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Instituto de Ciência e Tecnologia
Campus de São José dos Campos

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Radiographic signs of bone mineral density in panoramic radiographs from pre and postmenopausal patients

Sinais radiográficos da densidade mineral óssea em radiografias panorâmicas de pacientes pré e pós-menopausa.

Paula Cristina de FARIA[1], Maria Fernanda Lima VILLAÇA-CARVALHO[1], Sérgio Lúcio Pereira de Castro LOPES[1], Mari Eli Leonelli de MORAES[1], Luiz Roberto Coutinho MANHÃES JÚNIOR[1]

1 - Instituto de Ciência e Tecnologia – UNESP - Universidade Estadual Paulista Júlio de Mesquita Filho - São José dos Campos.

ABSTRACT

Objective: The aim of this study was to evaluate the potential of panoramic radiographs (PR) and their radiomorphometric indices as an auxiliary method for the diagnosis of osteoporosis. **Material and Methods:** Twenty five women were selected, who had been prescribed PR for different purposes. The PR were analysed according to the MCI, which evaluates the mandibular cortex below the mental foramen, and then divided into two groups: normal and bone mineral loss. Bone densitometry scans were obtained (DXA) from the lumbar spine and neck of the femur/whole femur, which were used as the gold standard for comparison against the MCI. Kappa test ($p<0.05$) was used to determine the association between the MCI and bone densitometry readings. **Results:** Regarding the DXA, 7 patients were normal at the lumbar spine or femur, 24 subjects showed osteopenia at the lumbar spine or femur and 9 subjects had osteoporosis at the lumbar spine or femur. Regarding the association between DXA and MCI, 18 subjects showed some degree of bone loss at the spine detected by both DXA and the Klemetti index. **Conclusions:** PR should not be used to confirm the diagnosis of osteoporosis or osteopenia, but may be useful to assess the risk of such diseases being present.

KEYWORDS

Osteoporosis; Menopause; Panoramic radiography.

RESUMO

Objetivo: O objetivo deste estudo foi avaliar o potencial de radiografias panorâmicas (RP) e seus índices radiomorfométricos como método auxiliar para o diagnóstico da osteoporose. **Material e Método:** Foram selecionadas vinte e cinco mulheres, que tinham sido encaminhadas para PR com fins diferentes. As PR foram analisadas de acordo com o MCI, que avalia o córtex mandibular abaixo do forame mentual, e, em seguida, divididos em dois grupos: normal, e perda mineral de osso. Scans de densitometria óssea foram obtidos (DXA) da coluna lombar e colo do fémur / fêmur inteiro, que foram utilizados como padrão-ouro para comparação com o MCI. Teste de Kappa ($p < 0,05$) foi utilizado para determinar a associação entre a MCI e leituras de densitometria óssea. **Resultados:** Em relação à DXA, 7 pacientes eram normais na coluna lombar ou fêmur, 24 pacientes apresentaram osteopenia na coluna lombar ou fémur e 9 indivíduos tinham osteoporose na coluna lombar ou fêmur. Em relação à associação entre a DXA e MCI, 18 pacientes apresentaram algum grau de perda óssea na coluna detectado por ambos DXA e o índice Klemetti. **Conclusões:** PR não deve ser utilizada para confirmar o diagnóstico de osteoporose ou osteopenia, mas pode ser útil para avaliar o risco de tais doenças estar presente.

PALAVRAS-CHAVE

Osteoporose; Menopausa; Radiografia panorâmica.

INTRODUCTION

Despite its rigid and sturdy appearance, bone is a living tissue and is in constant process of formation and resorption, also known as bone remodelling [1], which varies according to age and stage of life. Osteoporosis is a metabolic bone disease characterized by low bone mineral density (BMD) and deterioration of bone microarchitecture leading to bone fragility and susceptibility to fracture [1-5].

In men and women, bone formation is completed around the age of 30 years, although the peak bone mass is greater in males [6]. From that point, a slow negative balance begins, which will result in a discrete age-related bone loss at the end of each activation of remodelling units, i.e. senile osteoporosis, in which, throughout their lifetime, women will lose about 35% of cortical bone (femur, for example) and 50% of trabecular bone (vertebrae), whilst men will lose 2/3 of that amount [3,6,7]. There is evidence that the rapid bone loss in postmenopausal women is due to decreased oestrogen. Without oestrogen, osteoclasts become more active [6]. The great majority of women will undergo spontaneous cessation of menstruation between the ages of 47 and 55 years, when oestrogen production declines [4]. As a result, osteoporosis is three times more common in women than in men.

In white women, the risk of fractures of the spine, hip or wrist after the age of 50 years due to osteoporosis is estimated at 40-50%, similar to the risk of coronary heart disease [5]. Hip fractures are particularly serious so that 12-20% of all patients with hip fractures die in the first year after the event and 36% of women and 48% of men die within two years. Of those who survive, half do not regain their independence [4,6], making this disease a major culprit for high rates of morbidity and mortality amongst the elderly, with huge social and economic repercussions, causing major impact on quality of life and degree of independence [8]. Asymptomatic progression of osteoporosis and its consequences make this disorder a major public health priority in many countries.

Studies estimate that less than a third of Brazilians with osteoporosis have a diagnosis of the disease and only 20% of those are receiving treatment [3]. Osteoporosis is described by the World Health Organization as having a BMD less than or equal to 2.5 standard deviations below the normal young adult average [3,6,9], making it one of the most common disorders of the elderly [6].

Early diagnostic strategies for osteoporosis have been proposed and are the focus of studies in several countries where there is a real concern for prevention of osteoporosis and its complications. Amongst such methods, the analysis of radiomorphometric indices on panoramic radiographs (PR) has generated great interest, since the radiographic prescription guide (RPG) has extended the use of PR as the investigation of choice to complement dental diagnosis [1,3,5].

The purpose of screening for osteoporosis is to identify individuals who are likely to benefit from treatment [5,6]. It is noteworthy that one of the limiting factors of population studies on the prevalence of osteoporosis using the WHO criteria, i.e. using high precision equipment such as a DXA system - Dual-energy X-ray absorptiometry, is the cost. For this reason, the relationship between the mandibular and skeletal BMD has gained much attention in recent years, with most studies showing a good correlation between the two methods.

This study aimed to evaluate the practical application and effectiveness of a visual method obtained from PR to identify patients with predictive radiographic signs of osteoporosis.

MATERIAL AND METHODS

This study was approved by the Research Ethics Committee of the Institute of Science and Technology – Paulista State University Julio de Mesquita Filho (UNESP), protocol number 084/2011-PH / CEP.

Sample

Twenty five women were selected, aged 40 years or older, pre and postmenopausal, who had been prescribed a PR and who had undergone a DXA scan in the previous 12 months. The subjects agreed to provide a copy of their DXA and PR, as well as to participate in the study answering a medical history questionnaire. There was no exclusion criteria, since what intended to analyze were the radiographic signs of low density on panoramic radiography, regardless of cause.

Examinations

DXA scans were performed at several Radiology Centres at the Paraíba Valley region, following the WHO criteria for menopausal women [10].

PR were taken at the dental radiology clinic Centrum (Jacarei, SP, Brazil) using the digital equipment PAX 400 (Vatech Co Ltd, Republic of Korea), operating from 65 to 80kVp, 6 to10 mA and 13 seconds of exposure, according to the manufacturer's specifications.

Evaluation Criteria

DXA results can be expressed in value of bone mineral density and standard deviation compared to young adults (T-score). Thus, the results from the lumbar spine and neck of the femur/total femur were analysed, which are the areas at highest risk of fractures [4,7,8]. Each woman was classified into one of three groups according to BMD as normal (T-score of 0 to -1.0 Standard deviation (SD), osteopenic (T-score of - 1.0 to - 2.4 SD) and osteoporotic (T-score of -2.5 or less).

The PR images were identified with the initials of the patient's names in alphabetical order, so that patient information was anonymised in order to prevent bias. The images were evaluated by 2 dental surgeons, radiology specialists, experienced professionals in PR analysis, with an interval of at least one week between evaluations.

PR were analysed according to the condition of the lower cortical bone of the mandible by means of a qualitative index known as MCI proposed by Klemetti et al. [11], which analyses the mandibular cortex below the mental foramen on both sides of the jaw and ranks it into three groups: C1- smooth and regular cortex; C2- cortex showing semilunar defects; C3- cortical layer clearly porous. This graphical representation is illustrated in Figure 1.

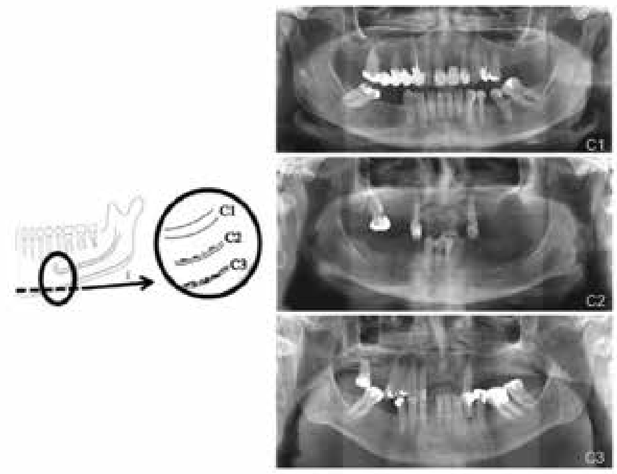

Figure 1 - Classification of the lower cortex of the mandible according to Klemetti et al. [11]. Examples of the cortical indices C1, C2 and C3.

Statistical Analysis

Intra-observer agreement was analysed using the Kappa test for evaluations of the right and left sides for each observer individually. The analysis of central tendency between observers was performed for the right and left sides using the function mode and the inter-observer agreement was assessed using Kappa statistics.

Interpretation of the values obtained was performed according to the classification proposed by Landis and Koch [12]; the procedure essentially involves the construction of functions of the observed proportions which are directed at the extent to which the observers agree among themselves and the construction of statistical tests for hypotheses involving these functions. Tests for interobserver bias are presented in terms of first-order marginal homogeneity and measures of interobserver agreement are developed as generalized kappa-type statistics.

The comparisons between the DXA scans and the mandibular cortex morphology according to the classification Klemetti [11] were performed taking into account a single observer as reference, also using the Kappa test. Subsequently, MCI sensitivity was assessed dividing the patients into two groups: normal and bone mineral loss, applying Kappa again to test agreement.

All statistical tests were considered significant when $p < 0.05$.

RESULTS

Overall, 17 (68%) of the individuals were normal at the lumbar spine or femur, 24 (96%) had osteopenia in the lumbar spine or femur, and 9 (36%) had osteoporosis at the lumbar spine or femoral regions. On the individual distribution of the bone region analysed using DXA scans, 9 (36%) patients were observed to be normal for the lumbar spine, 10 (40%) had osteopenia and 6 (24%) osteoporosis. For DXA of the femur, 8 (32%) patients were normal, 14 (56%) had osteopenia and 3 (12%) osteoporosis. When comparing the overall distribution of the sample, the region with the highest bone loss on DXA was the femur, which was mostly diagnosed as osteopenic.

The Kappa test results for intra-observer agreement of the right and left sides showed that, regarding the first observer, the most significant agreement was obtained between the 2nd and 3rd tests. For the right-hand side, however, the test showed only a moderate level of agreement. As for the second observer, the most significant agreement was found between tests 1 and 3, which was similar for both the right and the left sides.

The inter-observer evaluation was analysed using central tendency for the right and left sides, which was obtained via the function mode, i.e., using the most frequent rating within all three tests for each observer.

Kappa was used to analyse the inter-observer agreement (Table 1) for the MCI evaluations. For the left-hand side (LHS), kappa was - 0.061, whereas for the right (RHS) kappa was 0.052, showing no agreement for either side.

Table 1 - Inter-observer agreement for left and right MCI.

	Observed Agreement LHS (KAPPA)	Observed Agreement RHS (KAPPA)
BMD SPINE	11 (44%) (0.13-PA)	11 (44%) (0.12-PA)
BMD FEMUR	7 (31,82%) (0.01-NA)	15 (60%) (0.31-PA)

* NA (No Agreement), PA (Poor Agreement), LHS (Left Side), RHS (Right Side).

The morphological pattern of the mandibular cortex was compared to DXA (gold standard (GS)) using a single observer as reference, which revealed higher values of agreement.

From the 25 (100%) subjects, 18 (72%) were diagnosed with some degree of bone loss both on the spinal DXA scan (osteopenia or osteoporosis). On the Klemetti [11] index, grouping the data classified as C2 or C3, 16 patients (64%) revealed some degree of mandibular cortical bone loss in the right (Table 2).

Regarding the femur, 14 patients (72%) were diagnosed with some degree of bone loss on DXA. The Klemetti [11] index, grouping the data classified as C2 or C3, revealed that 16 patients (68%) had some degree of bone loss in the right mandibular cortex.

Table 2 - Klemetti Classification RHS x DXA result.

	NUMBER OF PATIENTS FOR DXA				
	Klemetti MCI	Normal	Osteopenia	Osteoporosis	Total
			DXA spine		
	C1	4 (44.44%)	4 (44.44%)	1 (11.11%)	9 (36%)
	C2	2 (20%)	6 (60%)	2 20%)	10 (40%)
	C3	1 (16.67%)	4 (66,67%)	1 (16.67%)	6 (24%)
Right hand side	TOTAL	7 (28%)	14 (56%)	4 (16%)	25 (100%)
			DXA Femur		
	C1	6 (75%)	2 (25%)	0 (0%)	8 (32%)
	C2	1 (7.14%)	9 (64.29%)	4 (28.57%)	14 (56%)
	C3	0 (0%)	3 (100%)	0 (0%)	3 (12%)
	TOTAL	7 (28%)	14 (56%)	4 (16%)	25 (100%)

Regarding the spine, 16 individuals (64%) were diagnosed with some degree of bone loss on the DXA (osteopenia or osteoporosis). On the Klemetti [11] index, grouping the data classified as C2 or C3, 19 (76%) patients showed some degree of mandibular cortical bone loss on the left side (Table 3).

Regarding the femur, 19 patients (76%) were diagnosed with some degree of bone loss on DXA. The Klemetti [11] index, grouping the data classified as C2 or C3, revealed that 16 patients (68%) had some degree of mandibular cortical bone loss on the left side.

According to the Kappa scale by Landis & Koch (1977) [12] (Table 4) and the results from Table 4, the agreement for the LHS and RHS x spinal BMD was considered poor, whilst LD x femur BMD was considered slight and for LE x femur BMD it was nil.

MCI sensitivity was assessed dividing the patients into two groups: normal and bone mineral loss. Thus, the patients diagnosed with osteopenia and osteoporosis were grouped together, as well as those classified as Klemetti [11] C2 and C3, as shown in Table 5.

Table 3 - Klemetti Classification LHS x DXA result

	NUMBER OF PATIENTS FOR DXA				
	Klemetti MCI	Normal	Osteopenia	Osteoporosis	Total
			DXA spine		
	C1	3 (33.33%)	5 (55.56%)	1 (11.11%)	9 (36%)
	C2	3 (30%)	5 (50%)	2 20%)	10 (40%)
	C3	0 (0%)	3 (50%)	3 (50%)	6 (24%)
Left hand side	TOTAL	6 (24%)	13 (52%)	6 (24%)	25 (100%)
			DXA Femur		
	C1	2 (25%)	5 (62.50%)	1 (12.50%)	8 (32%)
	C2	3 (21.43%)	7 (50%)	4 (28.57%)	14 (56%)
	C3	1 (33.33%)	1 (33.33%)	1 (33.33%)	3 (12%)
	TOTAL	6 (24%)	13 (52%)	6 (24%)	25 (100%)

Table 4 - Sample distribution according to DXA result.

Values	Interpretation
<0	No agreement (NA)
0.0-0.19	Poor agreement (PA)
0.20-0.39	Poor agreement (PA)
0.40-0.59	Moderate agreement (MA)
0.60-0.79	Considerable agreement (CA)
0.80-1.00	(almost) Perfect Agreement (APA)

DISCUSSION

DXA is the gold standard for the diagnosis of osteoporosis. However, difficulty of acces and high costs hinder its applicability and, consequently, early diagnosis of the disease. Considerable efforts have been made to establish methods to identify individuals with osteoporosis at an early stage in order to find effective ways to assess risk [6]. Among the proposed methods, the PR and bone quality of the jaws have frequently been discussed. Radiomorphometric indices obtained from the PR commonly used in dentistry have shown promising results in predicting low BMD [13-18], however, other authors have not observed such positive correlation in their studies [11, 18, 19].

In the present study, during random selection of patients who already had some change in BMD, the prevalence of osteoporosis in the lumbar spine (24%) was found to be higher than in the femur (12%), however, the highest agreement was observed for BMD of the femur when comparing the MCI and DXA, contradicting the findings of Klemetti et al. [11]. The morphology of the mandibular cortical bone on both sides by the method proposed by Klemetti et al. [11] as well as the indices obtained from bone density, from which the best result achieved was only a slight agreement (femur BMD x RHS - Table 3). By grouping the patients diagnosed with osteopenia and osteoporosis and those classified as C2 and C3 Klemetti [11] (Table 5), the correlation of the mandibular cortical morphology with the DXA showed better results (Table 4), thus suggesting the use of MCI to triage patients for DXA, since a suspicion of low BMD was detected when the C2 or C3 was obtained from one or both sides of the jaw, which was also reported by previous studies [3,5,15-17,19], yet opposing the results obtained by other authors [18,20,21].

Differences were observed between the left and right sides, future research may be able to establish whether such differences may be due to the condition of the teeth, to a functional increase in a preferred side for mastication or asymmetry of the facial skeleton.

According to Klemetti et al. [11], on a PR, the cortex of the mandible is the most suitable framework for such analyses because it is clearly visible. Our study, however, had other points in common, such as the low specificity and the ordinal ranking of the cortex (C1 -C3), which were not able to distinguish between the bone mineral statuses of the groups (Table 3).

Table 5 - ICM Distribution in relation to BMD in 2 groups

		BMD Spine			BMD Femur		
		Normal	Bone loss (Osteoporosis or Osteopenia)	TOTAL	Normal	Bone loss (Osteoporosis or Osteopenia)	TOTAL
LHS	Normal (C1)	3 (68.42%)	3 (50%)	6 (100%)	2 (33.33%)	4 (66.67%)	6 (100%)
	Bone loss (C2 or C3)	6 (31.58%)	13 (68.42%)	19 (100%)	6 (31.58%)	13 (68.42%)	19 (100%)
	TOTAL	9 (36%)	16 (64%)	25 (100%)	8 (85.71%)	17 (68%)	25 (100%)
RHS	Normal (C1)	4 (57.14%)	3 (42.86%)	7 (100%)	6 (85.71%)	1 (14.29%)	7 (100%)
	Bone loss (C2 or C3)	5 (27.78%)	13 (72.22%)	18 (100%)	2 (11.11%)	16 (88.89%)	18 (100%)
	TOTAL	9 (36%)	16 (64%)	25 (100%)	8 (32%)	17 (68%)	25 (100%)

The results of this study confirmed that when the mandibular cortex is isolatedly analyzed on PR, it bares relatively little information to diagnose the stage of BMD loss, but it may be useful to assess the risk of osteoporosis. Thus, it is suggested that the MCI is able to predict bone mineral loss, however it is not able to specify the degree of bone loss (osteopenia or osteoporosis). The MCI is easy to analyse and does not require much training to reach a level of confidence to suggest a case of BMD loss. It is an inconclusive test, but it provides reasonable evidence of osteopenia or osteoporosis, which can be used to justify a DXA scan.

Regardless of the region where it was diagnosed, low BMD may influence the lower cortex of the mandible. Our results showed that the highest correlation was found between the MCI from the RHS of mandible and the femoral DXA (Table 4).

Constant remodelling of the mandibular cortex happens with age, which is also influenced by the condition of the teeth as well as by gender, therefore, interfering with measurements in this region [2,23]. Although this could work unfavourably to the realization of such measurements, it should not interfere with the radiographic appearance of non-quantitative indices such as the MCI analysed in our study, thus strengthening the proposal of including PR images as a means of screening for of BMD loss.

PR can therefore predict low BMD, however, it should not be indicated to diagnose osteoporosis. Simplified visual methods should be proposed to be included in routine PR evaluation in order to address low BMD conditions, as observed by Watanabe [3]: radiolucency of the jaws, reduced cortical definition, erosion and highlighted oblique line due to severe loss of trabecular bone mass and elongation of the stylohyoid process. Bearing in mind other factors such as race, age, sex, history of fracture or loss of height, behaviours, such as exercise, smoking, drugs, including glucocorticoids, oestrogen or bisphosphonates and diet, including calcium intake. Other parameters to consider include mandibular bone mass measurements (densitometry), bone structure (panoramic mandibular cortical thickness) and trabecular analysis. Although there is strong evidence of the correlation between osteoporosis and jaw changes, the sensitivity and specificity are considered too low for clinical use. The fact that dental radiographs are used in much of the population and that dentists may hold useful clinical information make such radiographs potential bone health markers [6]. Future efforts in dental radiology should continue to seek oral radiographic signs with high sensitivity and specificity for osteoporosis, identifying clinical signs within the dental practice, developing multidisciplinary classification methods, including both radiographic and clinical parameters [6,23].

According to the results from the present study, despite a considerable evidence of the correlation between osteoporosis and jaw changes, MCI has statistically low correlation with BMD obtained from DXA in small samples. However, the mandibular cortex analyzed separately on PR should not be used to confirm a diagnosis, but it can be useful to assess the risk of osteoporosis.

Further studies in dental radiology should include a continuous search for specific oral radiographic signs of low BMD and associations with clinical, physical factors, age, diet, sedentary lifestyle, family history and radiomorphometric indices on panoramic radiographs.

It was concluded that PR should not be used to confirm the diagnosis of osteoporosis or osteopenia, but may be useful to assess the risk of such diseases being present.

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Maria Fernanda Lima Villaça-Carvalho (Corresponding address)
Rua José Augusto dos Santos, 36, ap 902.
Floradas de São José. São José dos Campos-SP-Brazil.
CEP:12280085
Email: mfervillaca@hotmail.com

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