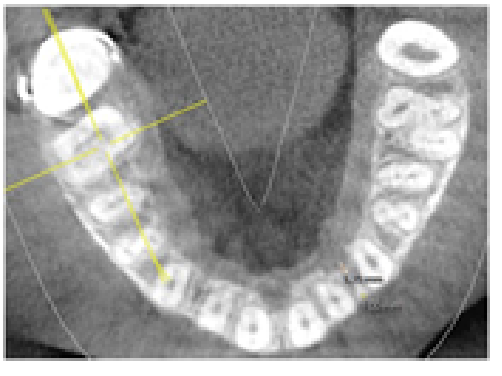

Figure 1: Measurement of buccal and lingual cortical bone thickness in maxilla between lateral incisor and canine in the axial slice

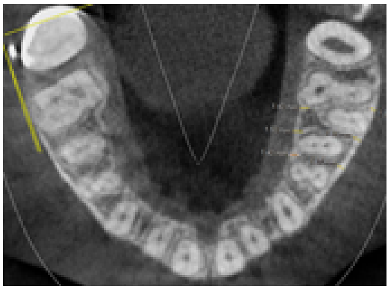

Figure 2: Measurement of buccal and lingual cortical bone thickness in maxilla between 1st -2nd premolar, 2nd premolar-1st molar and 1st-2nd molar in axial slice.

The lingual cortical plate in the mandible was not measured because of its limited use for mini-implant placement. The inter-radicular measurements were made at heights of 2, 4 and 6mm from CEJ. For each patient, only one side was measured because it was previously shown that there were no differences in cortical thickness between sides of the jaws.[6,7]

The inter radicular distance was measured by a line that passed the mesiodistal central groove of each tooth in the axial image. [8,9](Fig 3)

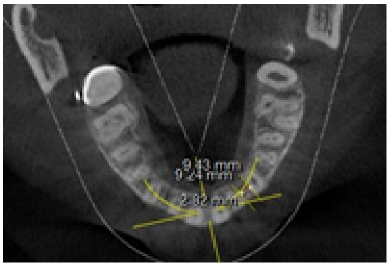

Figure 3: Measurements of inter radicular distance between maxillary lateral incisor-canine as the distance between parallel lines tangent to the adjacent proximal root surfaces and the root proximity was measured by a line that passed the mesiodistal central groove of tooth in the axial image.

The paramedian palate was measured 3,6, and 9mm dorsal and 3mm lateral to the incisive foramen.[10] (Fig 4, Fig 5)

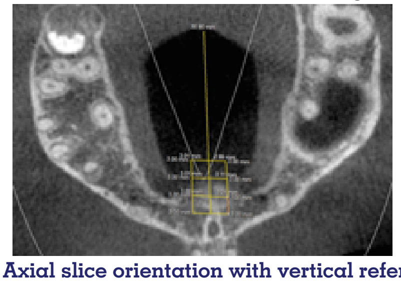

Figure 4: Axial slice orientation with vertical reference line moved to 3mm right of midline and measurements performed at distance of 3, 6 and 9 mm posterior to incisive foramen in palate.

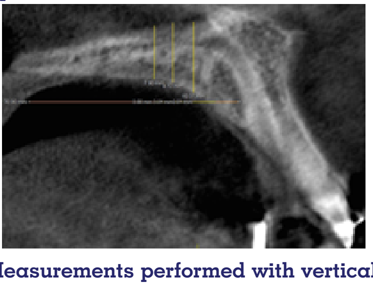

Figure 5: Measurements performed with vertical reference line moved 3, 6 and 9mm posterior to incisive foramen in sagittal slice.

A total of 60 measurements at 2,4,6 mm from CEJ were recorded for each sample in the axial slice. The cortical bone thickness buccally and lingually, was evaluated by measuring the distance between the internal and external aspects of the cortex in the middle of the inter-radicular distance between each two adjacent teeth. (Fig 2)

A second set of measurements was taken at each site in 5 randomly selected patients approximately a week after the first set of measurements to check for intra observer reliability.

Statistical Analysis:

The data obtained was subjected to statistical analysis in SPSS (Statistical Package for Social Sciences) Software version 21.0 and Epi-info version 3.0. The power analysis was done taking the variable "mean buccal bone level at 2mm" into consideration using the SAS software which came out to be 93%. One–Way ANOVA, Post-Hoc Bon Ferroni, Unpaired t-test was used for measurement of cortical bone thickness and inter-radicular distance in both the jaws.

RESULTS:

Cortical bone thickness:

There were significant differences in cortical thickness between sites in each region. In the mandible, the mean buccal cortical bone thickness increased from the lateral incisor- canine site to the site between 1st-2nd molar with significant difference in the thickness of buccal cortex between 2 and 6mm (Table 1).

Table No.1 Cortical bone thickness and inter radicular distance in mandible at distance of 2, 4 and 6 mm from CEJ:

CUT LEVEL	2mm from CEJ	4mm from CEJ	6mm from CEJ	p-value 2mm	p-value 4mm	p-value 6mm
2-3 Buccal	0.93±0.30	1.13±0.22	1.16±0.27	<0.001*	<0.001*	<0.001*
mesiodistal	1.56±0.68	1.92±0.59	2.29±1.19	<0.001*	<0.001*	<0.001*
4-5 buccal	1.16±0.23	1.31±0.20	1.46±0.27	<0.001*	<0.001*	<0.001*
Mesiodistal	2.99±0.93	3.04±0.98	3.42±1.11	<0.001*	<0.001*	<0.001*
5-6 buccal	1.50±0.33	1.58±0.33	1.71±0.52	<0.001*	<0.001*	<0.001*
Mesiodistal	3.51±0.98	3.20±0.94	3.59±1.01	<0.001*	<0.001*	<0.001*
6-7 buccal	2.62±0.69	2.65±0.78	4.21±0.61	<0.001*	<0.001*	<0.001*
Mesiodistal	3.96±1.31	3.95±1.12	4.44±1.55	<0.001*	<0.001*	<0.001*

On comparison amongst the four sites, the inter-radicular bone between 1st -2nd molar was thickest at all the three levels. In the maxillary buccal region, the highest cortical bone thickness was found at 2nd premolar and 1st molar at 6mm level (1.53±0.23), also the buccal cortical plate between 1st -2nd premolar was thicker than lateral incisor -canine and 1st- 2nd molar (Table 2). Although, the mean cortical bone thickness between lateral incisor and canine increased at a distance of 6mm from CEJ (1.45±0.22) (Table 2).

Table No.2 Buccal and palatal cortical bone thickness and inter radicular distance at 2, 4 and 6 mm from CEJ in maxilla

Cut levels	At 2mm from CEJ (mean ± S.D)	At 4mm from CEJ (Mean ± S.D)	AT 6mm from CEJ. (mean ± S.D)	p-value 2mm	p-value 4mm	p-value 6mm
2-3 Buccal	1.19±0.20	1.35±0.19	1.45±0.22	<0.001*	<0.001*	<0.001*
Palatal	1.43±0.29	1.58±0.26	1.70±0.26	0.001*	<0.001*	<0.001*

Mesiodistal	2.30±0.82	2.34±0.66	3.07±1.05	<0.001*	<0.001*	0.225
4-5 buccal	1.25±0.19	1.37±0.16	1.37±0.19	<0.001*	<0.001*	<0.001*
Palatal	1.41±0.20	1.60±0.31	1.63±0.26	0.002**	<0.001*	<0.001*
Mesio distal	3.28±0.94	3.19±1.07	3.38±1.11	<0.001*	<0.001*	0.225
5-6 buccal	1.44±0.19	1.47±0.25	1.53±0.23	<0.001*	<0.001*	<0.001*
Palatal	1.58±0.26	1.70±0.25	1.72±0.26	0.052	<0.001*	<0.001*
mesiodistal	3.39±1.17	3.45±1.14	3.63±1.17	<0.001*	<0.001*	0.225
6-7 buccal	1.19±0.21	1.30±0.19	1.32±0.19	<0.001*	<0.001*	<0.001*
Palatal	1.41±0.25	1.58±0.26	1.60±0.36	0.026*	<0.001*	<0.001*
Mesiodistal	3.01±1.12	3.00±1.09	3.18±1.27	<0.001*	<0.001*	0.225

The palatal cortical bone thickness was also highest between 2nd premolar and 1st molar at 6mm level (1.72±0.26), also the inter-radicular bone between lateral incisor-canine was greater than 1st-2nd premolar and 1st-2nd molar (Table 2). In addition, the palatal cortical plate was significantly thicker than buccal cortical plate at all the sites and there was significant difference in thickness of cortical plate between 2 and 6mm (Table 3).

Table No. 3 Comparison of buccal and palatal cortical bone thickness in maxilla

CUT LEVEL	At 2mm from CEJ	At 4mm from CEJ	AT 6mm from CEJ	p-value 2mm	p-value 4mm	p-value 6mm
2-3Buccal	1.1a9±0.20	1.35±0.19	1.45±0.22	<0.001*	<0.001*	<0.001*
Palatal	1.43±0.29	1.58±0.26	1.70±0.26			
4-5 buccal	1.25±0.19	1.37±0.16	1.37±0.19	0.002*	<0.001*	<0.001*
Palatal	1.41±0.20	1.60±0.31	1.63±0.26			
5-6 buccal	1.44±0.19	1.47±0.25	1.53±0.23	0.020*	<0.001*	0.003
Palatal	1.58±0.26	1.70±0.25	1.72±0.26			
6-7 buccal	1.19±0.21	1.30±0.19	1.32±0.19	<0.001*	<0.001*	<0.001*
Palatal	1.41±0.25	1.58±0.26	1.60±0.36			

The buccal cortical plate of mandible was also significantly thicker than maxilla especially between 1st and 2nd molar (Table 4).

Table No. 4 Comparison between buccal cortical bone thickness in maxilla and mandible

Buccal cortical plate thickness	2mm from CEJ (mean ±S.D)	4mm from CEJ(mean ±S.D)	6mm from CEJ (mean ±S.D)	p-value 2mm	p-value 4mm	p-value 6mm
2-3						
Maxilla	1.19±0.20	1.35±0.19	1.45 ±0.22	< 0.001*	< 0.001*	< 0.001*
Mandible	0.94±. 0.30	1.33±0.12	1.16±0.27			
4-5						
Maxilla	1.25± 0.19	1.37± 0.16	1.37± 0.19	0.101	0.241	0.141
Mandible	1.16±0.23	1.31±0.20	1.46±0.27			
5-6						
Maxilla	1.44±0.19	1.47±0.25	1.53±0.23	0.430	0.153	0.094
Mandible	1.50±0.33	1.58±0.33	1.71±0.52			
6-7						
Maxilla	1.19±0.21	1.30±0.19	1.32±0.19	< 0.001*	< 0.001*	0.001*
Mandible	2.62±0.69	2.65±0.78	4.21±4.61			

In the palatal region, bone thickness was greatest at distance of 3mm (9.99±3.57), followed by 6 and 9mm posterior to incisive foramen (Table 5).

Table No. 5 Thickness of paramedian plate

	3mm (mean ±S.D)	6mm (mean ±S.D)	9mm (mean ±S.D)	p-value -3mm	p-value –6mm	p-value-9mm
Palate thickness	9.99±3.57	7.38±3.19	5.41± 2.83	<0.001*	<0.001*	<0.001*

On comparing the three sites in the palatal region, 3mm site showed significant differences with a distance of 6 and 9mm from incisive foramen.

Inter –radicular distance:

In the maxilla, the highest inter radicular distance was found between 2nd premolar and 1st molar at 6mm level (3.63±1.17) and least was found between lateral incisor and canine at 2mm level (2.30±0.82) (Table 2). In the mandible the greatest inter radicular distance was found between 1st and 2nd molar at 6mm level (4.44±1.55) and least between lateral incisor and canine at 2mm level (1.56±0.68) (Table 1).

The results also depicts that the cortical bone thickness and the inter-radicular distance increases from cervical to apical region (Table 2, Table 1).

DISCUSSION:

It is advisable to place mini-implants in areas of attached gingiva, due to mobility of the mucosa in area of non-keratinized mucosa, moreover it compromises oral hygiene leading to tissue inflammation thus undermining mini-implant stability. Thus, the maximum level of measurement selected in this study is at a distance of 6mm from CEJ.[11] According to Jeong et al[12], buccal attached gingival width averaged 3.5 to 5.3 mm from the middle of free gingival margin. Thus, if the orthodontic mini-implant is placed within the attached gingival level (2-4 mm from the CEJ), it is predicted that there are no clinical difficulties for placement. Therefore, we have evaluated cortical bone thickness and inter radicular distance at 2, 4 and 6mm from CEJ.

Greatest cortical bone thickness both buccally and palatally was observed between maxillary 2nd premolar-1st molar and this findings has been unwavering even at different distances of CEJ and similar finding has been reported by Farnsworth et al[10], Hee et al[13], Arun et al[14] and Patrich et al[15]. This can probably be explained by trajectorial theory of force which states that the trabeculae are thicker in region of higher stress. The malar zygomatic buttress is a major stress trajectory which runs from buccal group of teeth through zygomatic arch to base of skull and as a consequence of vicinity of 1st molar to zygomatic buttress, this might be responsible for increased cortical bone thickness in region of 2nd premolar and 1st molar.

Katranji 2007[16], also observed that the thickness increased in the posterior regions in human cadavers which might be explained by differences in occlusal forces, maximum bite forces which have shown to increase from anterior to posterior through the first molars as the main contributory teeth in both jaws. [17] This causes increases in the longitudinal elastic modulus between the molar region and the symphysis and as a consequence of this stress and strain differences could give rise to the differences in cortical bone thickness in this region.

Although the greatest buccal cortical bone thickness was found between 2nd premolar -1st molar at all the heights, but there was variation in the sequence of cortical bone thickness observed at a distance of 6mm apical to CEJ both bucally and palatally as the thickness of inter radicular bone between lateral incisor and canine was greater than 1st -2nd premolar and 1st -2nd molar.

Although many of the studies have emphasized that the cortical bone thickness increases from anterior to posterior regions within the jaws. But Fayed et al[11] , Baumgaertel and Hans[18], Keri et al[19] have reported increased thickness of bone in the inter radicular areas between lateral incisor-canine which can be attributed to the likelihood of greater strain during mastication than in the posterior region because the maxillary canines serve as the cornerstones of the arch and are thus exposed to heavy occlusal forces, particularly during excursive movements. As the mandibular canine is guided over the lingual surface of the maxillary canine, strains are transmitted to the region of maxillary canine, thus giving rise to thicker bone in this region.[19]

The results of present study demonstrated greater bone thickness in the anterior palatal region at distance of 3mm distal to incisive foramen which affirms with findings of Kang et al[7], Farnsworth[10] and Baumga et al[20]. The Gracco[21], attributed greater palatal bone thickness in the region of anterior palate to the greater bone volume in the anterior hard palate. Enlow[22], hypothesized that anterior paramedian area showed greater bone thickness due to difference in amounts of remodeling growth between anterior and posterior part.

In the mandible, the thickness of buccal cortex and inter radicular distance was greatest between 1st-2nd molar which is agreement with other studies which have investigated the cortical bone thickness in the mandible.[8,10,13,18,23]

This can probably be due to the fact that the greatest amount of occlusal force is experienced on the buccal aspect of the mandibular molar region which accounts for maximum bone thickness between 1st -2nd molar in mandible.[24]

The sequence of increasing bone thickness appreciated in the mandibular posterior region can also be explained by presence of buccal shelf area since, it lies at right angle to vertically directed occlusal forces, therefore it acts as a primary stress bearing area in the mandible. As it has been claimed by Katranji[16], Hyalaner[24], Daegling[25], that region which is subjected to higher stress during function develops thicker cortical bones can act as an important factor accountable for maximum bone thickness in mandibular posterior region.

The largest inter radicular distance was found between maxillary 2nd premolar -1st molar and least between maxillary lateral incisor –canine at all the three levels which is in congruous with findings of Park and Cho[8],and Nattida et al[9].

A finding which was consistent in both the jaws is that the cortical bone thickness and the inter radicular distance increased, on advancing from CEJ towards apex as significant differences were observed in the bone thickness on moving from 2mm to 6mm level, whereas no statistically significant difference were found in region of maxillary 2nd premolar and 1st molar.

Although, in the present study quantity of bone could be assessed by making measurement of buccal, lingual cortical bone thickness and inter radicular distance but further studies need to be conducted in future to determine the quality of bone by analyzing the bone density as well to study the effect of bone quality on success of implant.

CONCLUSION:

1. The best site for mini –implant placement in maxilla is between 2nd premolar -1st molar as greatest amount of cortical bone thickness and inter radicular distance was observed in this region at all the three levels. In the anterior region, more apical placement of implant is indicated as the mean cortical bone thickness increases as we move from cervical to apical region.
2. In the palate the suitable site for placing implant can be 3mm posterior to incisive foramen as maximum bone thickness was reported in this region.
3. In the mandible, the bone thickness and inter radicular distance gradually increased from anterior to posterior indicative of site between 1st -2nd molar as best site at a distance of 4 to 6mm from CEJ due to maximum bone thickness and inter radicular distance found in these regions.
4. The inter radicular distance also increased along with bone thickness from cervical to apical region. Therefore, more apical placement of implant at a height 6 mm within the limitation of vestibular depth and keratinized mucosa can be recommended.

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