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Comparison of cortical bone thickness and root proximity at maxillary and mandibular inter-radicular sites for orthodontic mini-implant placement

Dr. Abdul Baais Akhoon, Dr. Mohammad Mushtaq and Dr. Assiya Ishaq

Abstract
Objectives: To compare maxillary and mandibular cortical bone thickness and root proximity for optimal mini-implant placement.
Materials and methods: CBCT images from 21 men and 26 women were used to evaluate buccal inter-radicular cortical bone thickness and root proximity from mesial of the lateral incisor to the 2nd molar in the maxilla and mandible. Cortical bone thickness, buccolingual thickness and inter-radicular distances were measured at 2, 5, 8 and 11 mm height from the alveolar crest using three-dimensional images.
Results: For the cortical bone thickness, there was no statistically significant difference between the maxilla and the mandible in the anterior area; however, there was a significant difference in the posterior area. Cortical bone in the maxilla, mesial and distal to canine inter-radicular sites, was thickest while thickness in the mandible exhibited a gradual anterior to posterior increase. Root proximity mesial and distal to 2nd premolar inter-radicular sites was greatest in maxilla, and for mandible it was greatest in mesial and distal to first molar.
Conclusion: Based on our results, cortical bone thickness depends on the inter-radicular site. It is greater in mandible as compared to maxilla and the difference is statistically significant for posterior regions. Buccolingual measurements are greater in maxilla than mandible and the difference is not statistically significant. Mesiodistal distances are greater in mandible than maxilla and the difference is statistically significant for posterior regions.

Keywords: Cortical bone thickness, inter-arch difference, root proximity

Introduction
Many studies have evaluated cortical bone thickness and bone density for placement of mini-implants because bone thickness and density are reported to be critical for stability [1-5]. It has been reported that there were no statistically significant differences in root proximity in the maxillary buccal inter-radicular sites, whereas the anterior mandibular region has shown insufficient root proximity [6, 7]. Root proximity is a critical factor when placing a 1.2-2.0 mm diameter mini-implant because a minimum of 3-4mm is required between the mini-implant and the surrounding structures [8]. In effect, buccal cortical bone thickness and root proximity appear to be critical for successful anchoring of a mini-implant [9, 10].
Studies have found that the stability of TAD was affected by age, sex, craniofacial skeletal pattern, site and side of implantation, latent period, loading protocol, dimension of TAD, angulation to bone, insertion torque, degree of TAD-bone contact, quality and quantity of the cortical bone, degree of inflammation of the peri-TAD-tissue, thickness and mobility of the soft tissue and root proximity [3, 9-14]. The stability of mini-implants is generally defined with two main components [15].

Primary stability is established from the mechanical retention between the mini-implant surface and bone; it is dependent on the thickness and integrity of the cortical bone, the mini-implant design, and loading protocol [16, 17].
Primary failure occurs when a mini-implant is clinically mobile at the time of insertion. This is due to inadequate cortical bone support in terms of its thickness and density, or close mini-implant proximity to an adjacent tooth root.

Secondary stability is achieved through continuous bone remodeling around the mini- implant, leading to osseointegration [18, 19]. The firmness of cortical bone is one of the principal factors controlling the stability of mini-implants [20, 21]. Secondary failure refers to a situation where the mini-implant is initially stable but then exhibits mobility, usually after 1-2 months. This delayed instability is due to bone necrosis around the mini-implant threads, which may result from thermal bone damage (during pilot drilling), excessive insertion torque, excessively close proximity to a tooth root, traction overload, or a combination of these.

Stability and safety are the two main factors that clinicians should consider during miniscrew implant placement. Stability, which plays a major role in preventing premature loosening and dislodging of the miniscrew implants, is influenced significantly by cortical bone thickness at the miniscrew implant placement site. Safety is related to avoiding anatomical damage during miniscrew implant placement or when teeth are displaced and is influenced by inter-proximal space between adjacent tooth roots.

Cortical bone thickness

The most important patient determinants of primary stability are the density and thickness of the maxillary and mandibular cortical plates. This helps to explain the variations seen in clinical studies of mini-implant success rates where both anatomical sites and individuals differ in terms of the cortical bone layer's quantity and quality. To achieve successful implantation, Motoyoshi *et al*. [22] suggested that the prepared site should be established in an area with a cortical bone thickness of more than 1.0 mm. The key factors to consider are:

- Cortical depth typically ranges from 1 to 2 mm and generally increases towards the apical aspect of the alveolus. In the maxillary alveolus cortical depth peaks both mesial and distal to the canines and the first molars, which partly accounts for the frequent use of these sites for anterior and posterior anchorage points, respectively. The highest alveolar values for both jaws occur in mandibular molar sites.
- An increase in either the cortical thickness or density leads to an increase in insertion torque (the resistance to rotational insertion). The ideal range of maximum insertion torque appears to be 5-15 Ncm for alveolar sites [23]. Maximum torque indicates adequate cortical support and occurs during final seating of the mini-implant and is felt as an increase in resistance on turning a manual screwdriver. Low torque equates to poor primary stability (inadequate cortical support) and excessive torque results in secondary failure because microscopic bone stress leads to subclinical ischaemic necrosis around the mini-implant threads.
- Cortex depth and density are greater in the mandible than the maxilla [24]. Therefore, mandible may provide greater primary stability, but the reported mandibular success rates (80 %) are less than those for the maxilla (90 %) [25] because excessive insertion torque appears to cause high levels of peri-implant bone stress, resulting in secondary microscopic bone necrosis around the threads and hence mini-implant failure.
- Cancellous bone, which has a similar density in both jaws, has little effect on primary stability, except when the cortex is less than 1 mm (as seen in some maxillary sites). In the long-term cancellous bone may influence secondary stability in terms of stabilizing the mini-implant body against migration and tipping.

Interproximal space

Interproximal space is important for the safety of mini-implant insertion. The literature [3, 10, 26, 27] provides data on the average amount of interproximal space available for mini-implant insertion, but it is crucial to recognize that there is wide individual variation depending on the adjacent teeth's root size, shape (degree of root taper and curvature) and alignment (root proximity/divergence). However, interproximal space is not an absolute barrier and clinically it may be increased by both oblique insertion and pre-insertion root divergence. To prevent damage to the dental root, Poggio *et al*. [3] recommended a minimum clearance of 1.0 mm of alveolar bone around the miniscrew implant in order to provide periodontal health. Monnerat *et al* 28 determined the risk for miniscrew implant placement by the mesiodistal distance. Any areas above 3.5 mm can be considered safe; between 3.0 and 3.5 mm, the risk is average; and below 3.0 mm, the risk is high.

Close proximity of the mini-implant body and adjacent roots should be avoided in order to avoid periodontal and root damage, although histological studies show that cellular cementum repair occurs after root trauma [29, 30]. The major problem with close implant-root proximity is that this provides inadequate bone coverage for the threads, destabilizes the mini-implant (rather than the tooth), and increases failure rates [10]. Indeed, root proximity appears to be more of a risk factor than variations in cortical thickness. In clinical terms, root contact, or even close proximity, is usually detected during mini-implant insertion by a sharp increase in insertion resistance, blunting of the mini-implant tip, patient discomfort (provided that only superficial anaesthesia has been used), and a dull note on percussion of the affected tooth. Consequently, these signs should be taken as indicators of close proximity and the mini-implant withdrawn and re-inserted at a different location or angle.

Oblique insertion (20-30^0 apically directed insertion angle) results in increased insertion torque values and increased secondary stability due to enhanced engagement of the cortex and appears to be especially favourable in the maxilla (where the cortex is less robust). Oblique insertions are also favourable in terms of reducing labio-lingual insertion depth and hence proximity to the roots [31].

The purpose of this study was to compare Maxillary and Mandibular cortical bone thickness, alveolar process width and root proximity for optimal mini-implant placement.

Materials and methods source of data

The Data for the study were obtained from CBCT scans taken as part of Orthodontic diagnosis and treatment planning protocol in the department of Orthodontics & Dentofacial Orthopaedics, Government Dental College and Hospital, Shereen Bagh, Srinagar. Maxillary CBCT scans of twenty three patients and Mandibular CBCT scans of twenty four patients were selected. The scans were selected according to the following inclusion and exclusion criteria:

Inclusion criteria

1. Complete eruption of permanent dentition (except for third molars).
2. No missing teeth (exclude third molars).

3. No severe craniofacial disorders.
4. No severe periodontitis or periapical lesion.
5. No severe crowding and spacing in the teeth.

Exclusion criteria

1. Periapical or periradicular pathologies or radiolucences of either periodontal or endodontic origin.
2. A significant medical or dental history (e.g., use of bisphosphonates or bone altering medications or diseases).
3. Severe facial or dental asymmetries.

Methodology

Sample Size and power

A sample size was calculated using G*Power software (Ver. 3.0.10). For a power of 80%, α=0.05 Type I, and β=0.20 Type II error rates, a sample size of at least 30 patients was determined.

The data were obtained using the NewTom 3G Volume Scanner QRsr 1 Verona, Italy. The Newtom 3G Volume Scanner is based on a cone-beam technique that uses x-ray emissions efficiently, thus reducing the dose absorbed by the patient. The following settings were used:

X ray source: HF, Constant potential (DC), 90 kV; 2 mA (pulsed) Imaging mode: CBCT
Focal spot: 0.5 mm Dose: 80-100 µSv
Scan: 11 cm × 8 cm and 8 cm × 8 cm Scan time: 18 seconds

All images were oriented using a standardized protocol. On the axial image, the CBCT image was oriented until the green line supplied by the software was perpendicular to the buccal bone surface and bisects the inter-radicular area to be measured. On the sagittal image, the CBCT image was oriented until the occlusal plane is parallel to the blue line. The cursor was adjusted until the red line in the axial image was centered on each contact area, at approximately the midroot level. For each inter-radicular area in the maxilla and the mandible, from the distal aspect of the lateral incisor to the mesial aspect of the second molar of maxilla and mandible, the following measurements were done at four different heights from the alveolar crest, that was, at 2, 5, 8 and 11 mm.

Mesiodistal distance: These measurements were taken at the widest distance between each two adjacent teeth (Fig. 1).

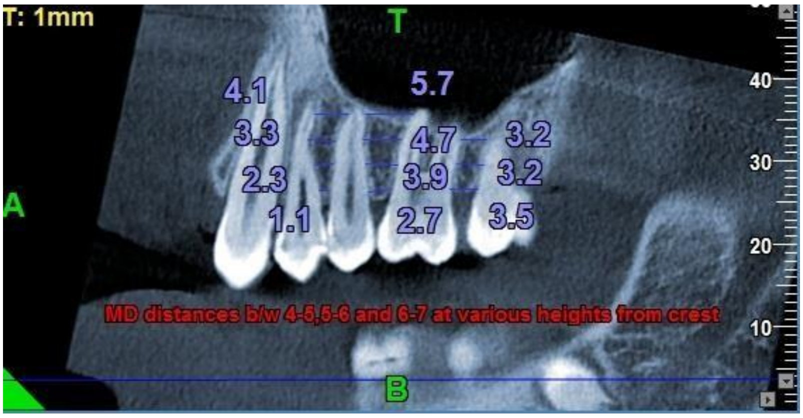

Fig 1: Measurement of the inter-radicular distances at 4 levels from the alveolar crest.

Buccolingual thickness: The thickness was measured from the outermost point on the buccal side to the outermost point on the palatal/lingual side at the middle of the distance between each two adjacent teeth (Fig. 2).

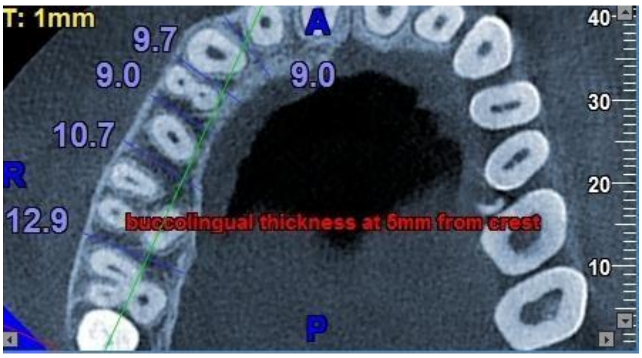

Fig 2: Measurement of the alveolar process width.

Buccal Cortical bone thickness: the distance between the internal and external aspects of the cortex in the middle of the inter-radicular distance between each two adjacent teeth was measured (Fig. 3).

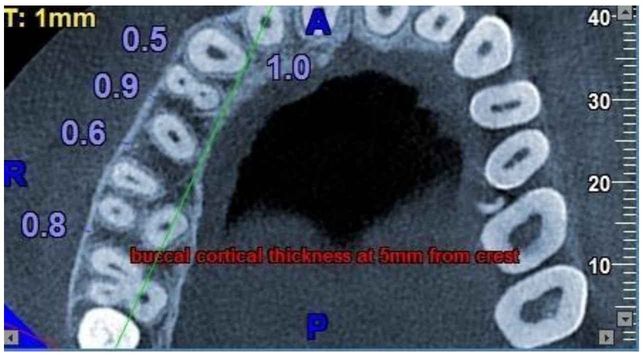

Fig 3: Measurement of the buccal cortical bone thickness.

Each measurement was taken on the computer display monitor with the Newtom® 3G measure softwear.

Statistical analysis

The statistical analysis of data was carried with the help of means, ranges and standard deviations.

Student's t-test was used to test the difference between means of various variables. A P-value of less than 0.05 was considered statistically significant. Statistical package SPSS (Version 20.0) was used to carry out the statistical analysis of data.

Based on the normalcy of the distribution of the data, results obtained were statistically analyzed and compared using SPSS software**.** The statistical analysis included:

Descriptive statistics: Including; mean, minimum, maximum, and standard deviation

Independent-samples t-test: For the comparison of various variables.
Informed consent regarding the benefits and protocol of study was obtained from all patients.

The study was carried out using the following parameters
1. Evaluation of buccolingual alveolar process width in interdental areas in between lateral incisor and canine, canine and first premolar, first premolar and second premolar, second premolar and first molar, first molar and second molar at 2mm, 5mm, 8mm and 11mm height from the alveolar crest in maxilla and mandible.
2. Evaluation of mesiodistal distance (inter-radicular spaces) in interdental areas in between lateral incisor and canine, canine and first premolar, first premolar and second premolar, second premolar and first molar, first molar and second molar at 2mm, 5mm, 8mm and 11mm height from the alveolar crest in maxilla and mandible.
3. Evaluation of buccal cortical bone thickness in interdental areas in between lateral incisor and canine, canine and first premolar, first premolar and second premolar, second premolar and first molar, first molar and second molar at 2mm, 5mm, 8mm and 11mm height from the alveolar crest in maxilla and mandible.

Results
The sample for this study consisted of 47 subjects with following age and gender distribution:

Table 1: Age distribution of studied patients

Age (years)	Number of Patients	Percentage
14-19	9	19.1
20-29	16	34.0
30-39	10	21.3
40-50	12	25.5
Total	47	100
Mean±SD=31.2±10.61		

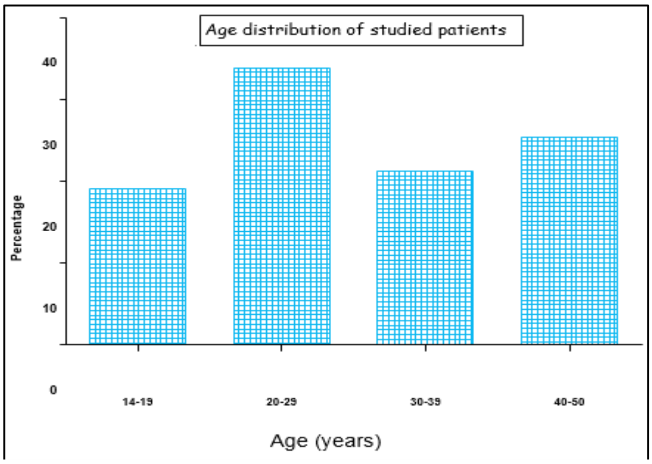

Fig 4: Age distribution of the sample.

Table 2: Gender distribution of studied patients

Gender	Number of Patients	Percentage
Male	21	44.7
Female	26	55.3
Total	47	100

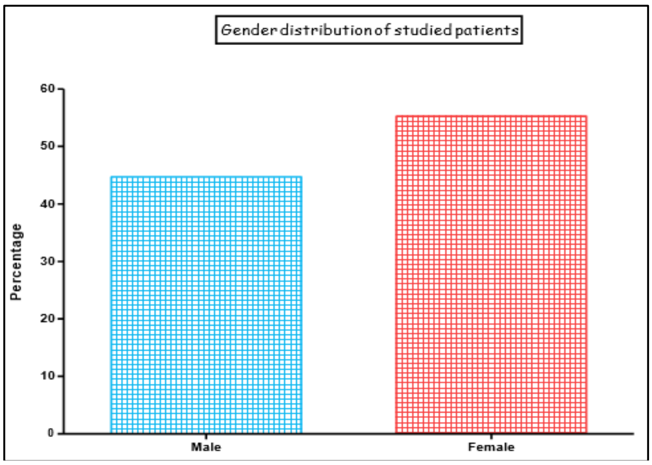

Fig 5: Gender distribution of the sample

The means and standard deviations of the buccolingual alveolar process width of the maxilla and mandible is shown in Table 3.

Table 3: Descriptive statistics of Buccolingual measurements in maxilla and mandible

Height from alveolar crest		Maxilla					Mandible				
		2&3	3&4	4&5	5&6	6&7	2&3	3&4	4&5	5&6	6&7
2 mm	Mean	5.64	6.68	7.90	9.08	10.64	6.84	6.69	6.63	8.14	9.59
	SD	1.22	0.95	1.08	1.34	1.88	1.47	1.58	1.21	1.34	1.93
	Min	3.5	4.4	5.1	6.6	7.5	4.4	3.5	3.4	3.7	6.6
	Max	7.5	8.2	10.4	11.4	13.8	10.3	8.9	9.0	10.4	14.3
5 m	Mean	7.71	8.50	8.63	9.95	12.08	6.67	8.01	8.24	9.51	11.86
	SD	1.30	0.99	1.02	1.49	2.16	1.48	1.68	1.48	1.52	1.73
	Min	5.2	6.5	6.3	6.9	7.8	3.0	3.8	4.0	4.4	9.2
	Max	10.0	9.8	10.3	12.4	16.9	8.9	10.6	10.7	12.2	15.9
8 mm	Mean	8.39	8.60	8.59	10.42	12.97	6.43	7.90	8.57	10.05	12.85
	SD	1.80	1.45	1.27	1.84	2.12	1.67	1.90	1.92	1.87	1.51
	Min	5.2	5.8	6.1	7.1	8.6	2.6	3.4	3.7	5.0	10.3
	Max	11.4	11.1	11.2	13.0	18.5	10.1	11.5	11.6	12.7	15.2
11 mm	Mean	8.37	8.68	9.20	11.38	13.07	6.71	8.05	8.90	10.36	11.94
	SD	2.66	2.35	1.82	2.22	1.93	1.81	2.03	2.19	1.72	1.63
	Min	4.1	5.0	6.0	7.6	8.8	2.4	3.6	4.2	6.7	8.0
	Max	12.7	13.8	13.0	15.2	16.1	9.8	11.3	12.1	13.0	14.9

Maxilla

The greatest buccolingual alveolar process width was between the first and second molar at 11 mm height (13.07 ± 1.93). The least buccolingual alveolar process width was between lateral incisor and canine at 2 mm height (5.64 ± 1.22 mm).

Mandible

The greatest buccolingual alveolar process width was between the first and second molar at 8 mm height (12.85 ± 1.51 mm). The least buccolingual alveolar process width was between lateral incisor and canine at 8 mm height (6.43 ± 1.67 mm).

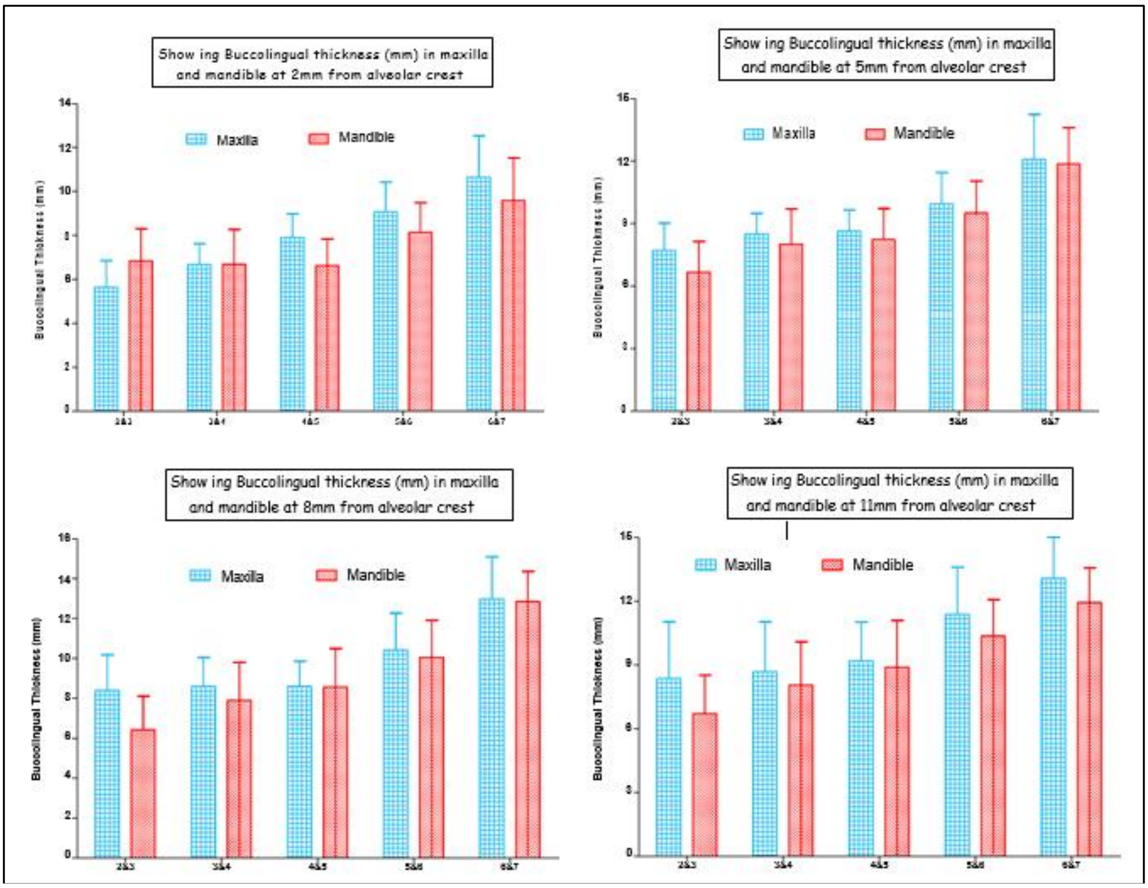

Fig 6: Buccolingual thickness in maxilla and mandible at different heights

The means and standard deviations of the mesiodistal distances of the maxilla and mandible is shown in Table 4.

Table 4: Descriptive statistics of mesiodistal distances (inter-radicular spaces) in maxilla and mandible.

Height from alveolar crest		Maxilla					Mandible				
		2&3	3&4	4&5	5&6	6&7	2&3	3&4	4&5	5&6	6&7
2 mm	Mean	1.75	2.06	2.15	2.36	2.25	1.71	2.08	2.70	2.85	″3.69
	SD	0.52	0.66	0.49	0.63	0.86	0.44	0.79	0.75	0.67	1.03
	Min	0.9	0.9	1.1	1.2	0.6	0.8	0.6	1.4	2.0	1.5
	Max	3.0	3.5	3.0	4.4	4.2	2.4	3.9	4.2	4.7	5.9
5 mm	Mean	2.30	2.32	2.50	2.47	2.01	2.59	2.66	x3.39	x3.23	″4.49
	SD	0.73	0.93	0.63	0.87	0.96	0.53	1.19	0.85	0.94	1.57
	Min	1.1	0.9	1.4	1.0	0.2	1.4	1.1	2.1	2.0	0.5
	Max	4.1	4.1	3.6	4.2	4.1	3.5	6.6	5.3	6.0	7.1
8 mm	Mean	2.93	2.80	2.93	x3.10	1.97	x3.50	x3.51	″4.17	″3.72	″5.83
	SD	0.97	0.98	0.83	0.90	1.06	0.76	1.83	1.00	1.55	2.11
	Min	0.9	0.9	1.7	1.2	0.2	2.0	1.2	1.7	2.1	0.5
	Max	5.1	4.7	4.1	5.4	5.3	5.1	10.1	6.3	9.5	9.5
11 mm	Mean	x3.07	x3.51	x3.38	″3.72	2.13	″3.98	″4.01	″4.75	″4.90	″6.70
	SD	0.97	1.31	1.02	1.09	1.40	1.14	1.39	1.12	1.77	1.89
	Min	1.2	0.9	1.5	1.7	0.6	2.9	1.7	2.6	2.6	1.6
	Max	4.4	5.3	4.8	5.7	5.0	6.2	6.8	6.8	10.7	11.0

Average risk site, Safe site

Maxilla

The greatest mesiodistal distance (inter-radicular space) was between the second premolar and first molar at 11 mm height from the alveolar crest (3.72 ± 1.09 mm). The least mesiodistal distance (inter-radicular space) was between lateral incisor and canine at 2 mm height (1.75 ± 0.52 mm).

Mandible

The greatest mesiodistal distance (inter-radicular space) was between the first and second molar at 11 mm height (6.70 ± 1.89 mm). The least mesiodistal distance (inter-radicular space) was between lateral incisor and canine at 2 mm height (1.71 ± 0.44 mm).

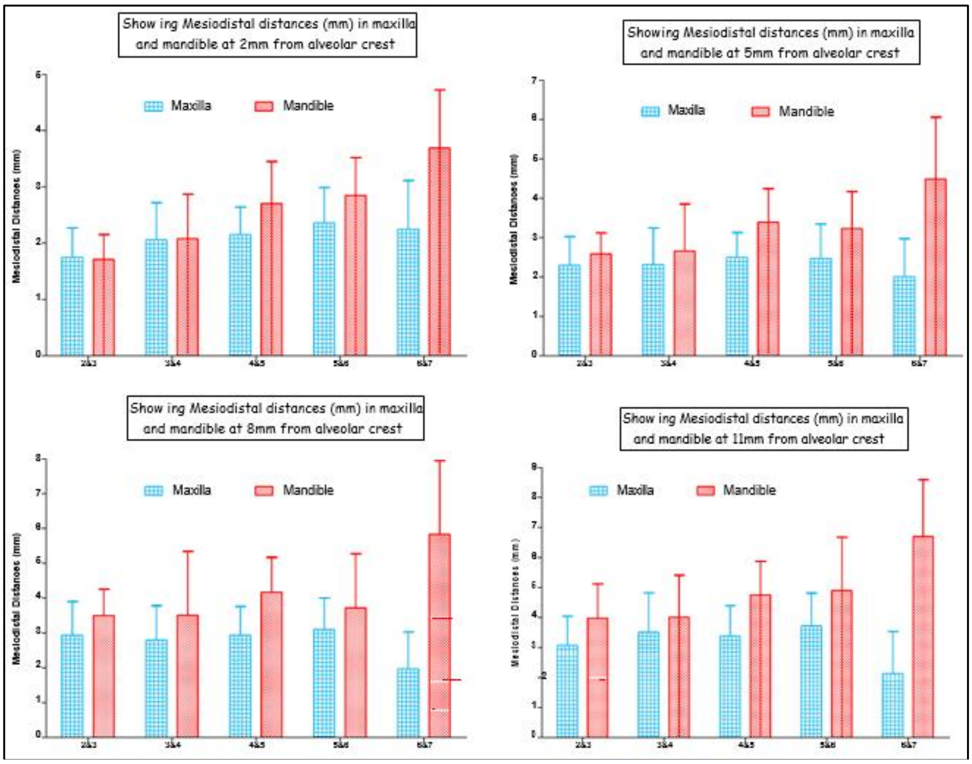

Fig 7: Mesiodistal distances in maxilla and mandible at various heights.

The means and standard deviations of the buccal cortical bone thickness of the maxilla and mandible is shown in Table 5.

Table 5: Descriptive statistics of buccal cortical bone thickness in maxilla and mandible.

Height from alveolar crest		Maxilla					Mandible				
		2&3	3&4	4&5	5&6	6&7	2&3	3&4	4&5	5&6	6&7
2 mm	Mean	0.93	0.92	0.86	0.86	1.00	0.84	0.79	0.84	0.93	1.29
	SD	0.39	0.34	0.30	0.32	0.34	0.37	0.31	0.35	0.32	0.57
	Min	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.2	0.4	0.4
	Max	1.9	1.5	1.5	1.7	2.0	1.8	1.6	1.6	1.6	2.2
5 mm	Mean	0.88	0.83	0.86	0.84	0.87	0.77	0.94	1.02	1.48	2.29
	SD	0.32	0.23	0.29	0.34	0.24	0.27	0.36	0.28	0.55	0.88
	Min	0.2	0.3	0.3	0.3	0.5	0.4	0.3	0.5	0.8	0.9
	Max	1.6	1.2	1.5	1.5	1.5	1.3	1.6	1.6	2.8	4.0
8 mm	Mean	1.11	1.15	0.91	0.93	0.93	0.90	1.10	1.36	1.70	2.69
	SD	0.33	0.35	0.25	0.35	0.43	0.28	0.38	0.48	0.42	0.62
	Min	0.3	0.5	0.2	0.5	0.3	0.3	0.5	0.5	0.8	1.5
	Max	2.0	2.1	1.4	1.6	1.9	1.4	2.0	2.1	2.6	3.9
11 mm	Mean	1.11	1.11	0.95	1.16	1.35	1.17	1.34	1.72	1.98	2.73
	SD	0.34	0.31	0.22	0.60	0.59	0.40	0.47	0.52	0.60	0.58
	Min	0.5	0.5	0.5	0.4	0.6	0.4	0.5	0.8	0.9	1.4
	Max	1.8	1.8	1.3	3.3	3.0	2.0	2.1	2.5	3.4	4.2

Maxilla

The greatest buccal cortical bone thickness was between the first and second molar at 11 mm height (1.35 ± 0.59 mm). The least buccal cortical bone thickness was between canine and first premolar at 5 mm height (0.83 ± 0.23 mm).

Mandible

The greatest buccal cortical bone thickness was between the first and second molar at 11 mm height (2.73 ± 0.58 mm). The least buccal cortical bone thickness was between lateral incisor and canine at 5 mm height (0.77 ± 0.27 mm).

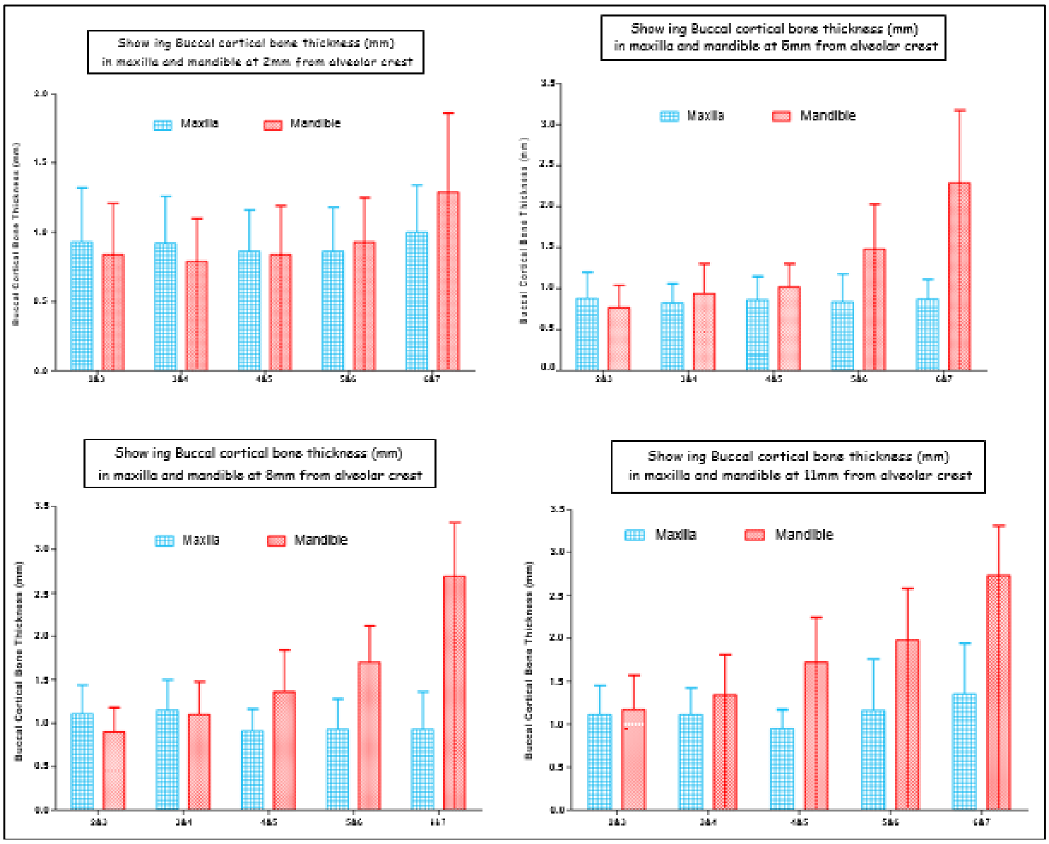

Fig 8: Buccal cortical bone thickness in maxilla and mandible at various heights

Table 6 shows comparison for buccal cortical bone thickness in maxilla and mandible, which is greater in mandible as compared to maxilla except for lateral incisor and canine region, where it is greater in maxilla.

Table 6: Comparison based on buccal cortical bone thinkness between maxilla and mandible

Region	Maxilla [n=23]		Mandible [n=24]		P-value
	Mean	SD	Mean	SD	
2&3	1.01	0.213	0.92	0.209	0.101
3&4	1.00	0.209	1.04	0.217	0.374
4&5	0.89	0.126	1.23	0.264	<0.001*
5&6	0.94	0.227	1.52	0.338	<0.001*
6&7	1.04	0.281	2.25	0.438	<0.001*
Overall	0.98	0.142	1.39	0.237	<0.001*

*Statistically Significant Difference (P-value<0.05)

Table 7 shows comparison for buccolingual measurements in maxilla and mandible, which is greater in maxilla than mandible and the difference is not statistically significant.

Table 7: Comparison based on buccolingual measurements between maxilla and mandible

Region	Maxilla [n=23]		Mandible [n=24]		P-value
	Mean	SD	Mean	SD	
2&3	7.53	1.56	6.66	1.46	0.056
3&4	8.12	1.29	7.66	1.57	0.287
4&5	8.58	1.11	8.09	1.47	0.205
5&6	10.21	1.46	9.51	1.43	0.108
6&7	12.19	1.76	11.56	1.29	0.167
Overall	9.33	1.18	8.70	1.28	0.084

Table 8 shows comparison for mesiodistal distances in maxilla and mandible, which is greater in mandible than maxilla.

Table 8: Comparison based on mesiodistal (inter-radicular spaces) between maxilla and mandible

Region	Maxilla [n=23]		Mandible [n=24]		P-value
	Mean	SD	Mean	SD	
2&3	2.45	0.61	2.77	0.56	0.065
3&4	2.66	0.87	3.03	1.23	0.245
4&5	2.74	0.64	3.73	0.82	<0.001*
5&6	2.84	0.68	3.67	1.18	0.005*
6&7	2.10	0.92	5.18	1.49	<0.001*
Overall	2.56	0.38	3.68	0.49	<0.001*

*Statistically Significant Difference (P-value<0.05)

Discussion

The present study evaluated the difference between maxillary and mandibular cortical bone thickness, alveolar process width and root proximity at four levels apical to the alveolar crest. These levels were relevant screening sites for optimal mini-implant placement. Significant differences in cortical bone thickness in the maxilla and mandible were detected in the posterior areas. On the other hand, there were no statistically significant differences between maxilla and mandible in anterior areas. Cortical bone thickness in the maxilla and mandible were different depending on the inter-radicular sites of specific teeth. The cortical bone thickness in the maxilla was greatest in the molar area while that in the mandible exhibited a gradual increase from anterior to posterior areas.

The cortical bone thickness in the mandibular buccal region was significantly greater than maxillary buccal region in our study. The results of this study in terms of cortical bone thickness for mini-implant placement are in agreement with the results obtained by Deguchi *et al.* [1] and Motoyoshi *et al.* [31] Thicker cortical bone in the buccal region of the mandible might be explained biomechanically. Whereas the mandible is under torsional and bending strains, the maxilla is generally subjected to more compressive forces. Animal experiments have demonstrated that regions that experience higher strain during function develop thicker cortical bones. Motoyoshi *et al*. [14] showed that the odds ratio of failure were 6.9 times greater when cortical bone was less than 1 mm thick than when it was thicker than 1 mm. Thick cortical bone could also be problematic because placement torque values greater than 10 Ncm (presumably due at least in part to thicker corticies) produce more failures than placement torque less than 8 Ncm [23]. Increased thickness of cortical bone in mandible could explain the higher failure rates reported for the mandible. Bone with thicker cortices, such as the mandible and infrazygomatic crest, might be expected to undergo greater damage (crushing and heat) during placement. Therefore, pilot holes might be required to mitigate this damage for certain patients.

In the maxilla, placement of a mini-implant in an inter-radicular site 8 mm from the alveolar crest with an increased insertion angle provides a greater bone to mini-implant contact area, while a mini-implant in the mandible would be better placed with an increased insertion angle in an inter-radicular site 5 mm from the alveolar crest for better bone to mini-implant contact. Moreover, the attached gingiva, in addition to cortical bone thickness and root proximity, should be considered to minimize inflammation when placing a mini-implant [8, 10, 32]. The attached gingiva in the maxilla is reported to range between 4.3 mm and 5.4 mm while that in the mandible is 3.3–4.6 mm [33, 34]. When an inter-radicular site with insufficient attached gingiva is selected for mini-implant placement, insertion angle needs to be increased for better bone to mini-implant contact. Clinically, most mini-implants have been placed in the premolar areas [35]. From our data, the areas mesial and distal to second premolar inter-radicular sites showed the greatest value for root proximity in the maxilla, and for mandible it is the site mesial and distal to the first molar. This may be a factor in the frequency of placement of mini-implants in premolar and molar areas. Root proximity increased as the inter-radicular sites moved away from the alveolar crest, which can be related to the general morphology of roots. Measurement of the cortical bone thickness and root proximity in inter-radicular sites depending on levels from the alveolar crest can provide valuable information that may be useful during clinical implant placement as well as provision of an anatomical map for use during implant placement planning. With regard to root proximity, placement of a mini-implant 2 mm from the alveolar crest may not be clinically applicable because the space between roots and a mini-implant may be insufficient.

Based on our study, placing a mini-implant in the maxilla at the 8 mm level apical to the alveolar crest would provide better cortical bone to mini-implant contact without root damage. In the mandible, such an implant can be placed at the 5 mm level from the alveolar crest to ensure better cortical bone to mini-implant contact. In addition, the range of attached gingiva should be taken into consideration when placing mini-implants for orthodontic anchorage.

Conclusions

Within the limits of this study, the observations suggest that cortical bone thickness depends on the inter-radicular site and varies for maxilla and mandible. It is greater in mandible than maxilla and the difference is statistically significant for posterior regions. It increases significantly from anterior to posterior regions of mandible.

Root proximity mesial and distal to 2nd premolar inter-radicular sites was greatest in maxilla, and for mandible it was greatest in mesial and distal to the first molar. The mesiodistal distances increase from cervical to apical area. They are greater in mandible than maxilla and the difference is statistically significant.

Buccolingual thickness increases from anterior to posterior regions. The buccolingual measurements are greater in maxilla than mandible, but the difference is not statistically significant.

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