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Tomographic mapping of mandibular inter-radicular spaces and Buccal cortical bone thickness for placement of orthodontic mini-implants using CBCT

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Abstract
Introduction: The purposes of this study were to determine the ideal sites for placement of orthodontic mini-implants in mandibular inter-radicular spaces by using cone beam computed tomography (CBCT).
Methods: Twenty four mandibles of 24 Kashmiri routine orthodontic patients were examined. The samples were imaged and measured using a CBCT system. Buccal inter-radicular cortical bone thickness, alveolar process width, and root proximity were measured in five inter-radicular sites from distal of lateral incisor to mesial of second molar. Buccal inter-radicular cortical bone thickness and alveolar process width were measured at 4 different vertical levels. Root proximity was measured at four different vertical levels.
Results: The mesiodistal distances increase from cervical to apical area. Root proximity inter- radicular sites was greatest in mesial and distal to the first molar. The greatest buccolingual alveolar process width was between first and second molar at 8 mm height (12.85 ± 1.51 mm) and the least was between lateral incisor and canine at 8 mm height (6.43 ± 1.67 mm). Buccolingual thickness increases from anterior to posterior regions.
Buccal cortical bone thickness increases from crest to apex and from anterior to posterior regions**.** The highest buccal cortical bone thickness was between first and second molar at 11 mm height (2.73 ± 0.58 mm) and the least was between lateral incisor and canine at 5 mm height (0.77 ± 0.27 mm).
Conclusions: Buccal inter-radicular cortical bone thickness and alveolar process width tended to increase from crest to base of alveolar process. The buccal inter-radicular cortical bone thickness between first molar and second molar was the greatest, and between lateral incisor and canine was the least. The root proximity between first molar and second molar was the widest and between lateral incisor and canine it was the narrowest.

Keywords: Parental attitude, participation, sports, girls

Introduction
Although dental implants were developed primarily to replace lost teeth, orthodontists have attempted to use skeletal anchorage for decades [1]. Implants have aroused considerable interest among orthodontists as a method for the absolute anchorage of dental movements; this has unlocked an enormous and hitherto untapped biomechanical potential [2-7]. As a result, the use of orthodontic mini-implants (OMIs) as temporary anchorage devices has become increasingly common [8-11]. Mini-implants are a new anchorage paradigm if compared with traditional procedures; they offer many advantages over conventional implants: placement without special preparation, stable and solid anchorage, lower cost, easy placement, and immediate loading. For orthodontic purposes, an implant should be small enough to allow ready placement in any area of the alveolar bone, including the apical bone, thus enabling various orthodontic movements [8]. Small implants, screws, pins, temporary anchorage devices, or, more specifically, OMIs used for anchorage are removed after treatment [12]. Therefore, they are functional for only a short time compared with prosthetic dental implants. To ensure their use as an optimum anchorage alternative, certain factors must be observed, such as the amount of force applied, the direction of the force, the available dimensions, and the sites where the implants will be placed [13]. Despite the many studies on OMIs, the literature clearly emphasizes the need to develop a more comprehensive body of knowledge comprising accurate indications, proper definition of implant features,

appropriate placement sites especially for long-term treatment, and accuracy in mini- implant placement. However, few studies have evaluated and measured reliable placement sites in inter-radicular spaces [11, 14-17]. It is well known that OMI stability is primarily achieved through mechanical interdigitation with the bone [18]. The thickness of the bone cortex, with its greater density, seems to have a bearing on implant success. Thus, an in-depth investigation of bone cortex thickness is strongly recommended. A limitation of mini-implants concerns the risk of damage to key anatomic structures, such as blood vessels, nerves, and dental roots; these devices can shift up to 1.5 mm under orthodontic forces, compromising the integrity of roots, vessels, or nerves [19]. Surgical placement of miniscrew implants for orthodontic anchorage requires consideration of the placement site based on anatomic characteristics20. Although interalveolar spaces tend to increase toward the apical region, the extent of the increase has not yet been accurately determined [11]. The prepared site should have cortical bone at least 1.0 mm thick [21].

Whenever possible, it is advisable to place OMIs in areas of attached gingiva [9, 22] because the mucous membrane is more likely to encroach on the implant and compromise hygiene; this can cause tissue irritation or inflammation, thus undermining mini-implant stability. Furthermore, the minimum amount of bone between mini-implants and dental roots required to preserve periodontal health and prevent damage to dental roots is 1 mm around the mini-implant [17].

The purposes of this study were to assess the amount of mandibular inter-radicular bone and to determine the most reliable implant sites.

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. 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 radioluciences 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 20 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 mandible, from the distal aspect of the lateral incisor to the mesial aspect of the second molar of 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).

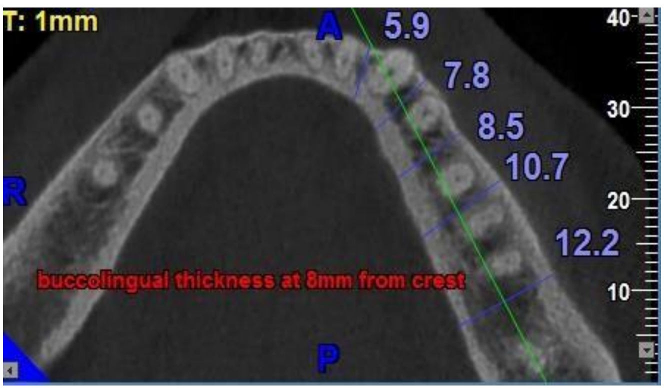

Fig. 2: Measurement of the alveolar process width.

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).

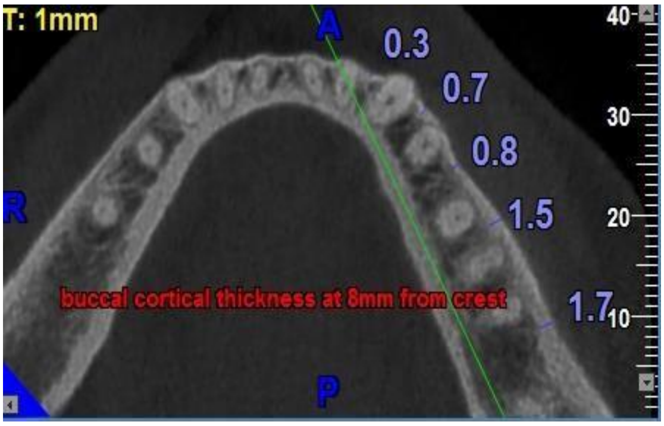

Fig 3: Measurement of the buccal cortical bone thickness.

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 from the alveolar crest in 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 from the alveolar crest in 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 from the alveolar crest in mandible.

Results

The means and standard deviations of the buccolingual alveolar process width of the mandible is shown in Table 1.

Table 1: Descriptive statistics of Buccolingual measurements in mandible

Height from alveolar crest		Mandible				
		2&3	**3&4**	**4&5**	**5&6**	**6&7**
2 mm	Mean	6.84	6.69	6.63	8.14	9.59
	SD	1.47	1.58	1.21	1.34	1.93
	Min	4.4	3.5	3.4	3.7	6.6
	Max	10.3	8.9	9.0	10.4	14.3
5 mm	Mean	6.67	8.01	8.24	9.51	11.86
	SD	1.48	1.68	1.48	1.52	1.73
	Min	3.0	3.8	4.0	4.4	9.2
	Max	8.9	10.6	10.7	12.2	15.9
8 mm	Mean	6.43	7.90	8.57	10.05	12.85
	SD	1.67	1.90	1.92	1.87	1.51
	Min	2.6	3.4	3.7	5.0	10.3
	Max	10.1	11.5	11.6	12.7	15.2
11 mm	Mean	6.71	8.05	8.90	10.36	11.94
	SD	1.81	2.03	2.19	1.72	1.63
	Min	2.4	3.6	4.2	6.7	8.0
	Max	9.8	11.3	12.1	13.0	14.9

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).

The means and standard deviations of the mesiodistal distances of the mandible is shown in Table 2.

Table 2: Descriptive statistics of mesiodistal distances (inter-radicular spaces) in mandible.

Height from alveolar crest		Mandible				
		2&3	**3&4**	**4&5**	**5&6**	**6&7**
2 mm	Mean	1.71	2.08	2.70	2.85	″3.69
	SD	0.44	0.79	0.75	0.67	1.03
	Min	0.8	0.6	1.4	2.0	1.5
	Max	2.4	3.9	4.2	4.7	5.9
5 mm	Mean	2.59	2.66	˟3.39	˟3.23	″4.49
	SD	0.53	1.19	0.85	0.94	1.57
	Min	1.4	1.1	2.1	2.0	0.5
	Max	3.5	6.6	5.3	6.0	7.1
8 mm	Mean	˟3.50	˟3.51	″4.17	″3.72	″5.83
	SD	0.76	1.83	1.00	1.55	2.11
	Min	2.0	1.2	1.7	2.1	0.5
	Max	5.1	10.1	6.3	9.5	9.5
11 mm	Mean	″3.98	″4.01	″4.75	″4.90	″6.70
	SD	1.14	1.39	1.12	1.77	1.89
	Min	2.9	1.7	2.6	2.6	1.6
	Max	6.2	6.8	6.8	10.7	11.0

Average risk site ″ Safe site

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).

The means and standard deviations of the buccal cortical bone thickness of the mandible is shown in Table 3.

Table 3: Descriptive statistics of buccal cortical bone thickness in mandible.

Height from alveolar crest		Mandible				
		2 & 3	3 & 4	4 & 5	5 & 6	6 & 7
2 mm	Mean	0.84	0.79	0.84	0.93	1.29
	SD	0.37	0.31	0.35	0.32	0.57
	Min	0.3	0.4	0.2	0.4	0.4
	Max	1.8	1.6	1.6	1.6	2.2
5 mm	Mean	0.77	0.94	1.02	1.48	2.29
	SD	0.27	0.36	0.28	0.55	0.88
	Min	0.4	0.3	0.5	0.8	0.9
	Max	1.3	1.6	1.6	2.8	4.0
8 mm	Mean	0.90	1.10	1.36	1.70	2.69
	SD	0.28	0.38	0.48	0.42	0.62
	Min	0.3	0.5	0.5	0.8	1.5
	Max	1.4	2.0	2.1	2.6	3.9
11 mm	Mean	1.17	1.34	1.72	1.98	2.73
	SD	0.40	0.47	0.52	0.60	0.58
	Min	0.4	0.5	0.8	0.9	1.4
	Max	2.0	2.1	2.5	3.4	4.2

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).

These data show that, for all variables, the measurements are generally increased from cervical area to apical area. A small variation from this trend was observed between the lateral incisor and canine at 5 mm height (for BC). The variation was also observed between lateral incisor and canine at 5 mm and 8 mm height, between canine and first premolar at 8 mm height, and between first and second molar at 11mm height (for BL), which were less thick than the height above it. The buccolingual width and buccal cortical thickness increase from the anterior to posterior regions. A small variation from this trend was observed between the canine and first premolar at 2 mm height which was less thick than the area between lateral incisor and canine (for BC); and between first and second premolar at 2 mm height which was less thick than the area between canine and first premolar (for BL).

Discussion

To achieve excellent results during orthodontic treatment, adequate control of anchorage is necessary [23]. The patients with bimaxillary dentoalveolar protrusion demonstrated protrusive and proclined upper and lower incisors and an increased procumbency of the lips. The primary goals of orthodontic treatment of these patients include retraction and retroclination of maxillary and mandibular incisors with a resultant decrease in soft tissue procumbency and convexity. This is most commonly achieved by orthodontic treatment in combination with extraction of four first premolars, and retraction of anterior teeth using maximum anchorage mechanics [24]. Recently, the use of miniscrew implants to obtain absolute anchorage has become very popular, because of the small size, uncomplicated surgical procedure, immediate load, lower medical cost, minimal patient cooperation, and multiple insertion positions [23, 25, 26]. The buccal inter-radicular area is commonly selected for miniscrew implant placement [27-29]. This area is not only easy for miniscrew implant placement, but also allows relatively simple orthodontic mechanics [29, 30].

Two factors that clinicians should consider during miniscrew implant placement are safety and stability. Safety is related to avoiding anatomical damage during miniscrew implant placement or when teeth are displaced [23, 31]. The insertion of a miniscrew implant in this buccal inter-radicular area carries a risk that the miniscrew implant may damage anatomic structures, such as the dental roots, maxillary sinus, nasal cavity, blood vessels, and nerves [31-33]. 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 [18, 23, 31]. To prevent damage to the dental root, Poggio *et al.* [17] recommended a minimum clearance of 1.0 mm of alveolar bone around the miniscrew implant in order to provide periodontal health. Therefore, the mesiodistal distance above 3.1 mm was safe for placement of miniscrew with a maximum diameter of 1.2-1.3 mm. The miniscrew implant with a 1.5-mm diameter required at least 3.5 mm of space. Monnerat *et al.* [32] 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. Moreover, Poggio *et al.* [17] suggested that it should not be embedded for more than 6-8 mm of buccolingual alveolar process width because it might reach the narrowest inter-radicular space. The mental foramen is usually located between the apices of the mandibular premolars.34 Therefore, the caution is advised when placing miniscrew implant in this area, particularly starting at the height of 9 mm from the alveolar crest or 10.5 mm from CEJ. 32 The cortical bone thickness is related to the stability of miniscrew implant. To achieve successful implantation, Motoyoshi *et al.* [35] suggested that the prepared site should be established in an area with a cortical bone thickness of more than 1.0 mm. Many studies have evaluated the dimensions and cortical bone thickness of the inter-radicular space for miniscrew implant placement, but the results are varied [17, 27, 28, 29, 31, 32].

Moreover, the three-dimensional study of the buccal inter-radicular area in Kashmiri population has not yet been investigated.

The purposes of this study, therefore, were to evaluate the three dimensional inter-radicular areas and cortical bone thickness in orthodontic patients using CBCT images, and to determine the safe and suitable sites for orthodontic miniscrew implant placement. The safe sites for placing mini-implants in the mandible of our study are between the lateral incisor and canine at 11 mm height (3.98 ± 1.14 mm); between the canine and first premolar at 11 mm height (4.01 ± 1.39 mm); between the first and second premolar at 8 and 11 mm height (4.17 ± 1.00 and 4.75 ± 1.12 mm, respectively); between the second premolar and first molar at 8 and 11- mm height (3.72 ± 1.55 mm and 4.90 ± 1.77 mm, respectively); and between the first and second molar at 2, 5, 8 and 11 mm height (3.69 ± 1.03 mm, 4.49 ± 1.57 mm, 5.83 ± 2.11 mm and 6.70 ± 1.89 mm, respectively). However, one should be careful about the mental foramen position between the first and second premolar. The average risk sites are between the lateral incisor and canine at 8 mm height (3.50 ± 0.76 mm); between the canine and first premolar at 8 mm height (3.51 ± 1.83 mm); between the first and second premolar at 5 mm height (3.39 ± 0.85 mm); and between the second premolar and first molar at 5 mm height (3.23 ± 0.94 mm). The results of this study in terms of the placement site of mini-implant screws in mandible are in agreement with the results obtained by Park *et al*. [31] and Monnerat *et al*. [32]

This study determines the inter-radicular areas in the mandible for safe and suitable orthodontic miniscrew implant placement. We reported the greatest mesiodistal distance was located between the first and second molar. According to the Table 4, this result agreed with those obtained in previous studies of both 2D and 3D method [30-32]. However, they are different from the studies in CBCT method of Poggio *et al.* [17] and Fayed *et al.* [28], probably due to difference in the method of measurement in these studies. Moreover, the vertical and horizontal magnifications are inherent in panoramic radiography, as the method of Schnelle *et al*. [15] the result from this study is slightly different.

According to the Table 1, 2 and 3, the sites of safe and average risk of miniscrew implant placement are more than 6–8 mm of buccolingual alveolar process width and more than 1.0 mm of cortical bone thickness, that are enough as Poggio *et al's* [17] and Motoyoshi *et al*'s [35] suggestion. Stability is influenced significantly by cortical bone thickness at the miniscrew implant placement site. In addition, the bone quality (bone mineral density) and the presence of attached gingiva are factors that influence stability [23, 31]. These factors should be studied further.

Table 4: Summary of articles identifying the greatest mesiodistal distance in the inter-radicular areas of mandible.

Author	Method	Greatest inter- radicular distance
Poggio *et al.*, 2006	CBCT	4-5
Park and Cho, 2009	CBCT	6-7
Fayed *et al.*, 2010	CBCT	5-6, 4-5
Monnerat et al., 2009	CT	6-7
Chaimanee *et al.*, 2011	IOPAR	6 -7
Schnelle *et al*., 2004	OPG	5-6, 6-7
Our study	CBCT	6-7

Motoyoshi *et al.* [36] 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 [37]. 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.

Conclusion

The mesiodistal distances increase from cervical to apical area. Root proximity inter-radicular sites was greatest in mesial and distal to the first molar.

The greatest buccolingual alveolar process width was between first and second molar at 8 mm height (12.85 ± 1.51 mm) and the least was between lateral incisor and canine at 8 mm height (6.43 ± 1.67 mm). Buccolingual thickness increases from anterior to posterior regions.

Buccal cortical bone thickness (important for initial stability of a microimplant) increases from crest to apex and from anterior to posterior regions**.** The highest buccal cortical bone thickness was between first and second molar at 11 mm height (2.73 ± 0.58 mm) and the least was between lateral incisor and canine at 5 mm height (0.77 ± 0.27 mm). Buccal cortical bone thickness is more in posterior sextants than in anterior sextants. For cortical bone thickness, the best available location for a miniscrew is mesial or distal to the first molar.

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