Assessment of the efficacy of digital panoramic radiographs in analyzing changes in bone mineral density in postmenopausal women

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ABSTRACT

Introduction: Osteoporosis is described by the World Health Organization (WHO) as a ‘progressive systemic skeletal disease characterized by low bone mass, microarchitectural deterioration of bone tissue, a consequent increase in bone fragility, and susceptibility to fracture. The maxilla and mandible are also affected by osteoporotic changes and these may be visualized using an Orthopantomogram. Aims and Objectives: To determine the radiomorphometric indices in the digital orthopantomograms, to determine the bone mineral density (BMD) of the lumbar spine and femur using DXA (Dual-Energy X-ray Absorptiometry) scan, to compare the measured indices between the BMD categories and to assess the correlation of these indices with the measured BMD. Materials and Methods: The study population included 30 postmenopausal female patients. The BMD was measured at the lumbar spine and the patients were divided into three groups of 10 subjects based on their BMD status (normal, osteopenia, and osteoporosis). The patients were then subjected to panoramic radiography and four panoramic indices were assessed (simple visual estimation, mandibular cortical index, mental index, and antegonial index). The measured indices were compared between the three BMD categories. The correlation between the indices and the BMD was also observed. Results: The measured indices showed significant difference among the BMD categories. The quantitative indices also demonstrated a positive correlation with the measured BMD of the lumbar spine and the femur. Conclusion: Panoramic radiography may be used as a diagnostic tool for screening and identifying subjects who are likely to have osteoporosis.

Keywords: DXA, osteoporosis, panoramic radiography, postmenopause

Osteoporosis is described by the World Health Organization (WHO) as a ‘systemic skeletal disease characterized by low bone mass, microarchitectural deterioration of bone tissue, a consequent increase in bone fragility and susceptibility to fracture.⁶

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Osteoporosis is a global health concern. The increase in the life expectancy of today’s population may be the cause of an increased prevalence of this common and insidious bone disorder.

Globally, it has been estimated that more than 200 million individuals suffer from osteoporosis. Around 30% of postmenopausal women in the United States and in Europe have osteoporosis. In the Indian population, the prevalence has been reported to be between 25 and 62%.[3]

**Estrogen and Menopause**

Estrogen deficiency in postmenopausal women causes an up regulation of the Receptor activator of nuclear factor kappa-B ligand (RANKL) which activates the osteoclasts and rapidly increases the turnover rate of bone resulting in bone resorption.[3][4]

**Bone Mineral Density in Menopause**

A significant reduction in bone mineral density (BMD) in the postmenopausal period compared to premenopausal women is a well-established fact and has been demonstrated in several studies. (Chowdhury S et al., Finkelstein JS et al., Mishra S et al., Seifert-Klauss V et al.)[7][9] The BMD has been found to substantially decline in the late perimenopausal stage at an average loss of 0.010 and 0.018 g/cm² per year from the hip and spine, respectively. This rapid decline continues in the early postmenopausal years (average rates of loss from the hip and spine at 0.013 and 0.022 g/cm² per year, respectively).[7][10]

**Osteoporosis and Oral Health**

Osteoporosis can adversely affect oral health. Systemic osteoporotic changes can manifest in the jaw bones resulting in resorption of the alveolar crest.[11] Other oral changes include a reduction in the jaw bone density, temporomandibular joint disorder, periodontal disease, and eventual tooth loss.[12][13]

A well-established positive correlation between osteoporosis and periodontitis has been identified and both diseases have numerous common risk factors.[14] This may be due to a reduction in the density of the alveolar bone in osteoporotic patients accelerating the rate of alveolar bone resorption. through inflammatory pathways, or due to genetic predisposition which can reduce systemic BMD as well as damage the alveolar bone through common pathophysiologic mechanisms.[14]

Studies reveal that women with periodontitis have significantly lower T-score value at the hip and metacarpal BMD compared to those without periodontitis.[15][16]

Untreated periodontitis can be a risk factor in the development of coronary artery disease, chronic pulmonary diseases, rheumatoid arthritis, diabetes, malignancies, and preterm or low birth weight.[17] Periodontal infection in itself may trigger the activation of RANKL resulting in the subsequent osteoclastic activation and activity which in turn can induce osteoporosis in individuals with periodontitis and hence a periodontal infection can hasten the onset of osteoporosis.[18]

**Diagnosis of Osteoporosis**

Unfortunately, osteoporosis often goes undiagnosed until or unless a fracture occurs. WHO has accepted Dual-energy X-ray absorptiometry (DXA) as the gold standard method to measure BMD.[19][21]

DXA facilities are scarce and expensive.[22][23] The number of DXA scanners in India is limited, with just around 0.26 scanners available for every 1 million people. This calls for a judicious utilization of DXA facilities and results in a pressing need for newer technologies which are widely available and affordable.[24]

**Role of Panoramic Radiograph**

Since osteoporosis is a systemic skeletal disease, the impaired bone metabolism which occurs in osteoporosis manifests in the maxilla and the mandible as well.[9] An association between osteoporosis and oral bone loss was first proposed in 1960. These changes may be visualized with an orthopantomogram (panoramic radiograph) and several radiographic indices have been identified which may potentially help reveal the presence of osteoporotic changes in the mandible.[9][22][23]

**Materials and Methods**

The study population included 30 postmenopausal female patients who had reported to the Department of Oral Medicine and Radiology in a South Eastern Indian population with a history of arthralgia. Subjects who were previously diagnosed with osteoporosis, those with systemic diseases and on medications were excluded from the study. Patient consent and ethical clearance from the institutional review board were obtained. All procedures carried out were in accordance with the Helsinki Declaration. The BMD was measured at the lumbar spine and at the femur in patients using IDXA-GE Machine (Lunar iDXA 40782). The patients were diagnosed as osteoporotic, osteopenic, or normal based on the BMD as per the WHO criteria from the T-score obtained from the scanning results. Normal (T-Score -1.0), Osteopenia (T-score between -1.0 and -2.5), and Osteoporosis (T-score -2.5)[23][25]

The patients were then subjected to panoramic radiography using Kodak 8200 Digital Panoramic Machine and four panoramic indices were assessed (simple visual estimation, mandibular cortical index, mental index, and antegonial index) using the Trophy DICOM viewer bilaterally and the average was taken. To maintain standardization, all the radiographic techniques were performed by the same operator.
It has been suggested that osteoporosis renders the mandibular cortex porous. These changes may be visualized by measuring the following panoramic indices which have been described below. In order to avoid subjective bias, both qualitative and quantitative indices were selected for the study.

Measured Indices:[5,26‑28]

1. Simple visual estimation (SVE):

   The mandibular cortex is classified qualitatively into three categories which are based on the simple visual estimations of the width of the inferior cortex as: normal, intermediate, and thin.

2. Mandibular cortical index (MCI), (Klemetti's Classification):

   C1 - The endosteal margin of the mandibular cortex is sharp and even

   C2 - The endosteal margin contains semilunar defects (lacunar resorption), or the margin contains endosteal cortical residues.

   C3 - The cortical layer of bone forms heavy endosteal cortical residues and is porous [Figure 1].

3. Mental Index:

   The mental index is measured as the width of the cortex at the region of the mental foramen. A line parallel to the long axis of the mandible as well as tangential to the lower border of the mandible is constructed. A second line which is perpendicular to this tangent is then drawn which intersects the inferior border of the mental foramen, along which the width of the mandibular cortex is measured [Figure 2].

4. Antegonial Index:

   The antegonial index is the measurement of the cortical width in the region anterior to the gonion at a point identified by extending a best fit line along the anterior border from the ascending ramus down to the lower border of the mandible [Figure 3].

The interobserver reliability was checked for the two qualitative indices (SVE and MCI). All 30 radiographs were checked by a second observer. The statistical analysis was done using Kappa statistics for the interobserver reliability, Chi-square test for evaluating the association between the qualitative indices and the BMD categories, Kruskal–Wallis test for the association of the quantitative indices and BMD groups and Spearman's rank correlation coefficient for evaluating the correlation between the quantitative indices and the BMD.

Results

Table 1 shows the mean values of the age of the subjects in each BMD category. There were a total of 10 patients per BMD category. No significant difference was observed in the age between the categories at $P = 0.134$.

The interobserver reliability was calculated for the two quantitative indices. The kappa statistics for SVE was 0.746 and 0.747 for MCI which demonstrated a good level of agreement.
Of the ten subjects in the normal group, eight (80.0%) were grouped under the SVE category of normal and two (20.0%) subjects were grouped under the category of intermediate. Of the ten subjects in the osteopenia group, eight (80.0%) were grouped under the SVE category intermediate and two (20.0%) subjects were grouped under the SVE category thin. Out of the ten osteoporotic subjects, eight (80.0%) subjects were grouped under the SVE category thin and two (20.0%) subjects were grouped under the SVE category intermediate. The association of SVE between the three BMD categories was significant with a $P = 0.000$. The mean and median values of BMD at the lumbar spine and the femur among the SVE index categories are given in Tables 2 and 3, respectively.

The mean BMD of the lumbar spine corresponding to the SVE Categories of Normal, Intermediate, and Thin was found to be $1.252 \pm 0.153 \text{ g/cm}^2$, $0.934 \pm 0.106 \text{ g/cm}^2$, and $0.863 \pm 0.075 \text{ g/cm}^2$, respectively.

The mean BMD of the femur corresponding to the SVE Categories of Normal, Intermediate, and Thin was found to be $1.082 \pm 0.149 \text{ g/cm}^2$, $0.901 \pm 0.049 \text{ g/cm}^2$, and $0.819 \pm 0.064 \text{ g/cm}^2$, respectively.

Of the 10 subjects in the normal group, 10 (100.0%) were grouped under the MCI category C1. Of the 10 subjects in the osteopenia group, 10 (100.0%) were grouped under the MCI category C2. Out of the ten osteoporotic subjects, seven (70.0%) subjects were grouped under the MCI category C3 and three (30.0%) subjects were grouped under the MCI category C2. The association of MCI between the three BMD categories was significant with $P < 0.001$. The mean and median values of BMD at the lumbar spine and the femur among the MCI index categories are given in Tables 2 and 3, respectively.

The mean BMD of the lumbar spine corresponding to the MCI Categories C1, C2, and C3 was found to be $1.211 \pm 0.161 \text{ g/cm}^2$, $0.917 \pm 0.091 \text{ g/cm}^2$, and $0.831 \pm 0.057 \text{ g/cm}^2$, respectively. The mean BMD of the femur corresponding to the MCI Categories C1, C2, and C3 was found to be $1.046 \pm 0.153 \text{ g/cm}^2$, $0.881 \pm 0.064 \text{ g/cm}^2$, and $0.819 \pm 0.064 \text{ g/cm}^2$, respectively.

The mean mental index values among the normal, osteopenic, and osteoporotic groups were $4.630 \pm 0.165$, $3.060 \pm 0.286$, and $2.500 \pm 0.141$, respectively. There was a highly significant difference in the median mental index values between the three BMD categories. (P = 0.000). The mental index demonstrated a strong positive correlation with the BMD at the lumbar spine ($r = 0.918$, $P = 0.000$) and the femur ($r = 0.889$, $P = 0.000$). The mean and median mental index values between the BMD groups are given in Table 4.

The mean antegonial index values among the normal, osteopenic, and osteoporotic groups was $3.350 \pm 0.796$, $2.300 \pm 0.494$, and $1.350 \pm 0.479$, respectively. There was a highly significant difference in the median antegonial index value between the three BMD categories. (P = 0.000). Antegonial index exhibited a strong positive correlation with the BMD at the lumbar spine ($r = 0.846$, $P = 0.000$) and with the femur ($r = 0.890$, $P = 0.000$). The mean and median antegonial index values between the BMD groups are given in Table 4.

### Discussion

It has been suggested that in osteoporotic patients, the mandible undergoes osteoporotic changes as well and these can be viewed with the help of a panoramic radiograph.

In the present study it was observed that there was a significant association between the SVE and the BMD. Individuals with lower BMD were found to have thinner cortex of the mandible. This in accordance to the study by Leite et al. in 2010.\[10\] In the mandibular cortical index, subjects with normal BMD were found to have a sharp and normal cortex. Those with lower BMD had eroded cortex. This is in accordance to the studies done by Marandi et al. in 2010 where 67 postmenopausal women were studied.\[11\] The mandibular cortical index demonstrated significant difference between the BMD categories. Studies by Khojastehpour et al. in 2011,\[12\] Leite et al. in 2010,\[13\] and BalciKoeunte et al.\[14\] in 2004 have all demonstrated similar results. However, a study by Choi et al.\[15\] in 2019, revealed that there was no association between MCI and BMD.
Table 4: Mean and median values of the quantitative indices in each of the three bone mineral density categories

| Group          | Mental Index | Antegonial Index |
|----------------|--------------|------------------|
|                | Mean±SD      | Median | Maximum | Minimum | Mean±SD      | Median | Maximum | Minimum |
| Normal         | 4.63±0.165   | 4.6    | 4.9     | 4.4     | 3.35±0.796   | 3.10   | 4.4     | 2.45    |
| Osteopenia     | 3.06±0.286   | 3.08   | 3.5     | 2.7     | 2.30±0.494   | 2.5    | 2.9     | 1.6     |
| Osteoporosis   | 2.50±0.141   | 2.53   | 2.7     | 2.3     | 1.35±0.479   | 1.51   | 1.9     | 0.5     |

Although both the SVE and MCI demonstrated significant association with the BMD in our present study, these indices may vary from observer to observer as they are qualitative indices and hence are subjective.

The mental index exhibited a strong positive correlation with the BMD. The mental index was found to be significantly higher in the normal BMD group when compared to the subjects who had a lower BMD. This is in accordance to the study conducted by Devlin et al.[27] in 2002 who assessed the mental index in 74 female patients and found that the mental index had a strong positive correlation with the BMD and was lower in osteoporotic patients compared to the normal patients. Similar results have been obtained by Esin Haster et al.[33] in 2011, Bosky Gaur et al.[32] in 2013.

The antegonial index demonstrated a strong positive correlation with the BMD. The antegonial index was found to be higher in the normal group than the osteoporotic group and this was found to be statistically significant. This is in accordance to a study by Pankaj Bodade et al.[29] in 2015 who analysed the antegonial index in 32 postmenopausal women and found that the antegonial index had a strong positive correlation with the measured BMD.

However, a few studies like those conducted by Akshita et al.[33] in 2017, Bosky Gaur et al.[32] in 2013 contradicted these results. These differences may be due to the difficulty in establishing a ‘best fit line’ along which the width of the mandibular cortex is measured in antegonial index. Antegonial index may also be influenced by the status of the dentition.

A close bi-directional relationship seems to exist between osteoporosis, jaw bone health, and oral health. Compromised periodontal health can also lead to osteoporosis.[39]

In addition to this, the treatment of osteoporosis can also affect the jaw bones. Bisphosphonate therapy in the management of osteoporosis, may cause necrosis of the jaws. Since dental treatment can be a causative factor in the development of bisphosphonate-related osteonecrosis of the jaws, any invasive dentoalveolar procedures must be carried out with extreme caution in patients who are undergoing bisphosphonate therapy. Moreover, any osteoporotic patient for whom therapy with bisphosphonate is being contemplated, should ideally have their dental health assessed prior to initiating the therapy.

Since the pathogenesis and treatment of osteoporosis can affect the jaw bones and oral health, family physicians and primary healthcare workers must keep in mind to make appropriate dental referrals whenever a patient has been diagnosed with osteoporosis to help avoid the onset of osteoporosis/ bisphosphonate associated oral diseases.[22,33,34]

**Conclusion**

In the present study, it has been observed that all the parameters which were identified and measured in an orthopantomogram like simple visual estimation, mandibular cortical index, mental index, and antegonial index demonstrated a significant difference between the BMD categories. All the measured quantitative indices demonstrated a positive correlation with the BMD.

Hence, the overall outcome of the study suggests that panoramic radiography can be used as a tool for screening and identifying subjects who are likely to have osteoporosis. Panoramic radiographs may serve as an initial diagnostic modality in postmenopausal patients who are at a high risk for osteoporosis. These patients can then be subjected to further diagnostic modalities for evaluating the BMD.

A review of the current literature reveals limited data exist regarding the correlation of systemic BMD with mandibular panoramic indices in a South Eastern Indian Population. Further studies similar to this one with larger sample size may be needed to establish a cut-off value for the quantitative indices and to validate panoramic radiography as an accurate tool to depict the patients who are likely to have osteoporosis.

Since osteoporosis is a disease which can manifest in the jaw bones as demonstrated in this study and can also affect oral health and vice versa, a well-coordinated interdisciplinary approach involving primary healthcare workers/family physicians and oral physicians will result in better management of these patients and help avoid possible disease-related and treatment-related complications.

**Declaration of patient consent**

The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient (s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.
Key Messages

The clinical relevance of osteoporosis lies in the increased risk of fracture among these patients. Osteoporosis often goes undiagnosed until a fracture occurs. DXA scans are scarce and expensive. Osteoporotic changes occurring in the mandible may be visualized with the help of panoramic radiographs. This will help identify patients who may have osteoporosis at an early stage before the disease progresses. Osteoporosis can affect oral health and result in periodontitis. Periodontal infections may also induce osteoporosis by activating RANKL. Bisphosphonate therapy in osteoporosis can lead to osteonecrosis of the jaws. Since there exists a bi-directional relationship between osteoporosis and oral health, a coordinated interdisciplinary approach between the primary healthcare workers/family physician and the dentist is necessary to manage osteoporotic patients in an efficient manner.

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Conflicts of interest

There are no conflicts of interest.

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