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## Evaluation of bone thickness around the mental foramen for potential fixation of a bone-borne functional appliance: a computer tomography scan study

Al-Kalaly, A A ; Wong, R W K ; Cheung, L K ; Purkayastha, S K ; Schätzle, M ; Rabie, A B M

**Abstract:** AIM: A mandible bone-borne Herbst appliance (MBBHA) would avoid the proclination of the lower incisors that occurs with any teeth-borne functional appliance. But mapping of the bone characteristics at potential fixation areas around the mental foramen has not been carried out so far. The aim of this computer tomographic (CT) study was to evaluate bone thickness at specific positions around the mental foramen. **MATERIAL AND METHODS:** CT scans of 60 randomly chosen adult Hong Kong Chinese subjects (mean age  $28 \pm 6.3$  years) were used to measure the bi-cortical bone thickness in the mandible in the mental foramen area. The thickness of buccal and lingual cortical and cancellous bone was assessed at the following locations: 10 mm (A10 mm) and 5 mm (A5 mm) anterior, 10 mm (P10 mm) and 5 mm (P5 mm) posterior, and 5 mm (Inf5 mm) below the mental foramen. **RESULTS:** The amount of buccal cortical bone thickness ranged between 1.89 mm, 10 mm anterior of the mental foramen, and 2.16 mm, 10 mm posterior to its location. At the A10 mm level, cortical thickness showed a marginal statistically significant difference between A5 and A10 mm. The total amount of bone thickness ranged from 10.19 to 12.06 mm. **CONCLUSION:** At the locations studied around the mental foramen, a mean bicortical bone thickness of 10-12 mm was measured. No large variation in the thickness was found between bicortical bone thicknesses in the measured locations around the mental foramen. Thorough evaluation on a case-by-case basis is advisable.

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# **Evaluation of bone thickness around the mental foramen for potential fixation of a bone borne functional appliance: A computer tomography scan study**

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Running title: Bone thickness around the mental foramen

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**Abstract:**

**Aim:** A mandible bone borne Herbst appliance (MBBHA) would avoid the proclination of the lower incisors that occurs with any teeth borne functional appliance. But mapping the bone characteristics at potential fixation areas around the mental foramen have not been done so far. The aim of this computer tomography study to evaluate bone thickness at specific positions around the mental foramen.

**Material and Methods:** Computer tomography scans of 60 randomly chosen adult Hong Kong Chinese subjects (mean age 28 +/- 6.3 years) were used to measure the bi-cortical bone thickness in the mandible in the mental foramen area. The thickness of buccal and lingual cortical and cancellous bone was assessed at locations: 10 mm (A10 mm) and 5 mm (A5 mm) anterior, 10 mm (P10 mm) and 5 mm (P5 mm) posterior, and 5 mm (Inf5 mm) below the mental foramen. After testing for normal distribution and equality of variances with Levene's F test, independent sample t-test was used to compare variables.

**Results:** The amount of buccal cortical bone thickness ranged from between 1.89 mm 10 mm anterior of the mental foramen to 2.16 mm 10 mm posterior to its location. At A10 mm level cortical thickness showed marginal statistically significant difference between A5 mm and A10 mm. The total amount of bone thickness ranged from 10.19 mm to 12.06 mm.

**Conclusion:** At the studied locations around the mental foramen a mean bicortical bone thickness of 10 to 12 mm was measured. No big variation in thickness was found between bicortical bone thicknesses in the measured locations around the mental foramen. Thorough evaluation on a case by case basis is advisable.

## Introduction

The correction of a Class II division 1 malocclusion by means of functional appliances is a frequent treatment approach (O'Connor 1993). Numerous studies have focused on the mode of action of the different types of removable functional appliances, evaluating their dental and skeletal effects. Several studies reported the effectiveness of fixed functional appliance for correction of class II malocclusion in adult human subjects (Ruf & Pancherz 1999a,b, 2003, 2006, Purkayastha et al. 2008) and experimental animals (McNamara et al. 2003, Xiong et al. 2005) and found a correction of 78% dental and 22 % skeletal (Purkayastha et al. 2008). None of the available removable and teeth borne functional appliances could fully address the problem of anchorage loss and the subsequent proclination of the lower anterior teeth (Pancherz 1997, Weschler & Pancherz 2005). Mandibular anchorage remains an unsolved problem. In Herbst treatment, a reality with which the orthodontist has to live (Pancherz & Ruf 2008).

The mandibular component of the Herbst appliance is anchored to the **mandibular** teeth, and the pivots which allow the attachment of the mandibular advancement mechanism are usually on the lower first premolars (Pancherz 2003). A Herbst appliance, with bone borne mandibular attachments (mandibular bone borne Herbst appliance (MBBHA) would avoid the proclination of the lower incisors. . This side effects occurs with any teeth borne functional appliance, whereas additionally the skeletal component to the mandible to correct mild skeletal class II malocclusion might even be increased. The use of MBBHA for the correction of intermaxillary relationship requires awareness of the amount of available bone for support in the insertion site. Many studies have evaluated the bone in different areas of the maxilla and the mandible for possible insertions sites and enhance stability and success of orthodontic mini-screws and distracters (Cheung et al. 2003, Schnelle et al. 2004, Deguchi et al. 2006, Poggio et al. 2006, Kang et al. 2007, Park et al. 2008, Monnerat et al. 2009). However, none appeared to have considered mapping the cortical characteristics at areas around the mental foramen for insertion of mini-screws or bone borne distracters for the particular reason of correction of intermaxillary discrepancy.

As MBBHA would be fixed to bone by means of osteosynthesis screws or miniscrews. Stability of mini-screws in the correction of skeletal class II malocclusion will be greatly affected by the forces created by

pull of the masticatory muscles (Al-kalaly et al. 2010). These acting forces should, however, not have a negative impact on the adjacent bone or impair the long-term prognosis of the MBBHA.

It was found that the resistance to movement of the mini-screw is greater for bicortical compared with monocortical placement (Brettin et al. 2008), pointing to the importance of evaluating the thickness of bone for deciding the method of anchorage which would withstand the anticipated load. If bicortical method is chosen, it is crucial to decide on the safe length of the mini-screw based on available bone thickness at the insertion site which would give best stability for the anchor plates, while preserving the surrounding vital structures such as nerves or teeth roots.

The aim of this study was to evaluate the bone thickness at specific positions in relation to the mental foramen, as a contributing factor to determine the appropriate length of the screws and pattern of mini-plates to be used in these areas.

### **Materials and methods:**

Computer tomography scans of 60 randomly chosen adult Hong Kong Chinese subjects (mean age 28 +/- 6.3 years) were used to measure the bi-cortical bone thickness in the mandible in the mental foramen area (distance between buccal and lingual cortical bone surfaces). The mean patients' age was  $28 \pm 6.3$  years, age range from 21 to 48.6 years.

The computer tomography (CT) scans were obtained from the records of Oral Radiology Department of the Faculty of Dentistry, The University of Hong Kong, Hong Kong, SAR PR China. A Hi-speed Advantage scanner (General Electric Medical System, Milwaukee, Wisconsin, USA) was used with the following parameters :140 kV, 80 mA, 1 mm contiguous slices, and FOV 13 cm. Axial cuts through the mandible were examined till the mental foramen became clear, the last clear mental foramen observed on the previous cross section but no longer observed in the next image was used. Using the measurements tool of the software (Advantage Workstation AW 4.0-5.0, GE Medical Systems, Milwaukee, Wisconsin, USA), a starting point was placed in the middle of the foramen from which a line was drawn parallel to the lateral part of the mandibular body (Figure 1). A cross section was obtained for this location (Figure 2) and the measurement procedures was done at 90 degrees to the bone surface following the method used by Cheung and coworkers (2003) where bone thickness was calculated by measuring the distance of inner and outer bony cortices and subtracting the cancellous space. The thickness of labial cortical bone, cancellous bone and lingual cortical bone was assessed in locations: 10 mm (A10 mm) and 5 mm (A5 mm) anterior to mental foramen; 10 mm (P10 mm) and 5 mm (P5 mm) posterior to the mental foramen; and 5 mm (Inf5 mm) below the mental foramen (Figure 3). Measurements were carried out by the same examiner, a dentist acquainted to distance measurement procedures on CT scans to by a radiology tutor.

The measurement error was calculated for all measurements on a randomly selected 15 CT scans and measured by the same observer after one month interval. The calculations were performed using the Dahlberg formula (1940),  $ME = \sqrt{\sum d^2 / 2n}$ , where d is the difference between two measurements of a pair and n is the number of paired double measurements. The error of measurements ranged from 0.05 to 0.25 mm, with a mean of 0.16 mm. Unpaired sample t-test was used to compare right and left side

measurements, no significant difference existed between measurements of all positions and the mean of the right and left sides was used for further statistical analysis.

Data analysis was carried out using the The Statistical Package for the Social Sciences version 13.0 for Windows (SPSS Inc., Chicago, Illinois, USA). Data were presented as mean and standard deviation of the bone thickness. After testing for normal distribution and equality of variances with Levene's F test, independent sample t-test was used to compare variables. The level of significance was set at  $\alpha = 0.05$ .



**Results:**

The mean cortical bone thickness for buccal and lingual side as well as the thickness of the cancellous bone and standard deviation for the different point of interest is depicted in Table 1. The amount of buccal cortical bone thickness increased between 1.9 mm 10 mm anterior of the mental foramen to 2.2 mm posterior to its location, respectively. Buccal cortical thickness showed marginal statistically significant difference between A5 mm and A10 mm. Also the amount of cancellous bone increased steadily in the anterior-posterior direction from 6.3 mm to 7.8 mm. The thickness of lingual cortical bone, in contrast, did not change and ranged between 2.0 to 2.2 mm. The total amount of bone thickness ranged from 10.2 mm to 12.1 mm, yielding the lowest values in the most anterior position and highest values in the most posterior location to the mental foramen, respectively.

At the level 5 mm inferior to the mental foramen, the assessed buccal cortical volume yielded the highest values of 2.4 mm, where as the spongeous bone reached similar results to values of the anterior region (6.4mm).

## **Discussion:**

Class II malocclusion represents one of the most common orthodontic problems in Caucasian (51.1 to 67.7 %) (Proffit et al. 1998) and in Asian populations (31%) (Chu et al. 2009). By holding the mandible in a forward position by means of a removable and tooth borne functional appliances, mechanical strain is created which triggers the condylar tissues to express a mechano-transduction mediator, Indian Hedgehog, which in turn helps condylar growth (Tang et al. 2004, Rabie & Al-kalaly 2008).

None of the available removable and tooth borne functional appliances could address the problem of anchorage loss and the subsequent proclination of the lower anterior teeth (Pancherz 1997, Weschler & Pancherz 2005). But if temporary anchorage devices (TAD), as they are in direct contact with bone and do not move when low forces are applied (Melsen & Lang 2001), could be used in a way for skeletal Class II corrections and would offer the field of orthodontics greater possibilities.

A mandibular bone borne Herbst appliance (MBBHA) would avoid the proclination of the lower incisors that occurs with any teeth borne functional appliance, whereas additionally the skeletal component to the mandible to correct mild skeletal class II malocclusion might even be increased. Less proclination of the lower incisors should allow more advancement with the subsequent added skeletal effect (Rabie and Al-kalaly 2008, Purkayastha et al. 2008). The purpose of this computer tomography study was to assess the average bone thickness in the mandibular basal bone in areas around the mental foramen as potential fixation sites for MBBHA for interarch antero-posterior correction.

Conventional Computer tomography (CT) is considered to be an accurate measurement tool for bony structures (Suomalainen et al. 2008). CT scan provides better accuracy than conventional radiographic methods (Sonick et al. 1994, Bou Serhal et al. 2002), where the measurement discrepancies during the use of different radiographic methods for the evaluation of the amount of bone coronal to the mental foramen had an average linear errors of 24% for panoramic radiographs, 14% for periapical films and 1.8% for CT scans (Sonick et al. 1994).

Conventional use of miniscrews for orthodontic purposes does not necessitate their use close to the mental foramen. Working in close proximity to the nerve could result in stretching, compressed, or

transection of the nerve which may lead to various degrees of numb feeling, sensitivity, pain in the lower teeth and lower lip, or the surrounding soft tissues (Sharawy & Misch 1999, Greenstein & Tarnow 2006).

The choice of the positions for measurement of bone thickness in this study is adapted from location considered to be within the safety zone recommended for placing dental implants in relation to the mental foramen, while taking into consideration the probability of existence of anterior loop of mental nerve (Misch & Crawford 1990, Bavitz et al. 1993, Wismeijer et al. 1997, Mardinger et al. 2000, Kieser et al. 2002, Kuzmanovic et al. 2003). A safety zone of 2 mm is recommended for placement of dental implants above the mental foramen and inferior alveolar canal (Greenstein & Tarnow 2006). This could be applied to miniscrews. Furthermore, in the anterior position after verification of presence or absence of anterior loop of the mental nerve, a 2 mm or more anterior to the mental foramen is advised for placement of the dental implant (Greenstein & Tarnow 2006) and likewise could be assumed for the miniscrews.

Evaluation of the difference in bone thickness at different distances anterior, posterior as well as inferior to the mental foramen would help us decide the pattern and position of mini-plates anchored by mini or osteosynthesis screws. The thickness of bone at insertion sites plays an important role in the stability of mini-screws (Miyawaki et al. 2003).

Single mini and osteosynthesis screws commonly used nowadays in orthodontics will not withstand the pull back effect of the masticatory muscles (Melsen & Lang 2001, Büchter et al. 2005, Hsieh et al. 2008). The voluntary muscle retrusion force could be of as high as 280 N of tangential force (Al-kalaly et al. submitted). Therefore, one would expect that multiple mini-screws connected by some sort of a plate could deliver a system that might withstand such high forces. The recent work by our group (Leung et al. 2008) reported that connected mini screws were more stable than single mini implants. Furthermore, Even though the length of mini screws was not identified as a risk factor for early failure (Schätzle et al. 2010, Männchen et al. submitted), bicortical mini-screws would provide the orthodontist superior anchorage resistance, reduced cortical bone stress, and superior stability compared with monocortical screws (Brettin et al. 2008).

It is crucial therefore to adequately evaluate the area of preference for insertion of the mini-screws. Based on the available thickness at each position, the information gained in this study would help identifying the location of insertion in areas with the best resistance to forces of the masticatory musculature.

In the mandibular canine fossa area in 20 white subjects the bicortical distance was assessed to be 9.97 mm (Costa et al. 2005) which is below the bicortical averages found in this study (10.2 to 12.1mm ). This difference may be attributed to different factors such as evaluating a region (Costa et al. 2005) rather than a determined point, difference in the population ethnic origin (Ong & Stevenson 1999), angulations of the measurements (perpendicular versus oblique). It is known that by angulating the miniscrew, the thickness of cortical bone contact with the mini-screw might increase (Deguchi et al. 2006) which implicate that the measurements would vary if taken at 90 degrees to the bone surface as in the current study. As a consequence the thickness of perpendicular measurements would therefore represent the least thickness available scenario in cases anatomy or other factors would not allow angulations of the mini-screw during insertion.

In another CT scan study lingual cortical bone thickness yielded slightly thicker values at the second premolar area (2.4 mm), but these measurements were done horizontally and not in a perpendicular manner to the bone surface. They did not measure the cancellous bone thickness and therefore no bicortical width could be compared (Tsunori et al. 1998).

A wide array of lengths and configurations of mini-screws are being used nowadays with a length which varies from 4-15 mm (Schätzle et al. 2010). Some studies found association between success rate of mini-screws and diameter but not with length (Schätzle et al. 2010, Männchen et al. 2010).

The bone at the studied positions in the basal bone could support mini or osteosynthesis screws of bigger diameters that could withstand high forces required for inter-arch correction. However, the unusual high forces that could be produced during skeletal correction (Al-kalaly et al. 2010), the length in addition to diameter might be of importance for the stability of mini and osteosynthesis screws which should be evaluated in future studies.

Although the total thickness at the P5 mm versus P10 mm was not statistically significant, there still may be a clinical relevance when deciding the length of the mini-screw to be used in this area as the inferior alveolar canal runs superiorly as it moves posteriorly and would therefore, for example, dictates the use of a 11 mm at the P5 mm due to inability to use a 12 mm screw at the P10 mm due to canal location. The statistical significance difference in the buccal thickness of A5 mm versus A10 mm may not be of clinical significance either, but consideration should be made on the location of anterior canal loop in relation to

the choice of the mini-screw. The bone thickness at the stated locations of this sample of adult Chinese would generally allow the insertion of slightly different lengths of mini-screws and the preference would be given to the appropriate mini-plate design and required direction of force application. Nevertheless, due to individual variation a thorough evaluation on a case by case basis should be practiced with particular attention to the length of teeth roots from the mental foramen and the path of the inferior alveolar canal. This study highlights the possible areas around the mental foramen which could be potential candidates for insertion of mini and/or osteosynthesis screws supported mini-plates to withstand high forces for skeletal correction, however further research is required to reach the best specification and configuration of the screws to be used for this purpose.

#### **Conclusion:**

Results at the studied locations around the mental foramen in this adult Chinese sample showed a mean bicortical bone thickness of 10 to 12 mm. No big variation in thickness was found between bicortical bone thicknesses in the measured locations around the mental foramen.

In general, there is adequate bone to support mini-screws of around 10 mm in length to be placed 5 and 10 mm anterior and 5 mm inferior to the mental foramen. Mini-screws of around 11 mm in length to be placed 5 mm posterior to the mental foramen and mini-screws of around 12 mm in length to be placed 10 mm posterior to the mental foramen.

Caution should be taken before applying these values in clinical settings due to individual variations, and the need for thorough case by case evaluation is emphasized.

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**Table 1:** Mean values and standard deviations for the different areas around the mental foramen

Location	N	Buccal cortical bone		Cancellous Bone		Lingual cortical bone		Total distance	
		Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation
<b>A5</b>	60	2.0	0.3	6.3	1.8	2.0	0.4	10.4	2.0
<b>A10</b>	60	1.9	0.3	6.3	1.9	2.0	0.3	10.2	2.0
<b>P5</b>	60	2.1	0.4	7.2	2.2	2.2	0.5	11.5	2.5
<b>P10</b>	60	2.2	0.4	7.8	2.3	2.1	0.6	12.1	2.7
<b>Inf5</b>	60	2.4	0.3	6.4	1.7	2.0	0.4	10.7	1.9

**Figures legend:**

**Figure 1:** Distance localization done on an axial cut.

**Figure 2:** Total thickness measurement on an oblique cut.

**Figure 3:** Locations around the mental foramen bone thickness was measured:  
5 mm (A5) and 10 mm (A10) anterior, 5 mm (P5) and 10 mm (P10) posterior; and 5 mm (Inf5) to the mental foramen  
(Courtesy of Roger Zwahlen and Werner Käser, University of Zurich, Zurich, Switzerland)