QUANTITATIVE ASSESSMENT OF BUCCAL CORTICAL BONE THICKNESS IN SOUTH INDIAN POPULATION FOR MINISCREW IMPLANT PLACEMENT USING COMPUTED TOMOGRAPHY – AN IN VITRO STUDY

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CERTIFICATE

This is to certify that this dissertation titled **"QUANTITATIVE ASSESSMENT OF BUCCAL CORTICAL BONE THICKNESS IN SOUTH INDIAN POPULATION FOR MINISCREW IMPLANT PLACEMENT USING COMPUTED TOMOGRAPHY – AN IN VITRO STUDY"** is a bonafide record of work done by **Dr. SREESAN. N. S** under my guidance during his postgraduate study period between 2009–2012.

This dissertation is submitted to **THE TAMIL NADU Dr. M.G.R. MEDICAL UNIVERSITY**, in partial fulfillment for the degree of **Master of Dental Surgery** in Branch V – Orthodontics and Dentofacial Orthopedics

It has not been submitted (partially or fully) for the award of any other degree or diploma.

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INTRODUCTION

Anchorage control is fundamental to successful orthodontic treatment. The struggle in establishing a stable anchorage has been concerning the orthodontists from the time when fixed appliance was introduced; hence anchorage is the primary problem in the treatment of dental and skeletal dysgnathia. Depending upon the goal of therapy in individual patients, orthodontic treatment is first orientated to the biological anchorage quality of the teeth.

Conventional anchorage was assumed to be stable if a light continuous force was applied on a few teeth against a large anchorage group, the rationale being that the force experienced by the anchorage unit could be below the minimum threshold that is essential to initiate movement of the anchorage unit. This belief was demolished by **Weinstein**[87] in 1967 when he demonstrated that a force as low as 4 grams could bring forth tooth movement. This was supported by the work of **Pilon**[67] et al who proved that a linear relationship between force and displacement did not exist. Despite these observations, clinicians continue to employ the philosophy of differential force and displacement in treatment planning.

Earlier, orthodontists used extraoral traction to reinforce intraoral anchorage. Skeletal anchorage using a headgear was first introduced as a treatment option in orthodontics in the late 1800s[8]. In the 1930s, esthetics became an important aspect of orthodontics due to patient demands. In 1936, **Oppenheim**[60] suggested that headgear as a treatment option was valuable. In the 1950s, with the advent of lateral cephalometric skull radiographs, headgear was shown to be effective at hindering or stimulating maxillary growth. Nevertheless, patients seldom used headgears 24 hours a day- 7 days a week.

Many factors including patient compliance and normal everyday activities such as eating decreases the overall wear time and patient compliance has been a major issue [9, 19]. Headgear has limitations, that it is only a valid treatment option during growth. Prevention of undesirable tooth movement in both arches is now possible. These disadvantages have led to a research in alternative types of anchorage for orthodontic treatment. Therefore implant assisted orthodontics was developed as a creditable alternative to conventional anchorage especially for extra oral anchorage devices, wherein areas apart from dentition were utilized for stabilizing the anchorage.

Creekmore and Eklund[21] first suggested implants as a possibility for alternative treatment options of skeletal anchorage, yet due to the large size of traditional implants, they had limited uses. Now mini-implants (MIs) are being used and have been advocated as anchors for stabilization, thereby replacing the external component of headgears.[2, 7, 36, 73, 80, 88.]

The use of small titanium bone screws has increased the envelope of orthodontic treatment, providing an alternative to orthognathic surgery (particularly in vertical dimension) and allowing asymmetric tooth movement in three planes of space. MIs provide the biomechanical advantage that allows more effective and efficient treatment with few auxiliaries and other appliances. Predicting resistance to tooth movement can minimize adverse responses, and lead to more successful treatment of complicated problems, and provide efficient care in less time.

Because they provide an excellent alternative to traditional compliance-dependent, tooth-borne anchorage methods, orthodontic MIs have expanded the scope of traditional orthodontic treatment.

Esthetic considerations and the growing demand for orthodontic treatment methods that require minimal compliance, especially by adults, have led to the expansion of mini implant (MI) technology[27]. In addition, the MIs has made it possible to overcome previous limitations of orthodontic movement[2]. For example, it is now possible to move the entire dentition in the same direction, intrude molars to correct an open bite or even control the vertical dimension.[6, 66, 82] MI anchorage is becoming an increasingly significant part of orthodontic treatment. Originally used for bone fixation in plastic and reconstructive surgery, titanium MIs have come to be used in orthodontics and many new designs for MIs have been introduced. [4, 18, 44, 45, 51, 65] MIs has further expanded the therapeutic potential.

MIs are placed in many anatomic sites, depending on the indication and the biomechanics used.[37, 62, 64] Popular implant sites appear to be the palate, the lingual aspect of the maxillary alveolar process, the retromolar area in the mandible, and the buccal cortical plate in the maxilla and the mandible.[37, 64, 66, 91] The latter has proven to be a versatile placement site.[68, 74]

More recently, an interest in Cortical bone thickness (CBT) and quality has developed in conjunction with orthodontic skeletal anchorage systems.[32, 36, 38, 68] The influence of bone quality on the long-term success of oral implants is undisputed and has been known for over a decade. [92] Studies showed that, it is not primarily the ratio of cortical bone to trabecular bone that impacts implant stability as much as the absolute amount of dense cortical bone.

Motoyoshi et al [59] in his study concentrated specifically at the correlation between CBT and success rates of MIs. The CBT was measured in limited areas, namely the maxillary tuberosities. A minimum of 1mm of cortical bone was shown to be necessary for increasing success rates. This study showed that knowledge of the thickness of cortical bone throughout the jaws is directly linked to the success of MIs. **Miyawaki et al** [56] suggested that thin cortical bone is associated with an increased failure of MIs.

Song and co-authors[78] showed that the thickness of cortical bone was an important factor in deciding which design of MI should be used. Different designs of MIs used in varying thickness of cortical bone showed a wide range of torques upon insertion and increased damage at the insertion site resulted due to increased torque.

Farnsworth et al [26] showed that there was a significant difference in CBT between adults and teens in both maxilla and mandible. Differences within each jaw bone were also noted in his study. Cortical bone was thicker in the posterior than the anterior interadicular sites of both the maxilla and the mandible.

Further, studies have been carried out to discover and evaluate ideal sites for the placement of MIs and most of these have indicated the suitability of buccal cortical bone [6, 38, 68, 74] Basically, the dimension of the MI should be congruent with the amount of bone available at the point of placement. Previous studies indicate that a certain amount of bone volume is critical for implant stability.[38, 45]

Images of the craniofacial region are an important component of the orthodontic patient record. The gold standard that orthodontic records attempt to achieve is the accurate replication of the anatomic truth. The anatomic truth is the accurate three dimensional anatomy, static and in function as it exists in vivo. Despite the diverse imaging acquisition technologies currently available, the types and standards for imaging presently used in practice routinely use an array of two dimensional static imaging techniques to record the three dimensional imaging of craniofacial region. Standardized analysis methodologies are used to describe the anatomic information with the help of linear and angular measurements that are generated manually and with computer assistance. These measurements are used for predicting growth and for evaluating treatment outcomes.

Advances in imaging technology have resulted in (Computed tomography) CT units that can provide sufficient detail of small areas in the jaws. This allows for accurate measurements to be made, thereby permitting establishment of which areas of the jaws are most likely to provide sufficient thickness of cortical bone for anchorage. The use of mini-implants has many advances, but there are still major concerns. Two major concerns are what is the best site for placement and which imaging modalities that should be used to determine these sites. There is a limited number of research articles on areas of adequate bone thickness in the literature and thus there is limited confirmation that implant placement is feasible on a routine basis.

From the above mentioned studies it is clear that, the buccal CBT differs between individuals and between different sites in the same individual. Bone quality and the age of the patient are other factors that decide the success rate of the MIs. Thus, it is necessary to measure the buccal CBT, to have an idea of the CBT at various locations in order to determine the optimum site for MI placement.

This study was therefore undertaken to evaluate the various anatomic characteristics, using CT scan, and to provide fundamental guidelines for MI placement in maxilla. Hence, the aims of the present study were:-

A) To evaluate the 3D mean CBT between all interradicular areas at different vertical levels from alveolar crest (2, 4, 6 and 8 mm) in maxilla in order to determine which location would provide the best anchorage for MI

B) To compare the differences between the mean CBT in male and female subjects in group A (15–24 years) and group B (25–41 years) separately,

C) To compare the mean CBT between group A and group B subjects in males and females separately.

The CT data set was subjected to three-dimensional (3D) reconstruction to produce a 3D virtual object; this allows measurement of any area in the scanned volume with better accuracy and avoids the projection or superimposition errors encountered in conventional two-dimensional (2D) techniques. Further, the development of modern medical imaging computer technology allows manufacturing of a physical model of the scanned data by rapid prototyping. In this study, 2D slice images were first obtained through CT scanning and 3D image data fields were reconstructed using a software program.

REVIEW OF LITERATURE

Pancherz H (1980) investigated temporal and masseter muscle activity in male subjects with normal occlusion, 11 years and 25 years of age. Integrated EMG recordings were analysed quantitatively during maximal biting in intercuspal position and during chewing of peanuts. The results of the investigation revealed the following: 1. Masseter muscle activity was greater in the older than in the younger age group. 2. Temporal muscle activity was the same in both age groups. 3. Masseter muscle activity was increased in relation to temporal muscle activity in the older subjects. In the younger subjects the same activity was found in the two muscles. 4. For the temporal muscle the chewing activity was positively correlated to maximal biting activity in both age groups. For the masseter muscle a clear correlation between chewing and biting activity was found in the younger age group only. The difference in EMG activity found between children and adults may be attributed to age changes and/or an exercising effect of the masseter muscle occurring during maturation.

Creekmore TD, Eklund MK (1983) stated that with screws, pins, or some other readily removable implant anchored to the jaws, forces might be applied to produce tooth movement in any direction without detrimental reciprocal forces. Orthopedic forces might be applied directly to the jaws through skeletal anchorage rather than through tooth borne anchorage. The need for extraoral forces and the removal of teeth might be greatly reduced.

Duckworth JE et al (1983) introduced a method for the geometric and densitometric standardization of intraoral radiographs. The interpretation of dental radiographs for the diagnosis of periodontal disease conditions poses several difficulties. These include the inability to adequately reproduce the projection geometry and optical density of the exposures. In order to improve the ability to extract accurate quantitative information from a radiographic survey of periodontal status, a method was developed which provided for consistent reproduction of both geometric and densitometric exposure parameters. This technique employed vertical bitewing projections in holders customized to individual segments of the dentition. A copper stepwedge was designed to provide densitometric standardization, and wire markers were included to permit measurement of angular variation. In a series of 53 paired radiographs, measurement of alveolar crest heights was found to be reproducible within approximately 0.1 mm. This method provided a full mouth radiographic survey using seven films, each complete with internal standards suitable for computer-based image processing.

Truhlar RS et al (1993) reviewed fundamentals of panoramic radiography including common errors in patient positioning, their effect on the radiographic image, and how to correct the errors. Radiographic follow-up of dental implants is one of the most important clinical parameters a practitioner can assess. Recent advances in the design of panoramic radiograph machines have increased their potential use in the longitudinal clinical evaluation of dental implants. Changes from the earliest designs allow for projection geometry that more closely approximates the shape of the human jaw. Pantomographic and cephalometric skull radiographs have limited views of the dentition and surrounding structures, and may not truly depict the anatomical relationship of structures, inasmuch as they only provide two-dimensional views. There is some magnification even with a properly positioned patient. Thus superimposition of the head and neck structures seen on these views can make certain regions more difficult to interpret.

Mikic B et al (1995) have shown that the structure of bone is correlated with vigorous activity, when the muscles of mastication contract they exert a certain amount of tension which is directed through the periosteum or tendons. The tension is dispersed over the surface of the bone and may lead to effects such as bending. Bending of bone under a load produces negative electrical potentials on the compressed side and positive potentials on the tensed side. The resulting effect is for osteoclasts and osteoblasts to respond by removing bone on the side experiencing tension and adding bone to the compressed side. In this way, bone is reshaped to best resist increased loading produced by increased muscle strength. With respect to the muscles of mastication, the weaker the musculature, the weaker the bite forces. Weakened bite forces lead to smaller functional effects on the maxilla and mandible. Since muscles exert the tensile forces on bone, the lighter the tensile force, the less dramatic is the bony adaptation.

Kanomi R et al (1997) stated that conventional dental implants are 3.5-5.5 mm in diameter and 11-21 mm long. The MI is only 1.2 mm in diameter and 6 mm long, making it much more useful in orthodontic applications. Besides intrusion, MIs could be used for horizontal traction if placed on the alveolar ridge. The screw is small enough to be inserted between the mesial and distal roots of a molar for molar intrusion, or, if placed in the palate, could provide anchorage for molar distalization. Another possible application is distraction osteogenesis, with the implant placed intraorally instead of extraorally. Care should be taken to prevent postoperative infection from inflammation of the peri-abutment mucosa. However, the MI is too small to cause irreversible damage, and can be removed any time either the orthodontist or the patient desires. Bone healing after removal should be uneventful.

Wehrbein H et al (1998) stated that implant-based anchorage in orthodontics is increasingly obtaining significance. In this study, implants were temporarily inserted into the mid-palatal and the mandibular retromolar areas in humans for orthodontic anchorage. Histological analysis of the implant-bone interface was performed following the retrieval of implants which were subjected to prolonged oblique orthodontic loading. The results of the histomorphometric evaluation indicated that all the implants serving for orthodontic anchorage were well integrated into the bone despite the prolonged application of the orthodontic loading. Hence, it may be concluded that small-size, one-part transmucosal implants with a self-tapping thread and an SLA surface seemed to provide adequate anchorage for orthodontic therapy. Furthermore, the successful integration and the subsequent oblique loading of these orthodontic implants provide evidence that continuous forces in the order of magnitude of 2-6 N are compatible with the maintenance of osseointegration.

Umemori M et al (1999) introduced the skeletal anchorage system to intrude the lower molars in open-bite malocclusion and evaluate the results of treatment in two severe open-bite cases that underwent orthodontic treatment with the system. Titanium miniplates were fixed at the buccal cortical bone around the apical regions of the lower first and second molars on both the right and left sides. Elastic threads were used as a source of orthodontic force to reduce excessive molar height. The lower molars were intruded about 3 to 5 mm, and open-bite was significantly improved with little if any extrusion of the lower incisors. No serious side-effects were observed during the orthodontic treatment. The system was also very effective for controlling the cant and level of the occlusal plane during orthodontic open-bite correction.

Cavalcanti et al (2000) determined the precision and accuracy of in vitro measurements of the volume of oral tumors with three-dimensional (3D) spiral CT and their precision in vivo. Two simulated tumors made of modelling compound mixed with contrast medium were positioned medial to the mandibles of five cadaver heads and examined with subsecond spiral CT. Two observers delineated the simulated tumors twice in axial, coronal and sagittal views and then measured the volume from multiplanar reconstructed images. The software tools automatically displayed the simulated tumors in 3D-reconstructed images with the volumetric measurements. The simulated tumors were removed and their volume measured by water displacement. The volume of 15 oral tumors associated with the mandible were measured in vivo with the same imaging methods and the precision analysed and found there were no statistically significant differences between or within observers or between imaging and physical measurements in vitro, nor between inter- and intra-observer measurements in vivo ($P > 0.05$).

Kyung SH (2001) conducted a study on the use of MI as an anchorage for the orthodontic tooth movement. He mentioned about various clinical application of MI through the general investigation and case reports about orthodontic use of MI, specially about screwing area and clinical consideration of MI's screwing on midpalate. The changes of treatment philosophy and methods by using skeletal anchorage were summarized and following results were obtained.1. The orthodontic anchorage changed from relative concept to absolute one.2. Bodily movement of teeth gets easier and determinate force system is possible on biomechanical consideration.3. Some part of treatment that needs surgical intervention is possible by just orthodontic treatment.

Sommerfeldt DW et al (2001) showed that, mechanical stimulation, such as compression or tension, can cause rapid production of woven bone in a field of mature bone. Therefore, the production of woven bone is a strategic means of rapidly responding to changes in functional activity. Lamellar bone appears within a few weeks after woven bone is deposited. It is the mature bone found in both cortical and trabecular bone. Cortical bone, otherwise known as compact bone, forms the cortex, or outer shell, of most bones and is much denser than its counterpart, cancellous bone.

Bae SM et al (2002) stated that controlled anchorage in orthodontic treatment using micro implants which was designed to fix the bone fragments in oral and maxillofacial or plastic surgery. These inexpensive micro-implants, which are small in diameter (1.2mm) and come in several lengths, can be inserted in any desired location, including interradicular space; can be loaded immediately; can withstand typical orthodontic forces of 200- 300g for the entire length of treatment; do not need osseointegration, unlike restorative implants; and can easily be removed by the orthodontist. The methods of bone anchorage such as retromolar implants, onplants, zygomatic wires, ankylosed teeth, palatal implants, miniplates, MIs, and MIs make it possible to overcome previous limitations of orthodontic tooth movement. These procedures may eventually change the way orthodontic treatment is planned and carried out.

Cole WA (2002) conducted a study to determining the accuracy of patient reporting hours of wearing headgear. In 20 samples, 69% of the patients reported their headgear use at an accuracy level of 84% or greater, while 31% reported their use at an accuracy level of 58%

or less. If fully one third of patients are significantly inaccurate in reporting headgear use, this has clear implications in patient education, expected treatment results, and informed consent. Some may consider the timing headgear a useful adjunct in promoting better patient compliance.

Favero L et al (2002) stated that the orthodontic-implant methodology has developed gradually, at first with the same fixtures as used for prostheses, and then with various improvements. Titanium is the material of first choice, but new and interesting concepts, such as reabsorbable materials, have been advanced. Much research has been directed towards reducing the size of the implant, in this context, it has been seen that primary stability plays a fundamental role. The surgical trauma involved has been reduced. The sites of anchorage respect the most important anatomical structures and the areas that govern skeletal growth.

Hyo-sang park et al (2002) conducted an anatomical study using CT images from 21 patients to determine the location for the implantation of micro implants found the thickness of the cortical bones at the alveolar bone region increased from the anterior to the posterior teeth area, the mandibular posterior teeth area showed thicker cortical bone, a greater distance was observed in distance between the second premolar root and first premolar root in the upper arch between the first molar root and second molar root in the lower arch. He concluded the study stating that the alveolar bone of the posterior teeth area is considered the best site for the implantation of micro implants.

Sherwood KH et al (2002) presented a study with a intent of threefold: (1) to validate true intrusion of molars in adults, (2) to test the stability of miniplates as anchorage for intruding posterior teeth in the maxilla, and (3) to record the skeletal and dental changes of open-bite closure. Four adult patients who had anterior open-bite malocclusions were selected to undergo posterior intrusion with miniplate anchorage to close the open bite; all had true intrusion of the maxillary molars. Mean molar intrusion was 1.99 mm (range, 1.45-3.32 mm). No movement of miniplates occurred at any time during their use or before intentional clinical removal. Open-bite closure was achieved for all 4 patients. Mean closure of incisors was 3.62 mm (range, 3.0-4.5 mm) as the mandibular plane closed 2.62 degrees (range, 1.5 degrees -4.5 degrees), and the occlusal plane decreased 2.25 degrees (range, 1.0 degrees -3.5 degrees). Anterior facial heights decreased as the mandible closed and B-point rotated anteriorly and upward.

Enriksen B et al (2003) conducted a study to determine the quantity of bone in the midline of the anterior hard palate, and specifically the thickness inferior to the incisive canal. They used 25 dry skulls and radiographed with a standardized cephalometric technique. The vertical thickness of the midsagittal palate was then measured to the nearest tenth of a millimeter. Next, gutta-percha was injected into the incisive canal, and the radiograph was repeated. The bone thicknesses were then measured from the inferior hard palate to the most Inferior part of the radiopaque canal. This is defined as the actual bone available for the implant without violating the canal. In their result all the measurements have shown that an average of 8.6 +/- 1.3 mm of bone is theoretically available for the implant. However, considering the canal (where only bone thickness inferior to it is utilized and measured), only 4.3 +/- 1.6 mm of bone exists. The canal itself averaged 2.5 +/- 0.6 mm in diameter. This study supports the continued use of implants, as approximately 50% of skulls still had the requisite minimum 4 mm of bone inferior to the incisive canal for maximum osseointegration with the 4-mm implants. However, 6-mm implants should be used with caution.

Kyung SH et al (2003) presented a case study of 10-year-old female presented with mandibular prognathism and an anterior crossbite. A Hyrax palatal expander was placed, and maxillary anterior protraction was begun with a facial mask. In five months, the molars were in a Class II relationship and the crossbite had improved. Upper molar distalization was initiated three months later with power chain to two midpalatal MIs, which were splinted together for stability. In five months, the maxillary molars moved distally 3.5 mm from the apices and 5 mm from the crowns.

Miyawaki S et al (2003) conducted a study to examine the success rates and to find the factors associated with the stability of titanium screws placed into the buccal alveolar bone of the posterior region. Fifty-one patients with malocclusions, 134 titanium screws of 3 types, and 17 miniplates were retrospectively examined in relation to clinical characteristics. The 1-year success rate of screws with 1.0-mm diameter was significantly less than that of other screws with 1.5-mm or 2.3-mm diameter or than that of miniplates. Flap surgery was associated with the patient's discomfort. A high mandibular plane angle and inflammation of peri-implant tissue after implantation were risk factors for mobility of screws. However, we could not detect a significant association between the success rate and the following variables: screw length, kind of placement surgery, immediate loading, location of implantation, age, gender, crowding of teeth, anteroposterior jaw base relationship, controlled periodontitis, and temporomandibular disorder symptoms. We concluded that the diameter of a screw of 1.0 mm or less, inflammation of the peri-implant tissue, and a high mandibular plane angle (ie, thin cortical bone), were associated with the mobility (ie, failure) of the titanium screw placed into the buccal alveolar bone of the posterior region for orthodontic anchorage.

Carano A et al (2004) evaluated three-dimensional images of fifty maxillas have been retrieved from a group of 200 patients. For each area mesio-distal and labio-lingual measurements from four horizontal cuts made at 2-5-8-11 mm below the bone-crest have been evaluated, the mean value of resistance to breakage in torsion was of 48.7 N.cm (around 5 Kg) for the MI of 1.5 diameter, while the mean value of resistance to breakage in torsion was of 23.4 N.cm (around 2 Kg) for the MI of 1.3 diameter. The mean value of resistance to breakage in flexion was of 120.4 N (around 12 Kg) for the MI of 1.5 diameter, while the mean value of resistance to the flexion is of 63.7 N (around 6 Kg) for the M of 1.3 diameter. On the maxillary alveolar bone the highest amount of bone was in mesio-distal dimension between 6 and 5 on the palatal side (minimum 1.9 mm at -11 mm cut; maximum 5.5 mm at -5 mm cut). The smallest amount of bone was in the tuberosity (minimum 0.2 mm; maximum 1.3 mm).The smallest amount of bone was recorded on the tuberosity (minimum 0.6 mm; maximum 4.1 mm).

Cheng S.J et al (2004) conducted a clinical study to assess the risk factors associated with failure of MIs used for orthodontic anchorage. They used a total of 140 MIs in 44 patients, including 48 miniplates and 92 freestanding MIs. The majority of implants were placed in the posterior maxilla, and the next most common location was the posterior mandible. A variety of orthodontic loads were applied. Their result showed that a cumulative survival rate of 89% (125/140). There was no significant difference in the survival rate between miniplates and freestanding MIs, but miniplates were used in more hazardous situations. The estimated relative risk of implant failure in the posterior mandible was 1.101. The risk ratio of failure for implants surrounded by nonkeratinized mucosa was 1.117. The results confirmed the effectiveness of orthodontic MIs, but in certain situations adjustment of the treatment plan or modifications in the technique of implant placement may lead to improved success rates.

Chung KR et al (2004) developed a new skeletal anchorage system called C-implant. It's a unique titanium device that provides absolute orthodontic anchorage, mainly from osseointegration. It has two components: A screw that measures 1.8 mm in diameter and 8.5 mm, 9.5 mm or 10.5 mm in length. The entire surface, except for the upper 2 mm, is sandblasted and acid etch for optimal osseointegration. A head that measures 2.5 mm in diameter and 5.35 mm, 6.35 mm or 7.35 mm in height. It contains a 0.8 mm diameter hole located 1 mm, 2 mm or 3 mm from the top of the screw. This two component system keeps the neck area from fracturing during implantation and removal.

Gahleitner A et al (2004) conducted a study to determine whether dental CT could serve as a tool to locate the optimal size and position for orthodontic implant placement. They used 32 patients, where palatal implant placement was planned; axial CT scans of the maxillary bone were acquired. Using a standard dental software package, paracoronal views were reconstructed and measurements of palatal bone height in 3 mm increments, dorsally from the incisive canal, were performed in the median and both paramedian regions. Their result showed that the overall mean bone height was 5.01 mm (S.D. 2.60), ranging from 0 to

16.9 mm. The maximum palatal bone height was 6.17 mm (S.D. 2.81) at 6 mm dorsally from the incisive canal. Due to the lack of adequate bone (less than 4 mm), implant placement was not performed in 3 cases (7%). In the remaining 39 cases (93.0%), primary implant stability was achieved and complications, such as perforation of the palate, could be avoided. So they demonstrate that dental CT promises to be a valuable tool in evaluating the potential and optimal size and site for orthodontic implant placement.

Asscherickx K et al (2005) in an animal-experimental study, 20 mini-screws (bracket screw bone anchors, BSBAs) were inserted into the mandible of five beagle dogs. Each dog received two BSBAs in each lower quadrant, between the roots of the second and third, and third and fourth premolars. Sequential point labelling was performed every 6 weeks with vital stains, and apical X-rays were taken every 6 weeks. Radiographic examination demonstrated damage at three roots because of insertion of the BSBAs. Histological examination at these three roots demonstrated an almost complete repair of the periodontal structure (e.g. cementum, periodontal ligament and bone) in a period of 12 weeks, following removal of the screws.

Costa A et al (2005) conducted a study to determine ideal sites for the placement of temporary anchorage devices (TADs), the depths of the hard and soft tissues of the oral cavity were evaluated in 20 patients. The bone depth was quantified by volumetric computed tomography (VCT). The mucosal depth was quantified by a needle with a rubber stop. The results indicate that bone thickness will allow TADs 10 mm in length only in the symphysis, retromolar, and palatal premaxillary regions. TADs 6 to 8 mm in length can be placed in the incisive fossa, in the upper and lower canine fossae. These TADs (4–5 mm) only engage monocortically, whereas the others have the ability to engage bicortically. When placing TADs in mobile alveolar mucosa, the results suggest that a transmucosal attachment may be required to traverse the thickness of the soft tissue.

Halazonetis DJ et al (2005) 3-dimensional data present new challenges and need a different approach from traditional viewing of static images to make the most of the available possibilities. Advances in computer hardware and software now enable interactive display of the data on personal computers, with the ability to selectively view soft or hard tissues from any angle. Transfer functions are used to apply transparency and color. Using the MPR slices improved the accuracy of landmark selection because there is increased variability when the 3D volume is used for landmark localization, depending on the segmentation threshold (ie, the levels of Hounsfield units) selected to construct the 3D volume.

Kim KD et al (2005) performed a study was to determine the precision and accuracy of facial soft tissue measurement using personal computer (PC)-based multiplanar reconstructed (MPR) CT images and to evaluate the effect of the various CT scanning protocols on the facial soft tissue thickness measurement. MPR reformations and three-dimensional (3D) reconstructions viewed on a laptop PC were used to make measurements at six specific sites on each set of images. These measurements were compared to physical measurements at the same sites. Increasing the slice thickness resulted in decreased image quality. Within the same slice thickness, increasing the pitch ratio in the spiral mode resulted in decreasing image quality. The image quality of conventional CT scanning was relatively poorer than that of the spiral CT scanning. However, the mean deviation from the physical measurement was within 0.43 mm in every instance. This mean deviation was quite small and clinically acceptable for measuring the soft tissue thickness of the facial area. PC-based MPR CT images of the face using routine scanning CT protocols can be used to accurately measure soft tissue thickness in the facial region. For more fine and accurate data collection, scanning protocols with slice thicknesses less than 5 mm, and a spiral/helical mode pitch less than 2:1 are recommended.

Kinzinger G et al (2005) described alternative anchorage designs, concentrating on types of anchorage that are applied with orthodontic anchoring implants of reduced diameter and length. Such implants offer several key advantages beyond that of facilitating proper hygiene, namely that they cause fewer or no side-effects in the anterior maxillary dentition area, and that a wider range of indications apply to children, adolescents and adults.

Turkyilmaz I et al (2005) conducted a study to determine the bone density in the designated implant sites using computerized tomography (CT), the fastening torque values of dental implants, and the implant stability values using resonance frequency analysis and to evaluate a possible correlation between bone density, fastening torque and implant stability. The average bone density and fastening torque values were 751.4 +/- 256 HU and 39.7 +/- 7 Ncm for 158 implants. The average primary implant stability was 73.2 +/- 6 ISQ for seventy implants. Strong correlations were observed between the bone density, fastening torque and implant stability values of implants used at implant placement ($P < 0.001$). These results strengthen the hypothesis that it may be possible to predict and quantify initial implant stability and bone quality from pre-surgical CT diagnosis.

Brandao M et al (2006) evaluated the compliance of patients using headgear with a timing device and to determine the efficiency of the electronic module timer as a patient motivator. The patients were instructed to wear their headgear equipped with electronic recorders 14 hours a day for a given number of days. T**heir results stated** Patients reported wearing their headgear an average of 13.6 hours per day; the mean actual hours of daily wear relative to the providers' requirement was 56.7%. This increased to 62.7% when patients knew a recording device was being used. Boys were more compliant than girls. Younger patients were more compliant than older ones. They concluded that a monitoring system can provide feedback to the patient, facilitate parental involvement, and motivate patients to comply with headgear wear.

Deguchi T et al (2006) conducted a study to quantitatively evaluate CBT in various locations in the maxilla and the mandible. In addition, the distances from intercortical bone surface to root surface, and distances between the roots of premolars and molars were also measured to determine the acceptable length and diameter of the MI for anchorage during orthodontic treatment. Their result showed significantly less CBT was observed at the buccal region distal to the second molar compared with other areas in the maxilla. Significantly more cortical bone was observed on the lingual side of the second molar compared with the buccal side. In the mandible, mesial and distal to the second molar, significantly more cortical bone was observed compared with the maxilla. CBT resulted in approximately 1.5 times as much at 30° compared with 90° significantly more distance from the intercortical bone surface to the root surface was observed at the lingual region than at the buccal region mesial to the first molar. They concluded that the safest location for placing MIs might be mesial or distal to the first molar, and an acceptable size of the MI is less than approximately 1.5 mm in diameter and approximately 6 to 8 mm in length.

Hoi-jeong-lim et al (2006) examined the success rates and find factors affecting the clinical success of screw implants used as orthodontic anchorage. Eighty-seven consecutive patients with a total of 227 screw implants of 4 types were examined. Success rates during a 15-month period of force application were determined according to 18 clinical variables. The overall success rate was 91.6%. The clinical variables of screw-implant factors (type, diameter, and length), local host factors (occlusogingival positioning), and management factors (angle of placement, onset and method of force application, ligature wire extension, exposure of screw head, and oral hygiene) did not show any statistical differences in success rates. General host factors (age, sex) had no statistical significance. Mobility, jaw (maxilla or mandible), and side of placement (right or left), and inflammation showed significant differences in success rates. Mobility, the right side of the jaw, and the mandible were the relative risk factors in the logistic regression analysis when excluding mobility, inflammation around the screw implants was added to the risk factors.

Hyo-sang park et al (2006) examined the success rates and factors affecting the clinical success of screw implants used as orthodontic anchorage during a 15-month period of force application. The overall success rate was 91.6%. The clinical variables of screw-implant factors (type, diameter, and length), local host factors (occlusogingival positioning), and management factors (angle of placement, onset and method of force application, ligature wire extension, exposure of screw head, and oral hygiene) did not show any statistical differences in success rates. General host factors (age, sex) had no statistical significance.

Mobility, jaw (maxilla or mandible), and side of placement (right or left), and inflammation showed significant differences in success rates. Mobility, the right side of the jaw, and the mandible were the relative risk factors in the logistic regression analysis when excluding mobility, inflammation around the screw implants was added to the risk factors. To minimize the failure of screw implants, inflammation around the implant must be controlled, especially for screws placed in the right side of the mandible.

Kim H. J et al (2006) conducted a study in which they measured soft-tissue and cortical-bone thicknesses, of the maxilla from 23 Korean cadavers which were decalcified, and buccopalatal cross-sectional specimens were obtained. These specimens were made at 3 maxillary midpalatal suture areas: the interdental area between the first and second premolars (group 1), the interdental area between the second premolar and the first molar (group 2), and the interdental area between the first and second molars (group 3). Their result showed in all groups, buccal soft tissues were thickest closest to and farthest from the cementoenamel junction (CEJ) and thinnest in the middle. Palatal soft-tissue thickness increased gradually from the CEJ toward the apical region in all groups. Buccal cortical-bone was thickest closest to and farthest from the CEJ and thinnest in the middle in groups 1 and 2. Palatal cortical-bone thickness was greatest 6 mm apical to the CEJ in groups 1 and 3, and 2 mm apical to the CEJ in group 2. Along the midpalatal suture, palatal mucosa remained uniformly 1 mm thick posterior to the incisive papilla. So they concluded surgical placement of MI for orthodontic anchorage in the maxillary molar region requires consideration of the placement site and angle based on anatomical characteristics.

Park H.S et al (2006) conducted a study to examine the success rates and find factors affecting the clinical success of screw implants used as orthodontic anchorage. The study included 87 patients (35 male, 52 female; mean age, 15.5 years) with a total of 227 screw implants of 4 types were examined. Success rates during a 15-month period of force application were determined according to 18 clinical variables. Their overall success rate was 91.6%. The clinical variables of screw-implant factors (type, diameter, and length), local host factors (occlusogingival positioning), and management factors (angle of placement, onset and method of force application, ligature wire extension, exposure of screw head, and oral hygiene) did not show any statistical differences in success rates. General host factors (age, sex) had no statistical significance. Mobility, on the right side of the jaw, and the mandible were the relative risk factors in the logistic regression analysis when excluding mobility, inflammation around the screw implants was added to the risk factors. So they concluded that to minimize the failure of screw implants, inflammation around the implant must be controlled, especially for screws placed in the right side of the mandible.

Poggio MP et al (2006) conducted a study to provide an anatomical map to assist the clinician in MI placement in a safe location between dental roots. Volumetric tomographic images of 25 maxillae and 25 mandibles taken with the NewTom System were examined. For each interradicular space, the mesiodistal and the buccolingual distances were measured at two, five, eight, and 11 mm from the alveolar crest. Their result showed that in the maxilla, the greatest amount of mesiodistal bone was on the palatal side between the second premolar and the first molar. The least amount of bone was in the tuberosity. The greatest thickness of bone in the buccopalatal dimension was between the first and second molars, whereas the least was found in the tuberosity. In the mandible, the greatest amount of mesiodistal dimension was between first and second premolar. The least amount of bone was between the first premolar and the canine. In the buccolingual dimension, the greatest thickness was between first and second molars. The least amount of bone was between first premolar and the canine.

Ruff C et al (2006) in his studies has shown that the amount of bone increases when mechanical strain increases beyond maintenance levels, such as is the case during intense mastication or exercise, the opposite is true for decreases in strain. The correspondence between bone strain patterns and bone structure is variable, depending on skeletal location and the general mechanical environment (e.g., distal vs. proximal limb elements, cursorial vs. noncursorial animals), so that mechanical/behavioral inferences based on structure alone should be limited to corresponding skeletal regions and animals with similar basic mechanical designs.

Tseng YC et al (2006) explored the use of MIs for skeletal anchorage, and to assess their stability and the causes of failure. 45 MIs were used in orthodontic treatment. The diameter of the implants was 2 mm, and their lengths were 8, 10, 12 and 14 mm. The drill procedure was directly through the cortical bone without any incision or flap operation. Two weeks later, a force of 100-200 g was applied by an elastomeric chain or NiTi coil spring. Their report stated that the average placement time of a MI was about 10-15 min. The overall success rate was 91.1%. The location of the implant was the significant factor related to failure. In conclusion, the MIs are easy to insert for skeletal anchorage and could be successful in the control of tooth movement.

Motoyoshi M et al (2007) conducted a study to examine the relationship between CBT, inter-root distance (horizontal space), distance from alveolar crest to the bottom of maxillary sinus (vertical space) at the prepared site, and implant placement torque and the success rate of MIs placed for orthodontic anchorage. After computerized tomography examination, MIs of 1.6 mm wide and 8 mm long were placed in the posterior alveolar bone. The MI was judged a success when orthodontic force could be applied for at least 6 months without pain or clinically detectable mobility. The success rate of the 87 implants was 87.4%. CBT was significantly greater in the success group (1.42 +/- 0.59 mm vs 0.97 +/- 0.31 mm, P = .015). The success rate was significantly higher in the group with an implant placement torque of 8 to 10 Ncm (100%) as compared to implants with higher or lower placement torques. The odds ratio for failure of the MI was 6.93 (P = .047) when the CBT was less than 1.0 mm relative to 1.0 mm or more. So they concluded stating that the prepared site should have a CBT of at least 1.0 mm, and the placement torque should be controlled up to 10 Ncm.

Kravitz ND (2007) reviewed the potential risks and complications of orthodontic MIs. The risks associated with MI placement should be clearly understood by both the clinician and the patient. Complications can arise during MI placement and after orthodontic loading that affect stability and patient safety. A thorough understanding of proper placement technique, bone density and landscape, peri-implant soft tissue, regional anatomic structures, and patient home care are imperative for optimal patient safety and MI success.

Lim WH et al (2007) conducted a study to provide a guideline to indicate the best location for MIs as it relates to the thickness of cortical bone and soft tissue, and to the height of the attached gingival field. CT images from 15 men and 15 women (mean age 27 years, range 23-35 years) were used to evaluate the buccal interradicular CBT from and mesial to the central incisor to the 1st molar. To record soft tissue depth at the site of assessment for CBT, the mucosa was pierced with #15 endodontic K-files until the attached rubber stop rested on the mucosa. The height of attached gingiva was measured at the mid-aspect of each tooth using a caliper. There were no significant differences in CBT within interradicular sites except for the 2nd premolar/1st molar site. There were also no significant differences in soft tissue thickness within interradicular sites except for the lateral incisor/canine and 2nd premolar/1st molar sites. The height of attached gingiva was greater in the anterior compared to the posterior region and was shortest in the premolar region. Given the limits of this study, MIs for orthodontic anchorage may be well placed with equivalent bone-implant contact anywhere within the zone of attached gingiva up to 6 mm apical to the alveolar crest with adequate interradicular space.

Park et al (2007) stated orthodontic MIs allows clinicians to retract anterior teeth.. The anterior teeth were splinted on the lingual side and retracted by an elastomeric chain connected to orthodontic MIs without the use of an archwire or brackets. After space closure, brackets were bonded for detailing individual teeth. The desired movement of the anterior teeth was achieved by changing the application point of the retraction force and adjusting the line of force.

Song YY et al (2007) evaluated the effect of CBT on the maximum insertion and removal torque of different types of self-drilling mini-screws and also determine the torque depends on the screw design. They used three different types of self-drilling mini-screws (cylindrical type [Cl], taper type [Ta], taper type [Tb]) and inserted with the use of a driving torque tester at a constant speed of 3 rotations per minute. Experimental bone blocks with different CBT were used as specimens. Their result showed differences in the CBT had little effect on the maximum insertion and removal torque in Cl. However, with Ta and Tb, the maximum insertion torque increased as the CBT increased. The maximum insertion torque of Tb was highest in all situations, followed by Ta and Tb, in that order. Cl showed less torque loss in all CBT and a longer removal time compared to Ta or Tb. There were significant relationships between CBT, maximum insertion and removal torque, and implantation time in each type of self-drilling mini-screw. So they concluded different screw designs showed different insertion torques with increases in CBT, the suitable screw design should be selected according to the cortical thickness at the implant site.

Usui et al (2007) conducted a study to clarify the correlation between variations in maximum occlusal force and the maxillofacial skeletal pattern in subjects with malocclusion using a compact device. The maximum occlusal force was measured with a simplified occlusal force meter. The maximum occlusal force tended to increase with age, with a tendency to be greater in male than in female subjects. In the male subjects, up to their 20s, the maximum occlusal force continued to increase, while in the female subjects its increase almost terminated in the later teens. In some of the age groups, the maximum occlusal force showed a negative correlation with the mandibular plane angle. Maximum occlusal force tended to increase with age. There was a gender difference in the maximum occlusal force at all age groups, values being larger in the males. In the males, the maximum occlusal force continued to increase until their 20s, while in the females, this increase almost terminated at the age of 17.

Wiechmann D et al (2007) conducted this prospective clinical study to evaluate the success rate of micro-implants used for orthodontic anchorage. They examined a total of 133 MIs (79 Abso Anchor, 54 Dual Top implants) placed in 49 patients to support orthodontic tooth movements. The majority of the implants were placed in the maxilla (82), followed by the vestibular (42) and lingual (nine) aspect of the mandible. Their results stated that an overall cumulative survival rate of 86.8% (102/133) was found. The failure rate between Dual Top implants (13%) and Abso Anchor implants (30.4%) differed significantly. The cumulative failure rate of implants was found to be significantly higher when implants were placed in the lingual aspect of the mandible compared with the other localizations. Clinical evaluation revealed successful dental movements when implants remained stable during the orthodontic therapy. This study confirms the effectiveness of orthodontic micro-implants used as anchorage elements.

Chen YH et al (2008) surgically placed seventy-two MIs in the mandibular alveolar bone of six adult mongrel dogs with metabolic bone labeling at 3-week intervals. MIs of the experimental group were placed so that they contacted the root of the adjacent teeth, were retained for different time durations, and were then removed. The insertion torque, clinical measurements, removal torque, and histological findings were analyzed. (1) MIs contacting the roots showed a significantly higher insertion torque than those without contact; (2) there was a significant difference in the removal torque measurements based on the mobility of

MIs and the state of root contact; and (3) MIs contacting the root were at greater risk of failure. During placement of MIs in the aveolar process, increased failure rates were noticed among those contacting adjacent roots. Failed MIs appeared to be surrounded with a greater volume of soft tissue. When more inflammation was present, the adjacent roots seemed to experience more resorption. Nevertheless, the created lesion was repaired with a narrow zone of mineralized tissue deposited on the root surface, which was likely cellular cementum, and was mainly filled with alveolar bone, with the periodontal ligament space being maintained.

Sofie Host et al (2008) reviewed the general and local risk factors involved when using temporary anchorage devices (TADs) and the prerequisites for placement and, to illustrate the orthodontic indications of various TADs. They stated that the general risk factors concerning general health were tobacco smoking, age, infective endocarditis, diabetes, juvenile idiopathic arthritis and medication. Bone quality, gingivitis and periodontitis, reduced mouth opening, radiotherapy and oral hygiene are local risk factors. Aspects of the placement procedure discussed were: primary stability, loading protocols, pre-drilling diameter and whether or not to make an intra-oral incision. Careful treatment planning involving radiographic examination is essential. Consultation with an oral surgeon is advisable if a soft tissue flap is required. Excellent patient compliance, particularly avoidance of inflammation around the implant, is an important consideration for successful use of TADs.

Aranyawongsakorn *S* et al (2009) investigated the effects of insertion angulation on the biomechanical performance of MIs implanted in the dentoalveolar bone. In the maxilla, no significant difference in the maximum insertion torque and pullout strength was observed between MIs implanted at 30, 60 or 90 degrees. Although MIs inserted at 30 degrees exhibited the highest mechanical performance than those inserted at 60 and 90 degress in the anterior portion of the mandible, they exhibited significantly reduced insertion torque and pullout strength values than those inserted at 60 and 90 degress in the middle and posterior sites. No significant difference was observed between MIs inserted at 60 and 90 degrees.

Ludlow JB et al (2009) compared the precision of landmark identification using displays of multi-planar cone-beam computed tomographic (CBCT) volumes and conventional lateral cephalograms (Ceph). Twenty presurgical orthodontic patients were radiographed with conventional Ceph and CBCT techniques. Five observers plotted 24 landmarks using computer displays of multi-planer reconstruction (MPR) CBCT and Ceph views during separate sessions. Absolute differences between each observer's plot and the mean of all observers were averaged as 1 measure of variability (ODM). The absolute difference of each observer from any other observer was averaged as a second measure of variability (DEO). Radiographic modality and landmark were significant at P <0.0001 for DEO and ODM calculations. DEO calculations of observer variability were consistently greater than ODM. The overall correlation of 1920 paired ODM and DEO measurements was excellent at 0.972. All bilateral landmarks had increased precision when identified in the MPR views. Mediolateral variability was statistically greater than anteroposterior or caudal-cranial variability for 5 landmarks in the MPR views.The MPR displays of CBCT volume images provide generally more precise identification of traditional cephalometric landmarks. More precise location of condylion, gonion, and orbitale overcomes the problem of superimposition of these bilateral landmarks seen in Ceph. Greater variability of certain landmarks in the mediolateral direction is probably related to inadequate definition of the landmarks in the third dimension.

Reynders R et al (2009) systematically reviewed the literature to quantify success and complications encountered with the use of MIs for orthodontic anchorage, and to analyze factors associated with success or failure. The analysis of success rates was complicated because of various definitions of primary outcomes, different timings of success assessment, poor methodologies, and lack of clarity in most studies. Rates of primary outcomes of MIs with diameters of 1.0 to 2.3 mm ranged from 0% to 100%. Most studies reported success rates greater than 80% if mobile and displaced implants were included as successful. Adverse effects of MIs included biologic damage, inflammation, and pain and discomfort. Few articles reported on these outcomes. Variables suggested as having an association with the success of MIs were divided into 6 categories: implant, patient, location, surgery, orthodontic, and implant-maintenance factors.

Baumgartel S et al (2009) investigated the buccal CBT of every interdental area as an aid in planning MI placement from the cone-beam CT scans of 30 dry skulls, 2-dimensional slices through every interdental area were generated. On these, CBT was measured at 2, 4, and 6 mm from the alveolar crest. The results showed that the buccal CBT was greater in the mandible than in the maxilla. Whereas this thickness increased with increasing distance from the alveolar crest in the mandible and in the maxillary anterior sextant, it behaved differently in the maxillary buccal sextants; it was thinnest at the 4-mm level.

Mona mohamed et al (2010) Investigated the optimal sites for MI placement in the maxilla and the mandible based on dimensional mapping of the interradicular spaces and CBT and the effect of age and sex on the studied anatomic measurements. The results showed that in maxilla, the highest buccolingual thickness existed between first and second molars; the highest mesiodistal buccal/palatal distances were between the second premolar and the first molar. The highest buccal cortical thickness was between the first and second premolars. The highest palatal cortical thickness was between central and lateral incisors. In the mandible, the highest buccolingual and buccal cortical thicknesses were between the first and second molars. The highest lingual cortical thickness was between the canine and the first premolar. The males and the older age group had significantly higher buccolingual, buccal, and palatal cortical thicknesses at specific sites and levels in the maxilla and the mandible.

Varghese S et al (2010) Evaluated the accuracy of linear measurements obtained from reconstructed spiral CT images of human dry skulls in three planes by comparing them with direct skull measurements, and then to compare these with measurements made on photostimulable phosphor cephalograms. Using a Siemens Somatom Sensation spiral CT scanner, CT images of six human dry skulls were imported into imaging software (Mimics 11.02 Materialise, Leuven, Belgium) and the measurements made were compared to the direct measurements made using a digital calliper . The measurements were also compared to those made on frontal and lateral cephalograms taken using a digital cephalostat. CT measurements did not show a significant difference from the direct skull measurements ($P < 0.05$) in all three planes except for two midsagittal measurements in the anteroposterior plane. Cephalometric measurements were comparable to direct skull measurements for midsagittal measurements in the anteroposterior plane, but showed a significant difference when bilateral measurements were considered. Cephalometric measurements also showed a significant difference in the transverse plane from direct measurements and CT measurements; however, they did not display a significant difference between direct skull measurements and CT measurements for most parameters in the vertical plane. Linear measurements on the spiral CT were comparable to anatomical measurements and were more reliable than cephalometric measurements.

David Farnsworth et al (2011) conducted a study to assess age, sex, and regional differences in the CBT of commonly used maxillary and mandibular MI implant placement site using conebeam CT images. Results showed no significant differences in CBT between the sexes. There were significant differences between adolescents and adults, with adult cortices significantly thicker. Cortical bone was thicker in the posterior than in the anterior mandibular sites. In the adults, interradicular bone in the maxillary first premolar-second premolar, and second premolar-first molar sites was thicker than bone at the lateral incisor-canine and first molar-second molar sites. The mandibular buccal and infrazygomatic crest regions had the thickest cortical bone; differences between the maxillary buccal, the maxillary lingual, and the palatal regions were small.

Gribel BF et al (2011) verified the accuracy of a mathematical model (algorithm) that corrects measurements made on conventional lateral head films to corresponding dimensions observed in a cone beam computed tomography (CBCT) scan in human subjects. All measurements from the lateral cephalogram were significantly different from the corresponding measurements derived from the CBCT. Simply taking into account the image magnification did not correct the 2-dimensional (2D) linear measurement obtained from a conventional cephalogram into a 3-dimensional (3D) linear measurement made on a CBCT scan, unless the structures from which the distance will be measured are located on the midsagittal plane. When the algorithm was used to correct the 2D measurements, however, there were no statistically significant differences between the CBCT group and the algorithm group.

Hoi-jeong lim et al (2011) Elucidated potential confounding factors affecting initial stability of MIs inserted to enhance orthodontic anchorage. Four hundred and seven MIs inserted in 168 patients treated by 17 orthodontic residents were analysed in a consecutive chart review. The outcome variable was the stability of the MI, measured as a dichotomous variable, 0 if the MI loosened during a 1 week period after insertion to the time of orthodontic force application and a value of 1 otherwise. Potential confounding variables examined were gender, age, jaw, insertion site, tissue type, length and diameter of the MI, and number of previous insertions. Generalized estimating equations (GEE) methods were used to estimate the influence of each factor on stability for the correlated binary outcomes of each patient. The overall success rate after 1 week was 93.1 per cent. The screws inserted by more experienced clinicians (more than 20 MIs) were found to have approximately a 3.6-fold higher success rate of initial stability compared with those inserted by less experienced clinicians after adjusting for the insertion site (*P* = 0.015). The initial stability depends on insertion site and clinician.

MATERIALS AND METHODS

Sample selection

CT images of the skulls of 60 subjects were collected from the KGS Advanced MRI and CT Scan Center, Madurai, India. CT images of patients with a history of trauma to the maxilla or any other dental or skeletal anomalies were eliminated. The sample was divided into two groups according to age. Group A consisted of 30 subjects (15 male and 15 female) with ages ranging from 15 years to 24 years, and group B consisted of 30 subjects (15 male and 15 female) with ages ranging from 25 years to 41 years.

Image acquisition

The CT images were recorded using a 3D volume computed tomography scanner (Siemens SOMATOM Sensation® 64-slice) under uniform conditions using high-resolution bone algorithm (slice thickness: 0.60 mm; 120 kV; 225 and 250 mAs) as shown in Figure 1. The CT images were saved in standard DICOM format. (Figure 2)

Three-dimensional reconstruction

The CT data were imported into CAD-based medical software, (Mimics®; Materialise, Belgium) for multiplanar reconstruction. The bone was segmented by thresholding and a 3D object of the maxilla was reconstructed for further evaluation. Automatic segmentation of the maxilla was done and reconstructed. The 2D data was converted into 3D data for accurate measurement of the landmarks, which would have otherwise been cumbersome in the DICOM format. The 3D software reconstruction helps to improve the observation skill and image quality of the object. The CT scan was done in a bone window with the Hounsfield units range between 850 and 1450 [32, 36, 58] Hence, the regular patient data like soft tissue and restorations were not taken into consideration.

The alveolar crests between all interdental spaces were marked in the 3D reconstructed object of the maxilla for each patient. (Figure 3) The same points also reflect in the other reconstructed axial, coronal and sagittal planes in 2D images.

Measurement approach

The measurements were made at 2, 4, 6 and 8 mm vertical levels from the alveolar crest at all inter dental spaces in maxilla. A total of 3600 measurements (60 for each of the 60 patients), were recorded and each measurement was entered into an MS-Excel worksheet. The minimum and maximum of the measurements were noted and the mean and standard deviation (SD) were calculated. (Figure 4 and Figure 5) To evaluate the error variability software, Anatomage, (In vivo 5, USA) was used. (Figure 6 and Figure 7)

Statistical analysis

The results of the present study were subjected to statistical analysis to calculate the mean and standard deviation of every measurement for buccal cortical bone thickness at different levels from the alveolar crest to interpret the differences between the thickness of the buccal cortical bone values in each of the two groups, and also between the groups. Student’s t-test and ANOVA were used for statistical analysis in the present study. Parametric and Non-Parametric methods were used to calculate the P-value. For the buccal cortical bone thickness values, the mean, standard deviation and minimum and maximum values were calculated. P value was limited to three digits.

Standard deviation (SD) is a measure of the dispersion of a set of data from its mean or is a quantity calculated to indicate the extent of deviation for a group as a whole. It is the square root of arithmetic mean of the squared deviations of the individual values from their arithmetic mean. One way to estimate the amount of variability is to calculate the SD. The larger the SD is, the greater the variability in the data or the more spread apart the data the higher the deviation.

P value – Level of significance is denoted by P value and is usually set as 5%.

This probability value indicates that the observed difference between the study group is a real difference and not by mere chance.

- P value – probability of differences
- $P > 0.05$ - difference is not significant (NS)
- $P < 0.05$ - difference is significant(S)
- $P < 0.01$ - difference is highly significant(S)
- $P < 0.001$ - difference is very highly significant (HS)

Student's t - test is a common parametric test used for a data showing normal distribution. This test is applied to unpaired data of independent observations made on individuals from two different or separate groups or samples drawn from two populations, to test if the difference between the two means is real or it can be attributed to sampling variability.

Analysis of variance (**ANOVA**) is a collection of statistical models, and their associated procedures, in which the observed variance in a particular variable is partitioned into components attributable to different sources of variation. In its simplest form ANOVA provides a statistical test of whether or not the means of several groups are all equal, and therefore generalizes *t*-test to more than two groups.

Figure 1: 3D Volume scanner

Figure 2: CT images stored in DICOM format

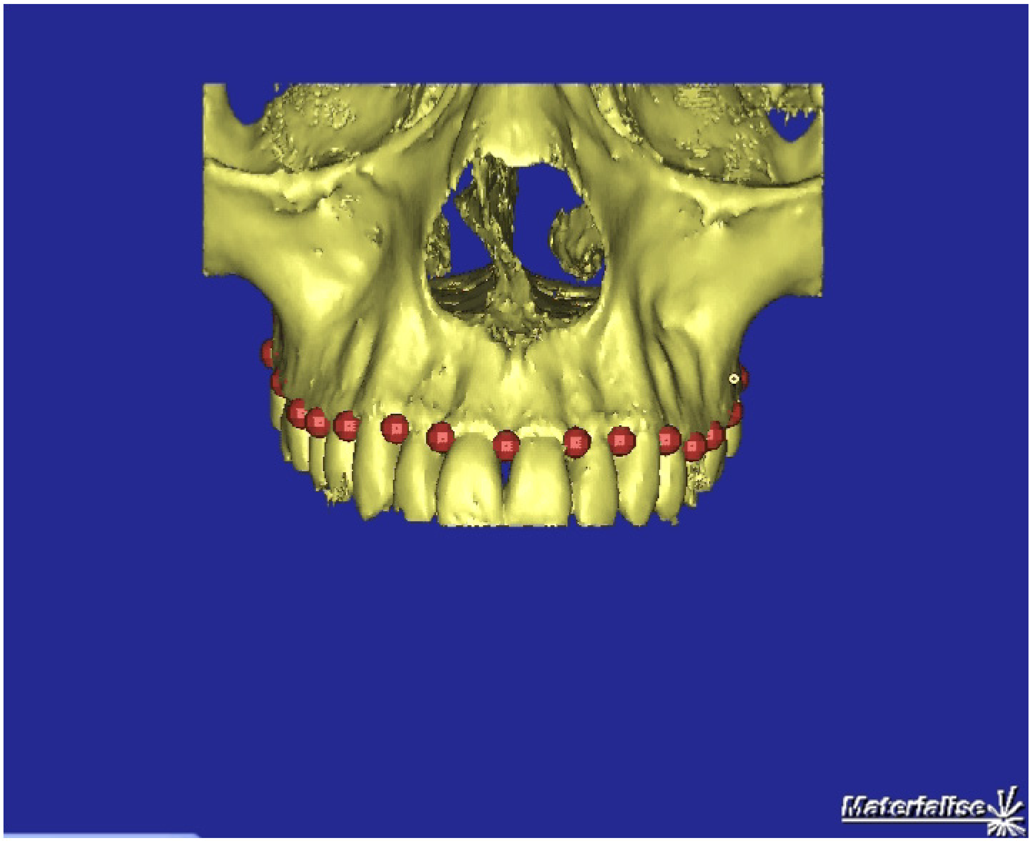


Figure 3: 3D reconstructed image of maxilla with points marked at alveolar crests

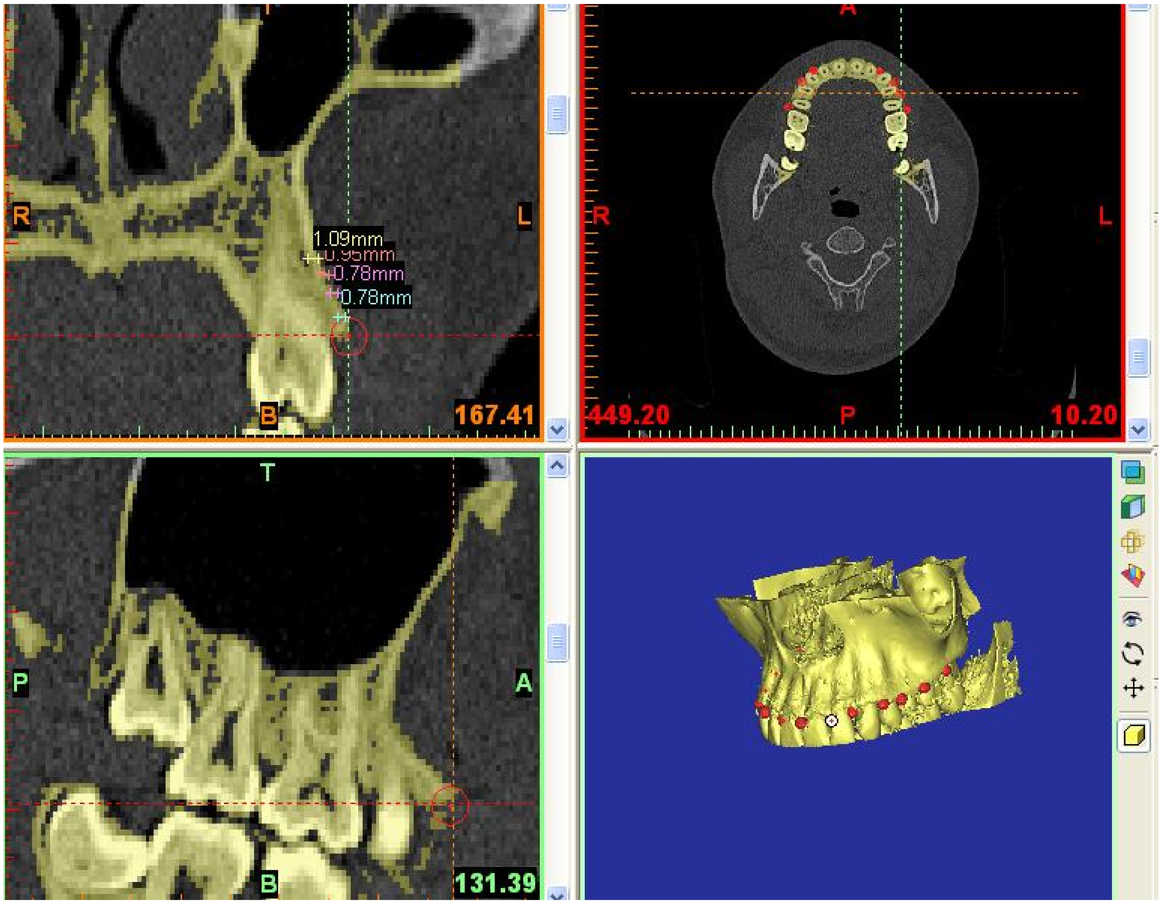


Figure 4: Screen shot of a multiplanar reconstruction with the measurements done. Coronal view, Axial view, Sagittal view, 3D image of the maxilla at 2 mm level between 24 and 25. (Mimics)

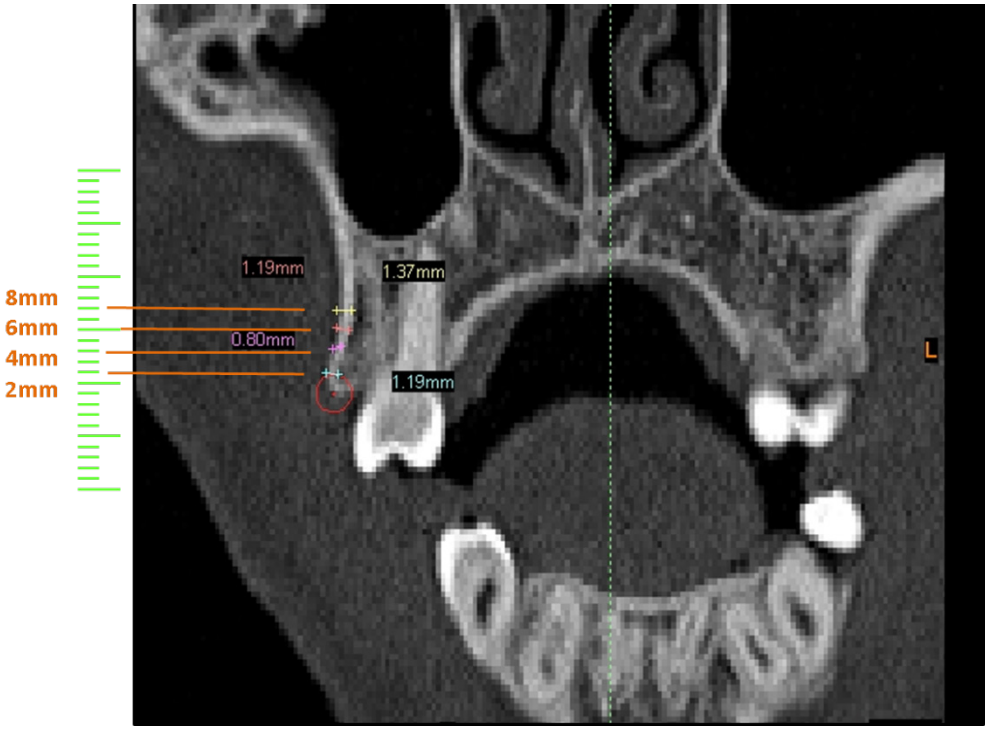


Figure 5: Screen shot of a multiplanar reconstruction with measurements done showing Coronal view.

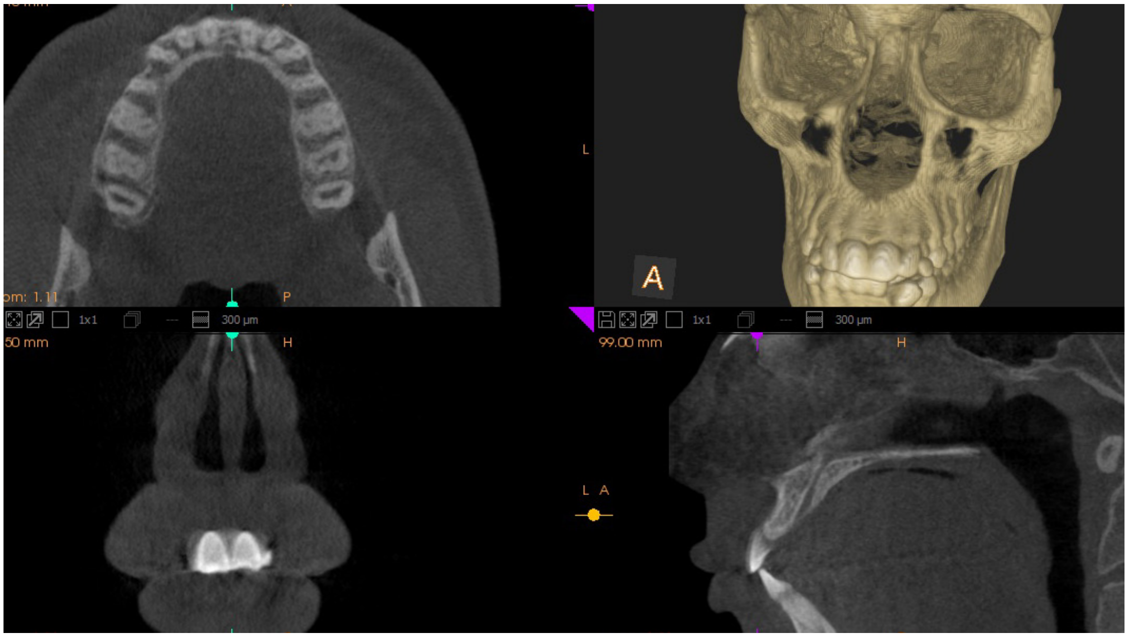


Figure 6: Screen shot of a multiplanar reconstruction showing coronal view, 3D image of maxilla, axial view and sagittal view of anterior maxilla. (Anatomage)

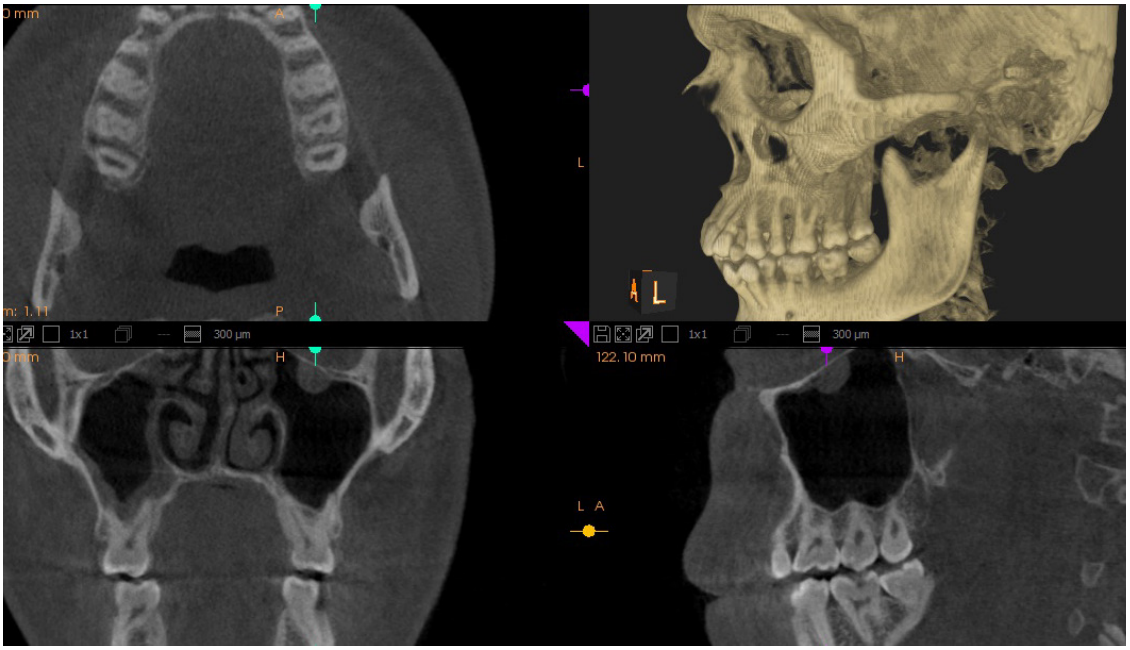


Figure 7: Screen shot of a multiplanar reconstruction showing Coronal view, 3D image of the maxilla, Axial view, Sagittal view of posterior maxilla (Anatomage)

RESULTS

The mean value, the standard deviation, and the minimum and maximum values of buccal cortical bone thickness (CBT) were calculated for groups A and B together and separately at different vertical levels (2, 4, 6 and 8 mm) from the alveolar crest.

Overall comparison of CBT in maxilla revealed the presence of thicker cortical bone in the posterior maxilla (maxilla left – MaxL and maxilla right - MaxR) than the anterior maxilla (maxilla middle – MaxM.). When the means of the measurement levels (2, 4, 6 and 8 mm) were compared, the differences were significant in the entire maxilla (MaxL, MaxM, and MaxR). In the posterior maxilla (MaxL and MaxR), buccal cortical bone was thickest at the 8 mm level and thinnest at the 4 mm level. In the maxillary anterior maxilla (MaxM), thickness increased progressively with increasing distance to the alveolar crest and was thickest at the 8 mm level and thinnest at 2 mm level. (Table 1 and Graph 1)

Buccal cortical bone thickness in the Posterior maxilla – Right side

At 8 mm Level

In posterior maxilla, on the right side (max R) at the level of 8 mm from the alveolar crest, a mean CBT of 1.690 ± 0.4036 mm ($P < 0.001$) was recorded between the second molar and third molar (17 & 18). A mean CBT of 1.844 ± 0.5041 mm ($P < 0.001$) was seen between the first molar and second molar (16 & 17). Between second premolar and first molar (15 & 16) a mean CBT of 1.875 ± 0.3419 mm ($P < 0.001$) was noticed. The mean CBT seen between first premolar and second premolar (14 & 15) was 1.750 ± 0.3551 mm ($P < 0.001$) followed by a mean CBT of 1.803 ± 0.5226 mm ($P = 0.012$) between canine and first premolar (13 & 14).

At 8mm level the minimum measurement noticed on the right side was 0.68 mm between the second molar and third molar, and the maximum measurement was 3.18 mm between the canine and first premolar.

At 6 mm Level

A mean CBT of 1.501 ± 0.3191 mm ($P < 0.001$) was seen between the second molar and third molar (17 & 18) at the level of 6 mm from the alveolar crest. Also, a mean of 1.620 ± 0.4813 mm ($P < 0.001$) CBT was found between the first molar and second molar (17 & 16). Between second premolar and first molar (16 & 15) a mean CBT of 1.767 ± 0.3498 mm ($P < 0.001$) was observed. The mean CBT seen between first premolar and second premolar (15 & 14) was 1.586 ± 0.3744 mm ($P < 0.001$) followed by a mean CBT of 1.741 ± 0.4872 mm ($P = 0.012$) between canine and first premolar (14 & 13).

The lowest measurement recorded at 6mm level on the right side was 0.68mm between the second molar and third molar and the highest measurement was 3.39 mm between the first molar and second molar.

At 4 mm Level

The calculated mean value for CBT between the second molar and third molar was 1.356 ± 0.2648 mm ($P < 0.001$) at the level of 4 mm from the alveolar crest, (17 & 18). A mean CBT of 1.343 ± 0.3312 mm ($P < 0.001$) was found between the first molar and second molar (16 & 17). Between the second premolar and first molar (15 & 16) a mean CBT of 1.483 ± 0.3189 mm ($P < 0.001$) was measured. The mean CBT seen between the first premolar and second premolar (14 & 15) was (1.439 ± 0.3606) mm ($P < 0.001$) followed by a mean CBT of 1.559 ± 0.4234 mm ($P = 0.012$) between canine and first premolar (13 & 14).

The observed minimum measurement on the right side at 4 mm level was 0.78 mm between the canine and first premolar, and the maximum measurement was 3 mm between the first premolar and second premolar.

At 2 mm Level

The 2 mm level from the alveolar crest, between the second molar and third molar (17 & 18) showed a mean CBT of 1.478 ± 0.3920 mm ($P < 0.001$). A mean CBT of 1.479 ± 0.3983 mm ($P < 0.001$) was recorded between the first molar and second molar (16 & 17). Also, a mean CBT of 1.562 ± 0.4078 mm ($P < 0.001$) was noticed between the second premolar and first molar (15 & 16). This level of measurement also showed that the mean CBT seen between first premolar and second premolar (14 & 15) was 1.546 ± 0.4098 mm ($P < 0.001$) followed by a mean CBT of 1.583 ± 0.4842 mm ($P = 0.012$) between canine and first premolar (13 & 14).

The minimum measurement recorded at 2 mm level on the right side was 0.7 mm between the second molar and third molar, and the maximum measurement was 2.92 mm between the canine and first premolar.

Buccal cortical bone thickness in the Posterior Maxilla - Left side

At 8 mm Level

In posterior maxilla, on the left side (Max L), at 8 mm from the alveolar crest, a mean CBT of 1.692 ± 0.4531 mm ($P < 0.001$) was measured between the second molar and third molar (27 & 28). The study also showed a mean CBT of 1.812 ± 0.3977 mm ($P < 0.001$) between the first molar and second molar (26 & 27). Between second premolar and first molar (25 & 26) a mean CBT of 1.892 ± 0.4733 mm ($P < 0.001$) was noticed. The mean CBT seen between first premolar and second premolar (24 & 25) was 1.825 ± 0.469 mm (P <

0.001) followed by a mean CBT of 1.823 ± 0.5176 mm ($P = 0.020$) between canine and first premolar (23 & 24).

The minimum measurement observed on the left side at 8 mm level was 0.78 mm between the first premolar and second premolar, and the maximum was 3.54 mm between the second premolar and first molar.

At 6 mm Level

At 6 mm level from the alveolar crest, a mean CBT of 1.566 ± 0.4501 mm ($P < 0.001$) was seen between the second molar and third molar (27 & 28). Between the first molar and second molar (26 & 27) a mean CBT of 1.605 ± 0.3488 mm ($P < 0.001$) was observed. The mean CBT noticed between second premolar and first molar (25 & 26) was 1.703 ± 0.4398 mm ($P < 0.001$). At 6mm level the study also indicated that the mean CBT seen between first premolar and second premolar (24 & 25) was 1.546 ± 0.4098 mm ($P < 0.001$) followed by a mean CBT of 1.589 ± 0.4131 mm ($P = 0.020$) between canine and first premolar (23 & 24).

The minimum and the maximum measurements seen on the left side at 6 mm level were 0.6 mm between the second molar and third molar and 3.35 mm between first molar and second molar respectively.

At 4 mm Level

A mean CBT of 1.327 ± 0.3686 mm ($P < 0.001$) was seen between the second molar and third molar (27 & 28) at the level of 4 mm from the alveolar crest. The recorded CBT between the first molar and second molar (26 & 27) was 1.448 ± 0.3485 mm ($P < 0.001$). Between second premolar and first molar (25 & 26) a mean CBT of 1.479 ± 0.3861 mm ($P < 0.001$) was noticed. A mean CBT of 1.400 ± 0.3813 mm ($P < 0.001$) was seen between first premolar and second premolar (24 & 25) followed by a mean CBT of 1.640 ± 0.5991 mm ($P = 0.020$) between canine and first premolar (23 & 24).

The observed minimum measurement on the left side at 4 mm level was 0.52 mm between the second molar and third molar, and the maximum was 2.71 mm between first molar and second molar .

At 2 mm Level

At 2 mm level from the alveolar crest, a mean CBT of 1.410 ± 0.4609 mm ($P < 0.001$) was seen between the second molar and third molar (27 & 28). The mean CBT noticed between the first molar and second molar (26 & 27) was 1.573 ± 0.4167 mm. Between second premolar and first molar (25 & 26) a mean CBT of 1.572 ± 0.4272 mm was noticed. The mean CBT seen between first premolar and second premolar (24 & 25) was 1.506 ± 0.4428 mm ($P < 0.001$) followed by a mean CBT of 1.528 ± 0.3910 mm ($P = 0.020$) between canine and first premolar (23 & 24).

The minimum and the maximum measurement recorded on the left side at 2 mm level was 0.78 mm between second molar and third molars and 2.64 mm between the first premolar and second premolar, second premolar and first molar respectively.

Buccal cortical bone thickness in the Anterior Maxilla

At 8 mm Level

The 8 mm level in the anterior maxilla (Max M) from the alveolar crest showed a mean CBT of 1.685 ± 0.4531 mm ($P = 0.120$) between 12 & 13 and and 1.568 ± 0.4767 mm ($P = 0.218$) between 22 & 23 respectively. A mean CBT of 1.601 ± 0.4132 mm ($P < 0.001$) was noticed between 11 &12 and 1.502 ± 0.4108 mm ($P = 0.219$) of mean cortical bone was seen between 21 & 22. A mean CBT recorded between 11 & 21 was 1.608 ± 0.3882 mm ($P < 0.001$).

The minimum measurement noticed at 8 mm was 0.59 mm between 11&12 and maximum measurement was 1.98 mm between 22 & 23.

At 6 mm Level

In the anterior maxilla at the level of 6 mm from the alveolar crest, a mean CBT of 1.665 ± 0.4389 mm (P = 0.120) was seen between 12 & 13 and and 1.499 ± 0.4793 mm (P = 0.218) between 22 & 23 respectively. The mean CBT noticed between 11 &12 was 1.539 ± 0.3853 mm (P = 0.031) and 1.438 ± 0.4503 mm (P = 0.219) of mean cortical bone was seen between 21 & 22. A mean CBT of 1.517 ± 0.3456 mm (P < 0.001) was recorded between 11 & 21.

The lowest CBT recorded at 6 mm was 0.78 mm between 21&22 and highest was 2.16 mm between 22 & 23.

At 4 mm Level

At 4 mm level from the alveolar crest in the anterior maxilla, a mean CBT of 1.635 ± 0.4572 mm (P = 0.120) was seen between 12 & 13 and and 1.476 ± 0.3451 mm (P = 0.218) between 22 & 23 respectively. A mean CBT of 1.460 ± 0.3763 mm (P = 0.031) was noticed between 11 &12 and 1.469 ± 0.4053 mm (P = 0.219) of mean CBT was recorded between 21 & 22. A mean CBT of 1.418 ± 0.3815 mm (P < 0.001) was recorded between 11 & 21.

The highest and lowest measurements recorded at 4 mm were 0.61 mm between 11&21 and 1.99 mm between 11 & 12 respectively.

At 2 mm Level

A mean CBT in the anterior maxilla at the level of 2 mm from the alveolar crest between 12 & 13 was 1.517 ± 0.3759 mm (P = 0.120) and 1.409 ± 0.3397 mm (P = 0.218) between 22 & 23 respectively. A mean CBT of 1.405 ± 0.3668 mm (P = 0.031) was noticed between 11 &12 and 1.355 ± 0.3226 mm (P = 0.031) of mean cortical bone was seen between 21 & 22. Between 11 & 21 the mean CBT was 1.271 ± 0.3220 mm (P < 0.001)

The least measurement recorded at 2 mm was 0.5 mm between 21&21 and highest was 2.21 mm between 22 & 23.

Comparison of cortical bone thickness between anterior and posterior maxilla

The mean values of CBT between anterior maxilla (max M) and posterior maxilla (max R and max L) at 2, 4, 6 and 8 mm vertical levels from the alveolar crest were calculated. The results revealed that, the CBT was higher in posterior maxilla (max R and max L) than in anterior maxilla (max M). The values obtained were statistically significant (P < 0.001) in anterior and posterior maxilla (MaxR and MaxL) at all vertical levels. (Table 2 and Graph 2)

In the Anterior Maxilla at all levels

In the anterior maxilla, at 2 mm level the mean thickness of buccal cortical bone observed was 1.390 ± 0.352 mm. It was 1.492 ± 0.399 mm at 4 mm. The mean thickness at 6 mm was 1.532 ± 0.426 mm followed by 1.593 ± 0.431 mm of mean CBT at 8 mm level.

In the Posterior Maxilla at all levels - Right

The posterior maxilla on the right side showed a mean CBT of 1.530 ± 0.419 mm (P < 0.001) at 2 mm. It was 1.436 ± 0.351 mm at 4 mm. The mean thickness at 6 mm was 1.643 ± 0.418 mm (P < 0.001) and a mean CBT of 1.792 ± 0.434 mm at 8 mm level.

In the Posterior Maxilla at all levels - Left

The left side of posterior maxilla showed a mean CBT of 1.518 ± 0.430 mm (P < 0.001). It was 1.459 ± 0.437 mm (P < 0.001) at 4 mm. The mean thickness at 6 mm was 1.637 ± 0.455 mm (P < 0.001) and 1.809 ± 0.465 mm (P < 0.001) at 8 mm level.

Comparison of cortical bone thickness between Sexes

Between male and female subjects, the mean values of the CBT and the P values associated with the Student's t-test/Mann-Whitney test to determine the level of significance led to the following conclusions: (Table 3 and Graph 3) Males exhibited a higher CBT than females in both anterior and posterior maxilla at all vertical levels from the alveolar crest.

In the Posterior Maxilla at all levels – Right side

The right side of posterior maxilla at the level of 2 mm from alveolar crest showed a mean CBT of 1.595 ± 0.414 mm in males and 1.465 ± 0.414 mm in females. At 4 mm level a mean CBT of 1.510 ± 0.370 mm in males and 1.362 ± 0.315 mm in females was seen. A mean CBT of 1.717 ± 0.454 mm in males and 1.569 ± 0.364 mm in females was seen at 6 mm level. The mean CBT displayed at the level of 8mm from the alveolar crest on right side was 1.854 ± 0.489 mm in males and 1.731 ± 0.363 mm in females. In right maxilla the difference between the levels was significant ($P < 0.001$) and similarly difference between gender was also significant ($P < 0.001$) (Table 3)

In the Anterior Maxilla at all levels

In anterior maxilla the level of 2 mm displayed a mean CBT of 1.475 ± 0.373 mm in males and 1.306 ± 0.310 mm in females. A mean CBT of 1.610 ± 0.396 mm in males and 1.373 ± 0.367 mm in females was recorded at 4 mm level. At 6 mm level, a mean CBT of 1.653 ± 0.456 mm in males and 1.411 ± 0.357 mm in females was observed and at 8 mm level the mean CBT recorded was 1.702 ± 0.471 in males and 1.484 ± 0.355 in females. The difference between the levels was significant ($P < 0.001$) in anterior maxilla and likewise difference between gender was also significant ($P < 0.001$) (Table 3)

In the Posterior Maxilla at all levels – Left side

At 2 mm level the detected CBT in the left side of posterior maxilla was 1.565 ± 0.468 mm in males and 1.471 ± 0.384 mm in females. A mean CBT of 1.509 ± 0.491 mm in males and 1.409 ± 0.369 mm in females was noticed at 4 mm level from the alveolar crest. At 6mm level the left side of maxilla showed a mean CBT of 1.673 ± 0.483 mm in males and 1.601 ± 0.424 mm in females.A mean CBT of 1.852 ± 0.499 mm in males and 1.766 ± 0.426 mm in females was observed at 8 mm level. In left maxilla the difference between the levels was significant ($P < 0.001$). Similarly difference between gender was also significant ($P = 0.001$) (Table 3)

Comparison of cortical bone thickness between two age groups

The overall comparison of mean CBT between two age groups, (group A and group B) presented a significant difference. Both in anterior and posterior maxilla, a higher CBT was seen in group B than group A at 2, 4, 6and 8 mm levels from the alveolar crest. (Table 4 and Graph 4)

In the Posterior Maxilla at all levels – Right side

The observed mean CBT at 2 mm level on right side of posterior maxilla was 1.511 ± 0.435 mm in group A and 1.547 ± 0.405 mm in group B. At 4 mm level in right maxilla, the mean CBT observed in group A was 1.395 ± 0.329 mm and 1.474 ± 0.367 mm in group B. The mean CBT noted at 6mm level in group A was 1.612 ± 0.418 mm and 1.672 ± 0.416 mm in group B. 8mm level displayed mean CBT of 1.753 ± 0.448 mm in group A and 1.830 ± 0.419 mm in group B. In right maxilla the difference between the levels was significant ($P < 0.001$) and difference between genders was also significant ($P = 0.007$).

In the Anterior Maxilla at all levels

At 2 mm level in anterior maxilla, a mean thickness of 1.328 ± 0.302 mm in group A and 1.448 ± 0.386 mm in group B was seen. A mean thickness of 1.448 ± 0.356 mm in group A and 1.492 ± 0.399 mm in group B was observed at 4 mm level. The observed CBT at 6 mm level was 1.471 ± 0.371 mm in group A and 1.589 ± 0.466 mm in group B and also a mean thickness of 1.534 ± 0.351mm in group A and 1.648 ± 0.489 mm in group B was seen at 8 mm level. The difference between the levels was significant ($P < 0.001$) in anterior maxilla and variance between genders was also significant ($P < 0.001$).

In the Posterior Maxilla at all levels – Right side

On the left side of posterior maxilla, the mean CBT at 2 mm level in group A and group B was 1.510 ± 0.370 mm and 1.525 ± 0.480 mm respectively. The recorded CBT at 4 mm level was 1.427 ± 0.440 mm in group A and 1.489 ± 0.433 mm in group B. At 6 mm level the mean thickness in group A and group B was 1.616 ± 0.441 mm and 1.657 ± 0.468 mm respectively. The 8 mm level showed a mean thickness of 1.799 ± 0.461 mm in group A and 1.818 ± 0.471 mm in group B. The difference between levels was significant in left maxilla ($P < 0.001$) likewise difference between gender was also significant ($P = 0.181$). (Table 4)

Error variability

On comparing the mean CBT as measured by two softwares, mimics and anatomage, the observed mean difference in thickness at 2mm level differed significantly between both techniques. ($p = 0.003$). On the other hand at 4, 6 and 8mm level there was no difference. (Table 5)

Table 1: Statistical analysis of buccal cortical bone thickness at 2, 4, 6 and 8 mm from the alveolar crest in 60 patients between all interradicular spaces in the maxilla

Tooth Position Area	2mm		4mm		6mm		8mm		P-Value
	Mean (mm)	SD	Mean (mm)	SD	Mean (mm)	SD	Mean (mm)	SD	
18 & 17	1.478	0.3920	1.356	0.2648	1.501	0.3191	1.690	0.4036	<0.001
17 & 16	1.479	0.3983	1.343	0.3312	1.620	0.4813	1.844	0.5041	<0.001
16 & 15	1.562	0.4078	1.483	0.3189	1.767	0.3498	1.875	0.3419	<0.001
15 & 14	1.546	0.4098	1.439	0.3606	1.586	0.3744	1.750	0.3551	<0.001
14 & 13	1.583	0.4842	1.559	0.4234	1.741	0.4872	1.803	0.5226	0.012
13 & 12	1.517	0.3759	1.635	0.4572	1.665	0.4389	1.685	0.4531	0.120
12 & 11	1.405	0.3668	1.460	0.3763	1.539	0.3853	1.601	0.4132	0.031
11 & 21	1.271	0.3220	1.418	0.3815	1.517	0.3456	1.608	0.3882	<0.001
21 & 22	1.355	0.3226	1.469	0.4053	1.438	0.4503	1.502	0.4108	0.219
22 & 23	1.409	0.3397	1.476	0.3451	1.499	0.4793	1.568	0.4767	0.218
23 & 24	1.528	0.3910	1.640	0.5991	1.722	0.5823	1.823	0.5176	0.020
24 & 25	1.506	0.4428	1.400	0.3813	1.589	0.4131	1.825	0.469	<0.001
25 & 26	1.572	0.4272	1.479	0.3861	1.703	0.4398	1.892	0.4733	<0.001
26 & 27	1.573	0.4167	1.448	0.3485	1.605	0.3488	1.812	0.3977	<0.001
27 & 28	1.410	0.4609	1.327	0.3686	1.566	0.4501	1.692	0.4531	<0.001

Table 2: Comparison of buccal cortical thickness between Anterior and Posterior maxilla

	2mm		4mm		6mm		8mm		
	Mean (mm)	SD	Mean (mm)	SD	Mean (mm)	SD	Mean (mm)	SD	P-Value
RIGHT MAXILLA	1.530	0.419	1.436	0.351	1.643	0.418	1.792	0.434	<0.001
ANTERIOR	1.390	0.352	1.412	0.399	1.532	0.426	1.593	0.431	<0.001
LEFT MAXILLA	1.518	0.430	1.459	0.437	1.637	0.455	1.809	0.465	<0.001

Table 3: Comparison of buccal cortical bone thickness between male and female subjects.

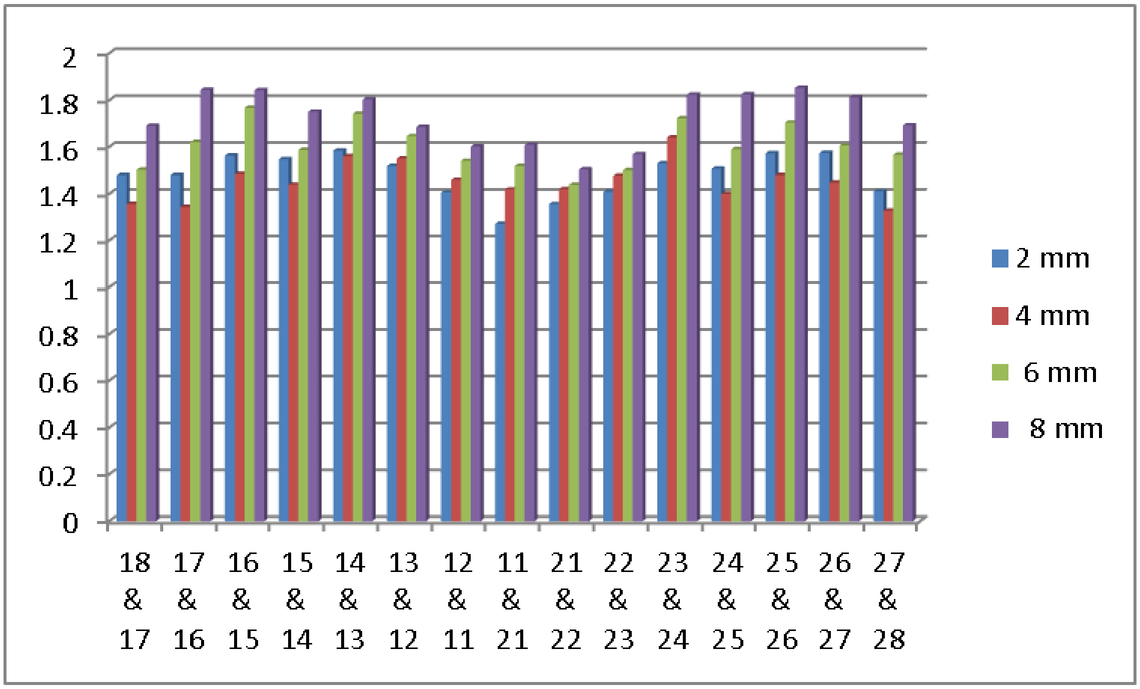
	RIGHT MAXILLA					**ANTERIOR**					**LEFT MAXILLA**				
	MALE		FEMALE			MALE			FEMALE		MALE		FEMALE		
	Mean (mm)	SD	Mean (mm)	SD	P-Value	Mean (mm)	SD	Mean (mm)	Mean (mm)	P-Value	Mean (mm)	SD	Mean (mm)	SD	P-Value
2mm	1.595	0.414	1.465	0.416	P<0.001	1.475	0.373	1.306	0.31	P<0.001	1.565	0.468	1.471	0.384	P<0.001
4mm	1.51	0.37	1.362	0.315	P<0.001	1.61	0.396	1.373	0.367	P<0.001	1.509	0.491	1.409	0.369	P<0.001
6mm	1.717	0.454	1.569	0.364	P<0.001	1.653	0.456	1.411	0.357	P<0.001	1.673	0.483	1.601	0.424	P<0.001
8mm	1.854	0.489	1.731	0.363	P<0.001	1.702	0.471	1.484	0.355	P=0.001	1.852	0.499	1.766	0.426	P=0.001
	P < 0.001					P < 0.001					P < 0.001				

Table 4: Comparison of buccal cortical bone thickness between two age groups

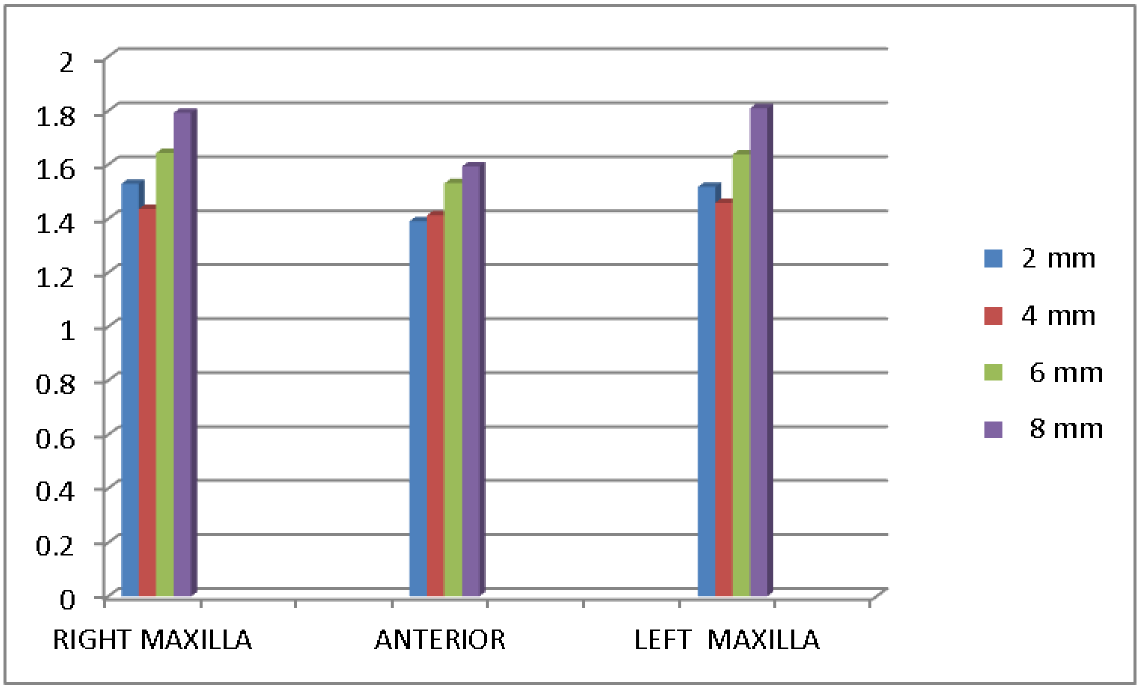
	RIGHT MAXILLA					**ANTERIOR**					**LEFT MAXILLA**				
	13 -24 Years		25-41 Years			13-24 Years		25-41 Years			13-24 Years		25-41 Years		
	Mean mm	SD	Mean mm	SD	P-Value	Mean mm	SD	Mean mm	SD	P-Value	Mean mm	SD	Mean mm	SD	P-Value
2mm	1.511	0.435	1.547	0.41	P<0.001	1.328	0.3	1.448	0.39	P<0.001	1.51	0.37	1.525	0.48	P<0.001
4mm	1.395	0.329	1.474	0.37	P<0.001	1.367	0.36	1.433	0.4	P<0.001	1.427	0.44	1.489	0.43	P<0.001
6mm	1.612	0.418	1.672	0.42	P<0.001	1.471	0.37	1.589	0.47	P<0.001	1.616	0.44	1.657	0.47	P<0.001
8mm	1.753	0.448	1.83	0.42	P<0.001	1.534	0.35	1.648	0.49	P<0.001	1.799	0.46	1.818	0.47	P<0.001
	P = 0.007					P < 0.001					P = 0.181				

Table 5: Compare the mean values between two measurement methods

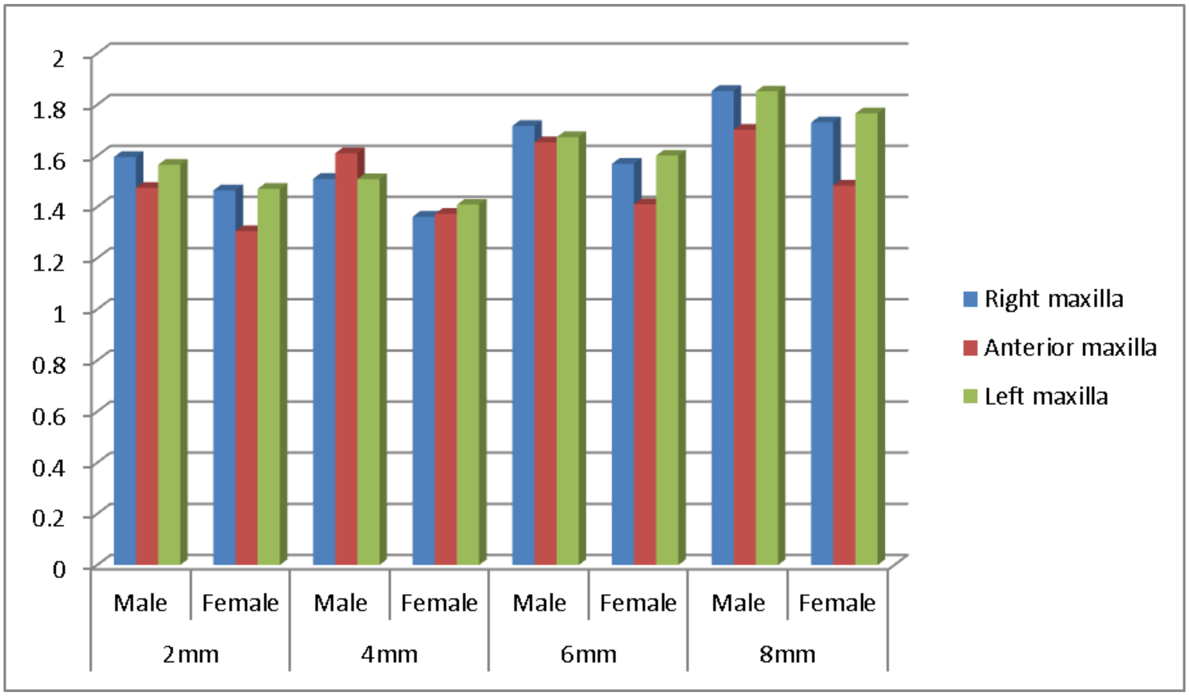
Methods	N	Mean	Std. Dev	t-Value	P-Value
MIMICS: 2MM	135	1.402	0.385	3.044	0.003
ANATOMAGE: 2MM	135	1.456	0.353		
MIMICS: 4MM	135	1.404	0.333	1.825	0.07
ANATOMAGE: 4MM	135	1.434	0.347		
MIMICS: 6MM	135	1.558	0.373	1.775	0.078
ANATOMAGE: 6MM	135	1.59	0.39		
MIMICS: 8MM	135	1.73	0.393	0.282	0.778
ANATOMAGE: 8MM	135	1.736	0.382		



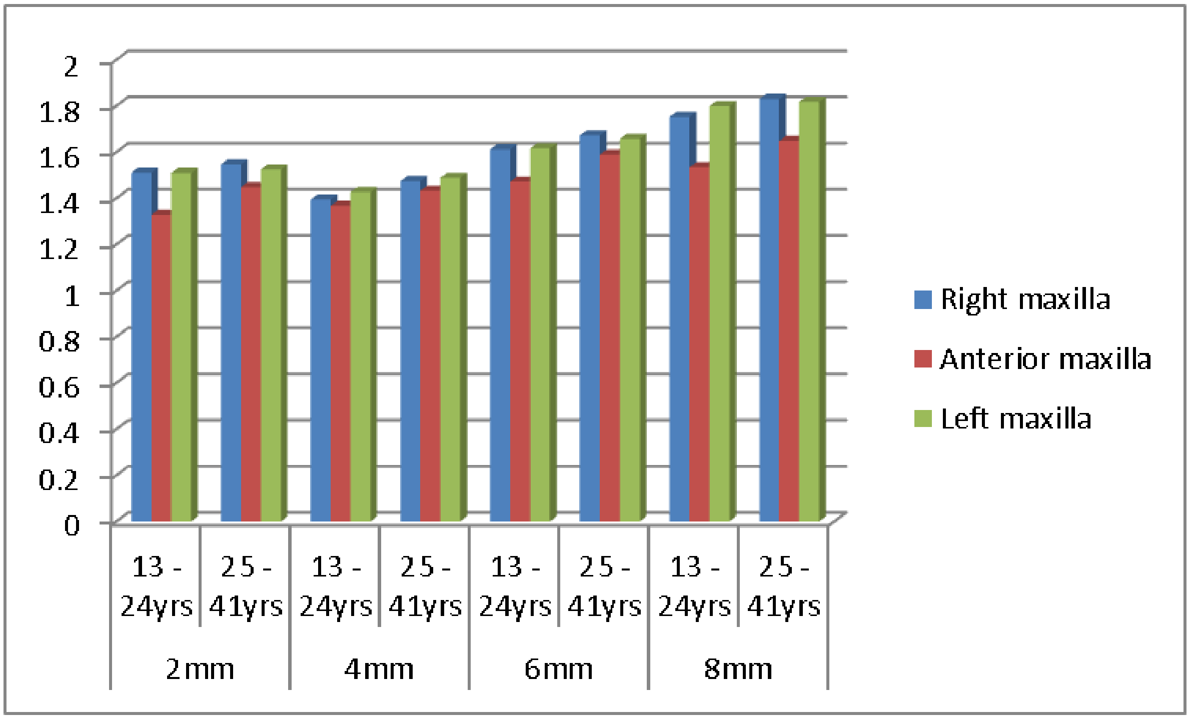
Graph 1: Statistical analysis of buccal cortical bone thickness at 2, 4, 6,and 8 mm from the alveolar crest in 60 patients between all interradicular space in the maxilla



Graph 2 Comparison of buccal cortical bone thickness between anterior and posterior maxilla



Graph 3: Comparison of buccal cortical bone thickness between Sexes



Graph 4Comparison of buccal cortical bone thickness between two age groups

DISCUSSION

Mini-implants have excelled in the preference of professionals due to their ease of insertion and removal, the possibility of immediate loading, their small size and low cost. .Many factors could affect the success rates and effectiveness of mini-implants used for establishing skeletal orthodontic anchorage.

Some of these factors included by **Reynders R et al**[70] in his review of literature were: 1) Implant related such as type, diameter, and length of the implant, 2) Patient related like sex, age, physical status, 3) Surgical related like direction of mini-implant placement and placement torque, 4) Orthodontic related like magnitude and timing of force, 5) Location related such as peri-implant bone quantity, CBT, keratinized versus oral mucosa, and implant-maintenance related. The exact role of these factors, however, is not fully understood.

Studies by **Kravitz ND**[43] **et al** and **Baumgartal S et al**[6] stated, many local anatomic factors must be considered and no single factor can be isolated to mark the ideal placement site and among the more important factors for placement in the buccal cortex are soft-tissue anatomy, interradicular distance, sinus morphology and buccolingual bone depth.

Henry Gray[33] in anatomy of human body, the maxillae are the largest bones of the face, excepting the mandible, and form, by their union, the whole of the upper jaw. Each assists in forming the boundaries of three cavities, viz., the roof of the mouth, the floor and lateral wall of the nose and the floor of the orbit; it also enters into the formation of two fossa, the infratemporal and pterygopalatine, and two fissures, the inferior orbital and pterygomaxillary.

The anterior surface is directed forward and lateralward. It presents at its lower part a series of eminences corresponding to the positions of the roots of the teeth. It is separated from the anterior surface by the zygomatic process and by a strong ridge, extending upward from the socket of the first molar tooth. It is pierced about its centre by the apertures of the alveolar canals, which transmit the posterior superior alveolar vessels and nerves.

The alveolar process is the thickest and most spongy part of the bone. It is broader behind than in front, and excavated into deep cavities for the reception of the teeth. These cavities are eight in number, and vary in size and depth according to the teeth they contain. That for the canine tooth is the deepest; those for the molars are the widest, and are subdivided into minor cavities by septa; those for the incisors are single, but deep and narrow. The CBT was defined as the thickness from periosteum to the cortical-trabecular interface.[75]

Literature is rich in case reports which show varying thickness of cortical bone between roots of the teeth in the maxilla. Cortical bone has a higher modulus of elasticity than trabecular bone, is stronger and more resistant to deformation, and will bear more load in clinical situations than trabecular bone.[35] Studies by **Homolka P et al[35], Miyamoto et al[55]** and **Wilmes B et al[89,90]** proved that, thicker cortical bone provides greater primary stability.

According to **Park H S et al[62]** the factors affecting the clinical success of screw implants used as orthodontic anchorage were mobility, the right side of the jaw, and the mandible and when excluding mobility, inflammation around the screw implants was added to the risk factors.

According to **Lim H J et al[47]** the screws inserted by more experienced clinicians have approximately a 3.6 fold higher success rate of initial stability compared with those inserted by less experienced clinicians after adjusting for the insertion site. He also suggested that the initial stability of mini implants depends on insertion site and clinician’s experience.

Thus most of the implant failures occur due to clinician's inability in selecting the preferred implant site. Therefore this study on assessment of buccal CBT in maxilla has a relevant clinical significance.

Studies by **Asscherickx K et al**[3] and **Chen YH et al** [17] cautioned that, although there are continual advances in the use of mini-implants, one of the major concern is the safe placement of mini-implants without damage to vital structures, such as roots of teeth. Most orthodontic practices are limited in their radiographic imaging to pantomographic, cephalometric and intraoral units.

According to **Truhlar RS et al**[79] Pantomographic and cephalometric skull radiographs have limited views of the dentition and surrounding structures, and may not truly depict the anatomical relationship of structures, inasmuch as they only provide two-dimensional views.

He also added that, there are magnification errors even with a properly positioned patient.

Thus superimposition of the head and neck structures seen on these views can make certain regions more difficult to interpret.

Duckworth JE et al[25] found that periapical radiographs may reduce the amount of superimposition, but angulation of the beam and projection geometry may distort the image.

In the posterior maxilla there is superimposition of the zygomatic arch making it difficult to correctly depict the location of the roots of the maxillary molars. This is important, as the exact location of the roots needs to be known to avoid damage during mini-implant placement.

Gribel BF et al[30] tested the accuracy of a mathematical model (algorithm) that corrects measurements made on conventional lateral head films to corresponding dimensions observed in a cone beam computed tomography (CBCT) scan in human subjects. All measurements from the lateral cephalogram were significantly different from the corresponding measurements derived from the CBCT. When the algorithm was used to correct the 2D measurements, however, there were no statistically significant differences between the CBCT group and the algorithm group.

Cavalcanti MG et al[14–16] calculated the accuracy and precision of spiral CT in the assessment of neoplastic lesions associated with the mandible and **Kim et al**[38] studied the accuracy of facial soft tissue thickness measurements in personal computer-based multiplanar reconstructed computed tomographic images found that, CT images can provide accurate measurements of small areas in bone to determine where anchors can best be placed. CBT at the interradicular sites can be assessed from computerized tomograms, which can be a good reference for the placement of the screw.

Turkyilmaz et al[81] demonstrated that it is possible to estimate primary implant stability from presurgical computerized tomography (CT) diagnosis. Therefore, it would be desirable to image every patient with CT.

Motoyoshi et al[59] in his study looked specifically at the correlation between CBT and success rates of mini-implants. He measured CBT in limited areas, namely the maxillary tuberosities and concluded that a minimum of 1mm of cortical bone was shown to be necessary for increasing success rates. This study showed that knowledge of the thickness of cortical bone throughout the jaws is directly linked to the success of mini-implants.

Most of the studies on evaluation of buccal CBT were carried out on Caucasian population. A definitive thorough knowledge of the buccal CBT in the local population is essential for implant selection. Therefore, this study was designed and carried out in our department to evaluate the buccal CBT in south Indian population. The present study investigated anatomic data gathered from 60 CT images to determine the optimal sites for mini-implant placement in maxilla.

The 64 slice 3D scanner delivers high-speed and high-resolution imaging, which allows physicians to capture precise images of any area of the body. With each rotation, it produces 64 simultaneous 0.5 mm slices and gives isotropic volumetric data with a resolution of 350 microns. Thin-slice volume data is reconstructed and sent to the workstation for further processing. Post processing and visualization algorithms allow the extraction of specific body parts. This allows understanding the complex anatomy and diseases.

The raw data from the CT scan were reconstructed and converted into a Dicom file format. The Dicom files then were imported to software (Mimics 11.2, Materialise co, Leuvan, BELGIUM) for multiplanar reconstruction (MPR). The bone was segmented by thresholding and 3-D object of the maxilla was reconstructed for further assessment.

We measured the buccal CBT from MPR images of 60 subjects at all the inter radicular areas in maxilla at 2, 4, 6 and 8 mm vertical levels from the alveolar crest and to check the error variability, a second software (Anatomage, invivo 5, USA) was used .

On comparing the mean buccal CBT as measured by two softwares, Mimics and Anatomage, it was found that the mean difference in thickness at 2mm level differed significantly between both techniques. (p = 0.003). On the other hand there were no difference.at 4, 6 and 8 mm levels.

Ludlow JB et al[29] and **Grauer D et al**[49] recommended to identify landmarks in the MPR images (ie, the three simultaneous views of a landmark location available in most 3D software analysis programs) and not on the rendered or segmented 3D volume (i.e. the 3D virtual model that can be rotated in all three planes).. According to **Halazonetis DJ et al**[31] Using the MPR slices improved the accuracy of landmark selection because there is increased variability when the 3D volume is used for landmark localization, depending on the segmentation threshold (ie, the levels of Hounsfield units) selected to construct the 3D volume.

Disler et al[24] reported, segmented 3D volumes derived from CBCT images demonstrated less than 1% relative error when compared to the gold standard of physical measures directly from skulls. **Ludlow et al**[50] reported even better results (0.6% error) were accomplished when axial MPR images where used.

Varghese S et al[84] evaluated the accuracy of linear measurements obtained from reconstructed spiral CT images of human dry skulls in three planes by comparing them with direct skull measurements, and then to compare these with measurements made on photostimulable phosphor cephalograms. Using a Siemens Somatom Sensation spiral CT scanner (Munich, Germany), CT images of six human dry skulls were imported into imaging software (Mimics 11.02 Materialise, Leuven, Belgium) and the measurements made were compared to the direct measurements made using a digital caliper. The measurements were also compared to those made on frontal and lateral cephalograms taken using a digital cephalostat. CT measurements did not show a significant difference from the direct skull measurements ($P < 0.05$) in all three planes except for two midsagittal measurements in the anteroposterior plane. Cephalometric measurements were comparable to direct skull measurements for midsagittal measurements in the anteroposterior plane, but showed a significant difference when bilateral measurements were considered. Cephalometric measurements also showed a significant difference in the transverse plane from direct measurements and CT measurements; however, they did not display a significant difference between direct skull measurements and CT measurements for most parameters in the vertical plane. The measurements obtained from spiral CT images were comparable to direct skull measurements in all three planes and were far more reliable than cephalometric measurements, which showed significant variation from actual anatomical measurements in most parameters. Therefore, it would be desirable for orthodontic diagnosis and treatment planning to be based on 3D CT scans rather than on conventional cephalograms especially when decisions depend on accurate linear measurements.

Earlier researches on buccal CBT have aimed to determine the safest sites for mini-screw placement by focusing on the posterior region of the jaws.[12, 13, 63, 68] The fact, however, that mini-implants are often useful in the anterior region for space closure [64] or correction of overbite problems [91] necessitated the evaluation of the anterior region as well.

In this study the maximum level of measurement was selected to be 8 mm from alveolar crest, as it is advisable to place the mini-implants in areas of attached gingiva.[53] **Lim et al** [48] omitted levels higher than 6 mm from CEJ in their study on interradicular soft tissue for the same reason.

The results of this study showed that buccal cortical bone was thicker in posterior maxilla than in anterior maxilla. The maximum measurement noted in the posterior maxilla was between second premolar and first molar at 8 mm level on the left side (1.892 ± 0.4733) ($P<0.001$). The minimum measurement marked in the posterior maxilla was between second molar and third molar at 4mm level on the left side (1.327 ± 0.3686) ($P<0.001$).

The maximum measurement noted in the anterior maxilla was between lateral incisor and canine (12 & 13) at 8 mm level (1.685 ± 0.4531) (P 0.120). The minimum measurement marked in the anterior maxilla was between the two central incisors at 2 mm level (1.271 ± 0.3220) ($P<0.001$). The buccal cortical thickness in maxilla displayed a certain pattern. In the posterior maxilla, buccal CBT was highest at 8 mm level from the alveolar crest. The bone thickness decreased at the 4 mm level before it progressively increased again at the 6 and 8 mm levels. This finding agrees with **Kim et al**[41] who found that, in the buccal interproximal areas of the maxilla that they investigated, the cortical bone was thickest closest to and farthest from the CEJ and thinnest in the middle.

This result demonstrates that, to take full advantage of cortical bone anchorage in the posterior maxilla, the mini-implant should be placed more than 4 mm apically from the alveolar crest. This means that most mini-implants in the posterior maxilla must be placed close to the mucogingival junction or perhaps even in mucosa.

It was seen that on many of the CT images the maxillary sinus invaginates between the teeth often. This shows the importance of accurate radiographic evaluation of this area before the placement of a mini-implant. Implantation into the sinus has many consequences including failure of the implant as it is only stabilized by the cortical bone, an increased chance of infection in the maxillary sinus due to disruption of the border of the sinus, and the possibility of introducing foreign objects into the sinus. A CT scan of the area is highly recommended to ensure this not to happen.

Poggio et al [68] ranked the safest sites available in interradicular spaces in the posterior maxilla, discouraged the insertion of any type of screws in the maxillary molar region above 8–11 mm from the bone crest because of the presence of the maxillary sinus.

In the anterior maxilla, buccal cortical bone was thinnest at 2mm level and progressively increased at 4, 6 and 8mm levels from the alveolar crest. This finding agrees with the findings of **Baumgartal et al**[6] who investigated buccal CBT from CBCT scans of dry skulls and **Mona Mohamed et al** [57], who measured CBT from CBCT images of patients.

Another finding was that buccal cortical bone is thinnest in the anterior maxilla and increases gradually toward the posterior, except distally to the maxillary second molars, where the buccal cortical bone is on average thin.

The implications for clinical purposes are that, to place the implant in a more beneficial spot, biomechanics should be ideally designed so that placement is possible in the posterior maxilla, excluding the maxillary retromolar area that offers inadequate buccal cortical bone. This finding supports a similar one by **Deguchi et al**[22] and **Baumgartal et al**[6] who found considerably less buccal cortical bone distal to the maxillary second molars. According to **Poggio et al**[68] maxillary tuberosity is not suitable for screw implantation, where the amount of bone is very limited by the presence of wisdom teeth. Of course, in cases where the wisdom teeth are extracted, the tuberosity might become eligible for screw application if the quantity of bone reflects the minimum clearance.

Deguchi T et al[22] found inadequacies in CBT can be compensated for by variations of mini-implant angulation or perhaps implant design (cylindrical vs. conical shank).

Aranyawongsakorn S et al[1] investigated the effects of insertion angulation on the biomechanical performance of miniscrews implanted in the dentoalveolar bone. In the maxilla, no significant difference in the maximum insertion torque and pullout strength was observed between miniscrews implanted at 30, 60 or 90 degrees. Although miniscrews inserted at 30 degrees exhibited the highest mechanical performance than those inserted at 60 and 90 degress in the anterior portion of the mandible, they exhibited significantly reduced insertion torque and pullout strength values than those inserted at 60 and 90 degress in the middle and posterior sites. No significant difference was observed between miniscrews inserted at 60 and 90 degrees. **Miyamoto et al** [55] suggested that, the initial stability at the time of implant installation is influenced more by CBT than by implant length and overall CBT is important in implant stability and therefore should be considered when selecting the preferred implant site.

Miyawaki et al[56] examined the success rates and the factors associated with the stability of titanium screws placed into the buccal alveolar bone of the posterior region. They suggested that, thin cortical bone is associated with an increased failure of mini-implants and sufficient mechanical interdigitation between the screw and the cortical bone is an important factor that affects the stability. He also found that, the diameter of a screw of 1.0 mm or less, inflammation of the peri-implant tissue, and a high mandibular plane angle (ie, thin cortical bone), were associated with the mobility of the titanium screw placed into the buccal alveolar bone of the posterior region for orthodontic anchorage.

These studies show that CBT plays a large part in the success of mini-implants, and that it may vary from place to place in the jaws. This information is helpful for practitioners and should be verified so that the practitioner is able to determine the best possible site for inserting mini-implants. Therefore, in addition to the statistical significance, our findings appear to have clinical significance also.

In the present study, males had significantly higher buccal cortical thickness than females. This is in agreement with the study by **Mona Mohammed et al** [57] on the cone beam computed tomography images of patients which showed, males had a significantly higher buccolingual and buccal cortical thickness at the 4 mm and 6 mm level from the CEJ in the posterior maxilla.

Ruff C et al [72] in his studies has shown that the amount of bone increases when mechanical strain increases beyond maintenance levels, such as is the case during intense mastication or exercise; the opposite is true for decreases in strain. Studies by **Mikic and Carter**[54]**, Demes et al**[23] have shown that the structure of bone is correlated with vigorous activity. When muscles of mastication contract they exert a certain amount of tension which is directed through the periosteum or tendons. The tension is dispersed over the surface of the bone and may lead to effects such as bending. Bending of bone under a load produces negative electrical potentials on the compressed side and positive potentials on the tensed side. The resulting effect is for osteoclasts and osteoblasts to respond by removing bone on the side experiencing tension and adding bone to the compressed side. In this way, bone is reshaped to best resist increased loading produced by increased muscle strength. With respect to the muscles of mastication, the weaker the musculature, the weaker the bite forces.

Weakened bite forces lead to smaller functional effects on the maxilla and mandible. Since muscles exert the tensile forces on bone, the lighter the tensile force, the less dramatic is the bony adaptation.

Studies by **Sommerfeldt DW et al**[77], **Rubin CT et al**[71] showed that mechanical stimulation, such as compression or tension, can cause rapid production of woven bone in a field of mature bone. Therefore, the production of woven bone is a strategic means of rapidly responding to changes in functional activity. Lamellar bone appears within a few weeks after woven bone is deposited. It is the mature bone found in both cortical and trabecular bone. Cortical bone, otherwise known as compact bone, forms the cortex, or outer shell, of most bones and is much denser than its counterpart, cancellous bone.

Studies by **Bakke M et al**[5], **Shinogaya T et al**[76], **Waltimo A et al**[85] proved, maximum bite force is higher in males than females. The greater muscular potential of the males may be attributed to the anatomic differences. The masseter muscles of males have type 2 fibres with larger diameter and greater sectional area than those of the females. The authors have suggested that hormonal differences in males and females might contribute to the composition of the muscle fibres. In addition, the correlation of maximum bite force and gender is not evident up to age 18. It is apparent that maximum bite force increases throughout growth and development without gender specificity. During the post-pubertal period, maximum bite force increases at a greater rate in males than in females and thus becomes gender-related.

Ferrario et al[28] performed a maximum voluntary clench (MVC) directly on the occlusal surfaces, recorded submaximal bite forces on two transducers positioned on the left and right first mandibular molars and surface EMG potentials of the masseter and temporalis anterior muscles. He recorded larger bite force values in males and explained this result by their larger dental size. Because the larger dental size presents larger periodontal ligament areas, it can give a greater bite force. Significant linear relationships were found between bite force and EMG potentials. ($p<0.01$)

Usui T et al[83] studied the correlation between variations in maximum occlusal force and the maxillofacial skeletal pattern in subjects with malocclusion using a compact device. The occlusal force was measured with a simplified occlusal force meter and the maxillofacial skeletal pattern was analysed with lateral cephalograms. On the basis of these data, the correlation between the maximum occlusal force and the maxillofacial skeletal pattern in each age group was calculated and found a gender difference in the maximum occlusal force at all age groups with values being larger in the males. The maximum occlusal force tended to increase with age, with a tendency to be greater in male than in female subjects.

Braun et al [10, 11]studied potential correlations of maximum bite force to gender, age, weight, body type, stature, previous history of orthodontic treatment, presence of TMJ symptoms (jaw motion limitation, clicking with pain, or joint pain), or missing teeth in a sample of 142 dental students by measuring the bilateral bite force in molar and premolar region and found an increase in maximum bite force with regard to decreasing mandibular plane/palatal plane angle and to decreasing mandibular plane angles. Maximum bite force increased with an increasing ratio of posterior facial height to anterior facial height. The mean maximum bite force as related to gender was found to be statistically significant with maximum bite force in males, while the correlation coefficients for age, weight, stature, and body type were found to be low. Thus, it is reasonable to expect sex differences in CBT would exist because males have larger masticatory mucles and greater maximum bite forces than females.

In the present study the older age group (25– 41 years) had a significantly higher buccal cortical thickness both in anterior and posterior maxilla. This finding is in accordance with **Farnsworth et al**[26] who measured and compared CBT in common mini-screw implant sites of 26 adults and 26 teenagers and found that there was a significant difference in thickness between adults and adolescents.

Shinogaya et al[74] evaluated the effects of age on maximum bite force, average magnitudes of pressure, and occlusal contact areas in elderly (53–62 years) and young (20–26 years) Japanese subjects. The occlusal contact areas and maximum bite force were found to be significantly larger in the senior group than in the young group.

Raadsheer MC et al[67] measured masseter muscle thickness by ultrasonography and found, muscle thickness was related to age, stature and weight, and to facial dimensions, measured by means of anthropological calipers. Masseter muscle thickness increased with age in both sexes. For each age group (and corrected for stature and weight), males had significantly thicker masseters than females ($p < 0.01$). Variation in muscle size and facial dimensions mainly coincided with variation in age, stature and weight.

Pancherz H et al[59] did an electromyographic investigation of temporal and masseter muscle activity in children and adults with normal occlusion. Masseter muscle activity was greater in the older than in the younger age group. The difference in electromyographic activity found between children and adults may be attributed to age changes and/or an exercising effect of the masseter muscle occurring during maturation.

From the above studies it is predictable that, age related changes in CBT would exist because adults have greater masseter muscle activity and greater maximum bite forces than adolescents. Thus, it would be expected that mini implants placed in males and in those older than 25 years to have better primary stability and higher success rates in maxilla because of the thicker cortical bone.

This study is unique as it involves the data of local population which may be of paramount importance in MI planning for anchorage purposes. It also emphasizes the importance of pre-diagnostic evaluation of the supporting alveolar bone surface used for anchorage purposes. The significant difference of CBT between the sexes is of clinical significance which enables the clinician to plan the MI parameters for that particular biomechanical preparation. The significant difference of CBT between the age groups will also alter the MI parameters like, length and diameter for different biomechanical considerations. MI should be used with caution in the anterior maxilla considering the inter root distance and also the CBT which is thinner compared to the posterior segments. In the anterior segment the CBT increases as we go apically and junction of attached gingiva and alveolar mucosa could be the most suitable spot for MI placement, at 4 mm to 6 mm region at the bone level.

The important finding was the 4 mm level in the posterior segment which shows a change in pattern of the CBT. This spot should be avoided or minimized even though it is at the level of attached gingiva, as it can increase the failure rate. The bone support will be superior as we go apical from the 6 mm region. Exteriorly this will be in the alveolar mucosa, nevertheless the underlying bone thickness will be the deciding factor of the success rate and this region can be judiciously used for MI placement for anchorage purposes. The region beyond 2nd molar on the buccal aspect is the thinnest in the posterior segment and it can be avoided for MI usage. Increasing the angulation of the MI could increase the stability, as it involves the thicker bone. But all these above mentioned factors are subject to individual variability and there are a multitude of factors which govern the success rate.

More elaborative study should be carried out with a larger sample size to ascertain the established fact about the CBT variations in the local population.

SUMMARY AND CONCLUSION

The results of the study revealed that, buccal cortical bone is thinnest in the anterior maxilla and increases gradually towards the posterior maxilla. There is a gradual increase in thickness till the 2nd molar level beyond which the CBT decreases bilaterally.

An interesting finding in the study was the decrease in CBT at the level of 4mm from the alveolar crest in the posterior maxilla on both right and left sides. This variation was different from the usual pattern seen in the anterior maxilla, where the CBT increases as the distance from alveolar bone to basal bone increased. Comparison between sexes revealed that, there was a male predominance with greater CBT than female population. The comparison between age groups revealed that the adult age group had a greater CBT than the adolescent age group.

The clinical implications of the study are:-

- In the anterior maxilla, the thickest region is at 8 mm level vertically and between central incisors and lateral incisors anteroposteriorly.
- In the posterior maxilla, the thickest region is at 8 mm level vertically and between 2nd bicuspid and 1st molar anteroposteriorly in both the sexes.
- In the anterior maxilla, the thinnest region is at 2 mm level vertically and between the central incisors anteroposteriorly in both the sexes.
- In the posterior maxilla, the thinnest region is at 4 mm level vertically and between 2nd molar and 3rd molar anteroposteriorly in both the sexes.

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