Relationship between Bone Mineral Densities of Cervical and Lumbar Vertebrae in Postmenopausal Women

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Abstract: For dental implant treatment, it is important to assess the general bone condition. Using multi-slice CT scans, we assessed the relationships between the bone mineral densities (BMDs) of the cervical and lumbar vertebrae in postmenopausal women to see if such data might be useful for imaging-based diagnosis prior to dental implant treatment. Thirty postmenopausal women were enrolled in this investigation, and their third cervical vertebrae were scanned for BMD using multi-slice computed tomography (CT) while the lumbar vertebrae were measured using dual energy X-ray absorptiometry, after which the percentage of the young adult mean (YAM) was calculated. The correlations between the BMD of the cervical vertebra and percentage of YAM were analyzed. The mean BMD of the cervical vertebra was 255 mg/cm³ HA (s.d.: 28.8) in the normal group, 233 mg/cm³ HA (s.d.: 44.3) in the osteopenic group, and 178 mg/cm³ HA (s.d.: 35.9) in the osteoporosis group. A significant difference was observed between the normal and osteoporosis groups, and between the osteopenic and osteoporosis groups. A correlation (r = 0.705) was observed between the BMD of the cervical vertebrae and percentage of YAM of the lumbar vertebrae. The BMD of the third cervical vertebrae obtained from multi-slice CT images might be applicable in dental implant treatment to evaluate the influence of the general bone condition.

Key words: Computed tomography, Osteoporosis, Bone mineral density, Cervical vertebra, Dental implant treatment

Introduction

After menopause, the general skeletal bone mass decreases due to estrogen deficiency, and this process often leads to osteoporosis1). 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 not2-4).

Osteoporosis is diagnosed based on bone mineral densities (BMDs) of lumbar vertebrae using dual energy X-ray absorptiometry (DXA) 5). However, the general bone status was assessed using microdensitometry of the second metacarpal or quantitative ultrasound densitometry of the calcaneus for dental implant treatment6). Multi-slice CT scans were used for the presurgical imaging of designed implant sites7-10). Although lumbar vertebrae were excluded from the exposure volume, super-cervical vertebrae could be included in scans of jaws.

Yoganandan et al.11) reported a strong correlation between the BMDs of cervical and lumbar vertebrae in young adult healthy male volunteers. Also, the range of the correlation coefficients between the BMDs of cervical (C2-C7) and lumbar vertebrae (L2-L4) in young adult healthy female volunteers was from 0.330 to 0.667, and the correlation coefficients of C2 and C3 were lower than those of C6 and C712).

The purpose of this investigation was to clarify the relationship between the BMDs of cervical and lumbar vertebrae in postmenopausal women. If a strong correlation between them in postmenopausal women is obtained, BMDs of cervical vertebrae may be useful for presurgical imaging-based diagnosis in dental implant treatment using multi-slice CT scans.

Materials and Methods

Subjects

Thirty postmenopausal women with more than 24 remaining teeth were enrolled in this investigation. They were diagnosed with chronic periodontitis, and underwent periodontal treatment.
The mean age was 63.7 years (range: 53.4-74.5), 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. This patient group in this study was same as that reported in previous studies\textsuperscript{13,14). A series of investigations regarding osteoporosis with permission from the Ethical Committee, School of Dentistry, Aichi Gakuin University was conducted (No. 5, accepted on November 7, 2001).

Multi-slice CT scans

A multi-slice helical CT unit, HiSpeed NX/i 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. On performing CT, five blocks of Bone mineral density chart including 0, 100, 200, 300 and 400 mg/cm\textsuperscript{3} of hydroxyapatite (HA) were used (BMD chart, Kyoto Kagaku Co., Kyoto, Japan). The axial images were reconstructed with 1.0-mm-thick slices at 1.0-mm intervals and a 200-mm field of view (FOV).

Measurement of the BMDs of the cervical vertebra and mandible

The DICOM files of mandibular CT data were saved to an MO disk using medical display software (VOX-BASE\textsuperscript{p}, J-MAC SYSTEM, Sapporo, Japan). The BMD of the third cervical vertebra, included in mandibular scans of all subjects, was analyzed on a computer (Macintosh G4, Apple Computer Inc., Cupertino, USA) 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\textsuperscript{15). Three axial images were selected at the central level of the third cervical vertebra, and regions of interest (ROIs) with a 0.597 cm\textsuperscript{2} area were set in the body of the third cervical vertebra (Fig. 1A, B). The CT values were averaged, and then the mean CT value was transformed into the BMD using the BMD chart. Subsequently, BMD data of the mandible in the same patient group reported in our previous study\textsuperscript{14) were used. ROIs were set in the mandibular anterior cancellous bone at the level of the mental foramen, and CT values were obtained. Then, the CT values were transformed into BMDs using the BMD chart.

Measurement of the BMDs of the lumbar vertebrae

The data on the BMDs of the lumbar vertebrae (L2, 3 and 4) which were measured using DXA (Norland XR36, Fisher BioMedical Inc., Venice, FL) in the same patient group reported in our previous study\textsuperscript{15), were used. The mean period between multi-slice helical CT scans and the DXA for the lumbar vertebrae was 0.7 years (s.d.: 1.4). Measurements were classified into three groups: normal bone mass of the lumbar vertebrae (normal), osteopenic, and osteoporosis group, based on the diagnostic criteria of primary osteoporosis in Japanese (2012 revision)\textsuperscript{5). 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 osteoporosis group showed a bone mass of 70% of the YAM or less. 88 % of the YAM means –1.0 SD in T-score of World Health Organization (WHO) and 70 % of the YAM means –2.5 SD.

Statistical analysis

The correlations between the BMD of the cervical vertebra and percentage of YAM, and between BMDs of the cervical vertebra and mandible were analyzed using statistical analysis software (Stat View ver 4.0, Abacus Concept, Cary, USA). For correlation coefficients, values with $0 < r \leq 0.2$ were regarded as showing no correlation, $0.2 < r \leq 0.4$ indicated a weak correlation, $0.4 < r \leq 0.7$ a correlation and $0.7 > r$ a strong correlation. Moreover, the BMD of the cervical vertebra among the three groups was evaluated using the Mann-Whitney U test. Differences were considered significant at $P < 0.05$.

Results

The BMD of the third cervical vertebra

The BMD of the cervical vertebra ranged from 116 to 340 mg/cm\textsuperscript{3} HA, with a mean of 219 mg/cm\textsuperscript{3} HA (s.d.: 48.6) in the total subjects. The BMD of the cervical vertebra in the normal group ranged from 211 to 286 mg/cm\textsuperscript{3} HA, with a mean of 255 mg/cm\textsuperscript{3} HA (s.d.: 28.8). The BMD of the cervical vertebra in the

<table>
<thead>
<tr>
<th>Group</th>
<th>Number of patients</th>
<th>BMD of the cervical vertebra Mean (SD) (mg/cm\textsuperscript{3} HA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>6</td>
<td>255 (28.8)</td>
</tr>
<tr>
<td>Osteopenia</td>
<td>14</td>
<td>233 (44.3)</td>
</tr>
<tr>
<td>Osteoporosis</td>
<td>10</td>
<td>178 (35.9)</td>
</tr>
</tbody>
</table>

Figure 1. Setting the ROI in the third cervical vertebrae
A. Scout view image: The line corresponds to the measured axial CT scans. (Scale bar: 2.0 cm)
B. Multi-slice CT image: A circular ROI with a 0.597 cm\textsuperscript{2} area was set at the third cervical vertebra. (Scale bar: 2.0 cm)
osteopenic group ranged from 172 to 340 mg/cm$^3$ HA, with a mean of 233 mg/cm$^3$ HA (s.d.: 44.3). Moreover, the BMD of the cervical vertebra in the osteoporosis group ranged from 116 to 218 mg/cm$^3$ HA, with a mean of 178 mg/cm$^3$ HA (s.d.: 35.9). A significant difference was observed between the normal and osteoporosis groups, and between the osteopenic and osteoporosis groups (Table 1).

**Correlations between the BMD of the third cervical vertebra and percentage of YAM and between BMDs of the third cervical vertebra and mandible**

Correlation between the BMD of the cervical vertebra and percentage of YAM is shown in Fig. 2. Also, the correlation between the BMDs of the cervical vertebra and mandible is shown in Fig. 3. Table 2 shows correlation coefficients between the BMD of the cervical vertebra and percentage of YAM, and between the BMDs of the cervical vertebra and mandible. A strong correlation ($r = 0.705, \ P < 0.01$) was observed between the BMD of the cervical vertebra and percentage of YAM (Table 2).

**Discussion**

The relationship between the prognosis after receiving dental implants and osteoporosis has been assessed, and it is important to measure the general bone status in dental implant treatment.

Various methods to measure bone densities of the lumbar vertebra were applied. DXA for BMD measurement of the lumbar vertebra required a special unit, and quantitative CT scans of the lumbar vertebrae increased radiation doses. So, the second metacarpal or calcaneus was used to indicate the general bone status in dental implant treatment. Takeda et al. reported that correlation coefficients between the BMDs of the lumbar vertebrae and values using quantitative ultrasound densitometry ranged from 0.433 to 0.640.

On the other hand, presently, multi-slice and cone-beam CT are recommended for diagnostic imaging in dental implant treatment. The super cervical vertebrae could be included in multi-slice CT scans of the jaws. If a strong correlation between BMDs of the super-cervical and lumbar vertebrae is observed, BMD measurement of the super-cervical vertebra is valuable in presurgical imaging-based diagnosis in dental implant treatment using multi-slice CT scans.

In the study the diagnostic criteria of primary osteoporosis in Japanese (2012 revision) was used. The number of teeth present and any periodontal parameters, including probing depth, probing attachment level, bleeding on probing and alveolar bone loss, did not differ among 3 groups in our previous study with the same patient group.

Yoganandan et al. reported that the mean BMD of the third cervical vertebra in young healthy adult female volunteers was 264.7 mg/ml. Also, Weishaupt et al. reported that the mean BMD of the second cervical vertebra in young healthy adult female volunteers was 297.2 mg/cm$^3$. The mean BMD (255 mg/cm$^3$ HA) of the third cervical vertebra in the normal group of the study was
close to those of previous studies.

Yoganandan et al.11) reported that the correlation coefficients between the BMDs of the cervical and lumbar vertebrae ranged from 0.615 to 0.757 in young healthy adult male volunteers. The correlation coefficients in young healthy adult female volunteers ranged from 0.330 to 0.667, and the correlation coefficients of super-cervical vertebrae were lower than those of inferior cervical vertebrae12). Also, Weishaupt et al.19) reported that the correlation coefficient between the second cervical and fourth lumbar vertebra in young healthy adult female volunteers was 0.379. In the present study of postmenopausal women, the correlation coefficient was 0.705, with the value being in the range of young healthy adult male volunteers10). In previous studies which evaluated the correlation between the cervical and lumbar vertebrae in young healthy adult female volunteers, the mean BMD of the second cervical vertebra was 297.2 mg/cm² (s.d.: 53.2)19), and that from the second to seventh cervical vertebra was 260.8 mg/cm² (s.d.: 42.5)12). In the study, the BMD of the third cervical vertebra ranged from 116 to 340 mg/cm² HA, with a mean of 219 mg/cm² HA (s.d.: 48.6) in the total subjects, and it included a lower BMD of the cervical vertebra. BMDs of the third cervical vertebra estimated using a regression line between the BMD of the cervical vertebra and percentage of YAM was 286 mg/cm³ HA in 88% of the YAM and 188 mg/cm³ HA in 70% of the YAM.

In the present study with 30 postmenopausal women, the correlation coefficient between BMDs of third cervical vertebra and mandible was 0.550, being higher than that (r = 0.349) between BMDs of the lumbar vertebrae and mandible in a previous study4). The cervical vertebrae sustain the skull and the mandible closely connects with the skull via masticatory muscles. So, bone metabolism between the cervical vertebrae and mandible may show a stronger correlation than that between the lumbar vertebrae and mandible. Celenk C and Celenk P10) reported a correlation coefficient between bone densities of the fifth cervical vertebra and mandible of 0.269 in a total of 114 adults, including both men and women.

Further studies with an increased number of subjects are needed to assess the relationship between BMDs of the cervical vertebrae and mandibular cancellous bone.

The correlation between the BMD of the third cervical vertebra and percentage of YAM of the lumbar vertebrae was strong, and the BMD of the cervical vertebra may be useful for presurgical imaging-based diagnosis in dental implant treatment using multi-slice CT scans.

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References


