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Panoramic Radiomorphometric Indices as Reliable Parameters in Predicting Osteoporosis

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Abstract: Background: The purpose was to evaluate the significance of panoramic radiomorphometric indices (mandibular cortical index [MCI], mental index [MI] and panoramic mandibular index [PMI]) as useful tools for identifying osteoporosis. Methods: One hundred healthy women aged ≥ 30 years were included. Digital panoramic images and bone mineral density (BMD) of the lumbar spines were recorded. Radiomorphometric indices (MCI, MI and PMI) were measured and categorized. Results: Interobserver agreements were kappa = 0.922 for the MCI and alpha = 0.902 and 0.702 for the PMI and MI, respectively. The indices MI, PMI and BMD showed a statistically significant positive correlation with the t score (r = 0.47, 0.36 and 0.96, respectively). The MI showed a statistically significant positive correlation with the PMI (r = 0.72). Sensitivity, specificity and diagnostic accuracy of the MI at a cutoff point of 4.5 mm were 66.7%, 75.4% and 72%, respectively. Conclusions: Panoramic indices (MI, PMI and MCI) were positively correlated with the t score and BMD of the lumbar spines. The MCI was found to be the most reproducible index.

Key Indexing Terms: Panoramic radiograph; Radiomorphometric indices; Bone mineral density; Osteoporosis; Lumbar spines. [Am J Med Sci 2013;0(0):1–6.]

Osteoporosis is a skeletal disorder characterized by bone architectural disorientation and low bone mineral density (BMD) and micro-architectural deterioration, thereby resulting in increased bone fragility and/or susceptibility to fracture. According to the Surgeon General of the United States, nearly 50% of all American citizens older than 50 years will be at a greater risk for fractures from osteoporosis and low BMD when compared with younger Americans. A direct association between osteoporosis and architectural alterations in the inferior border of the mandible has been reported. In addition, patients with a history of osteoporotic fractures have been shown to have increased resorption and thinning of the mandibular lower cortex when compared with their respective healthy controls. Nevertheless, a large number of populations with increased risk of osteoporotic fractures remain underdiagnosed and/or untreated.

Panoramic radiographs are routinely taken for the assessment of oral diseases including dental caries and periodontal disease; however, other features of panoramic radiography such as the cortical width below the mental foramen (or mental index [MI]) may also be a useful tool in identifying patients with undetected low skeletal BMD. Studies have reported that patients with a thin MI of 3 mm or less may have latent osteoporosis and that a cortical width of 4.5 mm or less may be considered as a high risk indicator of osteoporosis. Furthermore, results by Taguchi et al. showed that the diagnostic performance of dental panoramic radiography measures for identifying postmenopausal women with suspected spinal osteoporosis was similar to that of the osteoporosis self-assessment tool. From these results, panoramic radiography seems to be a cost-effective means for screening latent osteoporosis in undiagnosed individuals. In this investigation, we hypothesized that panoramic radiomorphometric indices (mandibular cortical index [MCI], MI and panoramic mandibular index [PMI]) are useful tools for identifying osteoporosis.

The aim of this study was to evaluate the significance of panoramic radiomorphometric indices (MCI, MI and PMI) in identifying osteoporosis.

MATERIALS AND METHODS

Ethical Guidelines

The study design was revised and approved by the Research Ethics Committee of the Faculty of Dentistry, King Abdulaziz University, Jeddah, Saudi Arabia. An informed consent was obtained from all individuals. It was mandatory for all study participants to have read and signed the consent form before being included in this study.

Exclusion Criteria

The following exclusion criteria were imposed: (1) history of systemic disorders such as diabetes and/or renal disorders, (2) hormonal replacement therapy, (3) corticosteroid use within 3 months, (4) traumatic fracture, (5) history of hysterectomy and (6) habitual smoking and/or alcohol consumption.

Study Participants

One hundred self-reported medically healthy females with a mean age of 52.2 ± 9.5 years (aged between 30 and 74.2 years) were included. These individuals were recruited from the Department of Oral and Maxillofacial Radiology, College of Dentistry, King Abdulaziz University, Jeddah, Saudi Arabia.

Questionnaire

Demographic data were collected using a self-completed questionnaire. Patients were also inquired about history of systemic diseases (including diabetes and renal disorders), drug...
usage, alcohol/tobacco habits and bone/joint aches and menopausal status.

**Bone Mineral Density**

BMD (g/cm²) measurements of lumbar spines L2 to L4 were performed using dual-energy x-ray absorptiometry (DXA) (GE Lunar, Corp, Madison, WI). Height and weight were measured at the time of dual-energy x-ray absorptiometry testing. The study individuals were categorized into 3 skeletal mineral density groups based on World Health Organization criteria: normal (t score $\geq -2.5$); osteopenic (t score $-2.5$ to $-2.5$) and osteoporotic (t score $\leq -2.5$).

**Digital Panoramic Radiography**

Digital panoramic radiographs were taken by a calibrated single operator using an Orthopantomograph 200 D (Instrumentarium Dental, Inc, Milwaukee, WI) with exposure settings of 57 to 85 peak kV and tube current of 12 to 16 μA. The position of the patient’s head was standardized following the manufacturing instructions. All radiographs were assessed so that only the high-quality and correctly positioned panoramas were included. Linear measurements were made using an analytical software (Clini view 8.1; Kodak Dental Imaging Software “KDIS”) after correcting the magnification factor.

**Measurement of Panoramic Indices**

Panoramic indices (MI, PMI and MCI) were assessed twice by 2 calibrated oral radiologists within a 1-month interval wherein the data of the 1st session were masked at the 2nd session. By this, a general consensus was reached.

**MI, PMI and MCI**

The MI was measured as described elsewhere. In summary, a line was drawn parallel and tangent to the inferior border of the mandible (Figure 1). Line 1 was constructed perpendicular to the tangent, passing through the middle of the inferior cortical margin of the mental foramen. The cortical width was then measured along this perpendicular line (represented as line 2). The mean cortical width of both sides was used in this study. Osteoporosis was defined by MI cutoff points of $\leq 3$ mm and $\leq 4.5$ mm.

The PMI was measured as the ratio between the MI and the distance between the inferior margin of the mental foramen and the inferior border of the mandibular cortex (line 2/line 1). To our knowledge from indexed literature, there is no standard threshold for a PMI value. In this regard, the mean value derived from this study was used for statistical analysis.

The MCI was determined as C1 (normal), C2 (osteopenic) or C3 (osteoporotic) by examining the inferior cortex of the mandible from the mental foramen to the antegonial area on both sides. The most deteriorated cortex was adopted as the diagnosis of the cortical shape.

**Statistical Analysis**

Statistical analysis was performed using a software program (SPSS, Inc, Chicago, IL). The Pearson’s coefficient was used to determine the significant correlation between different variables. The Student $t$ test was used to compare between denate or partially dentate cases and the other variables, except for $t$ score data, in which case, the Mann-Whitney $U$ test was used because of the nonparametric distribution of the $t$ score data. One-way analysis of variance (ANOVA) was used to compare between MCI classes, except for the $t$ score, wherein the Kruskal-Wallis test was used. Tukey’s post-hoc test was used for pairwise comparison between the means when the ANOVA test was significant. The Mann-Whitney $U$ test was used for pairwise comparisons between groups for $t$ score results.
The interobserver agreement for numerical data was performed with Cronbach’s alpha reliability coefficient. The kappa statistic was used to measure interobserver agreement for qualitative data. The \( \chi^2 \) test was used to measure the association between the dentition and MCI. The level of significance was set at \( P < 0.05 \).

RESULTS

Lumbar Spine Bone Density

The mean \( t \) score of lumbar spine bone density was \(-0.43 \pm 1.35\), with a minimum of \(-3.50\) and a maximum of \(2.20\). Sixty-one percent of the study sample had a \( t \) score of \(-1\) (classified as normal); 34% had a \( t \) score of \(-1\) and \(-2.5\) (classified as osteopenic); and 5% had a \( t \) score of \(\geq -2.5\), indicating osteoporosis.

Radiomorphometric Indices

The mean MI and PMI were 4.36 \(\pm\) 0.92 (range, 2.40–6.80 mm) and 0.33 \(\pm\) 0.07 (range, 0.18–0.63 mm), respectively. According to the MCI, 59 subjects (59%) were C1, 38 (38%) were C2 and 3 (3%) were C3. In addition, the dental statuses of the subjects were 84 (84%) dentate, 1 (1%) edentulous and 15 (15%) partially edentulous.

Correlation Between the \( t \) Score and Each of BMD, MI and PMI

Pearson’s correlation coefficient showed a statistically significant positive correlation between the \( t \) score and each of BMD, MI and PMI \((r = 0.96, 0.47\) and 0.36, respectively\) (Figures 2 and 3). The BMD showed a statistically significant positive correlation with MI and PMI \((r = 0.43\) and 0.41, respectively\). The MI also showed a statistically significant positive correlation with PMI \((r = 0.72\)\), as shown in Table 1.

\begin{table}[h]
\centering
\begin{tabular}{|c|c|c|c|}
\hline
\textbf{Variable} & \textbf{BMD} & \textbf{MI} & \textbf{PMI} \\
\hline
\textbf{t} score & Pearson’s correlation & 0.960 & 0.475 & 0.369 \\
\textbf{P} & \multicolumn{3}{c|}{<0.001\textsuperscript{a}} & \multicolumn{3}{c|}{<0.001\textsuperscript{a}} & \multicolumn{3}{c|}{<0.001\textsuperscript{a}} \\
\hline
\textbf{BMD} & Pearson’s correlation & 0.434 & 0.414 & \\
\textbf{P} & \multicolumn{3}{c|}{<0.001\textsuperscript{a}} & \multicolumn{3}{c|}{<0.001\textsuperscript{a}} & \\
\hline
\textbf{MI} & Pearson’s correlation & 0.721 & \\
\textbf{P} & \multicolumn{3}{c|}{<0.001\textsuperscript{a}} & \\
\hline
\end{tabular}
\caption{Results of Pearson’s correlation coefficient for correlating between different variables}
\end{table}

\( \textsuperscript{a} \) Significant at \( P < 0.05 \).

Mandibular Cortical Index

The significant differences between the MCI (C1, C2 and C3) and other variables are presented in Table 2. The C1 cases showed the statistically significant highest mean \( t \) score (or lowest negative value) followed by C2, whereas the C3 cases showed the statistically significant lowest mean \( t \) score, with a statistically significant difference between them \((P = 0.002)\) (Figure 4).

The C1 cases showed the highest mean BMD, with a statistically significant difference compared with the C2 and C3 cases \((P = 0.001)\). However, there was no statistically significant difference between the C2 and C3 cases showing the lowest means BMD. For the MI, there was no statistically significant difference between the C1 and C2 cases, which showed the statistically significant highest mean MI, whereas the C3 cases showed the statistically significant lowest mean MI, with a significant difference between C1 and C2 \((P = 0.001)\). C1 cases showed statistically significant highest mean PMI, with a statistically significant difference between the C2 and C3 cases \((P = 0.01)\), whereas there was no statistically significant difference between the C2 and C3 cases, which showed the statistically significant lowest mean PMI.

The dental status data of the study subjects and different variables are presented in Table 3. The edentulous case was.
merged with the partially dentate group for statistical purposes. There was no statistically significant difference between the dentate and partially dentate cases regarding all variables ($P \geq 0.05$).

**Interobserver Agreement, Sensitivity, Specificity and Diagnostic Accuracy**

Interobserver agreement of the 3 radiomorphometric indices was found to be the highest for MCI (kappa = 0.922) and PMI (alpha = 0.902), whereas MI showed strong agreement (alpha = 0.702). The sensitivity and specificity of the MI were calculated. When we used an MI with a cutoff point of 3 mm, individuals with an MI $\geq 3$ mm were considered normal. Sensitivity, specificity and diagnostic accuracy were found to be 10.3%, 98.4% and 64%, respectively. However, when the MI cutoff point was changed to 4.5 mm, all individuals $\geq 4.5$ mm were considered normal. Sensitivity, specificity and diagnostic accuracy were found to be 76.9%, 54.1% and 63%, respectively (Table 4). The sensitivity, specificity and diagnostic accuracy of the MCI were found to be 66.7%, 75.4% and 72%, respectively.

**DISCUSSION**

The results demonstrated that panoramic indices (MI, PMI and MCI) are positively correlated with the $t$ score and BMD of the lumbar spines. Therefore, these indices could serve as simple and useful tools to assess latent osteoporosis. Our results are in accordance with previous studies, which reported that dental panoramic radiographs can be useful for detecting those at high risk for osteoporotic fractures. However, controversial results have also been reported.

Studies have focused primarily on radiomorphometric measurements with reference to gender and age; however, only a limited number of studies have evaluated changes in MCI, MI or PMI. The results of this study revealed that subjects classified as C3 on the MCI showed significantly
lowest mean t score and BMD, followed by C2 and C1 cases. This result could be attributed to the radiographic porosity of the mandibular cortex that have been detected in C3 cases and resulted in such low records. This reflects that the MCI is helpful in identifying female patients with low BMD. These findings are in agreement with the other studies. Furthermore, our results demonstrated that the C3 group showed the lowest MI, with a statistically significant difference from C1 and C2. Similarly, C2 and C3 groups showed significantly lowest PMI when compared with C1. Thus, MCI was found to be a fairly good index in detecting osteoporosis, and it can be used as a useful screening tool. In our results, the excellent harmony between interobserver interpretations of data reflects that oral radiologists may be able to perform a more accurate diagnosis than other general clinical dental practitioners.

Studies have assessed the sensitivity, specificity and diagnostic accuracy of MCIs. These studies concluded that measurement of MCI is a reliable method of identifying osteoporosis. Our results showed values of 66.7%, 75.4% and 72%, respectively, when compared with the study by Taguchi. It is generally agreed that tests with close values of sensitivity and specificity are considered reliable, a finding that is supported by our results. The results of this study demonstrated no statistically significant difference between the dental status of the patients and their t score, BMD, MI, PMI or MCI. This could possibly be explained by the fact that the basal bone remains unaffected following exodontia when compared with alveolar bone, which ultimately resorbs after tooth extraction. This is in accordance with other studies, however, Gulsahi et al and Sahyoun et al concluded that dental status was the 2nd most important parameter for MCI. Further studies are warranted to assess the relationship between dental status and MCI.

The results of this study showed a significant correlation between the MI and BMD. These results remarked that MI and MCI are precise indices for measuring osteoporosis in osteoporotic female patients as reported by other investigators. In addition, our results have shown that there was a statistically significant positive correlation between the MI and both the t score and the PMI. On correlating PMI with the t score, BMD and MI, it was found that there was a statistically significant positive correlation between them. This study findings supported our hypothesis, and we considered these indices valuable in predicting osteoporosis in the dental clinic. Thus, we recommend that the responsibility of oral radiologist to identify individuals at risk of osteoporosis be officially declared. Although the interobserver agreement of the PMI in this study was excellent, other studies have found that the PMI assessment has a limited repeatability that might limit its usefulness in clinical practice. This disagreement could be owed to the differences in the observers’ experiences.

### CONCLUSIONS

Panoramic indices (MI, PMI and MCI) were positively correlated with the t score and BMD of the lumbar spines. The MCI was found to be the most reproducible index.

### REFERENCES


### TABLE 4. Results of sensitivity, specificity and diagnostic accuracy of MI using 3 and 4.5 mm as cutoff points

<table>
<thead>
<tr>
<th>MI, 3 mm</th>
<th>t score</th>
<th>Osteoporotic</th>
<th>Normal</th>
<th>Total</th>
<th>MI, 4.5 mm</th>
<th>t score</th>
<th>Osteoporotic</th>
<th>Normal</th>
<th>Total</th>
</tr>
</thead>
<tbody>
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<td>Osteoporotic</td>
<td>4 (True +ve)</td>
<td>1 (False +ve)</td>
<td>5</td>
<td>Osteoporotic</td>
<td>30 (True +ve)</td>
<td>28 (False +ve)</td>
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</tr>
<tr>
<td>Normal</td>
<td>35 (False –ve)</td>
<td>60 (True –ve)</td>
<td>95</td>
<td>Normal</td>
<td>9 (False –ve)</td>
<td>33 (True –ve)</td>
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<tr>
<td>Total</td>
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<td>Total</td>
<td>39</td>
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</tr>
</tbody>
</table>

MI, mental index.


