Introduction

After menopause, the general skeletal bone mass decreases due to estrogen deficiency, and this process often leads to osteoporosis.\(^1\) Although the relationship between the prognosis after receiving dental implants and osteoporosis has been assessed, it has not been concluded whether the prognosis of dental implants related to osteoporosis or not.\(^2\)-\(^4\) It is important to assess the general bone condition in dental implant treatment.

Osteoporosis is diagnosed based on bone mineral densities (BMDs) of lumbar vertebrae using dual energy X-ray absorptiometry (DXA).\(^5\) The general bone condition was assessed using microdensitometry of the second metacarpal or quantitative ultrasound densitometry of the calcaneus for dental implant treatment.\(^6\) Correlation coefficients between BMDs of the lumbar vertebrae and values using quantitative ultrasound densitometry ranged from 0.433 to 0.640.\(^7\)

Also, multi-slice computed tomography (CT) was used for the presurgical imaging of designed implant sites.\(^8\)-\(^10\) The super-cervical vertebrae were included in scans of jaws, and a strong correlation between BMDs of the third cervical and lumbar vertebrae was noted in postmenopausal women.\(^11\)

On the other hand, measurement of the mandibular cortical bone in inferior border and bone mineral densities of lumbar vertebrae in postmenopausal women

By

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Summary: It is important to assess the general bone condition in dental implant treatment. The relationships between the bone mineral densities (BMDs) of lumbar vertebrae and mandibular cortical bone condition in the inferior border using multi-slice computed tomography (CT) were assessed in postmenopausal women. If a strong correlation between them is obtained, the mandibular cortical bone condition may be useful to evaluate the general bone condition. Twenty-two postmenopausal women were enrolled in this investigation. The maximum CT value and width of the mandibular cortical bone (MCW-MSCT) were measured, and the mandibular cortical bone index (MCI-MSCT) was classified using multi-slice CT. BMDs of lumbar vertebrae were measured using dual energy X-ray absorptiometry (DXA), and then the percentage of the young adult mean (YAM) was analyzed. The correlations were investigated between the mandibular cortical bone condition and values of lumbar vertebrae. Weak correlations were observed between MCW-MSCT and the percentage of YAM. Also, significant differences in the percentage of YAM were noted between types of MCI-MSCT. The mandibular cortical bone index (MCI-MSCT) in the inferior border using multi-slice CT may be applicable to evaluate the influence of the general bone condition.
ular cortical bone width (MCW) and classification of the mandibular cortical bone index (MCI) in the inferior border on panoramic radiography were useful in screening for osteoporosis, and computer-aided diagnosis (CAD) systems for MCW and MCI were recently developed. The correlation coefficient between MCW and BMD of the lumbar vertebra on panoramic radiography was reported to be 0.44 in postmenopausal women. Correlations between buccal and lingual cortical bones in the mandible and lumbar vertebrae were assessed in postmenopausal women using multi-slice CT.

So, we conducted an investigation involving postmenopausal women using the maximum CT value of cortical bone and MCW-MSCT in the mandibular inferior border, and MCI-MSCT was classified using multi-slice CT. Then, the relationship between values of mandibular cortical bone and BMDs of lumbar vertebrae were assessed.

Materials and Methods

Subjects

Twenty-two postmenopausal women with more than 24 remaining teeth and 0.5-mm-thick slices of multi-slice CT were enrolled in this investigation. They were diagnosed with chronic periodontitis, and underwent periodontal treatment. The mean age was 63.2 years (range: 55.3-71.9), and all patients were more than 5 years post-menopause. All patients were sufficiently informed of the aim of this study, and gave informed consent to participate. A series of investigations regarding the relationship between osteoporosis and the mandibular condition, with permission from the Ethical Committee, School of Dentistry, Aichi-Gakuin University (#5, accepted on November 7, 2001), was conducted.

Measurement of BMDs of the lumbar vertebrae

The data on BMDs of the lumbar vertebrae (L2, 3, and 4) measured using DXA (Norland XR36, Fisher BioMedical Inc., Venice, FL) and reported in our previous study were used. The mean period between multi-slice CT scans and DXA for the lumbar vertebra was 0.7 years (sd.: 1.4). Measurements were classified into three groups: normal bone mass of the lumbar vertebrae (normal), osteopenic, and osteoporotic groups, based on the diagnostic criteria of primary osteoporosis in Japanese (2012 revision). In the normal group, the bone mass was assessed as 88% of the young adult mean (YAM) or higher. The osteopenic group showed a bone mass of 70 to 88% of the YAM, and the osteoporotic group showed a bone mass of 70% of the YAM or less. A value of 88% of the YAM means -1.0 SD of the T-score of World Health Organization (WHO), and 70% of the YAM means -2.5 SD.

Multi-slice CT

A multi-slice CT unit, HiSpeed NXi Pro (GE Yokogawa Medical Systems, Tokyo, Japan), was used and a helical scan of the mandible was performed. The occlusal plane of each patient was set perpendicular to the floor base. The axial images with 0.5-mm-thick slices at 0.25-mm intervals and a 160-mm field of view (FOV) were reconstructed for the measurement and classification of the mandibular cortical bone in the inferior border.

Measurements and classification of the mandibular cortical bone using multi-slice CT

Cross-sectional images of the mental foramen were reconstructed using OsiriX imaging software which is three-dimensional visualization and measurement software for Mac OS and iOS, downloadable at the following Web Site: http://www.osirix-viewer.com, as follows (Fig. 1A, B, C): At first, a longitudinal section was mesio-distally set along the mandible in an axial image (Fig. 1A). Then, a cross-section in the mental section was set perpendicular to the inferior border of the mandible using the longitudinal image (Fig. 1B). Subsequently, a plot profile of CT values in mandibular cortical bone of the inferior border was analyzed (Fig. 2A, B). The maximum CT value of the peak in mandibular cortical bone was recorded (Fig. 2B). Subsequently, the threshold CT value for mandibular cortical bone was set at 960 Hounsfield units (HU), adopted in a previous study. Then, the width of the mandibular cortical bone (MCW-MSCT) was measured (Fig. 2B) and measurements of the left and right sides were averaged. Measurements of the maximum CT value and MCW-MSCT were repeated in the same way after 4 weeks. Moreover, the mandibular cortical bone index (MCI-MSCT) inferior to the mental foramen was visually classified into two types: homogeneous type with homogeneous cortical bone, and osteoporotic type with osteoporotic cortical bone (Fig. 3A, B). The images were set at 400 HU for the window level and 3000 HU for the window width. Cortical bones on the left and right sides were separately observed, and, if different types on the left and right sides were noted, the osteoporotic type was adopted. One of the authors (M.N.) measured the maximum CT value and MCW-MSCT. Also, MCI-MSCT was classified based on consultation between two authors (M.N. and S.T.).

Statistical analysis

The correlations between the maximum CT value of cortical bone and percentage of YAM, and between MCW-MSCT and percentage of YAM were analyzed using statistical analysis software (SPSS Statistics, Version 21, IBM, New York, NY, USA). For correlation coefficients, values with 0 < r < 0.2 were regarded as showing no correlation, 0.2 < r < 0.4 indicated a weak correlation, 0.4 < r < 0.7 a correlation, and 0.7 > r a strong correlation. Moreover, the percentage of YAM
between the two types in MCI-MSCT were evaluated using the Mann-Whitney U test. Differences were considered significant at P < 0.05.

**Results**

The percentage of young adult mean (YAM)

The normal group included 4 subjects, the osteopenic group 12 subjects, and the osteoporotic group 6 subjects.
Fig. 3. Classification of the mandibular cortical bone index (MCI-MSCT) on multi-slice CT. A. Homogeneous type. B. Osteoporotic type.

Fig. 4. Correlation between the maximum CT values and percentage of YAM. No correlations were observed between the maximum CT value and percentage of YAM.
The maximum CT value of cortical bone

The maximum CT value of cortical bone ranged from 1523 to 1799 HU, with a mean of 1655 HU (s.d.: 67) in the total subjects. No correlations were observed between the maximum CT value and percentage of YAM (r = 0.040) (Fig. 4).

The width of mandibular cortical bone (MCW-MSCT)

The width of cortical bone ranged from 1.57 to 4.53 mm, with a mean of 3.27 mm (s.d.: 0.89) in the total subjects. Weak correlations were observed between MCW-MSCT and the percentage of YAM (r = 0.206) (Fig. 5).

Classification of the mandibular cortical bone index (MCI-MSCT)

The homogeneous type included 8 subjects and the osteoporotic type included 14 subjects. The osteoporotic type included all subjects in the osteoporotic group using the percentage of YAM. And, the homogeneous type included all subjects in normal group. The sensitivity, specificity, and accuracy in the diagnosis between normality and osteoporosis were all 100% using MCI-MSCT. When osteopenia and osteoporosis were diagnosed as abnormal, the sensitivity, specificity, and accuracy were 77.8%, 100%, and 81.8%, respectively. In the homogeneous type the mean percentage of YAM was 84.6% (s.d.: 11.3) and in the osteoporotic type was 70.3% (s.d.: 9.3). Significant differences in the rate of YAM (P = 0.017) were noted between the homogeneous and osteoporotic types (Table 1).

Discussion

The measurements of MCW-MSCT and the maximum CT value of mandibular cortical bone in the inferior border were evaluated using multi-slice CT. The correlations between MCW-MSCT and percentage of YAM were weak (r = 0.206) in the study. Taguchi et al. \(^{16}\) reported a correlation between MCW on panoramic radiography and BMDs of lumbar vertebrae (r = 0.44). MCW was 0.54 mm thinner in subjects with an osteoporotic fracture than in controls.\(^ {19}\) In the study, cross-sectional images were reconstructed from axial images with 0.5-mm-thick slices. A small change in MCW-MSCT might not be detected due to the influence of the partial volume effect on multi-slice CT. Also, there was no correlation between the maximum CT value and percentage of YAM.

Moreover, MCI was classified into three categories on panoramic radiography.\(^ {13}\) Since the samples with 22 subjects were limited, MCI-MSCT inferior to the mental
foramen was classified into two types: homogeneous and osteoporotic types, using multi-slice CT.

Significant differences in the percentage of YAM (P = 0.017) were noted between the homogeneous and osteoporotic types in the study. The mean percentage of YAM in osteoporotic type (70.3%) was close to the threshold value (70%) for osteoporosis.

The correlation coefficient between MCI on panoramic radiography and BMD of the lumbar vertebrae was higher than that between MCW on panoramic radiography and BMD of the lumbar vertebrae. Also, Taguchi reported that the sensitivity was 82.9% and specificity was 43.1% using MCI on panoramic radiography.

On multi-slice CT of the jaws, BMD of the third cervical vertebra and MCI-MSCT with homogeneous and osteoporotic types may be applicable to evaluate the general bone condition. Presently, multi-slice and cone-beam CT are recommended for diagnostic imaging in dental implant treatment. The exposure volume in cone-beam CT was limited, and cervical vertebrae were excluded from the exposure volume. So, BMD of the cervical vertebrae could not be used for evaluating general bone condition in cone-beam CT. If MCI-CBCT could be classified using cone-beam CT, MCI-CBCT may be useful for evaluating the general bone condition.

Further studies are needed to clarify whether MCI-CBCT can be assessed using cone-beam CT. Also, intra- and inter-observer agreement analysis must be conducted in MCI-MSCT and MCI-CBCT.

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References


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Table 1. The percentage of YAM in MCI-MSCT.

<table>
<thead>
<tr>
<th>MCI-MSCT</th>
<th>Range</th>
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<th>SD</th>
<th>Median</th>
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<tr>
<td>Homogeneous</td>
<td>70.5–96.8</td>
<td>84.6</td>
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<tr>
<td>Osteoporotic</td>
<td>55.6–84.6</td>
<td>70.3</td>
<td>9.3</td>
<td>70.5</td>
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*: P < 0.05
