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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Key words: bone thickness, mandible, mini-screws, mental foramen

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 ± 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.

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 the correction of class II malocclusion in adult human subjects (Ruf & Pancherz 1999a, 1999b, 2003, 2006; Purkayastha et al. 2008) and experimental animals (McNamara Jr et al. 2003; Xiong et al. 2005) and found a correction of 78% dental and 22% skeletal (Purkayastha et al. 2008). None of the removable and teeth-borne functional appliances available 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 teeth, and the pivots that allow the attachment of the mandibular advancement mechanism are usually on the lower first premolars.
The aim of this study was to evaluate
the bone thickness at specific positions
in relation to the mental foramen, as a con-
tributing factor to determine the appropri-
ate length of the screws and pattern of
mini-plates to be used in these areas.

Material and methods

Computer tomographic (CT) scans of 60
randomly chosen adult Hong Kong Chi-
nese subjects were used to measure the bi-
cortical bone thickness in the mandible
in the mental foramen area (distance be-
tween buccal and lingual cortical bone sur-
faces). The mean patient age was 28 ± 6.3
years, age range from 21 to 48.6 years.

The CT scans were obtained from the
records of the Oral Radiology Department
of the Faculty of Dentistry, The University
of Hong Kong, Hong Kong, SAR, China.
A Hi-speed Advantage scanner (General
Electric Medical System, Milwaukee, WI,
USA) was used with the following param-
eters: 140 kV, 80 mA, 1 mm contiguous
slices, and FOV 13 cm. Axial cuts through
the mandible were examined until the men-
tal 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 measure-
ment tool of the software (Advantage
Workstation AW 4.0–5.0, GE Medical Sys-
tems), 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 (Fig. 1). A cross section
was obtained for this location [Fig. 2] and
the measurement procedures were per-
formed at 90° to the bone surface following
the method used by Cheung et al. (2003),
where bone thickness was calculated by
measuring the distance of inner and outer
bony cortices and subtracting the cancell-
lous space. The thickness of labial cortical
bone, cancellous bone, and lingual cortical
bone was assessed in the following locations:
10 mm [A10 mm] and 5 mm [A5 mm] ante-
rior to the 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 [Fig. 3]. Mea-
surements were carried out by the same ex-
aminer, a dentist familiar with distance
measurement procedures on CT scans by a
radiology instructor.

The measurement error was calculated
for all measurements on randomly selected
15 CT scans and measured by the same
observer after a 1-month interval. The
calculations were performed using the
Dahlberg formula [1940],
\[
\text{ME} = \sqrt{\frac{\sum d^2}{2n}}
\]
where \(d\) is the difference between two
measurements of a pair and \(n\) is the num-
ber of paired double measurements. The
error of measurements ranged from 0.05 to
0.25 mm, with a mean of 0.16 mm. An
unpaired sample t-test was used to com-
pare the right and the left side measure-
ments; no significant difference existed
between measurements of all positions.
and the mean of the right and the left sides
was used for further statistical analysis.

Data analysis was carried out using 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 using Levene’s F-test, an independent-sample t-test was used to compare the variables. The level of significance was set at \( \alpha = 0.05 \).

### Results

The mean cortical bone thickness for the buccal and lingual side as well as the thickness of the cancellous bone and standard deviation for the different points of interest is depicted in Table 1. Tables 2 and 3 show an independent samples test for A5 vs. A10 and P5 vs. P10 mm, respectively. The amount of buccal cortical bone thickness increased between 1.9 mm, 10 mm anterior of the mental foramen, and 2.2 mm, 10 mm posterior to its location, respectively. Buccal cortical thickness showed a marginal statistically significant difference between A5 and A10 mm. Also, the amount of cancellous bone increased steadily in the anterior–posterior direction from 6.3 to 7.8 mm. The thickness of the lingual cortical bone, in contrast, did not change and ranged between 2 and 2.2 mm. The total amount of bone thickness ranged from 10.2 to 12.1 mm, yielding the lowest values in the most anterior position and the highest values in the most posterior location to the mental foramen, respectively.

At the level 5 mm inferior to the mental foramen, the buccal cortical volume assessed yielded the highest values of 2.4 mm, whereas the spongy bone yielded results similar to the values of the anterior region [6.4 mm].

### Discussion

Class II malocclusion represents one of the most common orthodontic problems in Caucasian (31.1–67.7%) (Purkayastha et al. 1998) and in Asian populations (31%) (Chu et al. 2009). By holding the mandible in a forward position by means of removable and tooth-borne functional appliances, mechanical strain is created, which triggers the condylar tissues to express a mechanotransduction mediator, Indian Hedgehog, which in turn aids 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 2003). 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, it 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 & Al-Kalaly 2008, Purkayastha et al. 2008). The purpose of this CT 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 CT is considered to be an accurate measurement tool for bony

### Table 1. Mean values and standard deviations for the different areas around the mental foramen

<table>
<thead>
<tr>
<th>Location</th>
<th>N</th>
<th>Buccal cortical bone Mean</th>
<th>SD</th>
<th>Cancellous bone Mean</th>
<th>SD</th>
<th>Lingual cortical bone Mean</th>
<th>SD</th>
<th>Total distance Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>A5</td>
<td>60</td>
<td>2.01</td>
<td>0.34</td>
<td>6.33</td>
<td>1.75</td>
<td>2.04</td>
<td>0.37</td>
<td>10.37</td>
<td>1.96</td>
</tr>
<tr>
<td>A10</td>
<td>60</td>
<td>1.89</td>
<td>0.3</td>
<td>6.28</td>
<td>1.85</td>
<td>2.02</td>
<td>0.34</td>
<td>10.19</td>
<td>1.97</td>
</tr>
<tr>
<td>P5</td>
<td>60</td>
<td>2.1</td>
<td>0.39</td>
<td>7.19</td>
<td>2.2</td>
<td>2.2</td>
<td>0.49</td>
<td>11.48</td>
<td>2.45</td>
</tr>
<tr>
<td>P10</td>
<td>60</td>
<td>2.16</td>
<td>0.37</td>
<td>7.83</td>
<td>2.3</td>
<td>2.07</td>
<td>0.59</td>
<td>12.06</td>
<td>2.67</td>
</tr>
<tr>
<td>Inf5</td>
<td>60</td>
<td>2.38</td>
<td>0.33</td>
<td>6.39</td>
<td>1.7</td>
<td>1.97</td>
<td>0.42</td>
<td>10.73</td>
<td>1.93</td>
</tr>
</tbody>
</table>

### Table 2. Independent samples test for A5 vs. A10 mm

<table>
<thead>
<tr>
<th>Levene’s test for equality of variances</th>
<th>t-test for equality of means</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equal variances assumed</td>
<td>F</td>
</tr>
<tr>
<td>Equal variances not assumed</td>
<td>1.194</td>
</tr>
<tr>
<td>Equal variances assumed</td>
<td>1.993</td>
</tr>
<tr>
<td>Equal variances assumed</td>
<td>0.003</td>
</tr>
<tr>
<td>Equal variances assumed</td>
<td>0.157</td>
</tr>
<tr>
<td>Equal variances not assumed</td>
<td>0.003</td>
</tr>
<tr>
<td>Equal variances not assumed</td>
<td>0.502</td>
</tr>
</tbody>
</table>

*P = 0.05.
structures [Suomalainen et al. 2008]. A CT scan provides better accuracy than conventional radiographic methods [Sonicke 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 error of 24% for panoramic radiographs, 14% for periapical films, and 1.8% for CT scans [Sonick et al. 1994].

The conventional use of mini-screws 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 the measurement of bone thickness in this study is adapted from locations 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 the existence of an anterior loop of the mental nerve [Misch & Crawford 1999; 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 the placement of dental implants above the mental foramen and inferior alveolar canal [Greenstein & Tarnow 2006]. This could be applied to mini-screws. Furthermore, in the anterior position after verification of the presence or absence of the anterior loop of the mental nerve, a 2 mm or more anterior to the mental foramen is advised for the placement of the dental implant [Greenstein & Tarnow 2006] and likewise could be assumed for the mini-screws.

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 pullback effect of the masticatory muscles [Melsen & Lang 2001; Büchter et al. 2005; Hsieh et al. 2008]. The voluntary muscle retrusion force could be as high as 280 N of tangential force [A.S. Al-Kalaly, J.E. Dyson, R.W.K. Wong, M. Schätzle & A.B. Rabie, unpublished data]. 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 mini-implants connected with mini-plates provided higher pullout force, stiffness, and yield force to resist pulling force and deformation compared to mini-implants connected with wire connection system. Furthermore, even though the length of mini-screws was not identified as a risk factor for early failure [Schätzle et al. 2009; Männchen, K. Schätzle-Mayor, T. Peltonäki, R. Suuronen, & M. Schätzle, unpublished data], 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 identify 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 (10.2–12.1 mm). This difference may be attributed to different factors such as evaluating a region [Costa et al. 2005] rather than a determined point, a difference in the population ethnic origin [Ong & Stevenson 1999], and angulations of the measurements (perpendicular vs. oblique). It is known that by angulating the mini-screw, the thickness of cortical bone contact with the mini-screw might increases [Deguchi et al. 2006], which implies that the measurements would vary if taken at 90° 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 wherein anatomy

**Table 3. Independent samples test for P5 vs. P10 mm**

<table>
<thead>
<tr>
<th></th>
<th>Levene’s test for equality of variances</th>
<th>t-test for equality of means</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>F</td>
<td>Signed</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Buccal</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Equal variances assumed</td>
<td>.098</td>
<td>.755</td>
</tr>
<tr>
<td>Equal variances not assumed</td>
<td>.933</td>
<td>117.779</td>
</tr>
<tr>
<td><strong>Cancellous</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Equal variances assumed</td>
<td>.248</td>
<td>.619</td>
</tr>
<tr>
<td>Equal variances not assumed</td>
<td>-1.558</td>
<td>117.777</td>
</tr>
<tr>
<td><strong>Lingual</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Equal variances assumed</td>
<td>.016</td>
<td>.9</td>
</tr>
<tr>
<td>Equal variances not assumed</td>
<td>1.288</td>
<td>114.271</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Equal variances assumed</td>
<td>.517</td>
<td>.474</td>
</tr>
<tr>
<td>Equal variances not assumed</td>
<td>-1.234</td>
<td>117.131</td>
</tr>
</tbody>
</table>

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or other factors may 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 performed horizontally and not perpendicular 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 that varies from 4 to 15 mm [Schätzle et al. 2009]. Some studies found an association between the success rate of mini-screws and diameter but not length [Schätzle et al. 2009; R. Männchen, K. Schätzle-Mayor, T. Peltonäki, R. Suuronen, & M. Schätzle, unpublished data].

The bone at the studied positions in the basal bone could support mini- or osteosynthesis screws of larger diameters that could withstand the high forces required for inter-arch correction. However, the unusually high forces that could be produced during skeletal correction [A.S. Al-Kalaly, J.E. Dyson, R.W.K. Wong, M. Schätzle & A.B. Rabie, unpublished data], 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 vs. 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, dictate the use of an 11 mm screw at the P5 mm due to inability to use a 12 mm screw at the P10 mm due to canal location. The statistically significant difference in the buccal thickness of A5 vs. A10 mm may not be of clinical significance either, but the location of the anterior canal loop should be considered in relation to the choice of the mini-screw. The bone thickness at the stated locations of this sample of adult Chinese individuals would generally allow the insertion of slightly different lengths of mini-screws and preference would be given to the appropriate mini-plate design and the required direction of force application. Nevertheless, due to individual variation, a thorough evaluation on a case-by-case basis should be carried out 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 that could be potential sites for insertion of mini- and/or osteosynthesis screw-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

The results at the studied locations around the mental foramen in this adult Chinese sample showed a mean bicortical bone thickness of 10–12 mm. No large 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 around 10 mm in length to be placed 5 and 10 mm anterior and 5 mm inferior to the mental foramen and mini-screws around 11 mm in length to be placed 5 mm posterior to the mental foramen and mini-screws around 12 mm in length to be placed 10 mm posterior to the mental foramen.

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

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References


