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CBCT evaluation of interdental cortical bone thickness at common orthodontic miniscrew implant placement sites

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Abstract
Introduction: The aim of this study was to assess cortical bone thickness available for accurate placement of orthodontic miniscrew implants in different interdental areas and in different age groups, thereby benefiting in accurate placement of an orthodontic implant, suitable site for placement, its stability and better information to avoid any injury to vital structures in and around the site of implant.
Material & Method: Pre-treatment cone beam computed tomography of maxilla and mandible of 10 adult patients aged between 18-35 years and 10 adolescent patients aged between 12-17 years with equal distribution of males and females were taken using Kodak 9300(France). Cortical bone thickness in the interdental areas between first and second premolar, second premolar and molar, first and second molars at maxillary buccal and palatal sides and mandibular buccal sides only was measured at three different levels (at 2mm intervals each) from approximately 6 mm away from alveolar crest.
Results: The cortical bone thickness was found to be statistically significant ($P<0.001$) between adolescents and adults and between sites in each region. Higher cortical bone thickness is seen in adult mandibular buccal cortex region between first and second molars and at 10mm from the CEJ, followed by maxillary buccal region and maxillary palatal region, which increases from anterior to posterior sites.
Conclusion: The results indicated that adult mandibular buccal cortical bone to be thickest and adolescent palatal cortical bone thinnest among the sites evaluated. Hence CBCT provides reliable diagnostic information in accurate placement of mini-implants.

Keywords: CBCT (cone beam computed tomography), cortical bone thickness, mini-implants

1. Introduction

The law of nature that underlies orthodontic tooth movement is Newton's third law of motion: For every action there is an opposite and equal reaction. In most cases anchorage is produced within the orthodontic appliance with the strategy to dissipate the reaction forces over as many teeth as possible and thereby control anchorage. Pressure in the periodontal ligaments of the anchor teeth are thereby kept to a minimum [1-5].

Modern technologies have elevated implants as the method for absolute orthodontic anchorage, which is a critical consideration when planning treatment for patients with dental and skeletal malocclusions [6, 7].

For most dental practitioners, the use of advanced imaging has been limited because of cost, availability and radiation dose considerations; however, the introduction of cone-beam computed tomography (CBCT) for the maxillofacial region provides opportunities for dental practitioners to request multi-planar imaging. Most dental practitioners are familiar with the thin-slice images produced in the axial plane by conventional helical fan-beam CT [8-10].

CBCT allows the creation in "real time" of images not only in the axial plane but also 2-dimensional (2D) images in the coronal, sagittal and even oblique or curved image planes a process referred to as multiplanar reformation (MPR). In addition, CBCT data are amenable to reformation in a volume, rather than a slice, providing 3-dimensional (3D) information [8-14].

Critical factors include the quantity (bone volume) and quality (bone density) of alveolar bone for the stability of implants. Structurally, maxilla has relatively thin cortices that are interconnected by network of trabaculae. However the mandible is composed of thick cortices and has more radially oriented trabaculae. Thus anatomical characteristics such as thickness of cortical bone might differ between the two jaws. By angulating the miniscrew, the thickness of

Cortical bone contact with the miniscrew might increase. In addition, cortical bone thickness might have some effect on implant success rate [15-23].

2. Materials & Method

2.1 Source of data

This study was carried out on a sample containing 20 patients, presenting to the Department of Orthodontics & Dentofacial Orthopaedics, Dr. Syamala Reddy Dental College, for the treatment of malocclusion. This group of patients showed a definite indication that they would benefit from this modality of treatment.

2.2 Method of collection of data

Twenty consecutive patients, including 2 groups namely Group I, 10 adolescents (5 girls, 13-17 years of age; 5 boys, 13-17 years of age) and Group II, 10 adults (5 men and 5 women, 18-35 years of age), who presented to the Department of Orthodontics, Dr. Syamala Reddy Dental College, were subjected to Pre-treatment Cone Beam Computed Tomography (CBCT) Scans (Kodak 9000, France) at Oral –D diagnostic centre, Bangalore, India. (Figure: 1)

Fig 1: Cone Beam Computed Tomography Machine [CARESTREAM 9300]

2.3 Exclusion criteria

- Periapical or periradicular pathologies or radioluciences of either periodontal or endodontic origin.
- A significant medical or dental history (ex. Use of bisphosphonates or bone altering medications or diseases)
- Severe facial or dental asymmetries.

The CBCT scans were imported into 3-D software [version 10.5, Kodak (Care Stream) CS9300, 3D Imaging Software, France] for analysis as Digital Imaging and Communications in Medicine (DICOM) multi-files.

The study was carried out to find out the bucco-lingual cortical bone thickness for an appropriate location of implant placement on buccal (A) and palatal (B) sides in the maxilla and only on mandibular buccal (C) side. The buccal and palatal cortical bone thickness from Group A, B & C was measured at three different levels (at 2mm intervals each) from approximately 6 mm away from alveolar crest towards the apex on buccal and palatal sides.

Either right or left side was randomly selected for taking measurements. These measurements were taken on the computer display monitor with DICOM measuring software tool (in millimetre).

CBCT images of maxilla and mandible are obtained which are calibrated and measured for the bone quantity (interdental area) between the two premolars, second premolar and first molar, first molar and second molar.

2.4 Method

Before measurement, each site was oriented in all 3 planes of space (figure: 2). for the measurements made in the posterior interradicular areas of the maxilla and mandible, the sagittal slice was used to locate the interradicular area of interest. The slice was then oriented so that the vertical reference line bisected the interradicular space and was parallel to the long axis of the roots. The axial slice was then used to ensure that the horizontal reference line traversed the thinnest area of cortical bone while bisecting the interradicular area.

To determine reliability and repeatability of this method, measurements were taken by two operators, an orthodontist and by a radiologist (time interval-1 day) on the original reoriented volumetric image, and the mean of the two readings was considered.

Insertion of miniscrew at an oblique angle allows for the use of more space, reduces the possibility of root injury and increases the surface in contact with cortical bone.

The ethical and review committee of, Dr. Syamala Reddy Dental College which follows the guidelines from the Rajiv Gandhi University of Health Sciences, Bangalore, India; and has approved this study based on latest trends, its importance in the field of orthodontics and the benefits it offers to the patients and the orthodontists.

Informed and written consent of the patients was obtained before they were subjected for the study.

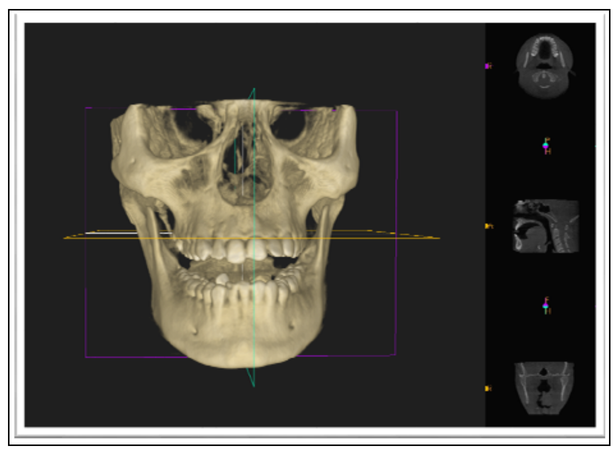


Fig 2: Reconstructed 3-Dimensional Image.

2.5 Statistical Analysis

2.5.1 Null Hypothesis: There is no significant difference in the mean cortical bone thickness of the three groups i.e. $\mu_1 = \mu_2 = \mu_3$

2.5.2 Alternate Hypothesis: There is a significant difference in the mean cortical bone thickness of the three groups i.e. $\mu_1 \neq \mu_2 \neq \mu_3$

2.5.3 Level of significance: α=0.05

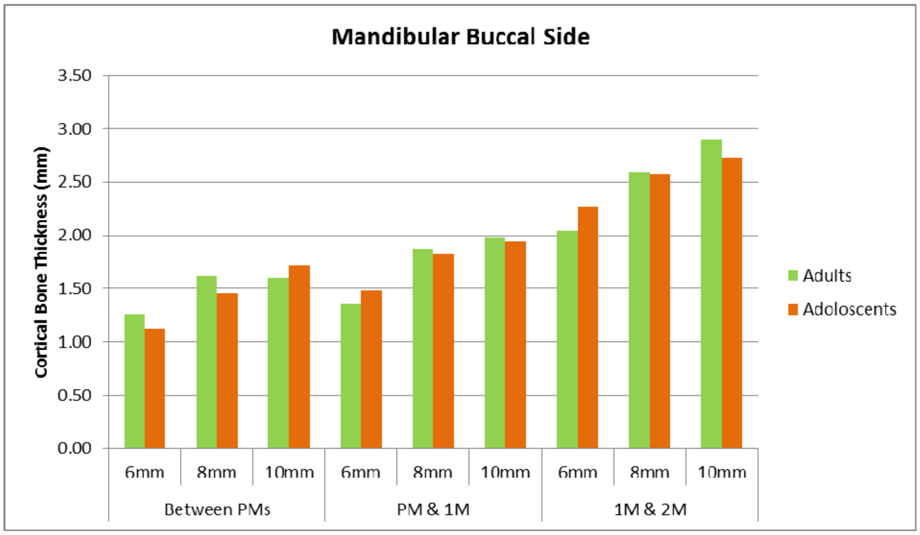
2.5.4 Statistical technique used: Analysis of Variance (ANOVA).

2.5.5 Decision criterion: The decision criterion is to reject the null hypothesis if the p-value is less than 0.05. Otherwise we accept the null hypothesis. If there is a significant difference between the groups, we carry out multiple comparisons (post-hoc test) using Bonferroni test.

3. Results

The cortical bone thickness was found to be statistically significant between adolescents and adults and between sites in each region. Higher cortical bone thickness is seen in adult mandibular buccal cortex region between first and second molars and at 10mm from the CEJ, followed by maxillary buccal region and maxillary palatal region, which increases from anterior to posterior sites.

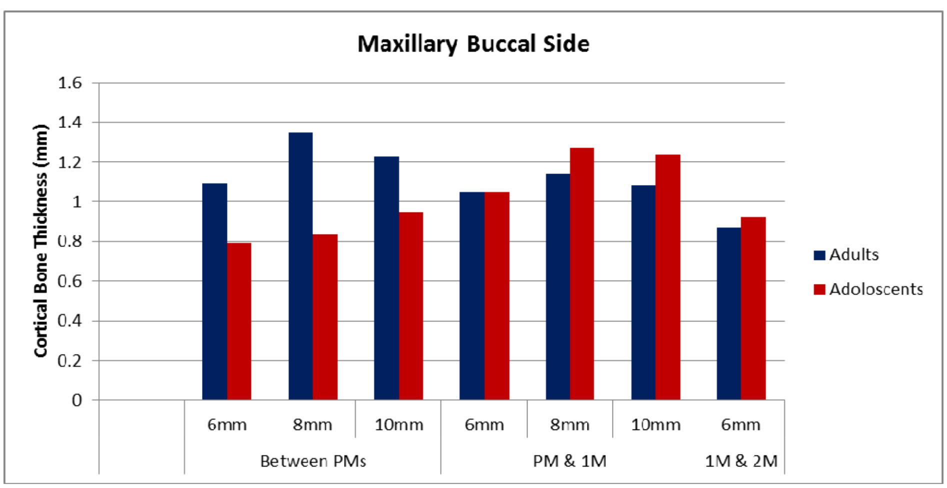
In adult mandibles, higher mean cortical bone thickness was recorded at 10mm distance followed by 8mm and 6mm distance respectively (figure:5). The difference in mean cortical bone thickness between the three distances was found to be statistically significant (*P*<0.001). Further, it was found that significant difference existed between 6mm & 8mm distance (*P*<0.01) as well as 6mm & 10mm distance (*P*<0.001) according to Bonferroni test. (Graph-1)



Graph 1: Mandibular Buccal side

		Adults	Adolescents
Between PMs	6mm	1.26	1.12
	8mm	1.62	1.46
	10mm	1.60	1.72
PM & 1M	6mm	1.35	1.48
	8mm	1.87	1.82
	10mm	1.98	1.94
1M & 2M	6mm	2.04	2.26
	8mm	2.60	2.57
	10mm	2.90	2.72

Cortical bone at premolar-molar region was thicker than between premolars, at the premolar-molar region, the cortical bone was thicker at 10mm distance followed by 8mm and 6mm respectively. The difference in mean cortical bone thickness between the three distances was found to be statistically significant (*P*<0.001). (Graph-2)



Graph 2: Maxillary Buccal side

		Adults	Adolescents
Between PMs	6mm	1.09	0.79
	8mm	1.35	0.84
	10mm	1.23	0.95
PM & 1M	6mm	1.05	1.05
	8mm	1.14	1.27
	10mm	1.08	1.24
1M & 2M	6mm	0.87	0.92
	8mm	1.14	1.08
	10mm	1.17	1.10

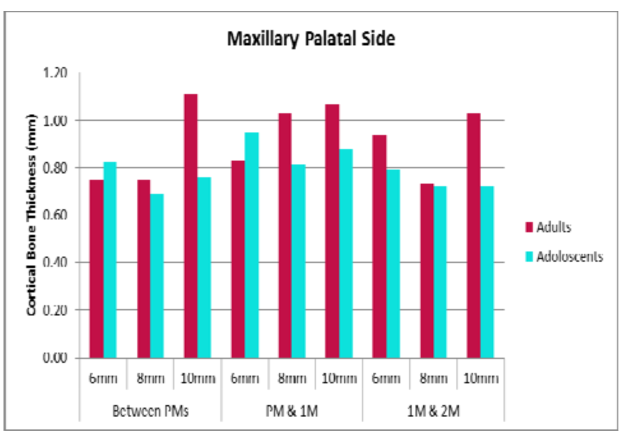
Whereas the interradicular bone thickness between premolars was thicker at 8mm followed by 10mm and 6mm respectively, and it was found that significant difference existed between 6mm & 8mm distance ($P<0.05$).

Maxillary adult bone thickness showed variation among buccal and palatal sides, among the palatal side thickness of bone was highest between the premolars and premolar-molar site at 10mm with a mean of 1.11 and 1.07 respectively and significant difference existed between 6mm & 8mm distance ($P<0.05$) as well as 8mm & 10mm distance ($P<0.01$).

Among the maxillary buccal and palatal bone thickness, the interdental cortical bone thickness between the premolars at 8mm and 10mm was highest in the buccal and palatal sites respectively. Least cortical thickness was recorded b/w the molars at 8mm from the CEJ, with a mean of 0.73mm along the palatal side. (Figure: 3 & 4)

The adolescent bone thickness showed similar results in the mandible, although in the maxilla maximum thickness was found along the buccal surface at 8mm b/w premolar-molar site but in the adult sample it was b/w the premolars. There was significant difference in the mandibular cortex b/w 6 and 10 mm with $P<0.001$.

Maxilla along the palatal surface showed decreasing thickness from the anterior towards the posterior region, also the thickness decreased with increase in the distance apically. Highest reading was found in the premolar-molar site at 6mm with a mean value of 0.95mm. (Graph-3)



Graph 3: Maxillary Palatal side

		Adults	Adolescents
Between PMs	6mm	0.75	0.82
	8mm	0.75	0.69
	10mm	1.11	0.76
PM & 1M	6mm	0.83	0.95
	8mm	1.03	0.81
	10mm	1.07	0.88
1M & 2M	6mm	0.94	0.79
	8mm	0.73	0.72
	10mm	1.03	0.72

Buccal maxillary bone thickness unlike the palatal side showed maximum thickness at the premolar-molar site and 8mm distance from the CEJ.

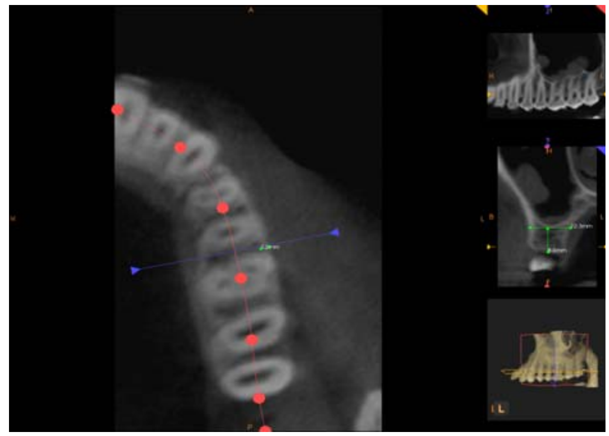


Fig 3: Maxillary buccal cortical bone thickness

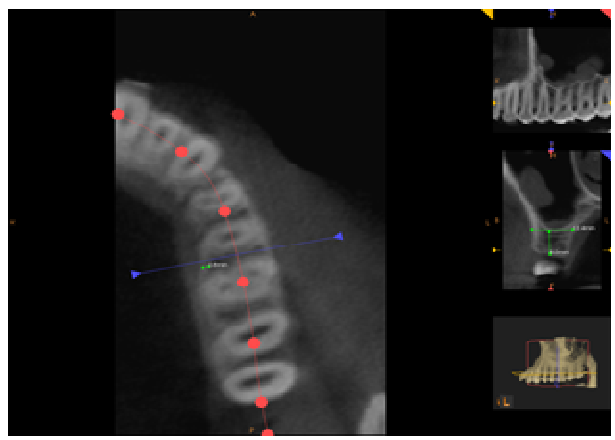


Fig 4: Maxillary palatal cortical bone thickness

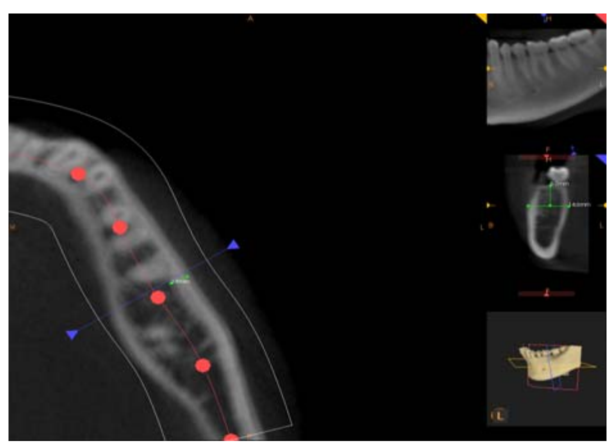


Fig 5: Mandibular buccal cortical bone thickness.

4. Discussion

Anchorage is a major concern and a pre-requisite in the design of orthodontic appliance for the successful treatment of dental and skeletal dysgnathia. It is essential in order to avoid possible anchorage loss, maximizing desired tooth movement and minimizing undesirable side effects.

With the introduction of skeletal anchorage system in orthodontics, the orthodontist could expect absolute or definite anchorage for tooth movement without depending on the patient's compliance. The use of osseointegrated implants, onplants, direct wiring from zygomatic arch and bone plates did help, but the bulk of the attachments led to gingival problems & failures and also proved to be inexpensive, time consuming and had limited application in orthodontics [24-27].

On the other hand, mini implants were smaller in diameter & length, and also could be inserted in any desired location (including inter radicular bone) and loaded immediately. It could withstand the orthodontic force applied during the entire treatment; osseointegration was not necessary and could be retrieved easily after the treatment completion by the orthodontist. In addition, these are less expensive, reduce treatment time, allow early force application and are more popular as compared to other types of orthodontic implants. These mini implants can be placed without raising the flap and it may be inserted with a pre drill or may be a self-tapping screw [27, 28].

Miniscrew can be placed into the alveolar bone in an oblique direction without causing any damage to the surrounding tissue (root, blood vessels & nerves, maxillary sinus). This will allow for use of more space, reduces the possibility of root injury and increases the surface in contact with cortical bone. It was therefore suggested, that miniscrews should be placed in the apical region. However, the problem with this was that screws placed in unattached gingiva can lead to periodontal soft tissue complications because of the difficulties in maintaining proper oral hygiene. Placement in the attached or on the junction between attached and unattached gingiva with thinner soft tissue is therefore preferable [29-32].

To locate an appropriate site for implant placement, it is necessary to measure the vertical distance from occlusal plane to the site of implant placement using OPG and then fabricating a resin template on the patient working model and / or using a dental X-ray (peri-apical radiograph) or CT with acrylic surgical stent / guide bar / brass wire attached to the teeth [29]. Locating a site with comparatively thick cortical bone and thin soft tissue area without nerves or vessels for implantation would be ideal [32].

These stents should be retained during implant insertion, which helps in placement of the mini implant exactly at the desired location. Therefore the main criterion for stability of an implant is the quality and quantity of cortical bone and thin soft tissue. From this perspective this study has been taken up to find out the cortical bone thickness on the buccal and palatal sides at the posterior region of the maxilla, and buccal sides at the posterior region of mandible [11, 25, 28].

Similar to previous studies adult cortical bone thickness was higher than the adolescent cortical bone, also there were no differences in cortical bone thickness between right or left side of the jaws [33-35]. However, we found no sex differences in cortical bone thickness in either he maxilla or the mandible, which is consistent with the results of Ono *et al* [36].

Difference in cortical bone thickness between younger and older patients might be explained by proportionate increases in overall body size and the size of the body parts. The age effects appear to be partially hormonally based [36]. Sex and age-related differences in cortical bone thickness might also be explained by changes in functional capacity, because maximum bite forces, masticatory muscle size, and muscle activity all tend to change with age and sex [37-40].

The adult mandibular buccal region had the thickest cortical bone of all regions evaluated. Mandibular buccal cortex also has a higher bone mineral density than buccal alveolar bone in the maxilla [33, 41]. 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 [42, 43].

Cortical bone thickness in the mandibular buccal region was thickest posteriorly and became progressively thinner anteriorly, this pattern might be explained by the higher functional demands placed on the posterior teeth [16].

Interestingly we found differences in cortical bone thickness between maxillary lingual and buccal regions in the adult group especially between the premolars unlike the work of Peterson *et al* [41].

Differences in cortical bone thickness were also evident between sites in the various regions. Cortical bone was thicker in the premolar-molar site at both buccal and palatal aspect followed by premolar region and between the molars respectively in the adolescent group [20, 41].

But in the adult group the maxilla along the buccal surface was found to be thicker between the two premolars at 8mm from the alveolar crest, followed by the premolar-molar site and between the molars respectively. These results were in line with studies conducted by Deguchi *et al* [20], this finding could probably be explained/attributed to the differences in the occlusal forces, and to the maximum bite forces which have are known to increase from anterior to posterior towards the molars [44-46].

The buccal surface of the maxilla at 8mm site was thicker than the 6mm and the 10mm sites. In case of palatal surface the, 6mm site was comparatively thicker then the 8mm and 10mm sites respectively, according to the bone volume and anatomy of the palate [47-49].

The results of this study showed that in the maxilla the buccal cortical thickness had a certain pattern: the thickness increased as the cuts moved apically from the CEJ to the 6mm site, and then they decreased again at the 8mm site and followed by an increased thickness at the 10mm. This is in similar observation with the study of Baumgaertel and Hans [50] on dry skulls. In the mandible, the thickness increased gradually in the apical direction, the highest was between the first and second molar. Lingual and palatal cortical bone thicknesses showed a gradual increase as the cuts moved apically.

Based on the findings of previous studies, the optimal site for mini-implant placement was between the second premolar and the first molar for the maxilla and between the first and second molars for the mandible [32, 34, 51].

Palatally, the optimal site is between the premolar-molar site followed by the first and second premolars at 8mm and 10mm as it has the advantage of the highest cortical bone thickness and the position of the first molar's palatal root and the buccal angulation of the second premolar provide excellent access for direct insertion for miniscrew [52]. But Baumgaertel *et al* suggests bone depth and cortical bone thickness of the palate were most favourable for temporary anchorage device placement at the level of the first and second premolars [53].

Bone depth decreased with higher measurement levels at about 12mm and was smallest at the most posterior-superior measurement points and possibilities of perforation into the maxillary sinus [54, 55].

5. Conclusion

The use of mini implant has widely been accepted because of its reliability and advantages over the conventional anchorage concern. Placement of mini implant is crucial and is largely dependent upon the bone availability and its thickness. Recent imaging techniques such as CBCT, MRI etc in the field of orthodontics have helped the clinician to overcome the previously encountered difficulties. Thus maxillofacial imaging determines the anatomy of the proposed implant site and how best to optimize the implant placement considering the needs and anatomic constraints.

In the present study, we found the adult mandibular cortical bone to be the thickest (2.9mm) and adolescent palatal bone thinnest (0.69mm), among all the other regions evaluated. Among the different sites considered, favourable position of placement of mini-implant was between the molars at 10mm from the alveolar crest for the mandible. In the maxillary palatal surface, cortical bone thickness between the premolars at 10mm site is ideal location for mini-implant placement.

Whereas, for the adult maxillary buccal region we found the cortical bone thickness to be highest between the premolars, while the most appropriate location being the second premolar-molar site. This difference could probably be explained due differences in occlusal forces and maximum bite forces.

For the adolescent group, only the mandibular buccal cortical bone thickness was sufficient for mini-implant placement, while the palatal and buccal maxillary cortical bone are of inadequate thickness for successful mini-implant insertion.

Interdental buccal cortical bone thickness appears to vary according to a distinctive pattern. Knowledge of this pattern can aid clinicians in implant site selection and proper site preparation. A visual aid (CBCT) was created to facilitate the clinical application of these results. Future studies are needed to determine the exact relationship between cortical bone thickness, the method of implant site preparation, and success rate.

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