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Bone mineral density and mandibular osteoporotic alterations in panoramic radiographs: Correlation by peripheral bone densitometry in men

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Abstract

Aim: Mandibular cortical index has proven to be inversely correlated to bone densitometry; however, trabecular bone pattern has not been widely studied. Thus, the main objectives of this study were: (1) to analyze the correlations between three different sites of peripheral dual-energy X-ray absorptiometry with the mandibular cortical index and the trabecular bone pattern classification; (2) to assess the correlation between the mandibular cortical index and the trabecular bone pattern; (3) to evaluate the diagnostic accuracy of the mandibular cortical index and the trabecular bone pattern using panoramic radiographs in a sample of Brazilian men. Additionally, peripheral dual-energy X-ray absorptiometry findings in men were described. **Materials and Methods:** There are about 44 men who had previously undergone panoramic radiography and bone densitometry were evaluated. Mandibular cortical index and trabecular bone pattern classifications were performed. The median T-scores of the men were analyzed. Spearman's test was performed to assess correlations. **Results:** An inverse correlation was found between mandibular cortical index and proximal bone densitometry site. No correlation was found between mandibular cortical index and trabecular bone pattern or between peripheral densitometry and trabecular bone pattern. Greater accuracy was observed in mandibular cortical index when compared to trabecular bone pattern. Mandibular cortical index evaluations by panoramic radiographs are a useful screening tool for low bone mineral density, but trabecular bone pattern cannot be applied to screen patients for osteoporosis risk. Mandibular cortical index has an inverse correlation with proximal sites of forearm densitometry.

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Full Text

Introduction

Systemic osteoporosis is a degenerative metabolic bone disease that affects mostly postmenopausal women. The major concern with osteoporosis is the increased risk of low energy fracture due to bone tissue deterioration, which leads to bone fragility.[1] Although, the prevalence of osteoporosis is lower in men than in women due to higher peak bone mass and larger bones in males,[2] between 30–40% of osteoporotic fractures[3] and 1/3 of all hip fractures worldwide affect men.[4]

The diagnosis of low bone mineral density (BMD) is usually performed by bone density measurements.[5],[6] Peripheral densitometric evaluation is a useful measurement technique, has been found to be highly accurate in diagnosing osteoporosis,[7] and correlates closely with axial BMD sites.[8] A peripheral dual-energy X-ray absorptiometry (DEXA) machine is able to detect proximal and distal radios at the same time,[9] and many different forearm sites can be used to measure BMD.[10] According to the World Health Organization (WHO), patients with normal BMD present DEXA results values higher than -1.0 standard deviation (SD); any densitometric value lower than -1.0 SD is already considered as low BMD.[11]

Early diagnosis of osteoporosis is essential to reduce osteoporotic fracture risk.[11] However, patients do not always have access to DEXA testing, especially in developing countries.[12] Furthermore, they may not be aware that although osteoporosis may be more common in women, it also affects men.[13] As a consequence, many older men could have undiagnosed osteoporosis.[5] However, low-cost BMD screening tools, such as panoramic radiographs,[14] quantitative ultrasound[15] may also be effective in recognizing patients at risk of low BMD.[14],[16] Opportunistically computed tomography scans (diagnostics scans performed to different purposes in which bone assessment could be applied) were also pointed to be useful in osteoporosis screening, and proper referring the patient to further DEXA evaluation when necessary.[17]

Panoramic radiographs are largely used in dentistry and allow the dentist to examine gnathic bone and related structures.[5] Clinical studies have reported that panoramic X-rays play an important role in identifying and evaluating patients at risk of developing osteoporosis[5],[14],[18],[19],[20] based on evidence of reduced BMD in jawbones, especially in the mandibular cortex.[21],[22] A correlation has been found between radiomorphometric indexes assessed by panoramic radiographs, such as the mandibular cortical index (MCI), and DEXA measurements.[5],[14],[18],[19],[22],[23] The trabecular bone pattern (TBP) classification, developed by Taguchi et al.,[24] which qualitatively verifies bone trabeculae pattern in panoramic radiographs, has also been advocated for as an effective way to detect low BMD[25] and as a strong predictor of fractures,[26] but how it correlates to DEXA, as assessed by panoramic radiographs, or to MCI has not been studied as of yet. Furthermore, it has already been determined that TBP has a significant correlation with computed tomography assessments and pointed that TBP classification applied in panoramic radiographs might be useful in the evaluation of mandibular bone prior to implant placement.[24]

Thus, the primary objectives of the present study were: 1) to analyze the correlations between three different sites of peripheral DEXA (proximal radius [R], proximal radius and ulna [R + U], and distal R + U) with the mandibular cortical index and the trabecular bone pattern classification; 2) to assess the correlation between the mandibular cortical index and the trabecular bone pattern; 3) to evaluate the diagnostic accuracy of the mandibular cortical index and the trabecular bone pattern using panoramic radiographs in a sample of Brazilian men. The secondary objective was to describe the peripheral DEXA findings in men.

Materials and Methods

Study participants

This research was conducted with 54 male patients referred for dental treatment at the Dental School. All patients willing to participate in this study signed an informed consent form. Approval from the ethics committee was obtained (number FR358902). The Helsinki Declaration of 1975 (revised in 2000) were followed in this investigation.

Inclusion and exclusion criteria

Men who had undergone examination by panoramic radiography at the beginning of dental treatment and by forearm DEXA for osteoporosis screening in an event promoted by the University of this Study named as “Osteoporosis Week” were included in this study. Both of these exams were performed on the same day. Patients filled out a form with personal information, lifestyle habits, and complete medical history (medications, comorbidities, and previous diseases). The presence of metabolic bone diseases other than osteoporosis or a history of medication intake affecting bone metabolism were considered as exclusion criteria, as were chronic tobacco or alcohol use. Patients who suffered from severe alveolar bone resorption, who had undergone any surgical procedures on their mandibular bone in the last 12 months, or who had a localized bone disease as detected by panoramic radiographs were excluded.

Dual x-ray absorptiometry

Bone densitometry measurements were carried out using peripheral DEXA (Norland Medical Systems, Inc., White Plains, NY, USA). Patients were diagnosed based on BMD values of the forearm of the non-dominant hand.[27] The values of proximal R, proximal R+U and distal R+U were also recorded. Median T-score values at different sites were described for the total sample according to different age ranges.

Panoramic radiographs

All digital panoramic radiography images were taken using a Kodak 8000 (Eastman Kodak Company, Rochester, NY, USA). Exposure parameters were: 60 kV, 4 mA, 0.5-, copper filter). Parameters were adjusted according to patient's body and dental structures, following equipment's' manual. All images were processed and evaluated on the same software (ImageJ, National Institute of Health, Bethesda, MD).

MCI assessment

MCI was determined by evaluating the appearance of the cortical bone below the mental foramen using a previously described classification.[19] The inferior mandibular cortex was classified as follows: C1 = normal, when presenting a distinct and welldefined endosteal margin with no erosions, C2 = moderately eroded, when presenting evidence of lacunar resorption or endosteal cortical residues, and C3 = severely eroded, when presenting evident porosity. An example of these classifications is shown in [Figure 1].{Figure 1}

TBP assessment

TBP was assessed by evaluating two different regions on either side of the mandible using a previously described classification.[24] TBP was classified as one of the following: TBP1 = no visible bone trabeculae, TBP2 = a few thin and irregular bone trabeculae, TBP3 = distinct bone trabeculae as observed in a normal alveolar bone, TBP4 = thick bone trabeculae, and TBP5 = dense bone without any visible bone trabeculae. An example of TBP classifications is shown in [Figure 2]. The two regions evaluated were the edentulous premolar and molar regions using the alveolar crest as the superior limit. In cases of patients who were not missing any teeth in the mandible, the premolar/molar interdental region was chosen; the area selection criterion in these cases was the largest mesiodistal interdental area near the alveolar crest.{Figure 2}

All the panoramic evaluations (MCI and TBP) were performed in random order by three observers having previous experience with MCI and expertise in oral radiology. Intraobserver and interobserver reliability were assessed between measurements and evaluations were performed 10 days apart to eliminate memory bias.

Statistical analysis

Normality was assessed for continuous variables using the Lilliefors test. Non-parametric correlations between T-score values from the three different sites of peripheral DEXA (proximal R, proximal R+U, and distal R+U) and MCI/TBP, as well as the correlations between MCI and TBP, were assessed using Spearman's test. For TBP, two different regions (right and left side) were evaluated, and each was assessed according to its respective DEXA results.

Receiver operating characteristic (ROC) curve analysis was applied to calculate MCI/TBP sensitivity and specificity for the diagnosis of low BMD. For DEXA results, the cut-off value of -1.0 SD was used to determine presence and absence of low BMD based on WHO classification.[11] For MCI, the C1 category was selected as the cut-off point, as this describes the absence of low BMD in panoramic radiographs.[14],[19] The C2 and C3 categories represented low MCI. For TBP, categories TBP1 and TBP2 were considered low, and categories TBP3 to TBP5 were considered normal.[24]

In performing the MCI and TBP evaluations, intraobserver reproducibility and interobserver agreement were confirmed by kappa test. MCI classification percentages and TBP category percentages were also described. All statistical analyses were performed at a 5% level of significance using IBM SPSS Statistics 24 (SPSS®, Inc., Chicago, IL, USA).

Results

Descriptive statistics

A total of 54 men were analyzed. The median age of the total sample was 60.16 (IR = 21.25). Total sample median T-scores for the different forearm sites were: proximal R = -1.59 (IR = 1.07), proximal R+U = -1.87 (IR = 1.35), and distal R+U = -0.99 (IR = 1.62). The median T-scores for each site and for the total sample are shown in [Table 1] according to age range. The number and percentage of men without low mineral density (DEXA values higher than -1.0 SD) were described in [Table 2], along with its MCI and TBP results.{Table 1}{Table 2}

MCI percentages and correlation between MCI and peripheral DEXA

Intraobserver reproducibility (kappa = 0.86, p = 0.01) and interobserver agreement (kappa = 0.79, p = 0.05) were confirmed for MCI categorical measurements. A moderate inverse correlation was found between MCI and the proximal forearm T-scores, but no correlation was found between MCI and distal R + U [Table 2]. MCI score percentages are also detailed in [Table 3]: the most prevalent score was C2 and the least prevalent was C3.{Table 3}

TBP percentages and correlation between TBP and peripheral DEXA

Intraobserver reproducibility (kappa = 0.81, p = 0.01) and interobserver reliability (kappa = 0.78, p = 0.04) were confirmed for TBP categorical measurements. No correlation between DEXA and TBP was found. The most prevalent TBP classification was TBP3 [Table 3]. Considering the total sample, when evaluating TBP, most of the patients were partially edentulous, and none of them were totally edentulous. The premolar/molar interdental region was evaluated on 5 cases only (patients without any teeth absence).

Correlation between MCI and TBP

No correlation was found between MCI and TBP (r = -0.13; p = 0.377).

ROC curve analysis: DEXA and MCI

The sensitivity, specificity, and accuracy for each forearm site DEXA result, as well as the ROC curve area, are exhibited in [Table 3]. Corresponding ROC graphics are illustrated in [Figure 3]. The proximal forearm sites showed higher accuracy when compared to distal sites.{Figure 3}

ROC curve analysis: DEXA and TBP

The sensitivity, specificity, and accuracy for each forearm site DEXA result, as well as the ROC curve area, are exhibited in [Table 4]. Corresponding ROC graphics are illustrated in [Figure 4]. Greater accuracy was noticed in MCI assessment when compared to TBP.{Table 4}{Figure 4}

Discussion

The men selected for this study were not exposed to risk factors and did not have any metabolic bone diseases or history of medication intake affecting bone metabolism. However, the median T-scores were below -1.0SD for proximal sites at the forearm, indicating low BMD or osteopenia.[11] The lack of previous investigations using peripheral DEXA in Brazilian men precluded direct comparison. However, it has been previously described that at least 12.8% of Brazilian men 40 years of age or older have osteoporosis.[28] Since male lowenergy bone fractures occur mostly with low bone mass (osteopenia),[29] the present results demonstrated the impact of the disease in a small sample of the Brazilian male population, reinforcing the need for early diagnosis and prevention of osteoporosis.[23] In the sample of this present study, DEXA results of males at the age range of 40-50 years old were slightly lower than that of when compared to other older age ranges, which could maybe be explained by lifestyle features, body composition characteristics or vitamin D levels of this group. The aforementioned findings should be further studied.

Peripheral DEXA is a valuable tool for diagnosing osteoporosis[30] because of the significant correlation between axial DEXA and the forearm,[31],[32] which is an area that reflects great cortical bone damage.[33] In countries like Brazil, central DEXA is not widely available. Peripheral densitometry device has advantages such as low cost and reduced size, which can allow its applicability in the field of epidemiologic study of osteoporosis.[34] The participants of the present investigation participated of an event promoted by the São Paulo University called “Osteoporosis Week” which aimed to offer DEXA examination using a donated peripheral DEXA equipment. Patients with low BMD were referred to further investigations. Also, the participants underwent panoramic radiograph as an initial examination for dental treatment at the Dentistry School.

Distinct forearm sites have been used to measure BMD;[10] for this reason, it is essential to investigate which site best correlates with the available screening tools for low BMD, such as MCI. The bone pattern along the forearm is diverse: the proportion of trabecular bone increases considerably in the distal direction along R,[9],[35] and the trabecular bone is more sensitive to bone loss than the cortical bone.[35],[36] Despite this, higher T-scores were found in the distal forearm than the proximal forearm in this investigation. Previous studies have pointed to the lack of competence in detecting osteoporosis using the distal forearm;[37],[38] however, some results have found lower BMD scores and higher BMD monitoring sensitivity at the distal site.[13],[39] Differences in bone composition among forearm sites may affect the ability to detect low BMD at each site; thus, the prognostic value of each site remains unknown.[10] Establishing standard regions of interest for evaluating the forearm would simplify interpretation of forearm results[39] and allow equivalence among studies.

Only at the distal site was there was no correlation between MCI and DEXA, probably due to the higher T-scores at the distal forearm as opposed to the moderate inverse correlation at proximal sites. To our knowledge, this is the first study that has researched the correlation between three forearm DEXA sites and MCI. The inverse correlation between proximal forearm DEXA and MCI indicates that mandible bone loss determined by MCI can be a useful screening tool to assess patients at risk for low BMD[1],[14],[18],[19],[40],[41],[42] and refer them accordingly.[42]

Panoramic radiographs used to screen patients at risk, widely requested in routine clinical dental practice, are already available at dental offices and are of great socioeconomic importance, especially in developing countries such as Brazil.[12] Therefore, anatomical changes in the endosteal margin of the mandible should be assessed qualitatively using MCI before introducing any dental treatment,[43] since a low BMD affects craniofacial and oral structures.[42] The presence of any kind of cortical erosion, classified by the MCI, can be considered an indicator of BMD reduction; its correlation to osteopenia has been found in approximately 80% of cases.[44]

In addition to MCI, TBP is a qualitative assessment, and it may be easily applied by clinicians using panoramic radiographs. The previous studies have supported the hypothesis that patients with low BMD have TBP alterations in the jaw[22],[45] because bone resorption changes occur both in cortical and trabecular bone structure in the mandibular body.[43] Bearing this in mind, Taguchi et al.[24] designed a classification system for TBP based on the aspect of the trabecular bone according to panoramic radiographs, and they observed that this classification showed good agreement with trabecular bone density in computed tomography. Nevertheless, whether the mandibular TBP is related to BMD has not been investigated for panoramic radiographs. Previous studies using periapical radiographs showed that a similar TBP classification,[45] devised with mandibular autopsy specimens, might be useful as a warning sign in detecting low BMD.[25] Another study also demonstrated a strong correlation between TBP and BMD using panoramic and periapical radiographs.[46] Sparse trabeculation observed in periapical radiographs was found to be a strong indicator of low BMD.[25]

Surprisingly, ever since TBP classification was developed for panoramic radiographs, no studies have attempted to find a correlation between DEXA and TBP or TBP and MCI using panoramic radiographs. Despite the findings on the trabecular bone and periapical radiograph or computed tomography, this study found no significant correlation between TBP and peripheral DEXA in panoramic radiographs. Since trabecular bone loss precedes cortical bone loss,[35] it was hypothesized that TBP would be strongly correlated with MCI. This hypothesis was not confirmed by the present study results.

Overall, TBP was less accurate than MCI for detecting patients with low BMD. This could indicate that MCI is more reliable than TBP for detecting low BMD using panoramic radiographs as a screening tool. Furthermore, the diagnostic accuracy of MCI was greater for DEXA proximal forearm sites than for distal sites. No preceding data was found in the literature testing TBP diagnostic accuracy or MCI in distinct forearm sites that could be compared with the present results. The moderate diagnostic accuracy for MCI was previously reported for distinct DEXA sites.[5],[47] and a detailed systematic review considering different skeletal DEXA sites concluded that, after full consideration of patient medical history, radio morphometric indexes are useful for referring patients for further investigation.[48]

The limitations of the present study are the retrospective design and the small sample size. Peripheral DEXA, as well as MCI and TBP correlations with DEXA, should be studied further.

Within the limitations of this study, the present results suggest that panoramic radiographs for MCI are a valuable screening tool for detecting low BMD. Furthermore, MCI has an inverse correlation with proximal forearm DEXA. However, no significant correlation was found between TBP and peripheral DEXA or MCI.

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Conflicts of interest

There are no conflicts of interest.

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