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Radiomorphometric Indicators, their Reliability in Detecting Early Signs of Osteoporosis in Menopausal Women

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Abstract

Background: The aim of this study was to evaluate the diagnostic value of panoramic radiography and the radiomorphometric indices in osteoporosis identification.

***Methods and Results*:** The research included 60 women (average age of 62.90±7.07 years) in the postmenopausal stage who were subjected to an assessment of bone density through the DEXA test and were divided into 2 groups based on the value of the DEXA test from the lumbar region (L1-L4): Main group (MG) included 30 women with osteoporosis (T-score <-2.5) and Comparison group (CG) included 30 women without osteoporosis (T-score >-2.5). Panoramic radiography were used to assess the mandibular cortical index (MCI), mental index (MI), panoramic mandibular index (PMI).

Based on the porosity level, Klemetti et al.(1994) has categorized MCI into three categories (C1, C2, and C3). MCI–C1, which represents the normal appearance of the lower jaw cortex without changes in bone quality, was found only in CG in 63.33%. MCI-C2 and MCI-C3 were found in 70% and 30% of cases, respectively, in MG. In CG, MCI-C2 was found in 36.67% of cases and MCI-C3 in 0% of cases. There was a significant difference between the two study groups in the distribution of MCI (P=0.000). MI below 3 mm was found in 19(63.33%) of cases in CG and 27(90.00%) in MG (OR=5.211, 95% CI: 1.278-21.237, P=0.0213). PMI below 0.3 mm was found in 7(23.33%) of cases in CG and 19(63.33%) in MG (OR=5.675 95% CI: 1.841-17.494, P=0.0025).

MCI sensitivity and specificity for osteoporosis were 70% (95% CI: 50.60%-85.27%) and 63.33% (95% CI: 43.86%-80.07%), respectively; PPV, NPV, and accuracy were 65.62% (95% CI: 53.03%-76.35%), 67.86% (95% CI: 53.41%-79.54%) and 66.67% (95% CI: 53.31%-78.31%), respectively. MI sensitivity and specificity at a cutoff point of 3 mm for osteoporosis were 90% (95% CI: 73.47%-97.89%) and 36.67% (95% CI: 19.93%-56.14%), respectively; PPV, NPV, and diagnostic accuracy were 58.70% (95% CI: 51.35%-65.67%), 78.57% (95% CI: 53.18%-92.21%) and 63.33% (95% CI: 49.90%-75.41%), respectively. PMI sensitivity and specificity at a cutoff point of 0.3 mm for osteoporosis were 63.33% (95% CI: 43.86%-80.07%) and 76.67% (95% CI: 57.72%-90.07%), respectively; PPV, NPV, and diagnostic accuracy were 73.08% (95% CI: 57.32%-84.58%), 67.65% (95% CI: 55.66%-77.69%) and 70.00% (95% CI: 56.79%-81.15%), respectively.

Conclusion: Panoramic radiography can be a useful tool to identify early signs of osteoporosis by using the evaluation of radiomorphometric indices. MCI, MI, and PMI can be potential screening tools for initial BMD loss.(**International Journal of Biomedicine. 2023;13(1):120-126.**)

Keywords: osteoporosis • panoramic radiography • radiomorphometric indices • mandibula

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Abbreviations

BMD, bone mineral density; **BMI**, body mass index; **DEXA**, dual-energy x-ray absorptiometry; **LR**, likelihood ratio; **MCI**, mandibular cortical index; **MI**, mental index; **MF**, mental foramen; **MC**, mandibular cortex; **MCW**, mandibular cortical width; **NPV**, negative predictive value; **PMI**, panoramic mandibular index; **PPV**, positive predictive value; **PR**, panoramic radiography.

Introduction

Osteoporosis is a metabolic disease of bones, which is characterized by a decrease in bone strength and an increase in the predisposition for fractures. The disease derives from micro-articular change with specific emphasis on trabecular bone, and most frequent fractures occur on the spine, wrist, and hip bones due to the predominance of trabecular bone

tissue in these structures. The disease affects more than 10 million people in the USA. Each year an estimated 1.5 million individuals suffer a fracture due to bone disease. Worldwide, osteoporosis causes 8.9 million fractures annually.[1] Besides the risk of fractures, osteoporosis is considered to be one of the most serious diseases due to the high degree of disability and the large number of people who remain bedridden as a result of severe complications. Disease usually develops in a progressive but latent form. In the overwhelming majority of cases, patients do not know that they suffer from the disease until the fractures occur. Fractures in these cases are the result of moderate knocks, but also cases of spontaneous fractures are not rare.[2]

Due to the high level of morbidity and its consequences, prevention and research to detect the early signs of disease are a priority among clinicians and researchers.

Osteoporosis is defined based on bone mineral density (BMD) values, referring to criteria determined by the World Health Organization (WHO). For body BMD values measured by DEXA scans, the WHO has defined a number of threshold values for osteoporosis. These values are based on units of standard deviation (SD) and are described as T- or Z-scores. T-score is a statistical definition that indicates the difference between a patient's BMD and the mean bone density of a normal population aged 20–30 years (reference population).[3] This value shows the difference in terms of SDs. According to the WHO classification system, T-scores under the value of -2.5 are considered as osteoporosis, and between -1 and -2.5 as osteopenia; a T-score at −1.0 and above is normal.

Access to examination tests using DEXA equipment is problematic, especially in developing countries and underdeveloped countries. Even in countries where equipment is available, cost reimbursement is at a low level due to the high cost of the examination.[4]

Osteoporosis affects women three times more than men. The disease progresses significantly with age, when many etiological factors complement each other and favor the disease development. Estrogen is a hormone that plays a key role in bone metabolism and the deposition of bone mass during puberty. With the decrease in the level of estrogen in a very complex metabolic process, the level of bone mass loss increases, which usually begins approximately at the age of 50, except for health conditions that are accompanied by a deficit of estrogen hormone. It is considered that in the first 5 years of menopause, women lose up to 25% of their bone mass. Each year this loss is between 1% and 5%, with an average annual loss of about 2% of bone mass. BMI is also directly related to osteoporosis. Weight loss also causes the inability to produce estrogen from adipose cells, which are considered the second most important producer of estrogen in the body after the ovaries. In the European population, the risk of fracture increases below the BMI threshold of 19 kg/m^2.[4,5]

Research regarding the correlation between osteoporosis and oral health dates to the 1960s. Osteoporotic changes affect both jaws, especially the lower jaw since the lower jaw consists of the cortical part of the bone, which surrounds the trabecular tissue structure of bone. The buccal cortex distal from the mental foramen (MF) is considered to be the most suitable part to evaluate the loss of bone density. Many researchers have been focused on finding radio morphometric indicators that would serve to identify early signs of osteoporosis in panoramic radiography of women with low bone density with the aim of referring them to specialists in this area for final diagnosis. For this purpose, several radiomorphometric indices have been used, such as mandibular cortical index (MCI), mental index (MI), and panoramic mandibular index (PMI), which are considered to have the highest significance to identify early signs of osteoporosis. MCI is a qualitative index that is attributed to the visibility of the lower edge cortex of the mandible distal from the MF on both sides. Based on the porosity level, Klemetti et al.[6] has categorized MCI into three categories: C1—the endosteal cortical margin is even and sharp on both sides, normal cortex; C2— moderately eroded cortex: the endosteal margin shows semilunar defects resulting from lacunar resorption, or forms endosteal cortical residues; C3—severely eroded or porous cortex: the cortex forms dense layers of endosteal and clearly porous cortical residues.

MI index refers to the width of the mandibular cortex in the region below the MF. Sizes under 3mm are considered abnormal values. PMI is the ratio between MI and distance from the lower edge of the MF to the lower edge of the mandible on both sides of the lower jaw—the method according to Benson et al.[7] Values below 0.3mm are considered abnormal sizes.[8-12]

The aim of this study was to evaluate the diagnostic value of PR and the radiomorphometric indices in osteoporosis identification.

Materials and Methods

A total of 60 patients aged 50–80 years (average age of 62.90±7.07 years with min/max of 51/77) included in this research were informed regarding the research and its purpose and, in a voluntary manner, agreed to be part of this research project by signing a voluntary declaration of their inclusion in research in the presence of a second witness. Before initiating medical procedures, patients have carefully read the information letter regarding details of inclusion in the research.

Inclusion criteria: women aged 50-80 in the natural postmenopausal stage that have undergone an examination to assess BMD with DEXA test, and the final diagnosis by a nuclear medicine specialist.

Exclusion criteria: patients with diseases that affect the condition of bones (hyperparathyroidism, carcinoma with metastases, and patients receiving therapy that affects bone metabolism); women in the unnatural postmenopausal stage.

The research included 60 women in the postmenopausal stage who were subjected to an assessment of bone density through the DEXA test and were divided into 2 groups based on the value of the DEXA test from the lumbar region (L1-L4):

•Main group (MG) included 30 women with osteoporosis (T-score <-2.5)

•Comparison group (CG) included 30 women without osteoporosis (T-score >-2.5)

BMI was measured using calculations according to WHO standards, and underweight was identified as <18.5 kg/m^2, normal weight as 18.5-24 kg/m^2, and overweight as 25-29 kg/m^2.

Radiological analysis

The DEXA test was done at the Nuclear Radiology Clinic of Kosovo University Clinical Center using the MEDILIN NK apparatus (MEDIX DR 2020).

Panoramic radiography was performed using Sirona Orthopos E2D. Radiological measurements were performed using the Sidexis SG system software. The following morphometric indices were assessed:

MCI: Visibility assessment of the lower edge of the mandible, distal from the MF, was done twice in timeframe intervals of 3 weeks. Based on the MC visibility assessment, patients were classified into three categories (C1-C3) according to Klemetti et al.[6] (Figure 1).

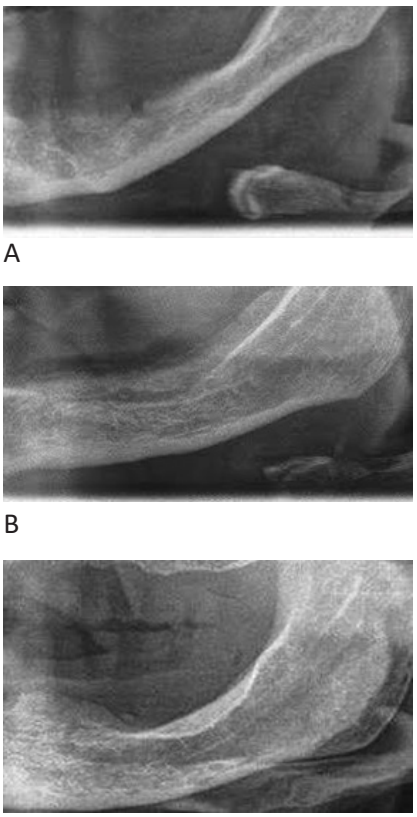

Fig. 1. *MCI categories (C1-C3) according to Klemetti et al.[6]*
A - Normal mandibular cortex with well-defined edges
B - Mandibular cortex with medium porosity and lacunar changes
C- Mandibular cortex with eroded cortex and visible deposits

MI: The MCW in PR was measured using the method according to the technique described by Lengerton,[13] as follows: First, the MF is identified, then a line was drawn from the lower end of the MF in a perpendicular direction parallel to the mandible axis to the lower end of the mandible. The other drawn line touches the edges of the mandible base in the region of the MF. At the place where these two lines meet, forming a straight right angle, the thickness of the mandible cortex is measured. The average width the lower edge border of the mandible under the MF gives values of the MI. Cortex thickness below 3 mm is considered an abnormal (reduced) value.

PMI: After identifying the MF, a perpendicular line is drawn from the lower edge of the MF to the lower edge of the mandible cortex. The ratio between MI and *h* (distance from the lower edge of the MF to the mandible lower edge) gives the data for the PMI values. PMI below 0.3mm is considered an abnormal (reduced) value. Measurements were performed on both sides of the mandible, and the average value was calculated, which gives the final result of PMI (Figure 2).

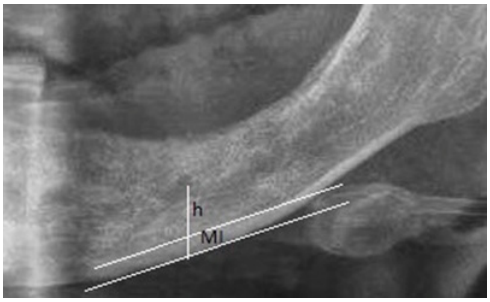

Fig.2. *The distance between the two parallel lines represents the MI (MCW). PMI is the ratio between the MI and the distance from the lower border of MF to the lower border of the mandibula. PMI=MI/h.*

Statistical analysis was performed using statistical software package SPSS version 23.0 (IBM Corp. Released 2019. IBM SPSS Statistics for Windows, Version 23.0. Armonk, NY: IBM Corp). Baseline characteristics were summarized as frequencies and percentages for categorical variables and as mean±SD for continuous variables. Inter-group comparisons were performed using Student's t-test. The Mann-Whitney U Test was used to compare the differences between the two independent groups (for nonparametric data). Categorical variables were analyzed using the Chi-square test with Yates' correction or, Fisher's exact test (2-tail), when appropriate. Odds ratios (ORs) and 95% confidence intervals (CIs) were calculated using logistic regression. We calculated the sensitivity, specificity, positive predictive value, negative predictive value, and likelihood ratios to determine the diagnostic value of signs. The area under the receiver operator characteristic (ROC) curve (AUC) using the MCW was measured to evaluate the diagnostic efficacy of the MCW. A probability value of P<0.05 was considered statistically significant.

The study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of the Ss. Cyril and Methodius University, Skopje, North Macedonia. All participants provided written informed consent.

Results

The range and degree of significance of characteristics of subjects participating in research are shown in Table 1. Age

difference between the two study groups was insignificant (*P*=0.787). T-score <-2.5 was found in all women of MG. In CG, 21(70%) had T-score of -1 up to -2.5 and 9(30%) had T-score >-1. BMI of CG women was higher than in MG women with osteoporosis (*P*=0.011). We did not find a significant difference between study groups regarding the time of menopause beginning (*P*=0.052).

Table 1.

Characteristics of subjects participating in research.

Characteristics	MG (n=30)	CG (n=30)	*P*-level
Age			
Mean ± SD	63.37±6.32	62.90±7.07	0.787
Min/Max	52/76	51/77	
Median	61	61	
DEXA test			
Mean ± SD	-2.98±0.76	-1.6±0.40	0.000
Min/Max	1.90/ -2.5	-2.10/ -0.40	
Median	-2.70	-1.10	
BMI			
Mean ± SD	27.25±1.95 кg/м^2	28.81±2.62 кg/м^2	0.011
Min/Max	27.70/22.50	24.66/34.60	
Median	27.70	29.79	
DEXA test values			
DEXA, T score <-2.5	30 (100%)	0 (0.00%)	0.000
DEXA, T score -1.0-2.5	0 (0.00%)	21 (70%)	
DEXA, T score >-1	0 (0.00%)	9(30%)	
Menopause stage			
Early stage <50 years	13 (43%)	6 (20.0%)	0.052
Normal stage >50 years	17 (56.7%)	24 (80%)	

MCI–C1, which represents the normal appearance of the lower jaw cortex without changes in bone quality, was found only in CG in 63.33%. MCI-C2 and MCI-C3 were found in 70% and 30% of cases, respectively, in MG. In CG, MCI-C2 was found in 36.67% of cases and MCI-C3 in 0% of cases. There was a significant difference between the two study groups in the distribution of MCI (*P*=0.000). MI below 3 mm was found in 19(63.33%) of cases in CG and 27(90.00%) in MG (OR=5.211, 95% CI: 1.278 to 21.237, *P*=0.0213). PMI below 0.3 mm was found in 7(23.33%) of cases in CG and 19(63.33%) in MG (OR=5.675, 95% CI: 1.841 to 17.494, *P*=0.0025) (Table 2).

Radiomorphometric indices were used to predict the osteoporosis disease. Through the Entry method, global accuracy of this model to predict osteoporosis was 65%. Sensitivity reaches 66.7% and specificity 63.30%. In determining the importance of radiomorphometric indices in predicting osteoporosis, it was found that MCI has the greatest impact (Wald index = 6.296/*P*=0.012), followed by PMI (Wald index =1.340/*P*=0.247), and the lowest impact by MI (Wald index = 0.847/*P*=0.357) (Table 3). Patients with MCI-C2 with moderate porosity of MC have a higher risk of developing osteoporosis (Exp(B)=4.130, 95% CI: 1.364 to 12.507, *P*<0.012) than patients with normal MC or MCI-C1. When the value of PMI increases by 0.1 mm, the chances of developing osteoporosis decrease by 42.2% (Exp(B)=0.578, 95% CI: 0.228 to 1.463); PMI impact is estimated to be insignificant (*P*>0.05). When the MI values increase by 1mm, the risk of osteoporosis decreases by 31.8%, (Exp(B)=0.682, 95% CI: 0.302 to 1.540, *P*>0.05) with an insignificant impact.

ROC analysis (MCI (1), MI, PMI) of the expected probability of detecting osteoporosis is presented in Figure 3. ROC zone was 0.720. In all possible pairs in which one has osteoporosis, and the other does not have osteoporosis, this model will determine the acceptable probability of osteoporosis.

Table 2.

The values of MCI, MI, and PMI in the study groups.

Characteristics	MG (n=30)	CG (n=30)	Statistics
MCI			
C1 Normal cortex	0	19 (63.33%)	Yates' χ2= 26.695 Yates' *P*=0.0000
C2 Moderate porosity of cortex	21 (70%)	11 (36.67%)	
C3 High porosity of cortex	9 (30%)	0 (0.00%)	
MI			
Normal value > 3 mm	3 (10%)	11 (36.67%)	OR= 5.211 95% CI (1.278-21.237) Z =2.303 *P*=0.0213
Reduce value < 3 mm	27 (90%)	19 (63.33%)	
PMI			
Normal value > 0.3 mm	11 (36.67%)	23 (76.67%)	OR= 5.675 95% CI (1.841-17.494) Z =3.023 *P*=0.0025
Reduce value < 0.3 mm	19 (63.33%)	7 (23.33%)	

Table 3.

Binary logistic regression for the prediction of osteoporosis

		B	S.E.	Wald	df	Sig.	Exp(B)	95% CI for EXP(B)	
								Lower	Upper
Step1[a]	MCI (1)	1.418	0.565	6.296	1	0.012	4.130	1.364	12.507
	MI	0.382	0.415	0.847	1	0.357	0.682	0.302	1.540
	PMI	0.549	0.474	1.340	1	0.247	0.578	0.228	1.463
	Constant	0.464	1.114	0.173	1	0.677	1.590		
a. Variable(s) entered on step 1: MCI (1), MI, PMI.									

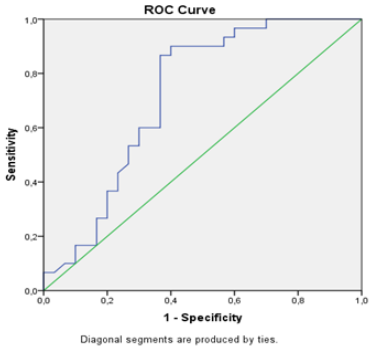

Fig. 3. *Receiver Operating Characteristic (ROC) curve analysis to assess the probability of detecting osteoporosis.*

Table 4 presents the sensitivity, specificity, positive predictive value, negative predictive value, and likelihood ratios to determine the diagnostic value of MCI, MI, and PMI. MCI sensitivity and specificity for osteoporosis were 70% (95% CI: 50.60% to 85.27%) and 63.33% (95% CI: 43.86% to 80.07%), respectively (code 1 is applied to MCI-C2, code 0 for MCI-C1 and MCI-C3); PPV, NPV, and accuracy were 65.62% (95% CI: 53.03% to 76.35%), 67.86% (95% CI: 53.41% to 79.54%) and 66.67% (95% CI: 53.31% to 78.31%), respectively.

MI sensitivity and specificity at a cutoff point of 3 mm for osteoporosis were 90% (95% CI: 73.47% to 97.89%) and 36.67% (95% CI: 19.93% to 56.14%), respectively (for MI<3mm, code 1 is applied; for MI > 3 mm, code 0 is applied); PPV, NPF, and diagnostic accuracy were 58.70% (95% CI: 51.35% to 65.67%), 78.57% (95% CI: 53.18% to 92.21%) and 63.33% (95% CI: 49.90% to 75.41%), respectively.

PMI sensitivity and specificity at a cutoff point of 0.3 mm for osteoporosis were 63.33% (95% CI: 43.86% to 80.07%) and 76.67% (95% CI: 57.72% to 90.07%), respectively (for PMI < 3 mm, code 1 is applied, code 0 for PMI > 3mm); PPV, NPF, and diagnostic accuracy were 73.08% (95% CI: 57.32% to 84.58%), 67.65% (95% CI: 55.66% to 77.69%) and 70.00% (95% CI: 56.79% to 81.15%), respectively (Table 4).

Discussion

The progressive but latent development of osteoporosis disease has directed many researchers to investigate more practical and accessible methods with the aim of identifying the early stages of osteoporosis. This will bring great benefits to science, medicine, the country, and its citizens since the disease manifests itself with severe complications of fractures that are accompanied by a long rehabilitation period and, at the same time, high costs for the country to reimburse health expenses.

Panoramic radiography and radiomorphometric indices have for a long time been considered a very practical option for identifying silent signs of osteoporosis, keeping in mind easy access to equipment frequently used in clinical dental practice, and technical advantages that offer a wide graphic area with easy identification of referral points.

In this study, the obtained data were compared based on research purposes. From women in the postmenopausal phase in both study groups, we received data from their anamnesis for the timeframe beginning with the menopause phase, dividing them into the group that had an early onset of menopause prior to the age of 50 and those that had a normal transition in the menopause time period, which is considered to be after the age of 50.

Data from our analysis show no significant correlation between the time of menopause onset and the DEXA test. This can be attributed to a small research sample because many studies have found a close connection between osteoporosis and menopause, attributing this connection to the action of rapid decline in estrogen hormone levels at this stage of life. Estrogen is considered as the key hormone that plays an essential role in complicated osteoblastic and osteolytic metabolic processes. Roberts et al.[9] concluded that the thinning of the MC in women begins at the age of 42.5. A study in Saudi Arabia,[5] which included 431 women in the postmenopausal phase, found a close correlation between the years that passed from the beginning of menopause and osteoporosis, classifying menopause as one of the risk factors for osteoporosis disease. It is considered that osteoporosis has a close correlation with body BMI.

Table 4.

Sensitivity and specificity of MCI, MI and PMI in identifying women with osteoporosis.

Index	Sensitivity Value (95% CI)	Specificity Value (95% CI)	PPV Value (95% CI)	NPV Value (95% CI)	+LR Value (95% CI)	-LR Value (95% CI)	Disease prevalence Value (95% CI)	Accuracy Value (95% CI)
MCI (any cortical shape)	70.00% (50.60%-85.27%)	63.33% (43.86%-80.07%)	65.62% (53.03%-76.35%)	67.86% (53.41-79.54%)	1.91 (1.13-3.23)	0.47 (0.26-0.87)	50% (36.81%-63.19%)	66.67% (53.31%-78.31%)
MI<3mm (MCW)	90.00% (73.47%-97.89%)	36.67% (19.93%-56.14%)	58.70% (51.35%-65.67%)	78.57% (53.18%-92.21%)	1.42 (1.06-1.91)	0.27 (0.08-0.88)	50.00% (36.81%-63.19%)	63.33% (49.90%-75.41)
PMI <0.3mm	63.33% (43.86%-80.07%)	76.67% (57.72%-90.07%)	73.08% (57.32%-84.58%)	67.65% (55.66%-77.69%)	2.71 (1.34-5.48)	0.48 (0.29-0.80)	50% (36.81%-63.19%)	70% (56.79%-81.15%)

The second source of estrogen after the ovaries is adipose cells. European women with osteoporosis are more prone to suffer fractures if the BMI is below the threshold of 19 kg/m^2.[8,9,14]

In our study, in women with T-score >-2.5, BMI was significantly greater than in women with T-score <-2.5. Numerous studies have been done with the aim of determining the reliability of the MCI as a qualitative index that describes morphological changes in the mandible cortex distally from the MF and the connection with the DEXA test. In 1998, Horner and Dalvin concluded that there is a correlation between BMD and MCI. A study by Devlin et al.,[10] which included 671 postmenopausal women 45 to 70 years of age, found that only those patients with the thinnest mandibular cortices (MCW<3 mm) should be referred for further osteoporosis investigation. Dutra et al.[11] concluded that the thickness of the cortical mandibular bone is highly influenced by age. Taguchi et al.[12] found that MCW determined from panoramic radiographs can be used to identify undetected low calcaneus BMD in young adult men, but not in young adult women (40 years) Ledgerton et al.[15] found that that MI and PMI showed a significant, negative correlation with age. MCI also showed an age-related distribution.

The findings of our research are in line with the conclusions above: we found reduced MI values of less than 3mm in 90% of women with osteoporosis.[10-12,15] Our data align with the conclusions of White et al.,[16] who emphasized the validity of MI in detecting low BMD values in the research done with 227 Japanese women. Also, Langerton et al.[15] have highlighted the high identification potential of MI and PMI in detecting osteoporosis. Our findings regarding MI and PMI ability in detecting osteoporosis align with the authors mentioned above.[8-12,15,16] Drozdowska et al.[17] concluded that MCI is not efficient enough to distinguish edentulous women with osteoporosis. The efficacy of the panoramic-based mandibular indices in diagnosing osteopenia/osteoporosis was low to moderate: specificity (ranging from 31% to 81%), sensitivity (ranging from 21% to 93%), negative and positive predictive values (ranging from 47% to 83% and 40% to 79%, respectively).

The present study sufficiently demonstrates the reliability of the radiomophometric indices in identifying menopausal women with a greater risk of osteoporosis. Further studies need to be carried out with a much larger population to ascertain the efficacy of these indices.

Conclusion

MCI presents a moderate sensitivity (70%) with low specificity (63.33%) to detect early signs of osteoporosis, but the C3 category corresponds to overall bone condition and can be used by dentists to refer patients for final examination and diagnosis. MI at a cutoff point of 3 mm presentes the moderate-high sensitivity (90%) for detecting bone mass loss, but the MI specificity is extremely low (36.67%). The efficacy of the PMI at a cutoff point of 0.3 mm is characterized by low sensitivity (63.33%) in diagnosing osteoporosis, but the PMI specificity is moderate (76.67%). PR can be a useful tool to identify early signs of osteoporosis by using the evaluation of radiomorphometric indices. MCI, MI, and PMI can be potential screening tools for initial BMD loss.

Disclosures

None

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