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ORIGINAL ARTICLE

Diagnostic Efficacy of Panoramic Radiography in Detection of Osteoporosis in Post-Menopausal Women with Low Bone Mineral Density

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ABSTRACT

Objective: The aim of the study was to evaluate panoramic radiograph, a commonly taken dental radiograph as a screening tool to detect early osseous changes (normal, mildly or severely eroded) of the mandibular inferior cortex and measure the mandibular cortical width (CW) in post-menopausal women and correlate it with the bone mineral density (BMD) measured by the ultrasound bone sonometer at the mid-shaft tibia region. **Materials and Methods:** The study included females between 45 years and 65 years of age in their post-menopausal stage (no menstruation for at least 6-12 months). Mandibular indices **(**mandibular CW and mandibular cortical shape) were evaluated from panoramic radiographs. The BMD assessment was carried out at the mid-shaft tibia region, exactly half-way between the heel and the knee joint perpendicular to the direction of the bone, using an ultrasound bone sonometer. It is a non-invasive device designed for quantitative measurement of the velocity of ultrasound waves as "speed of sound" in m/s, capable of measuring bone density at one or more skeletal sites. Using 1994 WHO criteria the study subjects were categorized as Group 1: Normal, Group 2: Osteopenia, Group 3: Osteoporosis. (WHO T score for tibia BMD can be used as a standard). **Results:** The diagnostic efficacy of the panoramic radiograph in detecting osseous changes in post-menopausal women with low BMD was shown to have 96% specificity and 60% sensitivity with mandibular cortical shape and 58% specificity and 73% sensitivity with mandibular CW measurement. Factorial ANOVA analysis carried out indicated a significant correlation of BMD classification with mandibular cortical shape ($F = 29.0$, $P < 0.001$, partial eta squared [η^2] =0.85), a non-significant correlation with mandibular CW, ($F = 1.6$, $P = 0.23$, $\eta^2 = 0.86$), and a more significant correlation with combined cortical shape and width ($F = 3.3$, $P < 0.05$, $\eta^2 = 0.70$). **Conclusion:** The study concludes that the combined mandibular cortical findings ($P < 0.05$) and mandibular cortical shape erosion alone ($P < 0.001$) on panoramic radiograph are effective indicators of osteoporosis in post-menopausal women.

Key words: Mandibular cortical shape, mandibular cortical width, osteoporosis, panoramic radiograph

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INTRODUCTION

Osteoporosis, after hypovitaminosis D is the second most common metabolic disease in India.[1] A silent epidemic, it is defined as " a disease characterized by low bone mass and micro-architectural deterioration of bone tissue, leading to enhanced bone fragility and a consequent increase in fracture risk."[1-3] Post-menopausal osteoporosis was characterized by Albright and colleagues in 1941.[4,5]

The oral implications of osteoporosis include loss of periodontal attachment,[6,7] loss of teeth,[8-10] loss in height of the alveolar bone due to resorption (i.e., from the crest at the level of cemento-enamel junction of the adjacent tooth until the root apex), erosion of inferior mandibular cortex, reduced mandibular inferior cortical width (CW) (indicating intracortical bone resorption similar to that in tubular bones), resorption of both condyles, and temporal components of temporomandibular joints.[11,12]

The earliest suggestion of an association between osteoporosis and oral bone loss was made in 1960.[13]

The aim of this study was to evaluate the diagnostic efficacy of the panoramic radiograph using morphometric analysis in early detection of Osteoporosis in post-menopausal women and to correlate it with the bone mineral density (BMD) measured by ultrasound bone sonometer at the mid-shaft tibia region.

MATERIALS AND METHODS

Subjects

The criteria used to select the subjects for the study included

1. Inclusion Criteria: Subjects selected were females between 45 years and 65 years of age in their post-menopausal stage (no mensturation for at least 6-12 months)
2. Exclusion Criteria: Subjects with a history of hysterectomy or oophorectomy, history of medication affecting bone metabolism such as glucocorticoids, anticonvulsants, excessive thyroxin doses, with diseases which alter bone metabolism such as hyperparathyroidism, multiple myeloma, on estrogen replacement therapy, malignancy with bone metastasis and with bone destructive lesions in the mandible or history of previous fractures.

Equipment

Assessment of mandibular cortical width and cortical shape

a. Panoramic radiographs were obtained, using "XTROPAN–2000, microprocessor based system, control panel with digital display and soft keypad".
b. The exposed films (Super HR-V,6 × 12 inches in size, green sensitive films, supplied by FUJI MEDICAL X-RAY FILMS) were processed, using (EXTRAORAL XE–VELOPEX X-RAY FILM PROCESSOR with day light loader extra–XE) supplied by D– Max imaging system.
c. Measurements were made using a digital vernier caliper with an LCD display screen and technical specifications of resolution– 0.01 mm, power 1-1.5 V button cell and measuring the speed of ≤1.5 m/s.

Assessment of bone mineral density

"Sunlight Omnisense® 7000 S/8000 S (Sunlight Medical, Ltd.) ultrasound bone sonometer, a quantitative ultrasound densitometer based on the principle of broadband ultrasonic attenuation" was used for BMD assessment. It has a main unit and a small hand held probe each designed to measure speed of sound (SOS) at one or more skeletal sites.

In this study, the SOS was assessed at the mid-shaft of the tibia, located exactly between the heel and knee joint on the dorso-anterior surface of the leg and perpendicular to the direction of the bone.

Following all the standard parameters and precautionary measures, analysis was performed over a frequency range of 0.2-0.6 MHz by moving the probe around the circumference of the tibia with its long vertical dimension parallel to the long axis of the bone. The anodic current of the equipment was an equal parameter in all cases.

Methodology

Procedure for assessment of mandibular CW and shape using panoramic radiograph

Panoramic radiograph for each study subject was taken with the following parameters:

Tube Voltage- 65-75 Kvp, Total exposure time - 14 s, Tube Current- 4-12 mA.

1. Technique for assessing cortical shape (visual assessment) Using a radiographic viewer, mandibular cortical shape was determined by observing the mandible distally from the mental foramen bilaterally and categorized into one of three groups, according to the method by Klemetti et al.,[14-18] as follows:
   - Normal cortex: The endosteal margin of the cortex is even and sharp on both sides.
   - Mildly to moderately eroded cortex: The endosteal margin shows semilunar defects (lacunar resorption) or appears to form endosteal cortical residues, one to three layers thick.
   - Severely eroded cortex: The cortical layer forms heavy endosteal cortical residues and is clearly porous [Figure 1].

2. Technique for measurement of mandibular CW.
   Measurement was made bilaterally on the radiographs at the site of the mental foramen. 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 inferior border of mental foramen was constructed along which mandibular CW was measured, using a digital vernier caliper.
   The location of the mental foramen relative to the inferior and superior borders of normal mandible as expressed by the mean ratios of total bone height to the height of the foramen above the inferior border appears to be consistent enough to justify its use as a reference point in clinical studies.
   Clinically, the lower edge of mental foramen appears to be a more useful reference mark in panoramic radiographs. By observing the distance between the inferior border of the mandible to the lower edge of the foramen and using the approximate ratio of 3:1, the original height of the mandible before resorption can be conveniently estimated. The amount of bone loss can then be expressed as the proportion of fraction of original height.[19,20] By using this method of assessing the extent of bone loss, patients can be grouped according to the severity of bone disease, i.e., osteopenia or osteoporosis.[21,22] As explained by Taguchi et al.,[23] the morphometric measurements were done bilaterally [Figures 2 and 3].
   - Half mandibular width – Distance between the base of the mental foramen to the inferior border of mandible
   - Full mandibular width – Distance between the alveolar ridge height (mesial to the 1st molar) to the inferior border of mandible
   - CW – measurement of the thickness of mandibular cortex
   - C – Distance between the center of mental foramen to the inferior border of mandible.

The calculations done on the basis of morphometric measurements were:

1. Panoramic mandibular index (PMI) = CW/half mandibular width
2. Alveolar crest resorption degree ratio M/M Ratio = Full mandibular width/C where C represents the distance between the center of mental foramen to the inferior border of mandible
3. Mean CW and mean M/M ratio of both right and left sides were calculated.

BMD assessment

Sunlight Omnisense®7000 S/8000 S (omnisense) ultrasound bone sonometer was used for assessing BMD.[19] The measurements done by the device were expressed as:[24]

1. Total Stiffness Index: Total calcium/proteins/mineral content in the bone. Normal value >85
2. Z-Score: Bone density compared to what is normally expected in a healthy individual of the same gender and age. Normal value >0
3. T-Score: Bone density compared to what is normally expected in healthy, young adult of the same gender and an ideal BMD. Normal value more than –0.1.

When T-score is above –1, bone density is considered normal. When between –0.1 and –2.5 it is a sign of

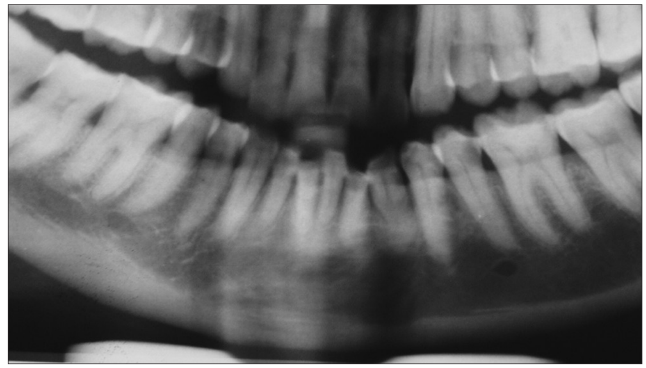

Figure 1: Section of panoramic radiograph depicts mandibular cortical shape erosion.

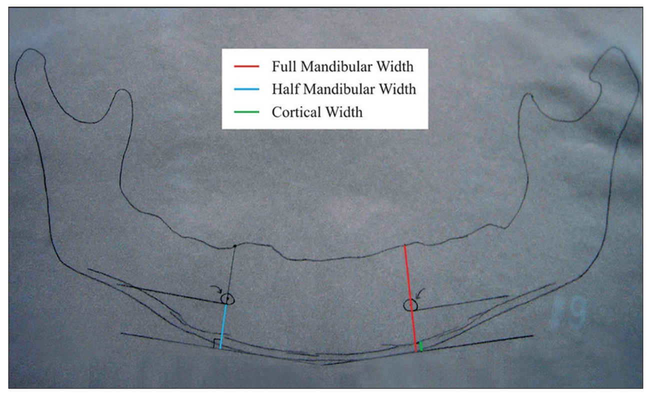

Figure 2: Line drawing shows how mandibular cortical width and other measurements are made.

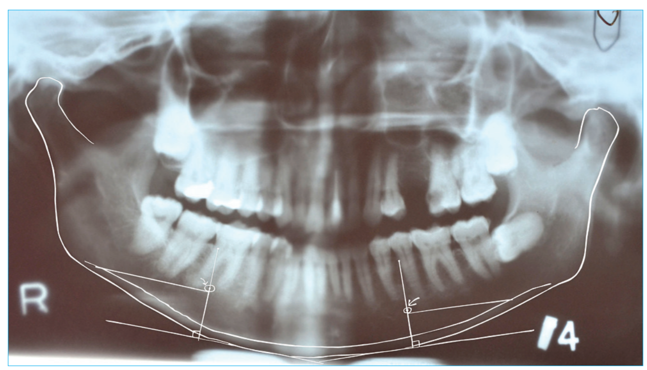

Figure 3: Panoramic radiograph reveals mandibular cortical width and other measurements with a radiographic image.

osteopenia, a condition in which bone density is below normal and may lead to osteoporosis. When the T-score is below −2.5, bone density indicates osteoporosis.

The WHO criteria[25] chose the T-score of the tibia as its standard for identifying BMD. It is the statistical measure of BMD that best correlates with risk of fracture. It was implied in this study to categorize the total number of study subjects into three groups:

- Group 1: Normal: A BMD value within 1 standard deviation (SD) of the young adult mean value
- Group 2: Osteopenia: A BMD value more than 1 SD (SD), but <2.5 SD, below the young adult mean value
- Group 3: Osteoporosis: A BMD value 2.5 SD (SD) or more, below the young adult mean value and when severe it is associated with one or more fragility fractures.

Statistical analysis

The strength of the relationship between measurements of mandibular CW and shape, PMI, M/M ratio, BMD classification was assessed by Pearson's correlation coefficient analysis. The data were analyzed using the statistical package for social sciences (SPSS: version 14.0). $P < 0.05$ were considered statistically significant.

RESULTS

This study was carried out to evaluate the diagnostic efficacy of the panoramic radiograph in detecting post-menopausal osteoporosis by assessing and comparing it with the BMD measure findings. Based on T-score, 30 subjects were osteoporotic (50%), 15 were normal (25%) and 15 were osteopenic (25%). Five different variables viz. age, time since menopause (months), mean CW, M/M ratio, mandibular cortical shape were evaluated.

Table 1 shows the mean values and SDs of these variables for osteoporotic, osteopenic, and normal groups. Table 2 shows the correlation between mandibular CW and BMD ($r = 0.257$, $P < 0.005$). Correlation between BMD classification and mandibular cortical shape ($r = 0.807$, $P < 0.001$) is detailed in Table 3. The correlation is plotted as bar graphs [Figures 4 and 5]. The ranges of the CW in the four quartiles were as follows: Lowermost quartile: <3.56 mm, second quartile: 3.56-4.27 mm, third quartile: 4.27-4.7 mm and highest quartile: >4.7 mm [Table 4]. The sensitivity and specificity of panoramic radiograph to classify patients based on BMD values showed 60% sensitivity and 96% specificity with respect to mandibular cortical shape and 73% sensitivity and 58% specificity with respect to mandibular CW [Table 5]. Factorial ANOVA analysis carried out indicated a significant effect for mandibular cortical shape: $F = 29.0$, $P < 0.001$, partial eta squared (η^2) =0.85; a non- significant effect for mandibular CW: $F = 1.6$, $P = 0.23$, $\eta^2 = 0.86$; a more significant combined effect or the interaction between cortical shape and width on BMD classification: $F = 3.3$, $P < 0.05$, $\eta^2 = 0.70$ [Table 6].

Table 1: Characteristics of study subjects

Characteristic	Range	Mean ± SD or number of women (%)
Age (years)	45-65	55.0±7.6
Time since menopause (months)	6-264	97.6±81.1
Mean cortical width	Right: 2.5-9.1, Left: 2.0-6.1	4.2±0.9*
M/M ratio	Right: 1.54-2.94, Left: 1.34-3.08	2.26±0.28*
Mandibular cortical shape	-	11 (18)
Normal	-	20 (33)
Mildly to moderately eroded cortex	-	29 (48)
Severely eroded cortex	−4.3-0.9	−2.0±1.2
T-score		
Bone mineral density		
Normal	-	15 (25)
Osteopenia	-	15 (25)
Osteoporosis	-	30 (50)

*Mean cortical width, M/M ratio for right and left taken together, SD: Standard deviation

Table 2: Pearson's correlation coefficient analysis

Characteristics	Pearson's correlation coefficient	*P* value
Mandibular cortical shape versus mean cortical width	−0.092	
Mandibular cortical shape versus BMD classification	0.807**	<0.001
Mean cortical width versus BMD classification	0.257*	<0.05
Mandibular cortical shape versus post-menopausal months	0.301*	<0.05
Mean cortical width versus post-menopausal months	−0.186	
M/M ratio versus BMD classification	0.277*	<0.05
PMI versus BMD classification	0.051	

*Statistically significant correlation, **Highly statistically significant correlation. BMD: Bone mineral density, PMI: Panoramic mandibular index

Table 3: Bone mineral density by mandibular cortical shape

Characteristic	BMD (%)		
	Normal	Osteopenia	Osteoporosis
Mandibular cortical shape			
Normal	81.8	18.2	-
Mild/moderate erosion	30.0	50.0	20.0
Severe erosion	-	10.3	89.7
Total study subjects	25.0	25.0	50.0

BMD: Bone mineral density

Table 4: Bone mineral density by cortical width quartile

Characteristic	BMD (%)		
	Normal	Osteopenia	Osteoporosis
Cortical width quartile			
Lowest	12.5	25.0	62.5
Second	14.3	21.4	64.3
Third	41.2	17.6	41.2
Highest	30.8	38.5	30.8
Total study subjects	25.0	25.0	50.0

BMD: Bone mineral density

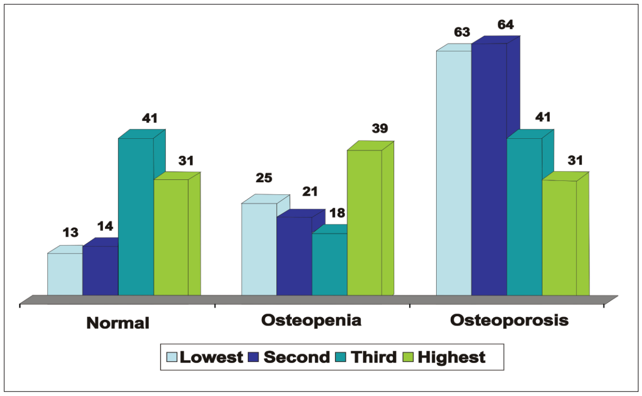

Figure 4: Graph depicting number of patients in each quartile diagnosed by the mean cortical width (Y axis – Number of patients).

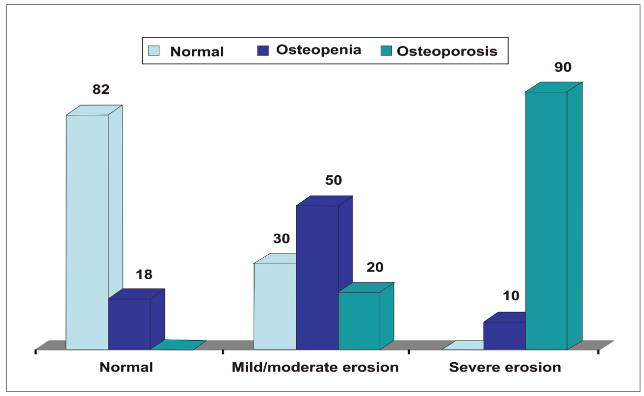

Figure 5: Graph depicting number of patients diagnosed by mandibular cortical shape (Y axis – Number of patients).

Table 5: Sensitivity and specificity measures of panoramic radiograph

Characteristic	Sensitivity %	Specificity %
Mandibular cortical shape (visual assessment)	60	96
Mandibular cortical width	73	58

Table 6: Factorial ANOVA analysis

Variables	*F*	*P* value	Partial eta squared
Mandibular cortical width	1.6		0.86
Mandibular cortical shape (visual assessment)	29.0	<0.01	0.85
Mandibular cortical width+mandibular cortical shape	3.3	<0.05	0.70

F: Factorial ANOVA value, P: Statistically significant value,ANOVA: Analysis of variance

Analysis of mandibular cortical shape (visual assessment) with BMD classification, showed: True positive – 9, False positive – 2, False negative – 6, True negative – 43. Analysis of mandibular CW with BMD classification showed: True positive – 11, False positive – 19, False negative – 4, True negative – 26. The sensitivity was calculated as

$$\text{Sensitivity} = \frac{\text{number of true positives}}{\text{number of true positives} + \text{number of false negatives}}$$

Where, True positive cases were osteoporotic women correctly diagnosed as osteoporotic. False negative cases were osteoporotic or osteopenic women wrongly identified as healthy, i.e., normal. The specificity was calculated as

$$\text{Sensitivity} = \frac{\text{number of true negatives}}{\text{number of true negatives} + \text{number of false positives}}$$

Where, True negative cases were normal women correctly identified as normal. False positive cases were normal women wrongly identified as osteopenic or osteoporotic.

DISCUSSION

In this study, subjects selected were females between 45 years and 65 years of age in their post-menopausal stage (no mensturation for at least 6-12 months). A panoramic radiograph was taken for each subject and assessed for mandibular cortical shape by visual assessment and CW by morphometric measurements, based on which the M/M ratio, i.e., alveolar crest resorption degree ratio and the PMI were calculated. Based on the BMD analysis T-score,[25] all the 60 study subjects were categorized into 3 groups: Normal, osteopenic, and osteoporotic.

The degree of mandibular cortical shape erosion was found to significantly correlate with BMD and panoramic radiograph showed 96% specificity and 60% sensitivity in assessing osteoporosis, establishing it to be an effective indicator. These are similar to the findings of the studies conducted by Taguchi et al.,[26] and by Devlin and Horner.,[27] It was reported that if dental panoramic radiograph was used as the basis of identifying women with spinal osteopenia or osteoporosis, the finding of any mandibular cortical erosion correctly identified a case of low BMD 80% of the time and a normal finding on the panoramic radiograph correctly identified normal spine BMD 60% of the time. However, Drozdzowska et al.,[28] reported that there was no relationship between osteoporosis and cortical shape erosion and found CW to be a good parameter in discriminating osteoporotic patients from non-osteoporotic patients.

Mandibular CW significantly correlates with BMD. Panoramic radiograph showed 58% specificity and 73% sensitivity in assessing osteoporosis. Devlin and Horner also found mean CW to significantly correlate with BMD. Klemitti et al., found the sensitivity and specificity to be low for CW measurement. Taguchi et al.,[29] recommended that a CW ≤4.5 mm should be used as an indicator of high osteoporosis risk. Horner et al., found that the thinning of the mandibular cortex below 3 mm at the mental foramen was associated with low skeletal bone mass. This provided a diagnostic test with high specificity of 98.7% but low sensitivity of 8%.

The combined effect of mandibular CW and degree of cortical shape erosion showed a significant interface and was found to be an effective indicator on Factorial ANOVA analysis for diagnosing osteoporosis.

Taguchi et al., studied the mandibular bone density of women who were in different post-menopausal stages and reported greater correlation of cortical bone changes with BMD in recent post-menopausal group than in long-term post-menopausal group.[30-33] Our study included women who had recently attained menopause and their mandibular cortical shape ($r = 0.301$, $P < 0.05$) correlated with bone changes.

M/M ratio is the degree of the alveolar crest resorption correlated with BMD in the osteoporotic group indicating that with progressing osteoporosis, alveolar crest showed greater resorption. White[34] also found M/M ratio to be effective in screening osteoporosis.

PMI showed a weak correlation with BMD. A similar evaluation was performed by Benson et al., who used PMI to compensate for the vertical magnification that differs among various panoramic machines, but found a very weak correlation between the index and BMD in spite of the fact that PMI is inclusive of other variable i.e., half mandibular width. Therefore, Benson et al., used CW, instead of PMI as an effective indicator.

Limitations of the study

This study has a limitation. As seen by Shankar V.V mandibular cortical shape assessment appears to have limitation in terms of observer variability. Thus, it requires adequate training of dentists for competent interpretation of information.[35]

CONCLUSION

The study concludes that the combined mandibular cortical findings (mandibular cortical shape erosion and mandibular cortical width CW) on panoramic radiographs are effective indicators of osseous changes in post-menopausal osteoporosis. It establishes that the routinely taken panoramic radiograph in general dental practice can be an effective screening tool and provide dentists with a means to identify patients with undetected low BMD and refer them to medical professionals for bone densitometry and required management, thus reducing its related morbidity.

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