Original Article

Digital Panoramic Radiographic Indices Correlated with BMD Status

Net-nada Chongruangsri[1], Pornchai Jansisyanont[1], Vannaporn Chuenchompoonut[2], Tanawat Amphansap[3], Nitirat Stitkitti[3]

[1]Department of Oral and Maxillofacial Surgery, Faculty of Dentistry, Chulalongkorn University, Bangkok, Thailand

[2]Department of Radiology, Faculty of Dentistry, Chulalongkorn University, Bangkok, Thailand

[3]Department of Orthopedics, Police General Hospital, Bangkok, Thailand

Abstract

This study aimed to investigate the correlation between panoramic radiographic indices and osteoporosis, and determine whether digital panoramic radiographs could be used as a screening tool for the diagnosis of osteoporosis in Thai postmenopausal women. This was a cross-sectional study of sixty Thai postmenopausal women with and without osteoporosis. The participants were divided into three groups based on a diagnosis of their bone mineral density (BMD) by dual-energy X-ray absorptiometry (DXA): normal, osteopenia, and osteoporosis equally in each group. Panoramic radiographic indices measured are mental index (MI) and mandibular cortical index (MCI). The Pearson's correlation test was performed to analyze the correlation among MI, MCI, and BMD t-score. To determine the ability of the indices, to classify disease and investigate the cut-off value of MI for diagnosis of osteoporosis, the receiver operating characteristic analysis was performed. The *P* value was set at 0.05. From this study, it was found that MCI were significant differences between the three groups ($p<0.001$). There were correlations between panoramic radiographic indices and BMD in the regions of the hip bone and the lumbar spine. MI was positively correlated with BMDs: lumbar spine: r=0.566, femoral neck: r= 0.554, and total hip: r= 0.524 ($p<0.001$). MCI was negatively correlated with BMDs: lumbar spine: r= -0.514, femoral neck: r= -0.507, total hip: r=-0.513 ($p<0.001$). The cut-off value of MI for the reduced skeletal BMD groups (both osteopenia and osteoporosis groups) was 3.9 mm and for the diagnosis of osteoporosis was 3.8 mm. The results of this study suggest that MI and MCI can be used as a screening tool for the diagnosis of osteoporosis in Thai postmenopausal women.

Keywords: Bone mineral density, Osteoporosis, Panoramic

Received Date: Oct 27, 2020 **Revised Date:** Nov 12, 2020 **Accepted Date:** Jan 26, 2021

Doi: 10.14456/jdat.2021.21

Correspondence to:

Pornchai Jansisyanont, Department of Oral and Maxillofacial Surgery, Faculty of Dentistry, Chulalongkorn University 34 Henri Dunant Rd. Pathum Wan Bangkok 10330 Tel: +662218-8581 Fax: +662218-8581 Email: jpornchai@hotmail.com

Introduction

Osteoporosis is a disease characterized by low bone mass and structural deterioration of bone tissue which leads to bone fragility and increases the risk of fractures in the hip, spine, and wrist. Men, as well as women, are affected by osteoporosis that are preventable and treatable. Osteoporosis is considered as a silent disease because bone loss occurs without symptoms or signs. When bones are weak, a sudden strain, bump, or fall can cause a hip to fracture or a vertebra to collapse. Collapsed vertebrae may initially be felt or seen in the form of loss of height.[1]

Osteoporosis causes more than 8.9 million fractures annually. In 2000, there were an estimated 9 million new osteoporotic fractures, of which 1.6 million were at the hip, and 1.4 million were clinical vertebral fractures. Following the hip fractures, up to 20 % of patients died in the first year, mostly due to pre-existing medical conditions. Less than half of those who survived a hip fracture regained their previous level of function.[2]

Osteoporosis is also considered as a public health problem in Thailand. Surveys (2008, 2011) on the prevalence of osteoporosis in Thai females at Thai governmental hospitals and in communities in every region in the country indicated that an estimated 20 % of females aged more than 40 years old would have lumbar spine osteoporosis and 12 % would have femoral neck osteoporosis. Hip fracture was a common osteoporotic fracture with the most clinical complications. During the first year after hip fracture, the average death rate was 21.1 %; 9.3 times higher than that of the general population. Increased hip fracture incidence in Thailand in 2025 and 2550 are expected to equal 34,246 and 56,443 cases, respectively.[3]

Bone mineral density (BMD) is considered to be the standard measure for the diagnosis of osteoporosis and the assessment of fracture risk. The majority of fragility fractures occur in patients with BMD in the osteopenic range. The measurement of BMD is performed by dual x-ray absorptiometry (DXA). It is expressed in absolute terms as grams of mineral per square centimeter scanned (g/cm^2). A patient's BMD can also be related to a reference value for young normal adults of the same sex by using the T-score. The T-score is the number of standard deviations that the BMD value of a patient is above or below the reference value for a healthy thirty-year-old adult. If the T-score for BMD assessed by DXA at the femoral neck or spine is defined as a value for BMD 2.5 SD or more below, the diagnosis is osteoporosis. This definition became widely used, and osteoporosis was subsequently defined by the standard deviation rather than by an absolute value of BMD.[4]

The fixed risk factors of osteoporosis are age 50 and older, female, previous fracture or family history of fracture, menopause, long term glucocorticoid, rheumatoid arthritis and ethnicity. A previous study of ethnicity and osteoporosis reported that osteoporosis is more common in Caucasian and Asian populations.[5] Hence, according to international guidelines, all women over 65 years old should perform bone densitometry, as should younger postmenopausal women with associated risk factors.[6]

Although a bone densitometry evaluation is important, it is not included in annual physical check-up programs. But the dentist is often the most regularly visited doctor for the elderly population who are also under the risk of osteoporosis and associated fractures. Dental radiographs are the most frequently used imaging modalities for these patients. Accordingly, there were several studies that investigated the correlation of digital panoramic radiograph and BMD score to identify patients with osteoporosis. However, the methods of these studies did not allow for a definitive conclusion on using panoramic radiographic indices to determine BMD status. Some studies investigated only in the osteoporosis group7-8 or osteopenia and osteoporosis[9] that did not compare the indices to the normal group. There was one study that classified patients as low skeletal BMD if they were osteopenia or osteoporosis and all other patients were classified as normal.[10] Nevertheless, there were studies that compared

the panoramic radiographic indices in osteoporosis, osteopenia and normal but did not clarify if their participants were already treated for osteoporosis or not.[11-12] Moreover, until now, previous studies using panoramic radiographic indices were performed in Caucasian[7-10] and other Asian[11-15] populations such as Korean, Japanese, Indian but there have not been a study with a Thai population.

Several panoramic radiographic indices were used in many studies. According to the study[13] that evaluated correlations between seven panoramic radiomorphometric indices and BMD in postmenopausal women, it was concluded that the most accurate indices were the mental index (MI), mandibular cortical index (MCI), and visual estimation of cortical width. Nevertheless, there was a study reported that the mean sensitivity in identifying women with skeletal low BMD by simple visual estimation of the mandibular cortex was low.[14] Overall low mean sensitivity indicated that about half of the women in the study with low skeletal BMD were not identified by the simple visual estimation. MI was a quantitative index, whereas MCI was a qualitative index. These indices were the most practical and reproducible for screening.[15] Thus, this study aimed to investigate the correlation between the digital panoramic radiographic indices MI and MCI and BMD score in Thai postmenopausal women and find out whether digital panoramic radiograph may be used as a screening tool for osteoporosis as well.

Materials and Methods

The present cross-sectional study evaluated the correlation of MI and MCI of 60 digital panoramic radiographs from Thai postmenopausal women and BMD scores at lumbar spine, femoral neck and total hip. Sample size estimation was perform by G*power version 3.1.9.2. The effect size (f) of 0.42 was calculated from previous study16 with significance level (α) of 0.05 and power (1-β) of 0.8. This study was approved by the human research ethics committee of the Faculty of Dentistry, Chulalongkorn University, HREC-DCU 2019-055 and Police General Hospital IRB, Bangkok, Thailand. All participants signed an informed consent agreement.

The participants were postmenopausal women who came to Police General Hospital for first-time bone densitometry tests. All BMD scans were conducted with Horizon® DXA System by a certified radiologist using standardized procedures and following protocols recommended by the manufacturer. The T-score was calculated and the diagnosis was based on WHO criteria. Osteoporosis was defined as a BMD T score of –2.5 or less, low bone mass (osteopenia) as a BMD T-score between –1 and –2.5 and normal as a BMD T-score above -1.[17] All panoramic radiographs were taken at Faculty of Dentistry, Chulalongkorn University using Carestream Kodak 9000C.

Eligibility Criteria

The inclusion criteria were: being a healthy female who had not had a period for one year (postmenopausal) with a panoramic radiograph that had adequate quality for locating the mental foramen, and the radiographic images had no bony pathology lesion at the mandible, hip or spine.

The exclusion criteria included: a previous uncontrolled or severe systemic condition such as cardiovascular disease, endocrine disorders, neoplastic disease, renal failure, rheumatoid arthritis, parathyroid, multiple myeloma or other metabolic bone diseases, or a history of radiation therapy or surgery/trauma in the head and neck region. Patients who had lesions, prostheses and/or fractures at the hip and spine area were excluded as well. Patients who smoked, consumed alcohol and/or currently were using medications such as steroids, chemotherapy, thyroid hormones and bisphosphonate or any antiresorptive and anti-anabolic drugs also were excluded.

Data Collection

Participants were divided into three groups based on diagnosis of osteoporosis: normal (n=20), osteopenia (n=20) and osteoporosis (n=20). Age, height, weight, BMI, and BMD scores were recorded.

In this study, two panoramic radiographic indices, MI and MCI, were measured by the main researcher under the close supervision of an experienced radiologist, using Infinitt® software. MI was assessed by measuring the lower border mandibular cortical width in the mental foramen

region. A line parallel to the long axis of the mandible and tangential to the inferior border of the mandible was drawn. A line perpendicular to this tangent intersecting the inferior border of the mental foramen was constructed, along which mandibular cortical width was measured[18] (Fig. 1).

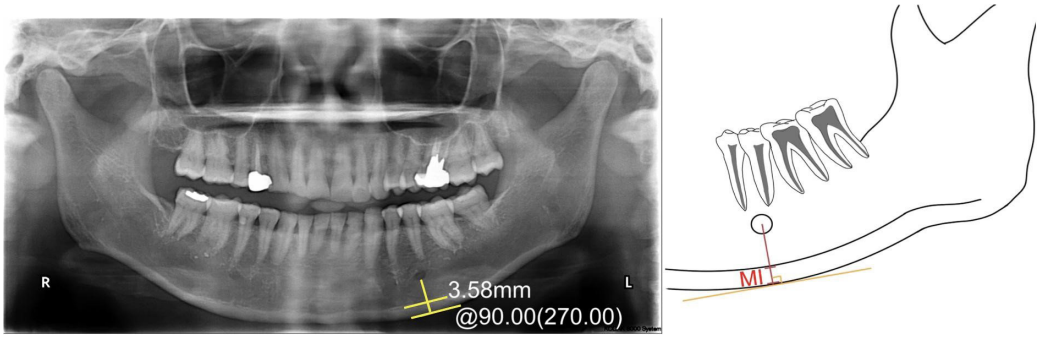

Figure 1 *A panoramic radiograph showing MI measurement. A line parallel to the long axis of the mandible and tangential to the inferior border of the mandible was drawn. A line perpendicular to this tangent intersecting the inferior border of the mental foramen was constructed, along which mandibular cortical width was measured*

MCI was measured by detecting the inferior cortex on both sides of the mandible at a distal edge of the mental foramen. Participants were classified into three groups according to the following classification of Klemetti[19]: C1 = the endosteal margin is even and sharp, C2 = the endosteal margin presents lacunar resorption or cortical residues, C3 = the cortical layer is clearly porous, with heavy endosteal cortical residues (Fig. 2).

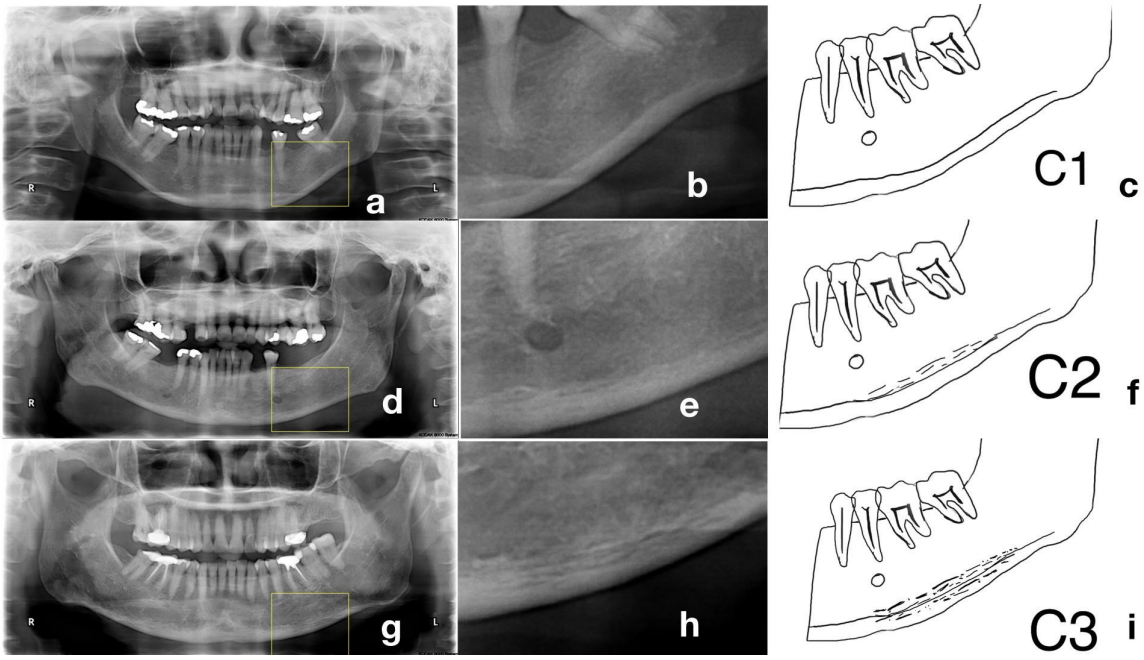

Figure 2 *Example of radiographic appearance of mandibular cortical morphology classified by mandibular cortical index (MCI). Figure A is the example of radiographic appearance of mandibular classified as C1. Figure B is a magnification of an example of radiographic appearance of mandibular classified as C1. Figure C is the illustration of mandibular morphology classified as C1. Figure D is the example of radiographic appearance of mandibular classified as C2. Figure E is the magnification of an example of radiographic appearance of mandibular classified as C2. Figure Fis the illustration of mandibular morphology classified as C2. Figure G is the example of radiographic appearance of mandibular classified as C3. Figure H is the magnification of an example of radiographic appearance of mandibular classified as C3. Figure I is the illustration of mandibular morphology classified as C3*

The MI which were the average value of the right and left sides of the mandible were used for statistical analysis in this study. For MCI, this study evaluated this index both the right and left sides of the mandible separately.

Statistical Analysis

The collected data were analyzed for the mean (±SD) and percentage. Each MI measurement was repeated twice on the right and the left sides, respectively, and the average value was calculated. MCI measurement calculated the right and the left sides separately. Intraclass correlation coefficient (ICC) was used to quantify intraobserver agreements and for measuring the reliability of measurement for data that had been collected as groups or sorted into groups. The intraclass correlation was also done to investigate that the measurements can be replicated. The relationship between panoramic radiographic indices and BMD was calculated by Pearson's correlation analysis. One-way ANOVA test was used to determine statistically significant difference between MI and the osteoporosis group and the osteopenia and the normal group. Kruskal-Wallis test was used to determine statistically significant difference between MCI and the osteoporosis group and the osteopenia and the normal group. The receiver operating characteristic (ROC) analysis was used to evaluate the ability of MI and MCI to diagnose osteoporosis or osteopenia. The optimal MI cut-off values for diagnosing osteoporosis and osteopenia were determined by using Youden's index. All statistical analysis was conducted with SPSS statistical software (version 21 software SPSS Inc., Chicago, IL.). A statistical significance level of 5% was considered.

Results

The intra-observer ICC was determined. It was found that the intraclass correlation coefficient values for intraobserver agreement in this study were 0.988 and at 95% CI was 0.980-0.993.

The mean age of the participants in this study was 58.62±10.03 (range 49-87). When divided by the diagnosis group, the mean age of the normal group was 56.95±5.89 (range 49-73), the osteopenia group was 64.9±9.06 (range 51-82), and the osteoporosis group was 69.75±10.4 (range 51-87) (Table1).

Table 1 *Basic characteristics and parameters of participants (a,b,c Different letters show significant differences, p<0.05)*

	Normal (N= 20)	Osteopenia (N=20)	Osteoporosis (N=20)
	Mean ± SD	Mean ± SD	Mean ± SD
Age (years old)	56.95±5.89[a]	64.9±9.06[b]	69.75±10.4[b]
Weight (kg)	69.87± 11.94[a]	56.27±8.21[b]	49.74±7.06[b]
Height (cm)	160.72±6.08[a]	153.64±5.37[b]	154.75±4.91[b]
BMI	27.09±4.63[a]	23.83±3.11[b]	20.76±2.76[c]
BMD t-score			
Lumbar Spine	0.83±1.47[a]	-1.32±0.92[b]	-2.54±0.79[c]
Femoral Neck	-0.04±0.98[a]	-1.58±0.49[b]	-2.61±0.90[c]
Total Hip	0.54±1.05[a]	-1.18±0.52[b]	-1.94±0.83[c]
MI (Average)	4.53±0.6[a]	4.00±0.57[b]	3.08±0.47[c]

There were significant differences of ages between normal and osteopenia (p=0.014), normal and osteoporosis (p<0.001), but no significant difference between osteopenia and osteoporosis group.

The mean height of the normal group was 160.72 cm, the osteopenia group was 153.64 cm, and the osteoporosis group was 154.75 cm (Table1). There were significant differences in height between normal and osteopenia (p<0.001), normal and osteoporosis (p=0.003), but there was no significant difference between osteopenia and osteoporosis group which was the same as the results of age and weight.

The osteoporosis group had the lowest mean weight which was 49.74 kg (Table1). There were significant differences of weight between normal and osteopenia (p<0.001), normal and osteoporosis (p<0.001), but no significant difference between osteopenia and osteoporosis group.

The osteoporosis group had the lowest mean BMI which was 20.76 (Table 1). There were significant differences of BMI between 3 groups, normal and osteopenia (p=0.016), normal and osteoporosis (p<0.001), and osteopenia and osteoporosis (p=0.024).

The mean BMD t-score at the lumbar spine, femoral neck, and total hip of the normal, osteopenia and osteoporosis groups were evaluated. It was found that the mean BMD t-score was 0.83, -1.32, and -2.54, respectively, the mean femoral neck BMD t-score osteoporosis was -0.04, -1.58, and -2.61 respectively, and the mean total hip BMD t-score was 0.54, -1.18, and -1.94, respectively (Table 1). There were significant differences of lumbar spine BMD t-score between the three groups, normal and osteopenia (p<0.001), normal and osteoporosis (p<0.001), and osteopenia and osteoporosis (p=0.002). There were significant differences of femoral neck BMD t-score between the three groups, normal and osteopenia (p<0.001), normal and osteoporosis (p<0.001), and osteopenia and osteoporosis (p=0.001). There were significant differences in total hip BMD t-score between the three groups, normal and osteopenia (p<0.001), normal and osteoporosis (p<0.001), and osteopenia and osteoporosis (p=0.015). The mean BMD t-score at femoral neck was the lowest among lumbar spine and total hip in the osteopenia and osteoporosis group.

The panoramic radiographic indices in this study were MI and MCI. The mean MI which was the average value of the right and left sides had no significant difference. The average MI of the mandible in normal, osteopenia, osteoporosis groups were 4.53, 4.00, and 3.08 respectively (Table 1). The MCI classified the morphology of the cortical border of the mandible into three groups: C1, C2, and C3. The results of MCI in this study were similar on both the right and left sides of the mandible. In the normal group, C1 was the most found index (90 %) and followed by C2 (10 %). C3 was absent in the normal group. In osteopenia, the most found index was C2 (60 %) and followed by C1 (30 %). In the osteoporosis group, C2 (55 %) was also the most found index and followed by C3 (40 %) as shown in Table 2.

Table 2 *Mandibular cortical index (MCI) distribution of participants*

	Normal (N=20) N (%)	Osteopenia (N=20) N (%)	Osteoporosis (N=20) N (%)
MCI			
C1	18 (90%)	6 (30%)	1 (5%)
C2	2 (10%)	12 (60%)	11 (55%)
C3	0 (0%)	2 (10%)	8 (40%)

The MI and MCI were significantly different between the normal, osteopenia, and osteoporosis groups (p<0.001). The analysis of Pearson's correlation between radiographic indicators of mandible and BMD t-score are both correlated. MI was positively correlated with BMDs: lumbar spine: r=0.566, femoral neck: r=0.554, and total hip: r=0.524 (p<0.001), respectively. MCI was negatively correlated with BMDs: lumbar spine: r=-0.514, femoral neck: r=-0.507, total hip: r=-0.513 (p<0.001), respectively as shown in Table3.

Table 3 *Correlation between radiographic indicators of mandible condition and BMD*

Correlation coefficient; r (*p*-value)	BMD t-score at lumbar spine	BMD t-score at femoral neck	BMD t-score at total hip
MI	0.566 (<0.001)	0.554 (<0.001)	0.524 (<0.001)
MCI	-0.514 (<0.001)	-0.507 (<0.001)	-0.513 (<0.001)

The area under the ROC curve were used for evaluating the ability of MI and MCI to classify the reduced BMD group (both osteopenia and osteoporosis) which were 0.845 and 0.875 (Fig. 3, 4) and the ability of MI and MCI to classify the osteoporosis group were 0.934 and 0.831, respectively (Fig. 5, 6).

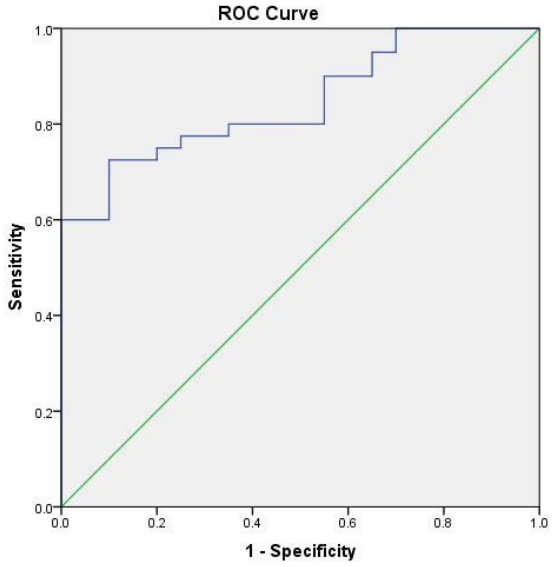

Figure 3 *The receiver operating characteristic (ROC) curve to determine the ability of mental index (MI) to evaluate reduced BMD group (Osteopenia and osteoporosis). Area under the ROC curve = 0.845*

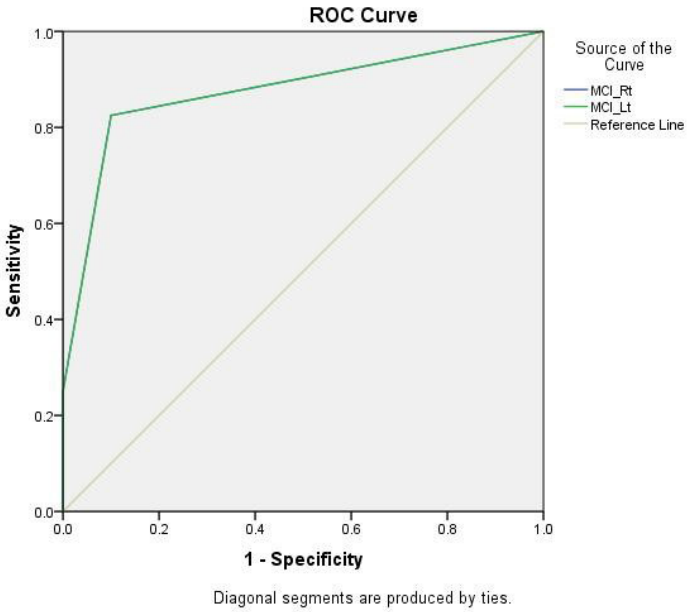

Figure 4 *The receiver operating characteristic (ROC) curve to determine the ability of mandibular cortical index (MCI) to evaluate reduced BMD group (Osteopenia and osteoporosis). Area under the ROC curve = 0.875*

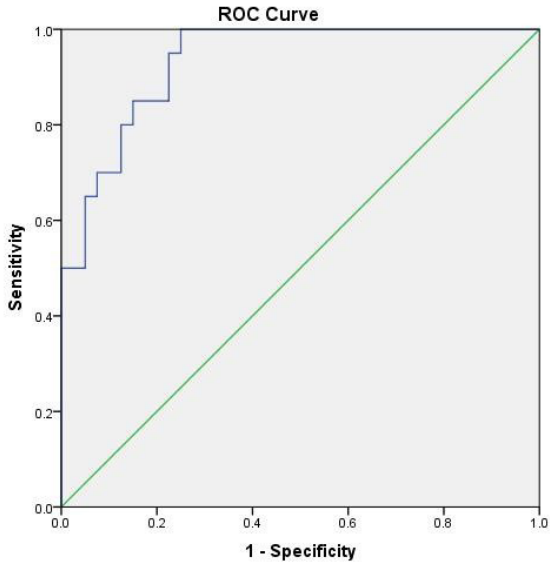

Figure 5 *The receiver operating characteristic (ROC) curve to determine the ability of mental index (MI) to evaluate osteoporosis. Area under the ROC curve = 0.934*

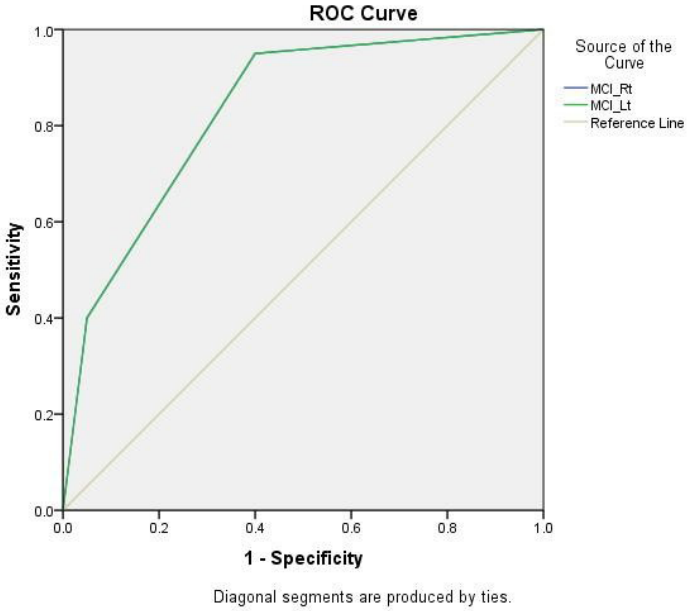

Figure 6 *The receiver operating characteristic (ROC) curve to determine the ability of mandibular cortical index (MCI) to evaluate osteoporosis. Area under the ROC curve = 0.831. The optimal cut-off value of MI for the reduced BMD group was 3.9 mm at sensitivity = 72.5% and specificity = 90%, and for the diagnosis of osteoporosis group was 3.8 mm at sensitivity 100% and specificity = 75% (Table 4)*

Table 4 *Diagnosis performance of mental index (MI) in predicting reduced BMD and osteoporosis*

	Mental index (MI)	Sensitivity	1-Specificity	Specificity	Youden's index	Diagnostic accuracy
Reduced BMD	3.9175	0.725	0.1	0.9	0.625	88.3 %
Osteoporosis	3.8075	1	0.25	0.75	0.75	77.5 %

For MCI, the sensitivity of the index was 82.5 % and specificity was 90 % for the diagnosis of the reduced BMD group. The sensitivity and specificity of MCI for the diagnosis of osteoporosis group were 95 % and 60 % respectively (Table 5).

Table 5 *Diagnosis performance of mandibular cortical index (MCI) in predicting reduced BMD and osteoporosis*

	Sensitivity	1-Specificity	Specificity	Youden's index	Diagnostic accuracy
Reduced BMD	0.825	0.1	0.9	0.725	89.3 %
Osteoporosis	0.95	0.4	0.6	0.55	63.5 %

Discussion

The aim of the present study was to investigate whether the panoramic radiograph can be a screening tool for the diagnosis of osteoporosis in Thai postmenopausal women or not. It was found that based on the results of this study, there were significant differences of ages between normal and osteopenia (p=0.014) and normal and osteoporosis (p<0.001). Because with increasing age, there is also a significant reduction in bone formation. Studies have shown that when a woman's estrogen levels drop after menopause, bone loss speeds up.[20] Thus, the reason that there was no significant differences the between osteopenia and osteoporosis group maybe because the timing of the onset and the duration of the menopausal transition and the timing of the final menstrual period were not the same in every women which was why the ages of women with osteopenia and osteoporosis were not different.[21]

The body mass index (BMI) is a measure that uses height and weight to work out if the weight is healthy. The BMI calculation divides an adult's weight in kilograms by their height in meters squared. For BMI and obesity, the World Health Organization defines obesity as a body mass index (BMI) ≥30, overweight as a BMI=25 to 29.9, and underweight as a BMI<18.5. A previous study reported that low BMI increases fracture risk, possibly because low BMI is associated with low BMD, less soft tissue, and muscle weakness.[22] In the same way as the results from this study, there were significant differences of BMI between the three groups, normal and osteopenia (p=0.016), normal and osteoporosis (p<0.001), and osteopenia and osteoporosis (p=0.024). However, the average BMI of the participants in this study was not considered as underweight. This data showed that not only postmenopausal women who were in the underweight group had a risk for osteoporosis but postmenopausal women who were in the normal weight group could be at risk as well, therefore BMI is not a good indicator.

The results of the present study demonstrated that panoramic indices (MI and MCI) were correlated with BMD t-score which are in accordance with previous studies[22-25] that MI was positively correlated with BMD t-score and MCI was negatively correlated with BMD t-score. MI was positively correlated with BMDs: lumbar spine: r=0.566, femoral neck: r= 0.554, and total hip: r= 0.524 (p<0.001), respectively. MCI was negatively correlated with BMDs: lumbar spine: r=-0.514, femoral neck: r=-0.507, total hip: r=-0.513 (p<0.001), respectively. Correlation is an effect size and can describe the strength of the correlation using the guideline for the absolute value of r. When r is between 0.40-0.59 it would be considered as moderate correlation. Thus, from this study, the strength of the correlations between MI and MCI and three BMD t-scores were moderately positive and moderately negative, respectively.[23]

The area under the ROC curve was used for evaluating the ability of MI and MCI to classify the reduced BMD group which were 0.845 and 0.875. The ability of MI and MCI to classify the osteoporosis group were 0.934 and 0.831, respectively. All the results from

this study were higher than other studies which meant the ability of the indices to classify the disease in this study were better. A previous study[24] reported that the area under the ROC curve in the appearance of MCI observed on digital panoramic radiographs for the reduced BMD group was 0.71. Another study[13] showed that the area under the ROC curve for identifying women with reduced BMD and osteoporosis were 0.751 and 0.703 for MI which were lower than this study as well.

The optimal cut-off value of MI for diagnosis of osteoporosis in this study was 3.8 mm which had a sensitivity of 100 %, specificity 75 % and for diagnosis of reduced BMD was 3.92 which had a sensitivity of 72.5 %, and a specificity of 90 %. Based on our results, Thai post-menopausal women with mandibular cortical thickness below 3.9 mm should be referred for bone densitometry evaluation. These results were similar to those found in other studies but there were some differences. A previous study of [10] the European population concluded that the thinnest MI (<3 mm) should be referred for further osteoporosis investigation. Another study that looked at the Brazilian population[13] reported that the MI optimal cut-off value for identifying women with osteoporosis was 3.15 mm and for reduced BMD was 3.38 mm. A study in Saudi Arabia[11] found that if the cut-off value of MI is <3 mm considered abnormal; sensitivity, specificity were 10.3 %, 98.4 % respectively. But, when the MI cut-off point was changed to 4.5 mm, sensitivity and specificity were found to be 76.9 %, and 54.1 % respectively. Another study done in Korea[8] reported a lower cut-off value of MI than in other studies. The optimal cut-off value of MI was 2.22 mm (sensitivity 67.9 %, specificity 78.5 %) for the diagnosis of osteoporosis. It was supposed that the reasons for difference cut-off value in every study would be the difference of statistical analysis for determining cut-off value, the difference in the magnifying ratio of the panoramic radiographs, ethnic/race differences which play an important role for the variation in BMD.

The sensitivity of MCI for diagnosis of reduced BMD was 82.5 % which was close to the study[24] in Brazil. According to a study[9] in Iran and compared with the results from this study, the distribution of MCI tended to be similar. The most indices found in osteopenia and osteoporosis patients were C2, and followed by C1 and C3, respectively. However, in a study8 of Korean postmenopausal women with osteoporosis, dissimilar distribution was found. It was reported that MCI distribution was 48.9 % for C2, 30.4 % for C3, and 23.7 % for C1. Nevertheless, C2 is still the most index that found in postmenopausal women with reduced BMD. Thus, the suggestion for the present study in Thai postmenopausal women who have mandibular cortical morphology that identified as C2 or C3 should be referred to evaluate the bone densitometry. The meta-analysis study[15] reported that MCI could be a reliable tool for screening the early BMD loss of osteopenia group in females with a summary point above 80 % sensitivity and also around 60 % of specificity. MCI for the reduced bone density group may have a potential value for screening because of high sensitivity. The index that has high sensitivity will describe as rarely missing participants with the disease via this index.

This study was based on ADA recommendations with the ALARA consideration that digital panoramic radiographs have low dose of radiation compared to an annual chest x-ray check-up. Furthermore, the protocol for the first visit at the Faculty of Dentistry, Chulalongkorn University included an oral examination, a panoramic radiograph and bite-wing. Bite-wing radiograph is necessary for dental caries evaluation. Meanwhile, a panoramic radiograph is also necessary for the dental treatment plan, because some lesions, such as cyst or tumors, were accidentally found in a panoramic radiograph. However, this study showed that panoramic images might have an additional benefit for suspected osteoporosis in post-menopausal women.

The present study has several limitations. First, this study only focuses on postmenopausal women and did not include elderly men. Second, this study could not report the change of panoramic radiographic indices after the patient received treatment with antiresorptive or anti-anabolic drugs.

Third, a small sample size causes low reliability of indices and cut off values in this study. Lack of a number of sample sizes was one of the limitations in this study. Further studies with the above considerations need to be done.

Conclusion

In conclusion, the results of this study suggest that MI and MCI can be used as a screening tool for the diagnosis of osteoporosis in Thai postmenopausal women. In daily practice, both MI and MCI can be useful tools for all dental specialists including general dentists. However, taking the MI measurement will be easier when it is done in a digital radiograph. But, an MCI will be more often recommended if the digital panoramic radiograph is not available because it is viable and does not require any measurement program.

Acknowledgments

The authors would like to thank the Division of Radiology, Police General Hospital, and the radiological technologist, Department of Radiology, Faculty of Dentistry, Chulalongkorn University, and Dr. Kevin Tompkins for language editing and manuscript revision.

References

1. Lorentzon M, Cummings SR. Osteoporosis: the evolution of a diagnosis. ***J Intern Med*** 2015;227(6):650-51.
2. Keene GS, Parker MJ, Pryor GA. Mortality and morbidity after hip fractures. ***BMJ*** 1993;307(6914):1248-50.
3. Songpatanasilp T, Sritara C, Kittisomprayoonkul W, Chaiumnuay S, Nimitphong H, Charatcharoenwitthaya N, *et al.* Thai Osteoporosis Foundation (TOPF) position statements on management of osteoporosis. ***Osteoporos Sarcopenia*** 2016;2(4):191-207.
4. Unnanuntana A, Gladnick BP, Donnelly E, Lane JM. The assessment of fracture risk. ***J Bone Joint Surg Am*** 2010;92(3):743-53.
5. Cauley JA. Defining ethnic and racial differences in osteoporosis and fragility fractures. ***Clin Orthop Relat Res*** 2011;469(7):1891-99.
6. Baccaro LF, Conde DM, Costa-Paiva L, Pinto-Neto AM. The epidemiology and management of postmenopausal osteoporosis: a viewpoint from Brazil. ***Clin Interv Aging*** 2015;10:583-91.
7. Roberts MG, Graham J, Devlin H. Image Texture in Dental Panoramic Radiographs as a Potential Biomarker of Osteoporosis. ***IEEE Trans Biomed Eng*** 2013;60(9):2384-92.
8. Kim OS, Shin MH, Song IH, Lim IG, Yoon SJ, Kim OJ, *et al.* Digital panoramic radiographs are useful for diagnosis of osteoporosis in Korean postmenopausal women. ***Gerodontology*** 2016;33:185-92.
9. Navabi N, Motaghi R, Rezazadeh M, Balooch H. Relationship between Two Panoramic Radiography Indices and Bone Mineral Density of Postmenopausal Women with Osteopenia and Osteoporosis. ***J Dent (Tehran)*** 2018;19(3):181-88.
10. Devlin H, Karayianni K, Mitsea A, Jacobs R, Lindh C, van der Stelt, *et al.* Diagnosing osteoporosis by using dental panoramic radiographs: The OSTEODENT project. ***Oral Surg Oral Med Oral Pathol Oral Radiol Endod*** 2007;104(6):821-28.
11. Mansour S, AlGhamdi AST, Javed F, Marzouk H, Khan EA. Panoramic radiomorphometric indices as reliable parameters in predicting osteoporosis. ***Am J Med Sci*** 2013;346(6):473-78.
12. Geary S, Selvi F, Chuang SK, August M. Identifying dental panoramic radiograph features for the screening of low bone mass in postmenopausal women. ***Int J Oral Maxillofac Surg*** 2015;44(3):395-99.
13. Leite AF, Figueiredo PTdS, Guia CM, Melo NS, de Paula AP. Correlations between seven panoramic radiomorphometric indices and bone mineral density in postmenopausal women. ***Oral Surg Oral Med Oral Pathol Oral Radiol*** 2010;109(3):449-56.
14. Lee K, Taguchi A, Ishii K, Suei Y, Fujita M, Nakamoto T, *et al.* Visual assessment of the mandibular cortex on panoramic radiographs to identify postmenopausal women with low bone mineral densities. ***Oral Surg Oral Med Oral Pathol Oral Radiol*** 2005;100(2):226-31.
15. Kinalski MA, Boscato N, Damian MF. The accuracy of panoramic radiography as a screening of bone mineral density in women: a systematic review. ***Dentomaxillofac Radiol*** 2020;49(2):20190149.
16. Gaur B, Chaudhary A, Wanjari PV, Sunil M, Basavaraj P. Evaluation of panoramic Radiographs as a Screening Tool of Osteoporosis in Post Menopausal Women: A Cross Sectional Study. ***J Clin Diagn Res*** 2013;7(9):2051-55.
17. National Osteoporosis F. Osteoporosis: Review of the Evidence for Prevention, Diagnosis and Treatment and Cost-Effective Analysis. ***Osteoporos Int*** 1998;8(Suppl 4):S7-80.
18. Taguchi A, Tanimoto K, Suei Y, Yamada T, Ohtsuka M, Sumida H, *et al.* The estimation of the radiomorphometric indices of the mandible using panoramic radiography. ***Shika Hoshasen*** 1993;33:309.
19. Klemetti E, Kolmakov S, Kröger H. Pantomography in assessment of the osteoporosis risk group. ***Eur J Oral Sci*** 1994;102(1):68-72.
20. Demontiero O, Vidal C, Duque G. Aging and bone loss: new insights for the clinician. ***Ther Adv Musculoskelet Dis*** 2012;4(2):61-76.
21. Gold EB. The timing of the age at which natural menopause occurs. ***Obstet Gynecol Clin North Am*** 2011;38(3):425-40.
22. Nielson CM, Srikanth P, Orwoll ES. Obesity and fracture in men and women: An epidemiologic perspective. ***J Bone Miner Res*** 2012;27(1):1-10.
23. Hinkle DE, Wiersma W, Jurs SG. Applied Statistics for the Behavioral Sciences. Boston, Mass: Houghton Mifflin, 2003
24. Valerio CS, Trindade AM, Mazzieiro ET, Amaral TP, Manzi FR. Use of digital panoramic radiography as an auxiliary means of low bone mineral density detection in post-menopausal women. ***Dentomaxillofac Radiol*** 2013;42(10):20120059.