Sex-related Differences in Cortical and Trabecular Bone Quantities at the Mandibular Molar

Takashi Matsuura1), Emiri Mizumachi1), Michitsuna Katafuchi1), Kentaro Tokutomi1), Hirofumi Kido2), Masaro Matsuura3) and Hironobu Sato1)

1) Section of Fixed Prosthodontics, Department of Oral Rehabilitation, Fukuoka Dental College, Fukuoka, Japan
2) Section of Oral Implantology, Department of Oral Rehabilitation, Fukuoka Dental College, Fukuoka, Japan

Abstract: Uncertainty exists regarding sex-, age- and tooth-related cortical and trabecular bone quantity tendencies at the mandibular first molar, a frequent implant recipient site in partially edentulous patients with missing molars. We assessed these tendencies for the mandibular first molar by using computed tomography in patients missing the first molar on one side. Eighty-two subjects were assessed. Cortical and trabecular bones were quantified using computed tomography image reformating software on a cross-sectional image, including the site of the mandibular first molars on sides with and without the first molar. Bone quantity associations with age and between the sides with and without the first molar were evaluated. Bone quantities were compared according to sex and between the two sides. Great interindividual variations between cortical and trabecular bone quantities were seen in both sexes and on the two sides. Although no sex-related or age-related difference in trabecular bone quantity existed, men demonstrated a greater cortical bone quantity than women; women, but not men, exhibited an age-related decline in cortical bone quantity. Bilateral symmetry of both bone quantities appeared only in women. Cortical bone quantity did not differ between the two sides in either sex, while trabecular bone quantity differed; the side without the first molar had greater values than that with it in women and, to a lesser extent, in men. A computed tomography analysis distinctively measured cortical and trabecular bone quantities and unveiled their sex-related differences in a clinical situation, as specifically designed in this study.

Key words: Age, Computed tomography, Mandibular bone, Partial edentulism, Tooth loss

Introduction

Bone comprises two types of mineralized tissue: cortical and trabecular. The 2 types demonstrate differences in functional and metabolic modes and sex- and age-related changes in bone quantity4). As for the cortical jaw bone, previous studies using panoramic assessment have shown that men have a thicker mandible than women5,13), and that dentate subjects have thicker mandibles than edentulous subjects11). Thickness decreases with age, greatly in women but only slightly in men5). Compared to cortical bone, information regarding the trabecular jaw bone is limited and controversial. Some previous studies using periapical radiography5), dual-energy photon absorptiometry (DPA)9), or dual-energy X-ray absorptiometry (DXA)9) have shown a decrease in trabecular bone density with age, while others have not5,19). However, these radiographic assessments cannot distinguish trabecular bone from cortical bone and thus cannot reveal the true trabecular bone density. It has been highlighted that the gold standard for trabecular bone density measurement is histological or morphometric analysis11,12). On the basis of this criterion, only computed tomography (CT) can measure the cortical and trabecular bone quantities separately and precisely. In orthopedics, architectural data assessed by CT has gradually clarified the details regarding sex- and age-related changes in the cortical and trabecular bones of the limbs and spine13-15). In dentistry, on the other hand, only 1 clinical study16) and 1 cadaveric study17) performed assessments using CT only for trabecular bone; it remains to be elucidated whether there are sex- and age-related differences in the exact quantities of cortical and trabecular jaw bones.

The mandibular molar is a susceptible site for loss18,19) and a frequent recipient site for implant insertion. The mandibular molar region has a great amount of trabecular bone, and therefore, it is easy to assess the cortical and trabecular bones distinctively, although the other regions are more difficult for distinctive...
assessment because of anatomical limitations. We performed preoperative implant CT scans of the patients, who have had a healthy mandibular first molar (FM) on one side but were missing an FM on the contralateral side. This situation can provide a comparison of the sex-, age-, and tooth-related tendencies of mandibular cortical and trabecular bones by using the side with the healthy FM (FM-present side) and the contralateral side with the missing FM (FM-absent side), which will be the implant recipient site. The purpose of the present study was to assess the cortical and trabecular bone quantity tendencies in the mandibular FM regions by using CT and in subjects who had an FM missing on one side.

**Materials and Methods**

This study was performed at Fukuoka Dental College Medical and Dental Hospital, Fukuoka, Japan, from April 2007 to October 2009. Among the patients who had a preoperative implant CT examination during that period, we selected 82 subjects, including 31 men and 51 women with an FM missing on one side. All subjects agreed to participate in this study and gave advance written consent. As for the tooth status on the FM-absent side, 6 men and 5 women were only missing an FM (named FM-alone group); 17 men and 28 women were missing an FM plus one of the neighboring teeth (NT; FM + 1 NT group); and 8 men and 18 women were missing an FM plus 2 or more of the neighboring teeth (FM + 2 NT or more group; Table 1). The purpose of the present study was to investigate the cortical and trabecular bone quantity tendencies in the mandibular FM regions by using CT and in subjects who had an FM missing on one side.

**Measurements of cortical and trabecular bone quantities**

The DICOM data were converted by SimPlant Pro 12.03 (Materialise Dental Japan, Tokyo, Japan) into a file that provides measurable images. The bone quantity assessment was performed on 2 cross-sectional images perpendicular to the occlusal plane and the mandibular molar sequence: 1 image on the FM-present side exhibiting the medial root apex of the FM and the other image on the FM-absent side (corresponding with the contralateral site), which had a marker on the radiographic template to indicate the FM position. Regions of interest (ROIs) were the bone area between a hypothetical horizontal line, which was 3 mm inferior to the root apex, and the bottom line of the mandible on the FM-present side and a similar measurement on the FM-absent side that was designed to compare the conditions between the 2 sides (Fig. 1). The cortical bone quantity was expressed as a ratio of the cortical bone area to the tissue area (%), because cortical thickness is difficult to express with the great anatomical variation among individuals. The trabecular bone quantity was measured as the mean bone density in the trabecular bone area (Hounsfield unit, HU), which was automatically calculated by the software. These histomorphometric measurements were based on the concept advocated by the American Society for Bone and Mineral Research committee.

**Associations and comparison tests**

To clarify whether there was age dependence, age associations were evaluated based on cortical bone and trabecular bone quantities in men and women as well as on the FM-present or FM-absent side. To determine whether there was bilateral symmetry in the cortical and trabecular bone quantities, quantity associations between FM-present and FM-absent sides were evaluated. To test sex- and tooth-related differences, cortical and trabecular bone quantities were compared among 4 groups: FM-present side in men, FM-absent side in men, FM-present side in women, and FM-absent side in women. To check whether the number of missing teeth affects the bone quantity on the FM-absent side, cortical and trabecular bone quantities were compared among 3 groups: FM alone, FM + 1 NT, and FM + 2 NT or more groups.

**Statistical analyses**

All statistical analyses were performed using GraphPad Prism 5.02 software (GraphPad Software Inc, La Jolla, CA, USA). Associations were tested by determining the Pearson correlation value. Intergroup comparisons between 2 groups were performed using the Student t test, and those among 3 groups or more used ANOVA and the Tukey’s post-hoc test. Data are expressed as the

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**Table 1. Patient Characteristics regarding Age and Unilateral Molar Edentulism**

<table>
<thead>
<tr>
<th></th>
<th>Men</th>
<th>Women</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>All subjects</td>
<td>55.7 ± 13.0 (31)</td>
<td>55.4 ± 10.9 (51)</td>
<td>0.89</td>
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<tr>
<td>Unilateral molar loss</td>
<td></td>
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<tr>
<td>FM alone</td>
<td>47.0 ± 18.8 (6)</td>
<td>42.8 ± 11.3 (5)</td>
<td>0.67</td>
</tr>
<tr>
<td>FM + 1 NT</td>
<td>57.3 ± 11.6 (17)</td>
<td>56.7 ± 11.6 (28)</td>
<td>0.87</td>
</tr>
<tr>
<td>FM + 2 NT or more</td>
<td>58.9 ± 9.1 (8)</td>
<td>56.7 ± 7.4 (18)</td>
<td>0.53</td>
</tr>
</tbody>
</table>

Ages are expressed as mean ± SD. The number of subject is shown in parenthesis. The P value is represented by the Student’s t test for comparison between men and women. FM, first molar; NT, neighboring tooth or teeth.
Takashi Matsuura et al.: Sex-related Differences in Mandibular Bone Quantity

Results

The mean age between men and women or among the FM alone, FM + 1 NT, or FM + 2 NT or more groups did not differ significantly (Table 1). Both cortical and trabecular bone quantities

mean ± SD. Significance was considered at $P < 0.05$. 

Figure 1. Regions of interest at the mandibular first molars.

Figure 2. Associations regarding the cortical and trabecular bones with age. A–D, cortical bone quantity; E–H, trabecular bone quantity.
exhibited great variations among the individuals (Fig. 2). The men did not demonstrate a significant association with the cortical bone quantity with respect to age on either the FM-present or FM-absent sides (Figures 2A and 2B), but the women did show a significantly negative association with age on both the FM-present ($r = -0.55, P < 0.0001$) and FM-absent ($r = -0.36, P < 0.01$) sides with respect to cortical bone quantity (Fig. 2C, D). The men and women did not show any significant association with age or on either the FM-present or FM-absent side with respect to the trabecular bone quantity (Fig. 2E-H).

With respect to the FM present and absent sides, the men had no significant association between the 2 sides in either cortical bone quantity (Fig. 3A) or trabecular bone quantity (Fig. 3B). In contrast, women had a significant association between the 2 sides in both cortical bone quantity ($r = 0.65; P < 0.0001$; Fig. 3C) and trabecular bone quantity ($r = 0.42; P < 0.001$; Fig. 3D). These findings suggest that women, but not men, have bilateral symmetry regarding cortical and trabecular bone quantities.

Cortical bone quantity differed by gender; on the FM-present side, the women had a lower quantity than the men on the FM-absent side, and also on the FM-absent side, the women had a lower quantity than the men on the FM-present side, as well as the men on the FM-absent side (Table 2). As for cortical bone, the women exhibited a lower bone quantity than the men, but both sexes had no quantity-related difference between the FM-present and FM-absent sides. As for the trabecular bone quantity, no difference on either the FM-present side or the FM-absent side was observed between men and women (Table 2). While comparing the FM-present and FM-absent sides, men demonstrated a greater trabecular bone quantity on the FM-absent side ($522.3 ± 198.4$ HU; not significant) than on the FM-present side ($432.0 ± 213.5$ HU); furthermore, women showed

### Table 3. Comparisons of Bone Quantity on the FM-absent Side among 3 Groups based on Unilateral Molar Loss

<table>
<thead>
<tr>
<th></th>
<th>FM alone</th>
<th>FM ± 1 NT</th>
<th>FM ± 2 NT or more</th>
<th>$P$</th>
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<tr>
<td>Cortical bone (%)</td>
<td></td>
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<tr>
<td>Men</td>
<td>59.8 ± 9.2</td>
<td>53.6 ± 10.8</td>
<td>51.3 ± 14.8</td>
<td>0.395</td>
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<tr>
<td>Women</td>
<td>42.5 ± 4.4</td>
<td>41.9 ± 12.1</td>
<td>47.6 ± 16.6</td>
<td>0.371</td>
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<tr>
<td>Trabecular bone (HU)</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Men</td>
<td>550.4 ± 180.0</td>
<td>478.4 ± 219.2</td>
<td>594.6 ± 155.9</td>
<td>0.377</td>
</tr>
<tr>
<td>Women</td>
<td>552.8 ± 88.3</td>
<td>644.1 ± 190.3</td>
<td>516.2 ± 160.2</td>
<td>0.054</td>
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</tbody>
</table>

Values are expressed as mean ± SD. The $P$ value is represented by ANOVA for comparison among the 3 groups. FM, first molar.
Takashi Matsuura et al.: Sex-related Differences in Mandibular Bone Quantity

significantly higher trabecular bone values on the FM-absent side (590.0 ± 180.7 HU) than on the FM-present side (485.9 ± 149.6 HU; Table 2).

On the FM-absent side, both sexes showed no significant difference in cortical bone or trabecular bone quantity among FM alone, FM + 1 NT, and FM + 2 NT or more groups (Table 3), suggesting that the number of missing teeth at the site had no effect on the bone quantities at the FM.

Discussion

As mandibular molar edentulism is most frequently treated in implant dentistry, sex-, age-, and tooth-related bone status trends at the molar can be of significance for the diagnosis and prognosis of implant treatment. This is the first study to perform definitive volume measurement of the cortical and trabecular bones in such a clinical situation. In the present study, quantitative assessment confirms that both cortical and trabecular bones demonstrate great variations among individuals, as supported by previous statements\(^{21,22}\). Despite the great variation, the cortical bone showed 2 expectable appearances: the men had a greater thickness than the women, and the women, but not the men, experienced a decrease in thickness with age. The former is consistent with previous reports regarding mandibles\(^{2,3}\) and other systemic bones\(^{23-28}\); the latter is also similar to prior findings from mandibles\(^{19}\), as well as other systemic bones\(^{24,25,27-30}\), as females experience a greater age-related cortical bone loss in comparison with males. The latter was thought to occur because females have lower sex hormones than males, and may exhibit different age-related cortical bone loss due to declining sex hormones. However, the present study indicated that the mandibular trabecular bone density does not differ by sex and is not altered with increasing age, which is consistent with previous mandibular findings using CT\(^{19}\). A previous cadaveric study involving micro-CT also showed that the trabecular bone ratio at the mandibular molars did not differ by sex and was not correlated with age in dentate subjects\(^{17}\). Considering the above, the trabecular bone density would be unlikely to exhibit sex-related differences or age-dependent changes in dentate mandibles. It is unclear why the mandibular trabecular bone was not dependent on sex and age. This variation could be attributed to the patient population, patient selection, and sample size in the present study. However, the mandible receives multidirectional and perpetual loadings with great intensity variation through mastication, distinct from other systemic bones, thus may lead to jawbone specificity with respect to mechanical response and bone metabolism\(^{19}\). These findings should be confirmed, and their mechanisms should be investigated.

The present study showed two unexpected findings: women, but not men, had bilateral symmetry regarding cortical and trabecular bone quantities, and a greater amount of trabecular bone was present on the FM-absent side than on the FM-present side in women and, to a lesser extent, in men. A mandibular molar receives the greatest bite force among the teeth, with a greater intensity on the preferred chewing side than on the nonpreferred chewing side\(^{19}\). Such a great intensity of bite force with interlateral disparity possibly leads to a bilateral difference in bone metabolism and the resultant quantity. Men have a greater bite force than women\(^{16,37}\), and thus men, rather than women, may elicit an interlateral discrepancy in bone quantity. It is uncertain why greater trabecular bone quantities were seen on the FM-absent side than on the FM-present side. It may have resulted because of the limited sample size. A previous study using CT described that the trabecular bone ratio had greater values at the molars in dentate mandibles than in edentulous mandibles\(^{19}\); however, a comparison between the dentate and the edentulous sides was not performed in the same subjects. The edentulous conditions were not limited to the mandible, and the number of missing teeth on the FM-absent side did not influence the bone quantity (Table 3), the effect of tooth loss on the bone may be minimized. Mandibular FMs are most frequently lost early in their lives. Many previous studies using non-CT radiographic analyses have also presented similar statements but used subjects with complete edentulism, rather than partial edentulism\(^{9,10,38}\). In the present study, for some subjects, the amount of time that the FM was missing was unknown but was known for all subjects with at least a 4-month interval before the CT scans. As the amount of time after the FM loss appeared to be shorter than that in the above-mentioned studies and the number of missing teeth on the FM-absent side did not influence the bone quantity (Table 3), the effect of tooth loss on the bone may be minimized. Mandibular FMs are most frequently lost\(^{19,19}\), usually on the preferred chewing side. The habitual mechanical force on the preferred chewing side may make the trabecular bone denser on this side than on the contralateral side. If a molar is missing on the preferred chewing side, after tooth extraction, the greater density may remain for a while. In addition, condensing osteitis or idiopathic osteosclerosis, showing sclerotic bone change, ranges from 4% to 31% among the population\(^{29-41}\). This sclerotic bone change tends to appear at mandibular molars, seems be related with traumatic occlusion and pulpal inflammation, and can remain for more than 10 years after tooth extraction\(^{19}\). If
the FM loss was caused by mechanical or traumatic factors, in some subjects, maintaining a greater density for a while after tooth loss could be plausible.

Because we measured bone quantity below the FM root but not around the FM root, the data cannot be directly translated into an index for implant insertion or stability. However, sex-, age-, and tooth-related bone trends help provide basic knowledge during implant treatment and maintenance of partially edentulous patients with missing molars. Even if the FM remains, the age-dependent decrease in the cortical bone of women should be considered for female patients as with aging, initiation of implant therapy could be more difficult. Even if implant therapy has been performed, with age, women’s cortical bone may become thinner, implying the necessity for female patients to have more precautionary maintenance than male patients. Unless there is a large bone defect caused by a root fracture, severe periodontitis, or severe periapical periodontitis, both men and women may maintain trabecular bone density for a while after molar loss, which is preferable for primary and long-term implant stability. With partial molar edentulism on one side, tooth loss is thought not to reduce the trabecular bone density directly or rapidly, but rather the density may be decided by individual’s heredity. In addition to sex-, age-, and tooth-related tendency, great variation in cortical and trabecular bone quantities among individuals is crucial for implant treatment preparations for partial molar-edentulous patients.

In conclusion, in subjects with a unilateral partial molar edentulism of the mandible, a great interindividual variations of cortical and trabecular bone quantities at the mandibular FM were seen in both sexes and on both FM-present and FM-absent sides. Although no sex-related differences in trabecular bone quantity or age-related quantity changes occurred in either sex, the men had a greater cortical bone quantity than women, but the women solely exhibited an age-related quantity decline. The women, but not the men, had bilateral symmetry with respect to cortical and trabecular bone quantities. The cortical bone quantity did not differ between FM-present and FM-absent sides in either gender, while the trabecular bone quantity on the FM-absent side appeared greater than that on the FM-present side in the women and to a lesser extent, in the men. A CT analysis unveiled distinguishable, yet undetectable, tendencies with respect to the cortical and trabecular bones in a clinical situation, which was specifically designed for the present study.

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