Digital Panoramic Radiography as a Useful Tool for Detection of Bone Loss: A Comparative Study

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Abstract- This study was aimed to investigate the use of panoramic radiography in patients with low bone mineral density (BMD) in order to diagnose and prevent osteoporotic fractures. Panoramic radiographs of 60 patients (20 men and 40 women) aged from 40 to 70 years with cortical thicknesses of less than 3 mm in the mandibular angle were selected from patients referred to a dentomaxillofacial radiology clinic and were then examined for mandibular cortical angles. These were measured using Computed Radiography (CR) software. The bone densitometry was carried out using Dual Energy X-ray Absorptiometry (DEXA). Cortical thicknesses at the lower border of the mandibles were also measured by panoramic radiographs. Statistics analyses were then undertaken using Fisher's exact test, Chi-square, t-test, ANOVA and receiver operating characteristic (ROC) curve. In most cases, no significant difference in mandibular angle cortical thickness was found between those patients with a normal BMD and those patients with a lowered BMD (P=0.621). There was a relationship between the cortical thicknesses of the mandibular lower border, and vertebral and femoral BMD (P<0.0001), and there was a significant difference between the thickness of the mandibular lower border and BMD. The results of this study also revealed a new marker of osteoporosis on the mandibular lower border under the third molar. A thickness of 2.80 mm of the mandibular lower border was detected as a threshold for the measurement of bone densitometry in the chosen Iranian population. Panoramic radiography is effective for screening patients who are at risk of having decreased bone mineral density. Patients with a threshold of 2.80 mm thickness of the mandibular lower border should be considered as individuals likely to have osteoporosis associated low bone density.

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Introduction

Osteoporosis is defined as a generalized bone loss due to an imbalance between bone formation and resorption, which increases the risk of fractures (1,2). Patients diagnosed with osteoporosis endure bone pain and most have a poor quality of life (3). Osteoporosis leads to a decrease in bone mineral density (BMD), as well as, to an alteration in the bone's structure and protein content. The World Health Organization (WHO) reports that osteoporosis is a bone mineral density with standard deviation (SD) of -2.5 (4).

Osteoporosis occurs when the BMD is equal to or less than a SD of 2.5 in a young referral population; this is called a T score (10). WHO also states that the mean peak of the bone mass should be measured by Dual Energy X-ray Absorptiometry (DEXA) (4). DEXA is known as the most reliable method for measuring BMD (8,9). Osteoporotic fractures play a critical role depending on the gender and increasing of the age of the patient. 30-50% of females and 15-30% of males experience osteoporotic fractures throughout their life (5,7). It should also be noted that osteoporotic fractures can lead to death. Prevention of these fractures is thus a top healthcare priority (5). Images of the facial structure including the mandible and maxilla should be obtained by panoramic radiographs. Panoramic radiography is, moreover, a useful tool for diagnosing problems related

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to the jaw region (3,11).

Radiographic changes of the mandible could be signs of osteopenia (12). It also appears to be a reliable tool for osteoporosis screening (12).

The mandibular cortical width (MCW), which is measured by panoramic radiography, can help to diagnosis osteoporosis in postmenopausal women (13). A thin or eroded lower mandibular cortex that is visualized on dental panoramic radiographs could thus be utilised to diagnose low BMD in menopausal women (14,15,18). Cortical thickness can also be a useful parameter for detecting the deterioration of metabolic bone, so a gonial thickness of less than 1 mm is a good descriptive metabolic bone deterioration index (16,17). Taguchi *et al.* compared diagnostic positions of panoramic measurements with osteoporosis self-assessment tool to diagnose women with a low BMD and osteoporosis (with a T score of -2.5 or less) (8). Taguchi *et al.* recommend that dentists should refer menopausal women aged below 65 years for BMD on the basis of the panoramic radiographical results (8). Ishii also studied the diagnostic effect of mandibular alveolar bone deterioration for recognizing menopausal women with femoral osteoporosis to evaluate the effectiveness of digital panoramic radiography in the diagnosis of reduced bone mass in the femur and spinal column (13).

Materials and Methods

In this study, 60 patients with a cortical thickness of less than 3 mm in the mandibular angle were selected from patients referred over one year to a the dentomaxillofacial radiology clinic located in Yazd, Iran. This group consisted of 40 females and 20 males aged from 40 to70 years. Patient characteristics such as a current pregnancy, a history of spinal surgery, hyperthyroidism, diabetes, thyroid dysfunction, inflammatory diseases, bilateral pelvic prosthesis and, also, weight above 90 kg were exclusion criteria for the chosen group.

An approval (No. 94407) from the Ethics Board of Yazd University of Medical Sciences was obtained before conducting this investigation. All patients also provided informed consent prior to this study. All participants filled out the questionnaire that included information on age, gender, body mass index (BMI), and menopausal condition (for females).

The cortex of the mandibular angle of all patients was measured on both sides of all panoramic radiographs. These panoramic radiographs were obtained using a Plan Meca EC Proline machine (from Helsinki, Finland) and a CR, Direct Digitizer, Regius 110 machine made by Konica Minolta, Japan (80 KVP, 12mA and 18seconds). The cortex thickness was measured on both sides by a digital ruler of the Computed Radiography (CR) software. The patients then visited a rheumatologist and a bone densitometry study was requested if necessary. Densitometry was performed using one device (Hologic, 1NC35 Crosby Drive Bedford MA.01730 USA) for DEXA scanning of the spinal column and femur. The results of the densitometry were interpreted by the consultant rheumatologist were then sent to the patients to inform them about their bone density status. The patients were categorized into 3 groups on the basis of their BMD status (normal (T score ≥ -1), osteopenia (T score -1 to -2.5) and osteoporosis (T score -2.5)).

In this study, the results obtained from the measurement of the mandibular angle cortex were very close to the results obtained in several previous studies (8,12,13,15,18,19).

These results revealed a significant new marker of osteoporosis which was plotted on the cortex of the lower border of the mandible under the third molar. The mean thickness of the cortex was recorded to compare the cortex thickness of the lower border of the mandible under the third molar with the results of the DEXA measurement (Figure 1).

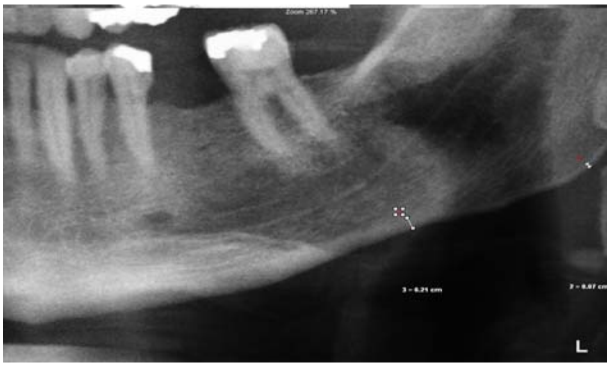
Statistical analysis

The data was coded after collection and then entered into a database using SPSS Version 17 software. The Fisher Exact and Chi-square tests were used to determine the relationship of the categorical parameters and t-test and ANOVA were used to compare and to analyze the continuous variables. A receiver operating characteristic (ROC) curve test was also used to determine the cut-off threshold of the panoramic radiography measurements in the diagnosis of the BMD state.

Results

This study evaluated the results obtained from the measurement of the mandibular angle cortex in 60 patients (33.3% males and 66.7% females, age 48.48±6.8 years). The mean BMI of the studied population was 28.15±3.92 kg/m^2. The mean cortex thicknesses of the mandible angle on the right and left sides were respectively 0.99 0.34 mm and 0.98±0.3 mm.

A: Individual with lowered BMD



B: Normal individual

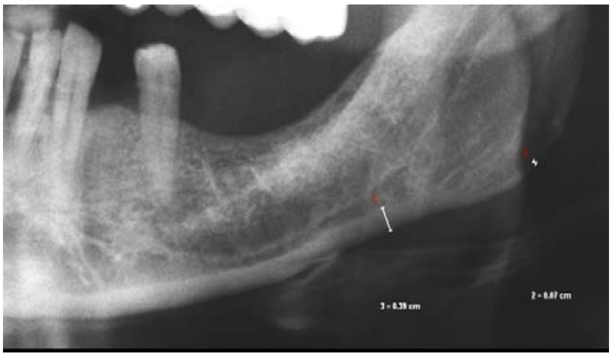


Figure 1. The Cortex thickness of the lower border of mandible, A: Individual with lowered BMD, B: A Normal individual.

The correlation coefficient of the mandibular cortex angle thickness on the left and right sides was 0.820 and that was significant (*P*<0.0001). Patients with a mandibular cortex thickness of less than 3 mm were sent for densitometry measurement. The results of the DEXA measurement showed that 80% of these cases displayed an abnormal BMD including osteopenia or osteoporosis. Table 1 describes the distribution of individuals with normal BMD, osteopenia and osteoporosis as determined by the DEXA method.

The mean mandibular angle cortex thickness on the right and left sides in osteoporotic individuals as compared to normal and osteopenic individuals, and the mean mandibular angular cortex thickness in individuals with a normal and an abnormal BMD are shown in tables 2 and 3. No significant relationship was seen by the t-test (*P*=0.621).

No significant relationship was observed between the mandibular angle cortex thickness (for both left and right sides) and the BMD state obtained by DEXA method.

Results obtained by the ANOVA test showed that there was a significant relationship between the BMI and the BMD state (*P*=0.026). Table 4 shows the mean BMI of the studied population on the basis of the BMD state. The BMI in osteoporotic individuals was reduced significantly by comparison with the BMI in osteopenic patients (*P*=0.007).

No significant relationship was observed between the mandibular angle cortex thickness (for both left and right sides) and the diagnosis of the BMD state as obtained from the DEXA method.

Table 1 Distribution of BMD in normal, osteopenia and osteoporosis cases on the basis of menopausal state.

BMD State	**Normal**		**Osteopenia**		**Osteoporosis**		**Total**	
Menopause	**Number**	**Percentage**	**Number**	**Percentage**	**Number**	**Percentage**	**Number**	**Percentage**
Menopause	0	0	9	69.2	4	30.8	13	100
Non	7	25.9	17	63	3	11.1	27	100
Total	7	17.5	26	65	7	17.5	40	100

P=0.069 (Chi-square)

Table 2. Distribution of BMD state (DEXA method) on the right and left sides of the mandibular angle cortex thickness.

BMD State	**Number**	**Mean cortex thickness (mm)**		**SD**		**Minimum (mm)**		**Maximum (mm)**		***P*-value**	
		Right	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**	**Left**
Normal	12	0.917	0.017	0.409	0.333	0.33	0.5	1.6	1.5	0.29	0.142
Osteopenia	35	1.063	1.006	0.291	0.307	0.6	0.3	1.8	1.8		
Osteoporosis	13	0.868	0.854	0.35	0.303	0.3	0.3	1.4	1.4		
Total	60	0.992	0.975	0.336	0.313	0.3	0.3	1.8	1.8		

Table 3. Distribution of BMD state (DEXA method) in the studied population on the basis of mean mandibular cortex angle thickness.

BMD State	Number	Mean mandibular angle cortex thickness (mm)	SD	Minimum (mm)	Maximum (mm)
Normal	12	0.89	0.37	0.3	1.5
Abnormal	48	0.94	0.31	0.3	1.8
Total	60	0.93	0.32	0.3	1.8

P=0.621 (t-test)

Although the DEXA results of the mandibular angle cortex thickness have shown that they are not suitable for use in diagnosing the BMD state, these results have, however, revealed a significant new indicator on the mandibular cortex under the lower-third molar tooth. This new point was selected and measured on the basis of the results of various studies (8,12,13,15,18,19). The relationship of the cortex thickness measurements was then studied and compared with the results of the DEXA measurements (Tables 5 and 6).

A Fisher's exact test was used to study the relationship between the panoramic radiography and the DEXA results; the results showed a significant relationship (*P*<0.000).

The use of a ROC curve test revealed that a cortex thickness of 2.80 mm (for the cut-off threshold) has the highest sensitivity and specificity for the diagnosis of the BMD state (sensitivity= 100%, specificity = 89.6%). The positive predictive value of this point was 100%, while the negative predictive value was 70.59%; similarly, the match index was 91.67%. Its coefficient correlation with DEXA was 0.622 and that was significant with a *P*-value of 0.000. A cortex thickness of 2.80 mm could thus be considered as a cut-off threshold, wherein the panoramic radiography and the densitometry measurement by DEXA confirm the other's results and, in cases of cortex thickness <2.80 mm, individuals would be abnormal with respect to their BMD and normal in cases of cortex thickness of more than 2.80 mm. Table 7 shows the relative frequency of osteoporotic individuals using the DEXA method on the basis of age.

Table 4. Mean BMI of the studied population on the basis of the BMD state (DEXA method).

BMD state	Number	Mean BMI (kg/m^2)	SD
Normal	12	28.03	3.06
Osteopenia	35	29.08	3.83
Osteoporosis	13	25.7	4.03
Total	60	28.15	3.92

P=0.026 (ANOVA)

Table 5. Distribution of the BMD state (DEXA method) in the studied population on the basis of the cortex thickness of the lower border of the mandible.

BMD State	Number	Mean cortex Thickness (mm)	Mean (SD)	Minimum (mm)	Maximum (mm)
Normal	12	3.33	0.414	2.8	4.1
Abnormal	48	2.71	0.472	1	3
Total	60	2.40	0.657	1	4.1

P=0.000 (t-test)

Table 6 Distribution of the panoramic radiography results on the basis of the DEXA measurement results in the diagnosis of normal and abnormal BMD.

DEXA/Panoramic	Abnormal BMD	Normal BMD	Total
Abnormal BMD	43	0	43
Normal BMD	5	12	17
Total	48	12	60

P=0.000

Table 7. Distribution of normal BMD, osteopenia and osteoporosis in the DEXA method on basis of age.

BMD state	Normal		Osteopenia		Osteoporosis		Total	
Age group	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage
40-49 years	8	23.5	20	58.8	6	17.6	34	100
50-59 years	4	15.4	15	57.7	7	26.9	26	100
Total	12	20	35	58.3	13	21.7	60	100

P=0.584 (Chi-square)

The relative frequency of osteoporotic individuals in men and women were 30% and 17.5% respectively. This relationship was tested by Chi-square test and gave a *P*=0.325.

There was no statistically significant relationship between gender and the distribution of osteoporosis and osteopenia. The relationship between osteoporosis and cortex thickness was calculated by regression analysis. This analysis demonstrated that only gender was significant in this relationship (*P*=0.000); this means that the diagnosis of osteoporosis by cortex thickness is different in females and in males.

A ROC curve test was used for both sexes to calculate the criteria for this and the results showed that the cut-off point for males was 2.85mm with sensitivity=93.3%, specificity=100%, positive predictive value (PPV)=100% and negative predictive value (NPV)=83.3%. The cut-off point for females was 2.75 mm with sensitivity=93.9%, specificity=85.7%, PPV=96.9% and NPV=75%.

The data obtained from the ROC curve test for both sexes demonstrated that a thickness of less than 3 mm can be used as criteria for osteoporosis, while a thickness above 3 mm is normal.

Discussion

Osteoporosis is one of the most common problems in older people. Osteoporosis causes an increase in morbidity and mortality (19). Risk factors include gender, old age, height, low weight, a history of fracture, the use of corticosteroids and a reduction in bone mass (19). Osteoporosis can be diagnosed by the use of dental mandibular radiographs, and especially in the majority of elderly patients (19). Osteoporotic patients who display mandibular morphological changes particularly, in the thinning of the cortex of the lower mandible show a close relationship with a reduced BMD of the hip and spinal column (18-21).

This study demonstrated that there is no statistically significant relationship between mandibular angle cortex thickness in patients with a normal BMD and in patients with a lowered BMD. These study results are similar to those previously presented by Devlin and Horner (18) and also by Law *et al.* (21). This data suggests that the thickness of the cortex of the mandibular angle is not suitable for screening patients for a lowered BMD. The mean thickness of the cortex of the mandible's lower border (under the third molar), in individuals with a normal BMD and with an abnormal BMD were 3.33±0.414 mm and 2.165±0.472 mm respectively (*P*<0.0001). Devlin and Horner (18) found significant differences in the mean cortex thickness in the antegonial region of individuals with a normal BMD and in those with a lowered BMD (*P*<0.005). Devlin and Horner (18) also found a significant difference in the mean cortex thickness in the region of the mental foramen in individuals with a normal BMD and in those with a lowered BMD (*P*=0.002). The study results of Devlin and Horner were different from the results of the present study (18). Factors such as a difference in the area of measurement, race or gender could be responsible for that the difference. The area under the curve (AUC) for distinguishing abnormal BMD patients in this study was 0.984; this result illustrates the high accordance of radiography with the DEXA method in the diagnosis of an abnormal BMD. An AUC of 0.779 was determined in the study of Ishii *et al.* for the diagnosis of femoral osteoporosis in post-menopausal women (13); an AUC of 0.733 was also determined in the study by Devlin and Horner for the diagnosis of decreased BMD in menopausal women (18), which is in agreement with the study by Ishii *et al.* (13) but is different from the results of the present study. This difference could also be due to the differences in the area of measurement of cortex thickness and also to differences in the population under study.

Only the femoral BMD was calculated in the study by Ishii *et al.* (13) while the Devlin and Horner (18) study measured the spinal column, the femur and the mental foramen. By contrast, the BMD of the femur and the L2-L4 spinal column in both men and women was used for measurement in the present study.

The mean age of the population in the present study was lower than for the other two studies (mean age in the present study was 48.48±6.8 years while mean ages in the former studies were 56.8±7.7 years and 62 years respectively). 64% of cases in the study by Devlin and Horner had reduced BMD (18) and 80% of individuals (48 out of 60 cases) had reduced BMD in this study.

Both height and weight were related to the BMD state (P<0.001) in a study by White *et al.* (19) and thus BMI was significantly related to femoral BMD. BMI and the BMD state were also significantly related (P=0.026) in the present study. In the study by Ishii *et al.* (13), the mean cortex thickness in the area of the mental foramen was 4.1±0.9 mm in normal BMD individuals and was 3.2±0.9 mm in osteoporotic individuals (P<0.001). A study by White *et al.* (19) and another by Drowzdzowska *et al.* (12) demonstrated that a cortex thickness of 4 mm can be used to distinguish abnormal BMD individuals from normal BMD individuals. A mandibular angle cortex height of 4 mm was recognized by Drowzdzowska *et al.* as a cut-off threshold with a sensitivity of 21% and a specificity of 81% (12). The specificity of that study is agreement with the specificity of the present study, but there is a large difference between the sensitivity of the two studies; this could be due to a difference in the area of measurement. Devlin and Horner (18) also recommend that a cut-off threshold of 3 mm of mandibular angle cortex with a sensitivity of 20% and a specificity of 100% should be considered for the diagnosis of osteopenia, and that a cut-off threshold of 3 mm with a sensitivity of 25.9% and a specificity of 93.6% should also be considered for the diagnosis of osteoporosis. On the basis of studies by Taguchi *et al.* (8,15), the cut-off threshold thickness of the mandibular angle cortex should employ values of 3 mm (8) and 2.8 mm (15) respectively. In this regard, Arifin *et al.* (22) recommended that the cut-off threshold value of the mandibular angle cortex should be 3.08mm for men and 2.69 mm for women (22); these values were much closer to the results of the present study.

A cut-off threshold value of 2.85 mm for men and 2.75 mm for women was determined by ROC analysis in the current study for recognition of osteopenic and osteoporotic individuals.

The studies previously undertaken by Devlin and Horner (18), Ishii *et al.* (13), Taguchi *et al.* (8, 15), Drowzdzowska *et al.* (12), White *et al.* (19), Nakamoto *et al.* (23) Arifin *et al.* (22) and also Ardakani *et al.* (24) demonstrated that the determined cortical measurements from panoramic radiography could be used for the diagnosis of menopausal women with a reduced BMD or with osteoporosis. The results of these studies confirmed that dentists should refer patients with a thin or eroded cortex for a specialist consultation. The results of the present study are also similar to the above mentioned studies.

In conclusion, dental panoramic radiography, which is used for the primary evaluation of teeth and adjacent areas, is also available for more anatomic landmark investigations. Dentists are able to refer patients at risk of decreased bone mineral density and osteoporosis for bone densitometry on the basis of incidental findings in panoramic radiographs.

This current study indicates that the detection of the lower border of the mandible cortical measurement could be useful for identifying individuals who are at risk of having a decreased BMD. This study suggests that a cut-off threshold of a 2.80 mm thickness in the mandibular lower border in the studied population should be considered for the screening for osteoporosis. The surprising finding in this study of a high incidence of individuals with a reduced BMD (80%) in a population with a lower mean age (48.48±6.8 years) than in previous studies indicates that more attention might need to be given to the BMD of these younger age groups.

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