Correlation between mandibular bone density and skeletal bone density in a Catalonian postmenopausal population

Albert Estrugo-Devesa, DDS, PhD, MD, a,b,c Juan Segura-Egea, DDS, PhD, MD, d
Laia García-Vicente, DDS, PhD, a,b,c Mayra Schemel-Suárez, DDS, a,b,c Ándres Blanco-Carrión, DDS, PhD, MD, e
Enric Jané-Salas, DDS, PhD, MD, a,b,c and José López-López, DDS, PhD, MD, a,b,c

Objectives. The aim of this study was to determine if the mandible (MD) experiences reductions in bone mineral density (BMD) similar to the lumbar spine (LS) and femoral neck (FN) in a postmenopausal population.

Study Design. A total of 137 postmenopausal women underwent 3 types of densitometric examinations: LS, FN, and MD as measured in 3 regions (MD-R1, MD-R2, and MD-R3), as well as the entire mandible (MD-Net) using a dual photon bone X-ray densitometer. Densitometry of the LS and FN were performed according to the protocol of the International Society for Clinical Densitometry. Mandibular densitometry was performed using a modification of a previous technique, placing the patient in the left lateral decubitus position, with the head supported by a 13-cm-thick cushion above the temporomandibular joint.

Results. Significant correlations were found between densitometry results for the LS and the MD, with P values of .021 at MD-R1 (ramus); .001 at MD-R2 (body); .050 at MD-R3 (symphysis), and .001 at MD-Net (total mandibular density). No correlation was found between mandibular and FN densitometry (P > .05).

Conclusions. According to the results, for this population, it can be affirmed that the MD responds to osteoporosis in ways similar to the LS. (Oral Surg Oral Med Oral Pathol Oral Radiol 2017; ■■:■■:■■)

Osteoporosis is a systemic disease characterized by a generalized reduction in bone mass and the deterioration of bone architecture.1 Currently, it is defined as a skeletal disorder characterized by compromised bone strength that predisposes the bones to a higher risk of fracture.2 Osteoporosis is the most prevalent metabolic bone disease in the developed world and affects 1 in 4 women and 1 in 8 men over age 50 years. Its clinical and social importance lies in the increased incidence of bone fractures among those affected.3 It is the most important health problem among middle-aged women, coinciding with menopause,4 and is the main cause of fractures among older women.4 In the United States, in 2010, among adults age 50 years and older, 10.2 million (10.3%) had osteoporosis at the FN or lumbar spine (LS) and 43.4 million (43.9%) had low bone mass at either skeletal site.5 The prevalence of osteoporosis in the European Union was estimated at 27.6 million in 2010.6 In Spain, over 3 million people suffer from osteoporosis, and with increasing life expectancy, its prevalence will rise along with age. Osteoporosis affects 35% of Spanish women over age 50 years and 60% of women over age 80 years.7 Among men over age 50 years, prevalence is estimated to be 8%. But in spite of the high prevalence of osteoporosis, less than 30% of sufferers are diagnosed, and fewer than 10% of them receive treatment.8

The most widespread osteoporosis-related fractures are vertebral, hip, and distal-third forearm fractures.7 Various factors, including bone geometry, the risk of falling, traumatic impact, and the weight of soft tissues, affect the risk of fracture.9

Bone densitometry is used to detect osteoporosis in the early stages.10 According to the report published by the World Health Organization (WHO) in 1994, osteoporosis diagnosis should only be performed by determining bone mineral density (BMD) using X-ray dual-photon absorptiometry (DXA).11,12 Following the WHO criteria, the diagnosis of osteoporosis is determined by bone densitometry values of 2.5 or more standard deviations (SDs) below the average value for a young healthy population (T-score <−2.5); osteopenia is diagnosed when the value is between 1 and 2.5 SD below average (T-score between −1 and −2.5).11,12 The LS and proximal femur should be analyzed systematically in all patients at risk. The lowest BMD found in the LS, femoral collar, or hip is used to establish the diagnosis.

In addition to low BMD values, other risk factors independent of BMD also increase the probability of future

Statement of Clinical Relevance

Bone mineral density results obtained in the mandible correlates with those obtained in the lumbar spine, indicating that in postmenopausal women, the mandibular bone behaves in a similar way to the lumbar spine.
fracture. These factors are age, a low body mass index, previous vertebral fracture, and family antecedents of hip fracture and/or peripheral fracture in individuals over age 50 years. Other risk factors, such as menopause, age, and life-style factors (smoking, alcohol or caffeine consumption, low calcium intake, and physical exercise) have shown a high degree of variability and poor uniformity across different research papers.

Orthopantomography and periapical radiographs are routinely used in current dental practice. Several studies have analyzed orthopantomography findings related to low BMD. These include the mandibular cortical and Klemetti visual indices, which assess the degree of resorption of the mandibular cortex at the level of the lower premolars. These indices can be used to detect osteoporosis in the early stages and may suggest the need for further examination and treatment. In an attempt to test whether the jaw behaves like other bones in the skeleton and to validate the findings related to decreases in bone density obtained from radiographs, various studies have performed densitometry in the jaw. These studies would appear to present significant results, suggesting that when bone mineral density decreases, the jaw behaves in the same way as do other bones.

The aim of this study was to determine whether the jaw shows the same densitometric behavior in terms of BMD reduction as do other bone regions (FN and LS) among a population of postmenopausal women in Catalonia.

**PATIENTS AND METHODS**

**Population**

The study population was drawn from a group of 694 women who had completed a health questionnaire on risk factors for bone fracture issued by the Rheumatology Service at Bellvitge University Hospital (L’Hospitalet de Llobregat, Barcelona, Spain) in 1999. The online FRAX (Fracture Risk Assessment Tool) questionnaire was used to assess the risk of fracture. A BMD study using DXA was conducted between 1996 and 1999 on these women. The results showed that 17.3% had osteoporosis, 49.1% had osteopenia, and 33.6% had normal BMD, according to the WHO classification criteria of 1994. Contact was re-established with 427 of the participants, of whom 137 were willing to take part in the present study. Data were collected between May 2009 and September 2012.

The study design was approved by the Ethics Committee of the Dental Clinic at the University of Barcelona Faculty of Dentistry (protocol 08/08). All participants were informed of the study’s objectives and procedures, and all gave their informed consent to take part in the study.

The inclusion criteria were being postmenopausal women, being willing to participate in the study, having given informed consent, and having completed the earlier questionnaire.

The exclusion criteria were women being unwilling to participate in the study, presenting metabolic bone diseases other than osteoporosis, and lacking mobility as a result of a disease that would prevent their participation in the study.

**Densitometry system**

Densitometry was carried out at the Densitometry Unit at Bellvitge University Hospital. A dual photon bone X-ray densitometer was used: Hologic QDR 4500 (1999-2000; Hologic Inc., Bedford, MA). All patients underwent 3 types of densitometric examination: LS, FN, and MD.

**Densitometry of the lumbar spine and proximal femur**

Patients were placed in positions recommended by the International Society for Clinical Densitometry. Densitometric examination of the LS in the vertebrae (L2, L3, and L4) and of the right FN was performed. The T-score involves an individual’s BMD compared with the mean value of a young healthy reference population, with the difference expressed as an SD. In this study the T-score was calculated against patients included in an epidemiologic study of LS BMD in the Spanish population and the Third National Health and Nutrition Examination Survey (NHANES III) study of the femoral collar. Classification of patients as normal, with osteopenia, or with osteoporosis followed diagnostic categories established by the WHO. Diagnosis was based on the lowest BMD registered in the LS or FN, from which the T-score was calculated.

**Mandibular densitometry.** To perform mandibular densitometry, patients were positioned according to a modified version of the indications proposed by Horner et al. in 1996. Each patient was placed in the left lateral decubitus position, with the head supported by a 13-cm-high cushion in the left parietal area above the temporomandibular joint, keeping the head level with the body’s axis and the neck bent back. The purpose of this position was to superimpose the contralateral aspects of the jaw without superimposing the cervical spine (Figure 1).

![Fig. 1. Patient position for mandibular densitometry.]
Variables analyzed

The following variables were analyzed.

- Densitometry of the LS—total BMD of the LS (L2-L4 in g/cm²) and T-score
- Densitometry of the FN—BMD of the FN (in g/cm²) and T-score
- Densitometry of the MD—3 regions of interest (ROI) were used: (1) MD-R1 (ramus), (2) MD-R2 (body of the MD), and (3) MD-R3 (symphysis), as proposed by Horner et al.20 (Figure 2). Total density was also obtained (MD-Net) and was calculated by the densitometer’s integrated software. To calculate these data, jaw data were compared against standard values included in the software for the forearm, as there were no specific data corresponding to the jaw. As a result, the following variables were obtained: MD-R1, MD-R2, MD-R3, and MD-Net, all expressed as g/cm².

In the case of mandibular BMD, a criterion of reliability of the measurements was established using recommendations made by the International Society for Clinical Densitometry (ISCD) in 2015.23 In this way, the researchers considered the patient body positions used as valid.

Statistical analysis

The Statistical Package for the Social Sciences version 12.0 (SPSS Inc., Chicago, IL) was used for the statistical analysis of the data. Descriptive analysis was performed for the variables LS, FN, MD-1, MD-2, MD-3, and MD-Net. Bivariate analysis using the χ² test was applied to the different parameters evaluated for each individual. The significance level was P < .05.

The data obtained in the densitometric examination of LS, FN (T-Score), mandibular symphysis (MD-R3), and net mandibular BMD (MD-Net) did not present a normal distribution, so the median and interquartile range (IQR) were used to analyze these results. The data for the BMD of FN, mandibular ramus (MD-R1), and mandibular body (MD-R2) presented a normal distribution; consequently, mean and SD were used to analyze the results.

RESULTS

The median age of the 137 patients participating in this study was 62 years, with a range of 32 to 72 years and an IQR of 3.

Densitometry results

Table I shows grouped descriptive densitometry results for LS, FN, mandibular ROIs, and total mandibular density. Of the total 137 patients who underwent densitometry, valid results for the LS were obtained for 136 patients, with 1 patient having been found to have an arthrodesis of the LS. In densitometry of the FN, valid results were obtained from 131 patients, with 4 having had hip prostheses and 2 being unable to adopt the correct position required to carry out densitometry. In mandibular densitometry, valid results were obtained for 110 patients in the designated regions. For the 27 remaining patients, it was not possible to achieve adequate superposition of both mandibular rami (Table I).

Description of osteoporosis/osteopenia according to densitometry results for LS and FN

According to the WHO diagnostic criteria1,10 based on the lowest T-score in the LS or FN, 23.5% (n = 32) of patients were classified as normal, 58.1% (n = 79) as presenting osteopenia, and 18.4% (n = 25) as presenting osteoporosis. Analyzing LS densitometry data alone, of the 136 valid readings, 32.4% of patients (n = 44) could be classified as normal, 49.2% (n = 67) as presenting osteopenia, and 18.4% (n = 25) as presenting osteoporosis. When FN densitometry of the 131 valid readings was analyzed independently, 43.5% of patients (n = 57) were classified as normal, 54.2% as presenting osteopenia (n = 71), and 2.3% (n = 3) as presenting osteoporosis. For
Table I. Densitometry values in lumbar spine (LS), femoral neck (FN), and mandible (MD)

<table>
<thead>
<tr>
<th></th>
<th>n</th>
<th>Lost</th>
<th>Valid</th>
<th>(Median) or Mean</th>
<th>Min</th>
<th>Max</th>
<th>(IQR) or SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>LS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BMD, g/cm²</td>
<td>137</td>
<td>1</td>
<td>136</td>
<td>(0.88)</td>
<td>0.63</td>
<td>1.043</td>
<td>(0.16)</td>
</tr>
<tr>
<td>T-score</td>
<td>137</td>
<td>1</td>
<td>136</td>
<td>(−1.1)</td>
<td>−3.78</td>
<td>3.82</td>
<td>(1)</td>
</tr>
<tr>
<td>FN</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BMD, g/cm²</td>
<td>137</td>
<td>6</td>
<td>131</td>
<td>0.730</td>
<td>0.54</td>
<td>0.73</td>
<td>0.09</td>
</tr>
<tr>
<td>T-score</td>
<td>137</td>
<td>6</td>
<td>131</td>
<td>(−1.38)</td>
<td>−2.71</td>
<td>−2.71</td>
<td>(1.6)</td>
</tr>
<tr>
<td>MD</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R1, g/cm²</td>
<td>137</td>
<td>27</td>
<td>110</td>
<td>0.676</td>
<td>0.11</td>
<td>1.23</td>
<td>0.25</td>
</tr>
<tr>
<td>R2, g/cm²</td>
<td>137</td>
<td>27</td>
<td>110</td>
<td>1.129</td>
<td>0.33</td>
<td>2.30</td>
<td>0.32</td>
</tr>
<tr>
<td>R3, g/cm²</td>
<td>137</td>
<td>27</td>
<td>110</td>
<td>(1.696)</td>
<td>0.34</td>
<td>3.12</td>
<td>(0.43)</td>
</tr>
<tr>
<td>Net, g/cm²</td>
<td>137</td>
<td>27</td>
<td>110</td>
<td>(1.071)</td>
<td>0.27</td>
<td>1.62</td>
<td>(0.34)</td>
</tr>
</tbody>
</table>

BMD, bone mineral density; IQR, interquartile range; SD, standard deviation.

Table II. Description of osteoporosis/osteopenia according to densitometry results for lumbar spine (LS) and femoral neck (FN)

<table>
<thead>
<tr>
<th>WHO criteria</th>
<th>n</th>
<th>%</th>
<th>LS</th>
<th>%</th>
<th>FN</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>32</td>
<td>23.5</td>
<td>Normal</td>
<td>44</td>
<td>32.4</td>
<td>Normal</td>
</tr>
<tr>
<td>Osteopenia</td>
<td>79</td>
<td>58.1</td>
<td>Osteopenia</td>
<td>67</td>
<td>49.2</td>
<td>Osteopenia</td>
</tr>
<tr>
<td>Osteoporosis</td>
<td>25</td>
<td>18.4</td>
<td>Osteoporosis</td>
<td>25</td>
<td>18.4</td>
<td>Osteoporosis</td>
</tr>
<tr>
<td>Total</td>
<td>136</td>
<td>100</td>
<td>Total</td>
<td>136</td>
<td>100</td>
<td>Total</td>
</tr>
</tbody>
</table>

World Health Organization (WHO) criteria: Based on the lowest T-score in the lumbar spine and/or femoral neck.

For several years, many studies have described the use of panoramic radiography as a tool to aid in the diagnosis of osteoporosis, assessing not only visual but also morphometric indices. Visual indices assess in a subjective way (using human perception) the shape and the appearance of the mandibular bone in panoramic images. In contrast, morphometric indices assess numerically diverse mandibular values and parameters. 

**Table I.**

The overall sample analysis, we followed the WHO diagnostic criteria (Table II).

**Mandibular densitometry**

The data obtained are shown in Table I. For the ramus (MD-R1), a total of 110 valid results were obtained. Mean BMD (expressed as g/cm²) was 0.676 (SD = 0.25; range 0.11-1.23). For the body of the jaw (MD-R2), a total of 110 valid results were obtained with a mean BMD of 1.129 (SD = 0.32; range 0.33-2.30). For the mandibular symphysis (MD-R3), a total of 110 valid results were obtained; this variable did not present a normal distribution, so the median and IQR were used to analyze the results. Median BMD was 1.696 with a minimum of 0.34 and a maximum of 3.12, with an IQR of 0.43. For net mandibular BMD (MD-Net), a total of 100 results were considered valid. Distribution was not normal, so the median and IQR were used for analysis. Median BMD was 1.071 with a minimum of 0.27 and a maximum of 1.62, with an IQR of 0.34.

**Bivariate analysis**

Bivariate analysis was applied to the different parameters evaluated for each individual, classifying the degree of affectation according to the WHO diagnostic criteria as normal, presenting osteopenia, or osteoporosis on the basis of the densitometry results obtained from LS or hip, calculating a P value for each variable. When FN and LS densitometry results were evaluated against results for the jaw, significant correlations were found (P < .05) between BMD values for MD-R1, MD-R2, and MD-Net, and the degree bone was affected.

On this basis, patients classified as normal showed higher BMD values in the jaw at MD-R1, MD-R2, and MD-Net, whereas women who presented with affected bone had lower BMD values in these regions. Significant correlation was not found between BMD values for MD-R3 (Table III).

When mandibular densitometry results were compared with LS and FN densitometry values, it was found that the results obtained in all mandibular regions showed statistically significant correlation to results obtained in the LS (P < .05), but compared with FN densitometry values, no significant correlation was found (Tables IV and V).

**DISCUSSION**

For several years, many studies have described the use of panoramic radiography as a tool to aid in the diagnosis of osteoporosis, assessing not only visual but also morphometric indices. Visual indices assess in a subjective way (using human perception) the shape and the appearance of the mandibular bone in panoramic images. In contrast, morphometric indices assess numerically diverse mandibular values and parameters.
Table III. Mandibular densitometry values (expressed as g/cm²) and degree of bone affection (LS and FN)

<table>
<thead>
<tr>
<th></th>
<th>Normal (Median) or Mean (IQR) or SD</th>
<th>Osteopenia (Median) or Mean (IQR) or SD</th>
<th>Osteoporosis (Median) or Mean (IQR) or SD</th>
<th>P value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>MD-R1</td>
<td>0.780</td>
<td>0.22*</td>
<td>0.670*</td>
<td>0.590</td>
</tr>
<tr>
<td>MD-R2</td>
<td>1.260*</td>
<td>0.31†</td>
<td>1.140†</td>
<td>0.33†</td>
</tr>
<tr>
<td>MD-R3</td>
<td>(1.910)*</td>
<td>(0.55)*</td>
<td>(1.680)*</td>
<td>(0.72)*</td>
</tr>
<tr>
<td>MD-Net</td>
<td>(1.240)*</td>
<td>(0.39)*</td>
<td>(1.100)*</td>
<td>(0.57)*</td>
</tr>
</tbody>
</table>

BMD, bone mineral density; IQR, interquartile range; MD, mandible; SD, standard deviation.
R1 indicates BMD ramus, in g/cm²; R2, BMD body, in g/cm²; R3, BMD symphysis, in g/cm²; Net, BMD total mandible, in g/cm².
*P value obtained by χ² test.
†Data presented a normal distribution.
‡Data presented a non-normal distribution.

Table IV. Mandibular densitometry values (expressed as g/cm²) and degree of bone affection in the lumbar spine

<table>
<thead>
<tr>
<th></th>
<th>Normal (Median) or Mean (IQR) or SD</th>
<th>Osteopenia (Median) or Mean (IQR) or SD</th>
<th>Osteoporosis (Median) or Mean (IQR) or SD</th>
<th>P value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>MD-R1</td>
<td>0.770†</td>
<td>0.20†</td>
<td>0.660†</td>
<td>0.27†</td>
</tr>
<tr>
<td>MD-R2</td>
<td>1.290†</td>
<td>0.33†</td>
<td>1.290†</td>
<td>0.31†</td>
</tr>
<tr>
<td>MD-R3</td>
<td>(1.890)†</td>
<td>(0.56)†</td>
<td>(1.660)†</td>
<td>(0.83)†</td>
</tr>
<tr>
<td>MD-Net</td>
<td>(1.220)†</td>
<td>(0.41)†</td>
<td>(1.090)†</td>
<td>(0.64)†</td>
</tr>
</tbody>
</table>

BMD, bone mineral density; IQR, interquartile range; MD, mandible; SD, standard deviation.
R1 indicates BMD ramus, in g/cm²; R2, BMD body, in g/cm²; R3, BMD symphysis, in g/cm²; Net, BMD total mandible, in g/cm².
*P value obtained by χ² test.
†Data presented a normal distribution.
‡Data presented a non-normal distribution.

Table V. Mandibular densitometry values (expressed as g/cm²) and degree of bone affection in the femoral neck

<table>
<thead>
<tr>
<th></th>
<th>Normal (Median) or Mean (IQR) or SD</th>
<th>Osteopenia (Median) or Mean (IQR) or SD</th>
<th>Osteoporosis (Median) or Mean (IQR) or SD</th>
<th>P value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>MD-R1</td>
<td>0.730†</td>
<td>0.25†</td>
<td>0.660†</td>
<td>0.22†</td>
</tr>
<tr>
<td>MD-R2</td>
<td>1.170†</td>
<td>0.32†</td>
<td>1.130†</td>
<td>0.29†</td>
</tr>
<tr>
<td>MD-R3</td>
<td>(1.820)†</td>
<td>(0.62)†</td>
<td>(1.750)†</td>
<td>(0.72)†</td>
</tr>
<tr>
<td>MD-Net</td>
<td>(1.150)†</td>
<td>(0.46)†</td>
<td>(1.070)†</td>
<td>(0.55)†</td>
</tr>
</tbody>
</table>

BMD, bone mineral density; IQR, interquartile range; MD, mandible; SD, standard deviation.
R1 indicates BMD ramus, in g/cm²; R2, BMD body, in g/cm²; R3, BMD symphysis, in g/cm²; Net, BMD total mandible, in g/cm².
*P value obtained by χ² test.
†Data presented a normal distribution.
‡Data presented a non-normal distribution.

Visual indices are obtained from the examiners’ observations of panoramic radiographs. These indices are easy to achieve because they require only the radiographic image and do not need software or a specific millimeter ruler. Their drawback is that they have little reproducibility.

Among the visual indices are the mandibular cortical index (MCI) or the Klemetti index, which assesses the bilateral characteristics of the lower mandibular cortex. There are 3 groups according to the cortical appearance: (1) C1, in which the inferior cortical margin is linear and thick in both sides (normal cortical bone); (2) C2, in which the inferior cortical margin has semilunar defects of lacunar resorption and/or intraosseous defects; and (3) C3, in which the cortical bone has large areas of lacunar resorption, large bone defects, and obvious porosity, as well as severe erosion of the inferior margin. Many studies use these indices, for example, the investigation performed by Valerio et al., where the indices were compared with the results obtained in bone densitometry. The authors found significant correlation between the width and the shape of the mandibular cortex and densitometry data in patients with low BMD (osteopenia and osteoporosis). According to the authors, mandibular data can be used to identify patients with low BMD.

Devlin’s review discussed the same subject and concluded that dentists are qualified to recognize patients with a higher risk of osteoporosis if they take into consideration the clinical risk factors and if they assess patients’ panoramic radiographs paying special attention...
to the thinning and porosity of the mandibular cortex. However, these findings have value in the prediction and prevention of hip fractures, but they do not give a precise diagnosis. Devlin also warned that panoramic radiography should not be performed specifically to diagnose osteoporosis because of its low sensitivity and additional radiation exposure to the patient.

When evaluating morphometric indices, Devlin and Horner found a significant relationship between the width of the mandibular cortex and BMD. A decrease in cortical width indicated a decrease in skeletal bone mineral density. More specifically, they found that ≤3 mm of mandibular cortical width in the lower premolar area led to 20% sensitivity (95% confidence interval [CI] = 10.4%–33%) and 100% specificity in the diagnosis of a reduction in BMD. The results of this study showed low sensitivity and good specificity in the use of panoramic radiography, but the measures did not give a satisfactory diagnosis of osteopenia and osteoporosis. The authors concluded that these measurements can be useful as part of a method of osteoporosis risk assessment.

A study performed by Hekmatin et al. assessed the bivariate correlation between BMD and T-score and found a significant correlation between BMD and the mandibular cortical width (MCW) \((r = 0.945)\) \((P < .001)\). It is important to highlight that in this research, only the mandibular cortical width was used. This coincides with the investigation performed by López-López et al., who reviewed the application of diverse indices to panoramic radiography and concluded that they could be used to identify patients with low BMD risk.

Similarly, a meta-analysis carried out in 2005 by Calciolari et al. assessing 50 studies found that both morphometric and visual indices had good specificity and sensitivity in showing a low BMD. The most specific index was MCW, with evidence suggesting that a width less than 4 mm indicated a low BMD in 90% of the cases. According to the data reported in the investigation, the panoramic mandibular index had an estimated sensitivity and specificity in the detection of low BMD of 0.723 (SE 0.160; 95% CI 0.352-0.926) and 0.733 (standard error [SE] 0.066; 95% CI 0.587-0.861), respectively. The presence of any mandibular cortical resorption had an estimated sensitivity and specificity in the detection of low BMD of 0.643 (SE 0.109; 95% CI 0.417-0.820), respectively. The authors concluded that the mandibular cortical width, the panoramic mandibular index, and the Klemetti index are useful tools that could be used by dentists to determine low BMD. The limitations are the varied experience between different professionals and the quality of the panoramic image.

By using both types of indices, Taguchi et al. found that the likelihood ratio to identify women with low BMD was 13.90 for thin cortical width (<3 mm) and 10.84 for the severely eroded cortex. The likelihood ratio to identify women with osteoporosis was 6.40 for the thin cortical width and 7.11 for the severely eroded cortex.

Considering these findings, the question arises about whether the BMD of the MD is altered in the same manner as the typically studied bones in cases of osteoporosis. This is why this study compared the densitometric characteristics of the MD to those of the LS and FN in postmenopausal women. The research was performed only on women because of their higher prevalence of osteoporosis and because routine densitometric studies are more frequently carried out on women.

The study used the methodology of Horner et al., who examined the early diagnosis of osteoporosis with mandibular densitometry compared with standard bone densitometry. These authors found significant correlations \((P < .02)\) between BMD of the body of the jaw, ramus, symphysis, and other skeletal areas, and a higher sensitivity (0.8) and specificity (0.97) in the body of the jaw. Since this study used a sample of 40 edentulous women and an uncomfortable mandibular position to make the densitometric measurements, a number of modifications were put in place on our study:

1. The sample size was increased. The present study included 137 patients, although to carry out densitometry, it was only possible to superpose the mandibular rami in 110 cases (82%). The work by Horner et al. achieved superposition of the rami in 35 of 40 cases (88%).
2. All patients underwent densitometry of the LS, the right femur, and the MD. Horner et al. analyzed densitometry of the forearm. The present study did not include densitometry of this region because it is not commonly used.
3. Most of the patients in the present study were not edentulous (96.35%; \(n = 132\)), whereas in the investigation of Horner et al., all patients were edentulous. In this way, the present study used a sample that would be more representative of the general population. For densitometric analysis of the mandibular subregions, a line was traced below the tooth roots so that they would not influence BMD values.
4. For mandibular evaluation, patients were positioned differently from the position proposed by Horner et al. The position in the earlier study was difficult to achieve for older patients or patients with back problems, making it impossible to attain superposition of the mandibular rami in some cases. For this reason, the present study used the position described above (Figure 1). Densitometry was performed in the same mandibular subregions as in the study of Horner et al.
(Figure 2), but the present study also calculated net mandibular densitometry (MD-Net), which was not used in the earlier investigation.

Similar to the findings of Horner et al., a significant correlation was found in the present study between standard bone densitometry and jaw densitometry. Horner et al. discovered a significant correlation between the BMD of the body of the jaw, ramus, symphysis, and all other skeletal areas \( (P < .02) \). In our investigation, significant correlations were found between densitometry values obtained from the LS and femur, analyzed together, following the WHO guidelines, but no correlation was found in the symphysis \( (P = .095) \). Likewise, as the values of the T-score decreased in the reference bone areas, the BMD also decreased in the MD (Table III).

In the present study all mandibular areas analyzed were significantly correlated in relationship to the LS \( (P < .05) \) but were not significantly correlated to the FN (Tables IV and V).

Our results also agree with those of Horner et al. with regard to the BMD (expressed as g/cm²). Although Horner et al. performed their study on edentulous patients and the present investigation was performed on a more generalized sample, the results were similar (Table I). The differences between the position used by Horner et al. and the ones used in the present study might explain the contrasting results on both investigations.

In contradiction to the present research, where a higher relationship was found between the MD and the LS only, Pluskiewicz et al. found a significant relationship \( (P < .01) \) between BMD of the jaw, hip, calcaneus, and hand phalanges in 42 edentulous patients (36 women and 6 men). The only difference that can be noted between these studies is that their sample was composed of completely edentulous patients.

The present investigation is also in concordance with a study carried out in China in 2011 by Li et al., who performed densitometry in the jaw and the LS; the study assessed 224 healthy patients (111 men and 113 women) aged between 20 and 70 years (unlike the present study, which only included older women). It also used the positions described by Horner et al. to carry out densitometry and obtained BMD measurements at the mandibular angles and the chin, placing the patient in a supine decubitus position with the head centered to capture an anterior image of the jaw. However, the study by Li et al. only compared densitometry data from the mandibular angle and symphysis with the LS. Li et al. found that BMD of the mandibular angle and LS decreased significantly in patients older than 50 years, concluding that BMD of the mandibular angle is correlated with the BMD of the LS.

Esfahanizadeh et al. performed a study to determine the correlation between the density of the lumbar vertebrae and femoral bones and different regions of the jaws in 110 patients from Iran. Their observations were different from ours because they found a significant correlation between the BMD of the femur and vertebrae and all areas of the jaw \( (P < .005) \), whereas we found a correlation only in the LS.

In contrast to these findings, a study performed by Çakur et al. in 2009, evaluated 80 women with osteoporosis, performing densitometry in the LS, hip, and jaw but did not find any significant correlation between densitometry values in mandibular and nonmandibular regions. For patient positioning, these authors used the deepest point of the antegonial region as the ROI, as this is an area free of teeth. Mandibular scanning was performed with patients in the supine position and with their heads positioned so that the plane between the labial commissure and the tragus was parallel to the floor while the sagittal plane was perpendicular. This position aimed to avoid the superimposition of the contralateral sides of the jaw and the LS. It also helped to obtain images that would be similar to a panoramic radiograph. In addition to performing densitometry, Çakur et al. also examined the MCI classification according to Klemetti. Çakur et al. found that this classification of 3 grades of mandibular cortical changes was unable to detect women with osteoporosis because MCI is not significantly correlated to DXA measures and therefore should not be used as a skeletal state indicator. The authors also mentioned the intrinsic errors of panoramic images as a result of their distortion.

Although the data in the present study agree in many aspects with the literature, a possible weakness of the investigation could be a bias in patient selection. These patients were taken from a previous study on osteoporosis, performed only on women, the majority of whom were over age 60 years. Therefore, extrapolation of the sample to the general population might not be appropriate. More studies are needed with diverse age groups and both genders to validate the current results.

One final matter to be considered is the relationship between osteoporosis and dental treatment. It is important to evaluate the bone quality to predict the success of dental implant treatment. If initial planning is performed with a panoramic radiograph, it could be helpful if the dentist has knowledge of the validity of bone density analysis on this initial radiograph. Although there is insufficient evidence in the literature to contraindicate the use of dental implants in patients with osteoporosis, several authors recommend a modification in the surgical technique.

CONCLUSIONS

According to the results, it can be affirmed that the MD responds to osteoporosis in similar ways to other bones, specifically the LS. In this population of Catalanian
postmenopausal women, densitometry BMD data for the MD correlated with those of the LS but not to the FN data. More studies are necessary to determine if these radiologic findings could correlate with low mineral density observed in panoramic radiographs, which could allow the dentist to play an important part in detecting the first signs of osteoporosis in patients not previously diagnosed.

REFERENCES

Reprint requests:
José López-López, DDS, PhD, MD
Faculty of Medicine and Health
Department of Odontostomatology Sciences
University of Barcelona
Barcelona Spain
Dental Hospital Barcelona University, Barcelona, Spain
Oral Health and Masticatory System Group (Bellvitge Biomedical Research Institute) IDIBELL, L’Hospitalet de Llobregat, Barcelona 08907, Spain
jl.lopez@ub.edu