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Assessment of Mandibular Cortical Bone Thickness – A Cone Beam Computed Tomography Study

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Abstract

Objective: To assess the thickness of the buccal and lingual cortical bone in the mandible among the south Indian population, assess the thickness of cortical bone at different levels in the mandible from the alveolar crest, determine the differences in the buccal and lingual cortical bone with gender and age, to evaluate the optimum location for mini screw placement.

Materials and methodology: The CBCT images of 32 subjects with the age range of 20 to 60 years who had undergone cone- beam computed tomographic (CBCT) examination of the mandible were retrieved from the archival records. There was an equal distribution of males and females.

Results: The test results demonstrate that the mean cortical bone thickness in the mandibular posterior region at different regions on the buccal side was significantly higher as compared to the lingual side at P<0.001. In the lower anterior region in different regions, cortical bone thickness on the lingual side was significantly higher as compared to the buccal side at P<0.001. The mean cortical bone thickness showed a significant increase in thickness from 2 to 10 mm length at P<0.001. Mean cortical bone thickness was significantly higher in males as compared to females and higher in age group >40 years as compared to < 40 years.

Conclusion: The current study revealed that the cortical bone thickness in the mandible is more on the buccal aspect in the posterior region and as we move anteriorly

the cortical bone thickness is more on the lingual aspect, also cortical bone thickness is more among males as compared to females. Hence, treatment planning should be carried out on a case-by-case basis using a three-dimensional imaging modality to assess the anatomy of the region, and evaluation of variation, that can increase the quality of treatment and reduce risk of complications.

It is suggested that for future studies various parameters like larger sample size, cortical bone thickness measurement at varying levels from the alveolar crest and different age group with diverse ethnicity can be considered.

Keywords: Cone Beam Computed Tomography, Cortical bone thickness, Indian ethnicity, Mandible

Introduction

The mandible (from Latin mandibula, "jawbone") is the largest, strongest bone of the face, it develops from the first pharyngeal arch. It has a horseshoe-shaped body which lodges the teeth, and a pair of rami which projects upwards from the posterior ends of the body.

Mandibular morphology, including cortical thickness, mandibular height, and width, can influence oral and maxillofacial surgical procedures such as mandibular osteotomies, and placement of dental and orthodontic anchorage implants. In orthognathic surgery, osteotomies are made through the mandibular cortex extending into the cancellous bone with control and precision to avoid damaging vital adjacent structures such as the roots of teeth, as well as the inferior alveolar and lingual nerves.

In many of the procedures related to the mandible, the surgeon is working in a small space with limited visualization, and effectively cutting a bone in increments of millimetres to establish the correct and favourable split or osteotomy. Procedures such as the bilateral sagittal split osteotomies and genioplasty rely on the surgeon's understanding of the mandibular anatomy to produce the ideal outcome.

In recent years, the use of orthodontic anchorage implants to assist in tooth movement without detrimental counter-movement has become a common practice among orthodontists. Unlike endosseous dental implants, these anchorage devices may be placed in areas where vital teeth are still maintained (i.e., in inter-radicular spaces). They are removed after the desired outcome is achieved, and they do not necessarily require complete integration,[1] so knowledge of cortical bone thickness in various areas can guide clinicians in selecting the placement site and the proper placement protocol to avoid any complications.[2]

It is well known that the Maxilla has relatively thin cortices that are interconnected by a network of trabeculae. The mandible, however, is composed of thick cortices and has more radially oriented trabeculae. Thus, anatomical characteristics such as the thickness of cortical bone might differ between both jaws.[3] Investigations have shown that implant stability mostly depends on the amount of cortical bone thickness present. Cortical bone has a higher modulus of elasticity than trabecular bone, it is stronger and more resistant to deformation, and it bears more load in clinical situations than trabecular bone, thicker cortical bone provides greater primary stability.[4]

Accurate assessment of cortical bone thickness is usually performed by utilizing the Three-dimensional imaging modalities like CT and CBCT. It is an important diagnostic tool in the assessment of cortical bone thickness, Conventional 3D imaging using multi-slice computed tomography (CTs) delivers a large radiation dose, that limits its routine use. The development of cone-beam computed tomography (CBCT) has changed the imaging paradigm.[5] CBCT is a preferred choice in Oral and Maxillofacial region as it has a lower radiation dose, rapid scan time as compared to CT.

The purpose of the present study being conducted was to assess the buccal and lingual cortical bone thickness at different levels of the mandible using CBCT.

Material and methods

The study was carried out in the department of Oral Medicine and Radiology in a Dental College in South India to assess the buccal and lingual cortical bone thickness of the mandible using CBCT. Thirty-two CBCT images of mandible (sixteen male and sixteen female) were retrieved randomly from CBCT archives. Measurements were carried out using ONDEMAND software. Ethical clearance for the study was obtained from the ethical committee, prior to the initiative of the study (RRDCET/02OMR/2018). Inclusion criteria were: CBCT images of the mandible, age group 20-60 years, presence of all permanent teeth from left second molar to right second molar on the mandibular arch. Exclusion criteria were: Pathologies such as cysts, tumors, evidence of fracture, errors and artefacts obscuring the visibility, periapical or periradicular pathologies, severe periodontitis, mixed dentition or incomplete crown eruption.

All images were assessed and measured using ONDEMAND 3D and SCANORA software of the CBCT machine [Figure 1]. A total of 15 mandibular cross-sections were obtained in the axial section for each patient. These cross-sections were taken between distal to the right 2nd molar and proceeding to the distal of the left 2nd molar in the mandible [2]. Cortical bone thickness was measured in all the interdental area on the buccal and lingual aspects at 2mm, 6mm and 10mm (with an interval of 4mm) from the alveolar crest on mandibular coronal view. Measurements were done using the ruler measuring tool in ONDEMAND software according to **Swasty D et al [1] (2009)** and **Baumgaertel Set al [2] (2009)**. Each patient had a total of 90 measurements, which was then subjected to statistical analysis. [Figure 2]

Statistical Analysis

Statistical Package for Social Sciences [SPSS] for Windows Version 22.0 Released 2013. Armonk, NY: IBM Corp., was used to perform statistical analyses. Student Paired t Test was used to compare the mean Cortical bone thickness b/w Buccal & Lingual sides at different levels in different lower Quadrants, Independent Student t test was performed for gender-based comparison, Repeated measures of ANOVA followed by Bonferroni's Post hoc Analysis was used to compare buccal and lingual cortical bone thickness between 2mm, 6mm & 10mm cortical bone height, The level of significance was set at $P<0.05$, Each CBCT image was analysed to assess inter-observer and intra-observer variabilities.

Results

Buccal cortical bone thickness

The statistical analysis showed that, on average, the mandibular buccal cortical bone was thicker in men than in women, but the difference was not statistically significant [Table no. 1a].

Lingual cortical bone thickness

The mandibular lingual cortical bone was thicker in women than in men except between the right and left 2nd and 3rd molar region of the mandible [Table no. 1b]

Comparison of mean cortical bone thickness between buccal and lingual sides at different levels

The test results demonstrate that the mean cortical bone thickness in the mandibular posterior region at different regions on the buccal side was significantly higher as compared to lingual side at $P<0.001$

Highest mean buccal cortical bone thickness in 48-47, 37-38 region at 2mm, 6mm and 10mm length and least in 44-43, 33-34 region at 2mm, 6mm, 10mm length at [$P<0.001$]. Highest mean lingual cortical bone thickness in

34-35, 44-45 region at 2mm, 6mm & 10mm length [P<0.001]. Least in 33-34, 43-44, 48-47 region at 2mm, 6mm length [P<0.001] and 37-38 region at 10mm length [P<0.001].

Also, it was observed that the buccal cortical bone thickness reduces progressively from posterior to anterior region and vice versa for the lingual cortical bone thickness that increases progressively from posterior to anterior region. Highest mean buccal cortical bone thickness in 43-42 region at 2mm and 6mm length and least in 42-41 region at 2mm and 6mm length and 31-32 region at 10 mm length [P<0.001] respectively. Highest mean lingual cortical bone thickness in 43-42 region at 2mm, 6mm & 10mm length [P<0.001]. Least in 31-32 region at 2mm, 6mm & 10mm length [P<0.001]. [Table no. 2]

Comparison of mean cortical bone thickness between different levels on buccal and lingual sides of the mandible

The mean cortical bone thickness in mandibular posterior region at different regions on the buccal and lingual sides, showed significant increase in thickness from 2 to 10 mm length [P<0.001]. with the highest buccal cortical bone thickness in 48-47, 37-38 region at 10mm length [P<0.001]**,** Highest lingual cortical bone thickness in 33-34 region at 10mm length [P<0.001] and least in 33-34 region at 2mm length [P<0.001].

In the mandibular anterior region, the highest buccal cortical bone thickness in 32-33 at 10mm length [P<0.001] and least in 31-32 region at 2mm length. Highest lingual cortical bone thickness in 43-42 region at 10mm length [P<0.001] and least in 31-32 region at 2mm length [P<0.001]. [Table no. 3]

Age wise comparison of mean Cortical bone thickness

The buccal cortical bone thickness of mandibular posterior quadrant was slightly higher in >40 years age group as compared to <40 age group, but the difference was not statistically significant. Highest buccal cortical bone thickness was seen in 47-48 region followed by 37-38 region at 10mm length in both the age groups and the highest lingual cortical bone thickness was seen in 45-44 region followed by 35-34 region at 10mm length in both the age groups. [Table no. 4a, 4b]

Intra and Inter Examiner Reliability

There was no significant difference in the intra examiner as well as inter examiner mean values of parameters [Table no. 5] and there is excellent correlation between intra and inter examiner vales.

Discussion

The cortical bone thickness of mandible is an important factor that plays a crucial role in the placement of orthodontic anchorage mini implants, surgical procedures such as mandibular osteotomies.[6] Hence, adequate knowledge of cortical bone thickness helps to avoid damaging vital adjacent structures such as tooth root, inferior alveolar nerve and lingual nerve. [7]

It is a well-known fact that the cortical bone thickness of the mandible varies with gender and age.[1] Previous studies conducted had revealed that cortical bone thickness to be more in males compared to females,[7] gets thicker as the age progresses which reduces with the declining age. To assess the cortical bone thickness three-dimensional imaging modalities like CT and CBCT are utilized.

CBCT scans allow assessing the patients hard tissue in three dimensions. The accuracy and reliability of three – dimensional images have been tested and found to be effective hence CBCT is a preferred choice in Oral and Maxillofacial region as it has a lower radiation dose, rapid scan time as compared to CT. With the above background the present study was conducted to assess the thickness of the buccal and lingual cortical bone in the mandible by

using 3- dimensional (3D) cone-beam computed tomography technology.

The current study revealed that that the mean buccal cortical bone thickness of the mandible was higher among males as compared to females and the lingual cortical bone thickness of the mandible is higher among females as compared to the males [Table no. 1a, 1b]. However, it did not show any significant differences. The findings are similar to the observations from the studies conducted by Cassetta M et al., Jung-Hoon kim et al., Vakil JK et al., Adiguzel O et al., Aktuna et al. and S Sathapana et al. [8,9,10,11,12] where the cortical bone thickness is greater in males than in females. The reason for this difference in cortical bone thickness among different gender might be expected as males have larger bite forces and masticatory muscles than females. [13,14]

However, in contrast to our study Ono A et al., Farnsworth D et al., Choi JH et al., Chun YS et al., Park HS et al., David Farnsworth et al, Fulya Ozdemi et. al [15,16,17,18,19,20] found no significant difference in cortical bone thickness among gender, which could be due to the size of the sample in their study and different methodology used for the measurement of cortical bone thickness.

On age-wise comparison, the results revealed that the mean buccal cortical bone thickness in the lower posterior and anterior quadrant is significantly higher in > 40 years' age group as compared to < 40 age group. However, it is statistically insignificant. (P>0.001) [Table no. 4a, 4b]. Similar results were also observed by Swasty D et al., Fayed MMS et al, David Farnsworth et al., S Sathapana et al., Michele et al., Adiguzel O et al. and Uday NM et al. [1, 21,16,12,8,10,22] the cortical bone is thicker in adults than in adolescents. This difference among age group could be due to the proportionate increases in overall body size and the size of the body parts, The mandible continues to mature through 40 to 49 years of age and then decreases in thickness particularly after 60 years of age, and these changes may be due to periodontal disease or a generalized age-related decrease in bone mass. As the age progresses there is gradually increase in bone resorption hence these leads to the reduction in the thickness of buccal cortical bone.

The mean cortical bone thickness in the mandibular posterior region at different levels showed that the buccal cortical bone thickness is higher as compared to the lingual side at P<0.001 [Table no. 2]. These results are in correlation with the studies conducted by Swasty D et al., Baumgaertel S et al, Jung-Hoon Kim et al., Michele et al. [1, 2, 8, 9] where they found that the buccal cortical bone thickness was greater in the mandible.

In our study, it is found that the mandibular lingual cortical bone is thickest between canine and 1st premolar followed by 1st and 2nd premolar. These results were in correlation with the study conducted by Jung-Hoon Kim et al.,[9] where the mandibular lingual cortical bone was thickest between the canine and 1st premolar, followed by the areas between the 1st and 2nd premolars and between 1st molar and 2nd molar. Also, in our study, it is found that the buccal cortical bone thickness is greatest at 2nd molar and 3rd molar region followed by 1st molar and 2nd molar region. [Table no. 2] These results were in correlation with the study conducted by W.M. Talaat et al. [23]

In our study, the buccal cortical bone thickness was thinner in the anterior region and premolar region. [Table no. 2] It is in correlation to the observation made in the study by Olavo et al. [24] as it is known that the cortical bone thickness varies according to the tooth, as well as by gender and age.

Another interesting finding is that the buccal cortical bone is thinnest in the lower anterior region of the mandible and increases progressively toward the posterior, this is in

contrast to the lingual cortical bone thickness, which decreased gradually from the anterior to posterior regions [Table no. 2]. These results are in accordance with those found Swasty D et al, Baumgaertel et al, David Farnsworth et al [1,2,16]

The reason for this difference could be related to the buccolingual molar inclination, the mandibular molars are inclined lingually due to masticatory muscle activity and function, [25, 26] the inclination is due to the force and direction of the muscles acting on the molars. So, because of the higher masticatory demands, the cortical bone thickness is more in the posterior teeth regions.[25]

The cortical bone thickness between different levels on the buccal & lingual sides of the mandible, we found that the mean cortical bone thickness at different regions on the buccal and lingual sides showed a significant increase in thickness from 2 to 10 mm length **(P<0.001)** [Table no. 3]. Swasty D et al., Baumgaertel S et. al, Ono A et al. [1,2,15] also observed similar results. This is no surprise since one would expect cortical bone thickness to increase from the alveolar bone to the basal bone.[3]

It is well known that the initial stability of micro implant anchorage depends on the cortical bone thickness**.** The gradual increase in the thickness of the buccal cortical bone from the anterior regions to the posterior regions implies that the stability of TADs would be greater if implanted in the molar region than in the premolar region. However, because the lingual cortical bone is thicker in the premolar regions than the molar regions, TADs implanted in the premolar region on the lingual side would be more stable than those implanted in the lingual molar region. This is because TADs are more stable when inserted into sites with the thicker cortical bone. [27,28]

According to Dalstra and Melsen et al. [29] a microimplant should have enough initial stability if peri-implant bone tissue has more than 1mm of cortical bone thickness. Motoyoshi et al. [30] stated that the mini-implant site should have a cortical bone thickness of at least 1.0 mm. In our study, it was found that the preferred region for micro implant (TAD) placement site in the mandible could be considered as second molar and third molar region on the buccal aspect and lingual aspect in canine and premolar region at 10mm length where the cortical bone thickness is more than 1.0mm which is adequate for micro implant stability. [Table no. 2] These results are agreed with those found by Ono et al.,2008 and Fayed et al.,2010.[15,21]

Implant placement in the anterior regions should be avoided for several reasons: in this area, there is little cortical bone for the anchorage of implants and little attached gingiva and there is often lack of sufficient interradicular distances.[29] Several studies revealed that the success rates of mini-implants mainly depends on the cortical bone thickness, [30,19] other factors that affect the success rate are anatomic factors, oral hygiene technique used, design of the mini-implant and force used**.** [31]

Additionally, this data could provide useful information of the buccal and lingual cortical bone thickness of the mandible at different levels from the alveolar crest which would help surgeons with orthognathic surgery in which osteotomies are placed through the buccal cortex to successfully achieve a sagittal split osteotomy or genioplasty. The goal of treatment includes the careful placement of the osteotomy avoiding damage to adjacent vital structures.

In our study, various parameters considered are related to the buccal and lingual cortical bone thickness at each interdental region of the mandible. To the best of our knowledge and literature search a limited number of studies have assessed cortical bone thickness in the mandible at each interdental region. Most of these studies have been carried out on small sample size or were limited to the posterior or only to the anterior part of the

mandible. Hence, our study findings could be of a valuable guide to future studies for more appropriate observations.

Conclusion

From the present study, the following observations were made:

- The mean cortical bone thickness in the mandibular posterior region on the buccal side was significantly higher as compared to lingual side.
- The mean cortical bone thickness in the mandibular anterior region on the lingual side was significantly higher as compared to buccal side.
- The mean cortical bone thickness in the posterior and anterior region at different regions on the buccal and lingual sides, showed a significant increase in thickness from 2 to 10 mm length.
- The mean cortical bone thickness of the mandible is higher among males as compared to females.
- The mean cortical bone thickness of the mandible is significantly higher in the > 40 years age group as compared to < 40 years age group.
- Optimum location for mini screw placement in mandible second molar and third molar region on the buccal aspect and lingual aspect in canine and premolar region at 10mm length.

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Legend Figure and Tables

Figure 1: ONDEMAND software showing Axial view, Coronal view, Sagittal view and 3D view - CBCT

Figure 2: Measurement of buccal and lingual cortical bone thickness at 2mm, 6mm & 10mm length from the alveolar crest in coronal section.

Table 1a: Gender wise comparison of mean Cortical bone thickness on Buccal side at different levels in the mandible using Independent Student t Test

Regions	Length	Males		Females		Mean Diff	P-Value
		Mean	SD	Mean	SD		
48 - 47	2 mm	2.35	0.71	1.98	0.55	0.38	0.10
	6 mm	2.74	0.67	2.10	0.84	0.64	0.87
	10 mm	2.92	0.63	2.70	0.67	0.22	0.74
47 - 46	2 mm	1.72	0.39	1.61	0.27	0.11	0.37
	6 mm	2.16	0.63	2.12	0.46	0.05	0.81
	10 mm	2.56	0.53	2.50	0.52	0.06	0.74
46 - 45	2 mm	1.30	0.31	1.36	0.32	-0.06	0.58
	6 mm	1.78	0.46	1.68	0.44	0.10	0.53
	10 mm	2.19	0.57	2.10	0.58	0.09	0.67
45 - 44	2 mm	1.19	0.35	1.22	0.24	-0.03	0.82
	6 mm	1.53	0.37	1.48	0.24	0.04	0.70
	10 mm	1.81	0.42	1.84	0.34	-0.04	0.79
44 - 43	2 mm	1.06	0.26	1.08	0.29	-0.02	0.84
	6 mm	1.40	0.34	1.33	0.41	0.07	0.60
	10 mm	1.61	0.47	1.58	0.40	0.04	0.82
43 - 42	2 mm	0.86	0.29	0.84	0.26	0.02	0.86
	6 mm	1.21	0.46	1.05	0.29	0.16	0.25
	10 mm	1.60	0.24	1.24	0.37	0.35	0.003*
42 - 41	2 mm	0.62	0.12	0.74	0.20	-0.12	0.04*
	6 mm	0.83	0.13	0.92	0.20	-0.09	0.14
	10 mm	1.26	0.27	1.27	0.38	-0.01	0.95
41 - 31	2 mm	0.69	0.20	0.76	0.17	-0.07	0.31
	6 mm	0.95	0.22	1.00	0.26	-0.05	0.60
	10 mm	1.41	0.23	1.23	0.30	0.18	0.07
31 - 32	2 mm	0.78	0.29	0.72	0.17	0.06	0.50
	6 mm	1.00	0.45	0.82	0.20	0.17	0.17
	10 mm	1.22	0.35	1.22	0.33	0.01	0.96
32 - 33	2 mm	0.87	0.34	0.80	0.31	0.07	0.53
	6 mm	1.13	0.45	1.09	0.33	0.04	0.77

	10 mm	1.65	0.86	1.33	0.30	0.31	0.18
33 - 34	2 mm	1.12	0.23	0.88	0.30	0.24	0.02*
	6 mm	1.36	0.40	1.26	0.37	0.10	0.46
	10 mm	1.75	0.47	1.63	0.49	0.12	0.50
34 - 35	2 mm	1.22	0.32	1.34	0.31	-0.11	0.32
	6 mm	1.57	0.39	1.64	0.46	-0.07	0.64
	10 mm	1.80	0.46	1.78	0.41	0.02	0.92
35 - 36	2 mm	1.36	0.43	1.41	0.38	-0.04	0.78
	6 mm	1.65	0.40	1.53	0.33	0.11	0.39
	10 mm	1.98	0.44	1.94	0.66	0.05	0.81
36 - 37	2 mm	1.62	0.50	1.84	0.43	-0.22	0.19
	6 mm	2.05	0.42	2.33	0.43	-0.28	0.08
	10 mm	2.44	0.45	2.73	0.63	-0.29	0.14
37 - 38	2 mm	1.99	0.36	1.80	0.52	0.19	0.24
	6 mm	2.49	0.39	2.71	0.60	-0.22	0.22
	10 mm	2.56	0.44	3.06	0.54	-0.51	0.007*

Table 1b: Gender wise comparison of mean Cortical bone thickness on Lingual side at different levels in the mandible using Independent Student t Test

Regions	Length	Males		Females		Mean Diff	P-Value
		Mean	SD	Mean	SD		
48 - 47	2 mm	1.72	0.37	1.56	0.42	0.15	0.28
	6 mm	1.81	0.45	1.78	0.54	0.03	0.86
	10 mm	1.74	0.41	1.83	0.60	-0.09	0.62
47 - 46	2 mm	1.53	0.37	1.64	0.35	-0.11	0.40
	6 mm	1.81	0.47	1.96	0.28	-0.15	0.29
	10 mm	1.69	0.48	1.94	0.37	-0.25	0.11
46 - 45	2 mm	1.48	0.42	1.66	0.36	-0.19	0.19
	6 mm	1.90	0.44	2.14	0.40	-0.24	0.13
	10 mm	1.97	0.33	2.20	0.36	-0.23	0.07
45 - 44	2 mm	1.38	0.33	1.60	0.38	-0.22	0.09
	6 mm	1.77	0.35	2.03	0.53	-0.26	0.12
	10 mm	2.07	0.38	2.04	0.48	0.02	0.88
44 - 43	2 mm	1.41	0.43	1.60	0.39	-0.19	0.21

	6 mm	1.77	0.49	1.92	0.40	-0.15	0.36
	10 mm	1.94	0.58	1.97	0.56	-0.03	0.89
43 - 42	2 mm	1.13	0.49	1.35	0.39	-0.22	0.18
	6 mm	1.51	0.37	1.67	0.39	-0.15	0.27
	10 mm	1.87	0.59	1.93	0.51	-0.06	0.76
42 - 41	2 mm	0.98	0.33	1.06	0.41	-0.07	0.59
	6 mm	1.35	0.30	1.29	0.38	0.06	0.60
	10 mm	1.72	0.24	1.61	0.50	0.12	0.41
41 - 31	2 mm	1.08	0.35	1.03	0.34	0.05	0.71
	6 mm	1.31	0.38	1.36	0.39	-0.06	0.68
	10 mm	1.56	0.42	1.71	0.40	-0.15	0.31
31 - 32	2 mm	0.93	0.28	0.99	0.39	-0.06	0.63
	6 mm	1.29	0.43	1.20	0.40	0.09	0.53
	10 mm	1.50	0.32	1.59	0.32	-0.09	0.42
32 - 33	2 mm	1.16	0.38	1.09	0.41	0.07	0.62
	6 mm	1.56	0.48	1.39	0.50	0.17	0.34
	10 mm	1.74	0.51	1.77	0.51	-0.03	0.86
33 - 34	2 mm	1.41	0.51	1.27	0.31	0.14	0.35
	6 mm	1.72	0.44	1.83	0.44	-0.11	0.47
	10 mm	1.89	0.41	2.06	0.67	-0.17	0.40
34 - 35	2 mm	1.51	0.42	1.66	0.37	-0.15	0.28
	6 mm	1.96	0.41	2.04	0.43	-0.07	0.62
	10 mm	1.97	0.48	2.07	0.37	-0.10	0.51
35 - 36	2 mm	1.44	0.58	1.55	0.36	-0.11	0.54
	6 mm	1.77	0.43	1.96	0.50	-0.19	0.26
	10 mm	1.87	0.27	1.99	0.52	-0.12	0.44
36 - 37	2 mm	1.46	0.37	1.70	0.36	-0.24	0.07
	6 mm	1.79	0.30	2.04	0.37	-0.26	0.04*
	10 mm	1.85	0.38	2.08	0.38	-0.23	0.09
37 - 38	2 mm	1.60	0.43	1.49	0.32	0.11	0.44
	6 mm	1.94	0.32	1.78	0.41	0.16	0.22
	10 mm	1.75	0.41	1.77	0.40	-0.01	0.93

Table 2: Comparison of mean Cortical bone thickness b/w Buccal & Lingual sides at different levels in the mandible using Student Paired t Test

Regions	Length	Buccal		Lingual		Mean Diff	P-Value
		Mean	SD	Mean	SD		
48 - 47	2 mm	2.17	0.65	1.64	0.40	0.53	<0.001*
	6 mm	2.76	0.75	1.80	0.49	0.97	<0.001*
	10 mm	2.95	0.64	1.79	0.51	1.17	<0.001*
47 - 46	2 mm	1.66	0.33	1.59	0.36	0.07	0.31
	6 mm	2.14	0.54	1.89	0.39	0.25	0.009*
	10 mm	2.53	0.52	1.82	0.44	0.72	<0.001*
46 - 45	2 mm	1.33	0.31	1.57	0.40	-0.24	0.001*
	6 mm	1.73	0.45	2.02	0.43	-0.29	0.005*
	10 mm	2.15	0.57	2.08	0.36	0.06	0.59
45 - 44	2 mm	1.21	0.30	1.49	0.37	-0.28	<0.001*
	6 mm	1.50	0.31	1.90	0.46	-0.40	<0.001*
	10 mm	1.82	0.38	2.05	0.43	-0.23	0.002*
44 - 43	2 mm	1.07	0.27	1.51	0.41	-0.43	<0.001*
	6 mm	1.37	0.37	1.85	0.44	-0.48	<0.001*
	10 mm	1.59	0.43	1.96	0.56	-0.36	<0.001*
43 - 42	2 mm	0.85	0.27	1.24	0.45	-0.39	<0.001*
	6 mm	1.13	0.38	1.59	0.38	-0.46	<0.001*
	10 mm	1.42	0.35	1.90	0.54	-0.48	<0.001*
42 - 41	2 mm	0.68	0.17	1.02	0.37	-0.34	<0.001*
	6 mm	0.87	0.18	1.32	0.34	-0.45	<0.001*
	10 mm	1.27	0.33	1.67	0.39	-0.40	<0.001*
41 - 31	2 mm	0.73	0.18	1.05	0.34	-0.33	<0.001*
	6 mm	0.98	0.24	1.34	0.38	-0.36	<0.001*
	10 mm	1.32	0.28	1.63	0.41	-0.31	<0.001*
31 - 32	2 mm	0.75	0.23	0.96	0.34	-0.21	<0.001*
	6 mm	0.91	0.35	1.25	0.41	-0.34	<0.001*
	10 mm	1.22	0.33	1.54	0.32	-0.32	<0.001*
32 - 33	2 mm	0.84	0.32	1.12	0.39	-0.29	<0.001*
	6 mm	1.11	0.39	1.47	0.49	-0.36	<0.001*
	10 mm	1.49	0.65	1.75	0.50	-0.26	0.06

33 - 34	2 mm	1.00	0.29	1.34	0.42	-0.34	<0.001*
	6 mm	1.31	0.38	1.78	0.44	-0.47	<0.001*
	10 mm	1.69	0.47	1.98	0.55	-0.29	0.003*
34 - 35	2 mm	1.28	0.32	1.59	0.40	-0.31	<0.001*
	6 mm	1.60	0.42	2.00	0.41	-0.40	<0.001*
	10 mm	1.79	0.43	2.02	0.42	-0.23	0.004*
35 - 36	2 mm	1.38	0.40	1.50	0.47	-0.11	0.11
	6 mm	1.59	0.37	1.86	0.47	-0.27	0.006*
	10 mm	1.96	0.55	1.93	0.41	0.03	0.80
36 - 37	2 mm	1.73	0.48	1.58	0.38	0.15	0.03*
	6 mm	2.19	0.44	1.92	0.36	0.27	0.002*
	10 mm	2.58	0.56	1.97	0.39	0.62	<0.001*
37 - 38	2 mm	1.89	0.45	1.54	0.38	0.35	<0.001*
	6 mm	2.60	0.51	1.86	0.37	0.74	<0.001*
	10 mm	2.81	0.55	1.76	0.40	1.05	<0.001*

Table 3: Comparison of mean Cortical bone thickness b/w different levels on Buccal & Lingual sides in the mandible using Repeated measures of ANOVA test followed by Bonferroni's post hoc Test

Region	Side	2 mm		6 mm		10 mm		P-Value	Bonferroni's Post hoc Test		
		Mean	SD	Mean	SD	Mean	SD		2 vs 6	2 vs 10	6 vs 10
48-47	Buccal	2.17	0.65	2.76	0.75	2.95	0.64	<0.001*	<0.001*	<0.001*	<0.001*
	Lingual	1.64	0.40	1.80	0.49	1.79	0.51	<0.001*	<0.001*	<0.001*	0.26
47-46	Buccal	1.66	0.33	2.14	0.54	2.53	0.52	<0.001*	<0.001*	<0.001*	<0.001*
	Lingual	1.59	0.36	1.89	0.39	1.82	0.44	0.001*	<0.001*	0.04*	1.00
46-45	Buccal	1.33	0.31	1.73	0.45	2.15	0.57	<0.001*	<0.001*	<0.001*	<0.001*
	Lingual	1.57	0.40	2.02	0.43	2.08	0.36	<0.001*	<0.001*	<0.001*	1.00
45-44	Buccal	1.21	0.30	1.50	0.31	1.82	0.38	<0.001*	<0.001*	<0.001*	<0.001*
	Lingual	1.49	0.37	1.90	0.46	2.05	0.43	<0.001*	<0.001*	<0.001*	0.09
44-43	Buccal	1.07	0.27	1.37	0.37	1.59	0.43	<0.001*	<0.001*	<0.001*	0.02*
	Lingual	1.51	0.41	1.85	0.44	1.96	0.56	<0.001*	<0.001*	<0.001*	0.49
43 - 42	Buccal	0.85	0.27	1.13	0.38	1.42	0.35	<0.001*	0.001*	<0.001*	<0.001*
	Lingual	1.24	0.45	1.59	0.38	1.90	0.54	<0.001*	<0.001*	<0.001*	0.001*
42 - 41	Buccal	0.68	0.17	0.87	0.18	1.27	0.33	<0.001*	<0.001*	<0.001*	<0.001*
	Lingual	1.02	0.37	1.32	0.34	1.67	0.39	0.001*	0.001*	0.001*	0.001*
41 - 31	Buccal	0.73	0.18	0.98	0.24	1.32	0.28	<0.001*	<0.001*	<0.001*	<0.001*

	Lingual	1.05	0.34	1.34	0.38	1.63	0.41	<0.001*	<0.001*	<0.001*	<0.001*
31 - 32	Buccal	0.75	0.23	0.91	0.35	1.22	0.33	<0.001*	0.008*	<0.001*	<0.001*
	Lingual	0.96	0.34	1.25	0.41	1.54	0.32	<0.001*	<0.001*	<0.001*	<0.001*
32 - 33	Buccal	0.84	0.32	1.11	0.39	1.49	0.65	<0.001*	0.002*	<0.001*	0.002*
	Lingual	1.12	0.39	1.47	0.49	1.75	0.50	<0.001*	<0.001*	<0.001*	0.01*
33 - 34	Buccal	1.00	0.29	1.31	0.38	1.69	0.47	<0.001*	<0.001*	<0.001*	<0.001*
	Lingual	1.34	0.42	1.78	0.44	1.98	0.55	<0.001*	<0.001*	<0.001*	0.09
34 - 35	Buccal	1.28	0.32	1.60	0.42	1.79	0.43	<0.001*	<0.001*	<0.001*	0.005*
	Lingual	1.59	0.40	2.00	0.41	2.02	0.42	0.001*	<0.001*	<0.001*	1.00
35 - 36	Buccal	1.38	0.40	1.59	0.37	1.96	0.55	<0.001*	0.03*	<0.001*	0.001*
	Lingual	1.50	0.47	1.86	0.47	1.93	0.41	<0.001*	<0.001*	<0.001*	1.00
36 - 37	Buccal	1.73	0.48	2.19	0.44	2.58	0.56	<0.001*	<0.001*	<0.001*	<0.001*
	Lingual	1.58	0.38	1.92	0.36	1.97	0.39	<0.001*	<0.001*	<0.001*	1.00
37 - 38	Buccal	1.89	0.45	2.60	0.51	2.81	0.55	<0.001*	<0.001*	<0.001*	0.08
	Lingual	1.54	0.38	1.86	0.37	1.76	0.40	0.003*	0.001*	0.12	0.70

Table 4a: Age wise comparison of mean Cortical bone thickness on Buccal side at different levels in the mandible using Independent Student t Test

Regions	Length	< 40 years		≥ 40 years		Mean Diff	P-Value
		Mean	SD	Mean	SD		
48 - 47	2 mm	2.05	0.78	2.28	0.50	-0.22	0.34
	6 mm	2.85	0.87	2.68	0.62	0.17	0.52
	10 mm	2.76	0.62	3.15	0.61	-0.40	0.08
47 - 46	2 mm	1.53	0.35	1.80	0.26	-0.26	0.02*
	6 mm	1.93	0.48	2.34	0.53	-0.41	0.03*
	10 mm	2.42	0.59	2.64	0.43	-0.22	0.23
46 - 45	2 mm	1.34	0.33	1.32	0.30	0.02	0.86
	6 mm	1.70	0.40	1.77	0.50	-0.07	0.68
	10 mm	2.16	0.58	2.14	0.57	0.02	0.94
45 - 44	2 mm	1.19	0.35	1.22	0.25	-0.03	0.81
	6 mm	1.58	0.34	1.43	0.27	0.15	0.19
	10 mm	1.80	0.40	1.85	0.37	-0.05	0.69
44 - 43	2 mm	0.95	0.26	1.20	0.23	-0.25	0.007*
	6 mm	1.27	0.32	1.46	0.41	-0.19	0.14

	10 mm	1.45	0.34	1.74	0.47	-0.29	0.04*
43 - 42	2 mm	0.79	0.25	0.91	0.28	-0.12	0.21
	6 mm	1.15	0.42	1.10	0.36	0.05	0.72
	10 mm	1.35	0.44	1.49	0.24	-0.14	0.27
42 - 41	2 mm	0.61	0.17	0.75	0.14	-0.14	0.02*
	6 mm	0.88	0.18	0.86	0.18	0.02	0.78
	10 mm	1.17	0.27	1.36	0.36	-0.19	0.10
41 - 31	2 mm	0.67	0.17	0.78	0.18	-0.12	0.07
	6 mm	1.00	0.27	0.95	0.22	0.05	0.55
	10 mm	1.25	0.28	1.39	0.27	-0.14	0.16
31 - 32	2 mm	0.68	0.17	0.81	0.27	-0.13	0.13
	6 mm	0.74	0.16	1.08	0.41	-0.33	0.005*
	10 mm	1.13	0.26	1.32	0.38	-0.19	0.10
32 - 33	2 mm	0.75	0.26	0.92	0.36	-0.17	0.12
	6 mm	0.93	0.33	1.30	0.36	-0.37	0.006*
	10 mm	1.31	0.33	1.67	0.83	-0.36	0.12
33 - 34	2 mm	0.98	0.29	1.02	0.30	-0.04	0.70
	6 mm	1.27	0.39	1.34	0.38	-0.08	0.59
	10 mm	1.53	0.47	1.85	0.43	-0.32	0.04*
34 - 35	2 mm	1.17	0.26	1.39	0.34	-0.22	0.04*
	6 mm	1.45	0.37	1.75	0.43	-0.30	0.04*
	10 mm	1.77	0.48	1.80	0.38	-0.03	0.83
35 - 36	2 mm	1.39	0.37	1.38	0.44	0.00	1.00
	6 mm	1.60	0.28	1.58	0.45	0.03	0.85
	10 mm	1.92	0.68	2.00	0.40	-0.09	0.66
36 - 37	2 mm	1.66	0.43	1.80	0.52	-0.14	0.42
	6 mm	2.15	0.50	2.23	0.39	-0.08	0.64
	10 mm	2.62	0.56	2.55	0.58	0.08	0.70
37 - 38	2 mm	1.87	0.52	1.92	0.37	-0.04	0.78
	6 mm	2.59	0.40	2.61	0.61	-0.02	0.91
	10 mm	2.89	0.51	2.72	0.58	0.17	0.39

Table 4b: Age wise comparison of mean Cortical bone thickness on Lingual side at different levels in the mandible using Independent Student t Test

Regions	Length	< 40 years		≥ 40 years		Mean Diff	P-Value
		Mean	SD	Mean	SD		
48 - 47	2 mm	1.64	0.49	1.64	0.30	0.00	0.99
	6 mm	1.80	0.48	1.80	0.52	-0.01	0.97
	10 mm	1.65	0.39	1.93	0.58	-0.28	0.12
47 - 46	2 mm	1.57	0.42	1.61	0.30	-0.04	0.75
	6 mm	1.85	0.33	1.92	0.45	-0.07	0.64
	10 mm	1.84	0.46	1.79	0.44	0.05	0.75
46 - 45	2 mm	1.53	0.48	1.61	0.30	-0.09	0.54
	6 mm	1.97	0.42	2.07	0.46	-0.11	0.50
	10 mm	2.01	0.25	2.16	0.44	-0.15	0.24
45 - 44	2 mm	1.43	0.40	1.55	0.34	-0.12	0.36
	6 mm	1.94	0.54	1.87	0.39	0.07	0.69
	10 mm	2.09	0.42	2.02	0.44	0.07	0.66
44 - 43	2 mm	1.38	0.43	1.63	0.37	-0.26	0.08
	6 mm	1.83	0.47	1.86	0.44	-0.02	0.88
	10 mm	1.96	0.63	1.95	0.51	0.01	0.96
43 - 42	2 mm	1.26	0.47	1.22	0.45	0.04	0.81
	6 mm	1.69	0.37	1.49	0.38	0.20	0.15
	10 mm	1.91	0.57	1.88	0.54	0.03	0.88
42 - 41	2 mm	1.05	0.41	0.99	0.33	0.06	0.68
	6 mm	1.35	0.38	1.29	0.30	0.06	0.60
	10 mm	1.60	0.39	1.73	0.39	-0.12	0.38
41 - 31	2 mm	0.95	0.29	1.16	0.37	-0.21	0.08
	6 mm	1.34	0.33	1.33	0.44	0.02	0.90
	10 mm	1.58	0.33	1.69	0.48	-0.11	0.45
31 - 32	2 mm	0.80	0.25	1.11	0.35	-0.31	0.007*
	6 mm	1.15	0.28	1.34	0.51	-0.19	0.19
	10 mm	1.50	0.27	1.59	0.36	-0.09	0.43
32 - 33	2 mm	1.03	0.47	1.22	0.28	-0.19	0.17
	6 mm	1.48	0.47	1.47	0.52	0.01	0.96
	10 mm	1.71	0.43	1.79	0.58	-0.08	0.64
33 - 34	2 mm	1.22	0.34	1.46	0.48	-0.23	0.12

	6 mm	1.78	0.47	1.77	0.41	0.01	0.95
	10 mm	2.01	0.55	1.95	0.58	0.06	0.78
34 - 35	2 mm	1.56	0.41	1.62	0.40	-0.06	0.68
	6 mm	1.89	0.43	2.11	0.38	-0.22	0.14
	10 mm	2.01	0.51	2.03	0.33	-0.02	0.90
35 - 36	2 mm	1.54	0.55	1.45	0.40	0.10	0.57
	6 mm	1.93	0.51	1.79	0.43	0.14	0.41
	10 mm	1.89	0.30	1.98	0.50	-0.09	0.55
36 - 37	2 mm	1.59	0.36	1.58	0.41	0.01	0.95
	6 mm	1.87	0.37	1.96	0.35	-0.09	0.48
	10 mm	1.87	0.40	2.06	0.37	-0.19	0.18
37 - 38	2 mm	1.49	0.34	1.60	0.42	-0.11	0.43
	6 mm	1.87	0.38	1.86	0.37	0.01	0.97
	10 mm	1.71	0.45	1.80	0.36	-0.09	0.53

Table 5: Intraclass correlation statistics to assess for the reproducibility of measurements b/w 2 Raters & different time intervals on Buccal and Lingual Side at different lengths

Side	Length	Interrater Reliability				Intrarater Reliability			
		ICC	95% CI		P-Value	ICC	95% CI		P-Value
			Lower	Upper			Lower	Upper	
Buccal	2 mm	0.91	0.78	0.95	<0.001*	0.99	0.89	0.97	<0.001*
	6 mm	0.94	0.70	0.98	<0.001*	0.99	0.89	0.97	<0.001*
	10 mm	0.96	0.46	0.98	0.001*	1.00	0.91	1.00	<0.001*
Lingual	2 mm	0.91	0.73	0.95	0.001*	0.98	0.81	1.00	<0.001*
	6 mm	0.93	0.77	0.95	<0.001*	0.99	0.89	0.97	<0.001*
	10 mm	0.92	0.62	0.97	<0.001*	1.00	0.91	1.00	<0.001*