Journal of Osteoporosis & Physical Activity

Brasileiro et al., J Osteopor Phys Act 2016, 4:1
DOI: 10.4172/2329-9509.1000170

Research | open access

Predictors Factors of Low Bone Mineral Density in Dental Panoramic Radiographs

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Received date: Feb 05, 2016; **Accepted date:** Feb 29, 2016; **Published date:** Mar 05, 2016

Abstract

Osteoporosis is a systemic disease that is considered a public health problem since it presents socioeconomic impacts. The disease results in micro architectural deterioration of bone tissue and decrease of bone mineral density (BMD) with consequent increase of bone fragility and susceptibility to fractures. Dual energy X-ray absorptiometry (DXA) is considered the gold standard for BMD evaluation, but investigations about several panoramic radiography indices have been done in order to seek a predictor of low BMD so that the dentist can play an important role in screening patients with low BMD and referring them properly for bone densitometry for osteoporosis investigation. The aim of this paper is to present a review of mandibular radio morphometric indices evaluated in dental panoramic radiographies and used to recognize patients with low BMD.

Keywords: Panoramic radiography; Bone mineral density; Osteoporosis

Introduction

Osteoporosis is a systemic skeletal disease characterized by deterioration of bone tissue and consequent decrease in bone mineral density (BMD). The World Health Organization (WHO) considers osteoporosis as a public health problem due to its prevalence at world's elderly population and socioeconomic impacts it generates [1]. The early diagnosis can prevent fractures, consequence of bone fragility. Many techniques are available to asses BMD, such as single or dual energy X-ray absorptiometry (SXA / DXA), single or dual photon absorptiometry (SPA / DPA), quantitative computerized tomography (QCT) and quantitative ultrasound (QUS) [2,3]. The most widely used is DXA of femur and lumbar spine and is expresses as a T score. According to WHO criteria, patients can be classified as normal (T score ≥-1.0), osteopenia (-1.0>T score>-2.5) and osteoporosis (T score ≤-2.5) [1]. However, unless the patient is subjected to the diagnostic test, hardly osteoporosis is detected before the fracture occurs, as it remains asymptomatic. In dentistry, many studies have investigated the applicability of panoramic radiography in recognizing patients with bone mass reduction and risk for osteoporosis, allowing the dentist to refer a patient medical evaluation to present this risk before it suffers a fracture. Radiography is the complementary exam most requested in dentistry and specifically the panoramic radiograph is commonly applied to patients by dentists to assess intra-osseous lesions, performing extractions or even as a routine dental examination. The purpose of this article is to present a review of panoramic radiography as a predictor of low bone mineral density (BMD). The methodology used in this paper included a search for literature related to panoramic radiomorphometric indices related to osteoporosis diagnosis performed on PubMed database from 2010 through November 2015. The search was conducted in English language and the keywords used were "bone mineral density and panoramic". It was found 154 articles related to the topic and the articles relating to bone mineral density with other diseases, genetic or congenital conditions, patients exposed to radiation and similar situations were excluded. After exclusion criteria, a total of 28 articles were included in this review.

Discussion

Most studies that assess the panoramic radiograph as a tool to predict low BMD evaluated postmenopausal women, especially because they are a risk group. The low concentration of estrogen is a factor that increases bone loss, initially in trabecular bone, and after in cortical bone. Most studies about panoramic radiographic changes associated with osteoporosis have been focused on measures of jaw bone mass or morphology. Klemetti et al. [4] was a pioneer to investigate the correlation between mandibular cortical morphology and low BMD to predict the risk for osteoporosis. In this study, the jaws of 365 women of postmenopausal age were evaluated by dental panoramic radiography and diagnosed for osteoporosis, osteopenia and regular examination by DXA. The researchers analyzed the mandibular cortical bilaterally of each patient and the patients were divided into three groups: class 1 (C1): the endosteal margin of the mandibular cortical is clear and sharp on both sides; class 2 (C2): the endosteal margin of the mandibular cortical shows semilunar defects (lacunar resorption) or appears to form endosteal cortical residues on one or both sides; and class 3 (C3): the edge of the mandibular cortical forms dense cortical endosteal residues and this clearly porous. The changes found in the mandibular cortex correlate with the BMD of each patient, being indicative of the risk of osteoporosis. The author points out; however, that is not an accurate diagnosis, only one predictor for the risk of the disease. The index proposed by Klemetti is called Klemetti Index (KI) or Mandibular Cortical Index (MCI).

Since Klemetti research, many studies have been developed with the goal to perform a qualitative analysis of the aspect of the mandible in dental panoramic radiographs. Renvert et al. [5] evaluated the mandibular cortex in the panoramic radiographs of 778 individuals (53% women) in the age of 59-96 years. The researchers observed the endosteal margin of the mandibular cortical, if it presented, full or

Citation: Tavares KNP, Mesquita RA, Amara PTM, Brasileiro CB (2016) Predictors Factors of Low Bone Mineral Density in Dental Panoramic Radiographs. J Osteopor Phys Act 4: 170. doi:10.4172/2329-9509.1000170

image of lacunar resorption and related to BMD previously assessed by DXA. The results were significant, with relationship between low BMD and lacunar resorption in mandibular cortical. Similar results were demonstrated by Singh et al. [6]. The authors showed significant correlation between MCI and BMD and demonstrated that none of the patients with osteoporosis was classified as C1 and there was a prevalence of C3 (77,42%). Normal BMD group was associated with the C1 finding (76,47%). Bajoria et al. [7] found that three of 23 showed were classified as C3 and all were elderly females. Valerio et al. [8] found a statiscally significant difference between the normal and low BMD groups (osteopenia and osteoporosis) for MCI. Bhatnagar et al. [9] also

Index	Index Description	Authors
Mandibular Cortical Index (MCI) or Klemetti Index (KI)	Mandibular cortical morphology that is classified as C1, C2 and C3	Khojastehpour et al. [13] Leite et al. [31] Renvert et al. [5] Bhatnagar et al. [9] Gaur et al. [11] Mansour et al. [10] Valerio et al. [8] Govindraju and Chandra [14] Kim et al. [12] Bajoria et al. [7] Singh et al. [6] Vijay et al. [22]
Pixel Intensity (PI)	Grayscale measurement	Khojastehpour et al. [13] Oliveira et al. [15]
Fractal Dimension (FD)	Mathematical analysis of the radiographic image , which evaluates its density and texture	Alman et al. [17] Koh et al. [18] Oliveira et al. [15] Sindeaux et al. [19]
Mandibular Cortical Width (MCW) or Mental Index (MI)	Thickness of the mandibular inferior cortical in the mental foramen region	Damilakis and Vlasiadis [35] Khojastehpour et al. [13] Leite et al. [31] Alman et al. [17] Passos et al. [24] Bhatnagar et al. [9] Gaur et al. [11] Jagelaviciene et al. [30] Mansour et al. [10] Valerio et al. [8] Govindraju and Chandra [14] Kim et al. [12] Nagi et al. [28] Sindeaux et al. [19] Bajoria et al. [7] Vijay et al. [22]
Panoramic Mandibular Index (PMI)	Ratio between the thickness of the mandibular cortical bone and the distance between the mental foramen and the mandibular inferior cortical bone	Damilakis and Vlasiadis [35] Passos et al. [24] Bhatnagar et al. [9] Gaur et al. [11] Mansour et al. [10] Govindraju and Chandra [14] Bajoria et al [7] Singh et al. [6]
Gonial Index (GI)	Thickness of the cortical bone in the area of the gonial angle	Gaur et al. [11] Bajoria et al. [7]]
Antegonial Index (AI)	Thickness of the cortical bone in the area located in front of the gonial angle	Gaur et al. [11] Vijay et al. [22] Bajoria et al. [7]
Antegonial Depth (AD)	Distance along a perpendicular line from the deepest point of antegonial notch concavity to the line parallel to the inferior cortical border of the mandible	Vijay et al. [22]
Gonial Angle (GA)	Angle formed by the intersection of a line traced tangent to the lower border of the mandible and another line tangent to the posterior border of ramus and condyle	Geary et al. [36] Vijay et al. [22]
Antegonial Angle (AA)	Angle formed by two lines traced parallel to the antegonial region that intersected the deepest point of the antegonial notch	Geary et al. [36] Vijay et al. [22]
Mandibular Angle (MA)	Angle formed by one line tangential to the posterior border of ramus and the condyle and another line tangential to the inferior most points at the gonial angle and the inferior border of the mandible	Shakeell et al. [23]
Mental Posterior Index 1, 2, 3 (MPI 1, MPI2, MPI3)	Obtained 1 cm, 2 cm and 3 cm posterior to MI, respectively	Valerio et al. [8]

Table 1: Indexes of the panoramic radiograph evaluated in the studies about low bone mineral density (PUBMED 2010-2015).

demonstrated a significant correlation between the degree of mandibular cortical shape erosion and BMD. Panoramic radiograph showed 96% specificity and 60% sensitivity in osteoporosis evaluation, indicating that this is an effective tool screening of osteoporosis. Mansour et al. [10] found significant correlation between MCI and BMD of the lumbar pines. The patients classified as C3 on the MCI presented significantly lowest mean BMD, followed by C2 and C1. Gaur et al. [11] evaluated panoramic radiographies of 40 postmenopausal women and assessed MCI. The results also indicated a significant relationship between BMD and MCI. For this index, the specificity was 88.88% and sensitivity was 100%. Kim et al. [12] performed a research with one hundred and ninety-four postmenopausal women and found that morphological changes of mandibular inferior cortical bone are associated with BMD independent of age, height and weight. Khojastehpour et al. [13] demonstrated a significant correlation between cortical shape of the mandible and age. The probability of the patients classified as C2 and C3 increased with age as also demonstrated by Govindraju and Chandra [14].

In osteoporosis, bone microarchitecture is changed and thus, the pattern radiographic image is affected. In digital radiography, shape and structural pattern of trabecular bone can be evaluated by pixel intensity (PI) and texture, including fractal dimension (FD). PI is a grayscale measurement, ranging from 0 (black) to 256 (white) in an 8 bit digital image [15]. Kjojastehpour et al. [16] investigated the relation between mandibular density measurement (gray scale) in panoramic radiography and BMD of 115 postmenopausal women. Significant difference in alveolar bone density was found between normal and osteoporotic group with Spine Bone Mineral Density (SBMD) and Femoral Bone Mineral Density (FBMD) T-score ≤ - 2.5 and between normal and osteoporotic patients with FBMD T-score ≤ - 2.5. The authors suggested that FBMD is more related to mandibular bone density than SBMD. For fractal analysis, regions of interest (ROI) are selected and manipulated in digital panoramic using software available for free, such as NIH's Image J [17]. Studies reported differences in FD between normal and osteoporotic patients, but the relation between mandibular FD and skeletal BMD is not demonstrated in all studies. Alman et al. [17] used fractal analysis of trabecular bone in dental panoramic radiographies to asses men and women BMD. The results indicated that FD is reliable tool to identify low BMD in both men and women and FD was significantly higher in males than females. Koh et al. [18] evaluated postmenopausal women and demonstrated that there was significant difference in the FD values between osteoporotic and normal patients (FD values decrease in osteoporotic group compared with normal group). There was a significant difference in the FD values among different sites of jaw and the lower premolar region was the most appropriate site of the jaws for evaluating the FD value on panoramic radiographs. Besides, age was significantly correlated with the BMD measurements and FD values were not significantly correlated with the BMD measurements. Oliveira et al. [15] showed that FD and PI of the mandibular trabecular bone are a promising tool to identify patients with low BMD. FD and PI values were significantly different between normal and osteoporotic groups for the right and left mandibular angle and for the left mandibular body. Sindeaux et al. [19] performed FD analysis on mandibular trabecular and cortical bone of 133 dental panoramic radiography from men under 60 year and postmenopausal women. The results showed differences with statistical significance in FD values on mandibular cortical bone between patients with normal BMD and with osteoporosis, however, this difference was not found on the trabecular bone.

In addition to qualitative analysis, quantitative assessment of panoramic radiography as low BMD predictor has been reported in several studies based on radiometric index. In iterature, the most studied index are: *Mandibular Cortical Width (*MCW), also called *Mental Index* (MI), and *Panoramic Mandibular Index* (PMI). Linear measurements less studied include *Gonial Index* (GI), *Antegonial Index* (AI) and *Antegonial Depth* (AD). Angular measurements including *Gonial Angle* (GA), *Antegonial Angle* (AA) and *Mandibular Angle* (MA) are also investigated. Most of the studies was performed in postmenopausal women and evaluated the MCW or MI, described by Ledgerton et al. [20], which is the measure thickness of the mandibular cortical bone at the mental foramen region. A line parallel to the long axis of the mandible and tangential to the inferior border of the mental foramen is drawn. A line perpendicular to this tangent intersecting the inferior border of the mental foramen is drawn, along which mandibular cortical width is measure [12]. PMI is a radiomorphometric method which was presented by Benson et al. [21]. PMI is the ratio between the mandibular cortical bone thickness and the distance from the mental foramen to the lower edge of the mandible. Measurements greater than or equal to 0.3 mm was considered normal values. GI is the measurement of the mandibular cortical thickness measured on the bisectrix of the angle between the tangent lines to the posterior border of the mandible ramus and the bottom of the mandible (normal value is higher than 1.2 mm) [7]. AI is the measurement of the cortical width in the region anterior to the gonial at a point identified by extending a line of best fit on the anterior border of mandible (normal value is 3.2 mm). AD is measured as the distance along a perpendicular line from the deepest point of antegonial notch concavity to the line parallel to the inferior cortical border of the mandible. Normal depth is 1.6 mm (±2). GA is measured by intersection of a line traced tangent to the lower border of the mandible and another line tangent to the posterior border of ramus and condyle on each side (normal GA is 128° ± 7). AA is formed by two lines traced parallel to the antegonial region that intersected the deepest point of the antegonial notch (normal angle is 163° ± 2) [22]. MA is angle formed by one line tangential to the posterior border of ramus and the condyle and another line tangential to the inferior most points at the gonial angle and the inferior border of the mandible [23].

Studies have demonstrated a significant correlation between thin MCW or MI and low BMD, especially in postmenopausal women. The mean cortical widths of the osteopenic/osteoporotic groups were lower than that of the normal group [13,24,25]. Shakeel et al. [23] demonstrated a positive correlation between MCW and BMD. Previous studies reported that mandibular cortical width below 3 mm at the mental foramen region may be considered threshold value when predicting low spinal and femoral BMD (osteoporosis or osteopenia) and is a criterion for referring patients for densitometric evaluation [26,27]. According to Nagi et al. [28], the inferior cortical presented thinner than 3 mm (threshold to differentiate normal) in panoramic radiographs of women with low BMD. For Kim et al. [12], the mean MCW was 2.7 mm for menopausal women, but the optimal cut-off value of MI for the diagnosis of osteoporosis was 2.22 mm (sensitivity 67.9% and specificity 78.5%). The authors suggested that women with mandibular cortical thickness less than 2.5 mm should be referred for osteoporosis evaluation. Passos et al. [24] observed that MCW was smaller in osteopenia or osteoporosis group (4.5 mm ± 0.9) than normal group (4.9 mm ± 1.2) and this difference was statistically significant. Mansour et al [10] showed that when MI cutoff point was 4.5 mm, all patients >4.5 mm were considered normal and the sensitivity and specificity were 76.9% and 54.1%, respectively. Maramatsu et al. [29] showed that the mean MCW for osteoporotic and normal group were 2.2 and 3.9 mm, respectively. When a threshold of 2.7 mm was applied, the sensitivity and specificity for identifying osteoporotic patients were 88.5 and 97.3%, respectively. Jagelaviciene et al. [30] evaluated the relationship between the bone mineral density in the calcaneus and the MI in panoramic radiography in postmenopausal women. The results indicated a significant correlation between calcaneal BMD and MI. Besides, the authors reported that when the mandibular cortical width is 3 mm or less, a reduction of BMD in the calcaneus may be predicted. Khojastehpour et al. [13] and Kim et al. [12] showed that age was significantly correlated with MI. As age increased, MI decreased. Govindraju and Chandra [14] showed similar results. MI values were significantly smaller in older females than males of the same age group. Savic and Pavicin (2014) demonstrated significant correlation between MI and BMD in the hip but not in the lumbar spine region.

Few studies have evaluated the relationship between BMD and mandibular cortical thickness in men. Leite et al. [31] demonstrated that MCW (MI) had a positive correlation with lumbar spine and femoral neck BMD. Taguchi et al. [32] investigated the relationship between MCW and calcaneal BMD in men and women aged 40 or younger. The results revealed that men with an undetected low calcaneal BMD could be identified by the MCW measured, while women with an undetected low calcaneal BMD could not be recognized. In contrast, Alman et al. [17] reported that MCW have better diagnostic performance for women with low BMD than men. Sindeaux et al. [19] evaluated the MCW of 133 dental panoramic radiographs from men aged under 60 years and postmenopausal women with osteoporosis and normal BMD. The study revealed that there are significant differences in MCW between women with osteoporosis and normal BMD, that presents mean values of MCW significantly higher (4.036 mm ± 0.930) than women with osteoporosis (2.752 mm ± 0.859 mm). The authors not found significant differences between mean values of MCW of men with normal BMD (3.982 mm ± 1.251) and osteoporosis (3.434 mm ± 0.839 mm). The mean values of MCW between men and women were statiscally the same, but higher values of MCW were found in men with osteoporosis. Bajoria et al. [7] also demonstrated that MCW values were smaller in women that in men. Valerio et al. [8] proposed three new indices based on MI: the mental posterior index 1 (MPI1), mental posterior index 2 (MPI2) and mental posterior index 3 (MPI3) obtained 1 cm, 2 cm and 3 cm posterior to MI, respectively. The results revealed statistically significant difference between osteoporosis group and the normal and osteopenia groups in all indices evaluated.

The majority of the studies were performed measuring index with a manual method. Softwares have been developed to detect the mandibular cortex on dental panoramic radiography and then the distance of the lower and upper boundaries is measure (cortical width). Kavitha et al. [33] developed a computer-aided diagnosis system to continuously measure mandibular inferior cortical width on dental panoramic radiographs. The sensitivity and specificity of CAD system in recognizing postmenopausal women with low spinal BMD was 90% and women with low femoral BMD was 81.8% and 69.2%, respectively.

Studies that evaluated the correlation between PMI and BMD are controversial. Singh et al. [6] revealed a significant correlation between PMI and BMD. About 48% of osteoporotic group presented PMI scores of < 0,4 and 50% of osteopenic group had a PMI score of 0,4-0,44. Normal patients presented a PMI score >0,44 (49,1%). Savic and Pavicin [34] found significant correlations between PMI values and BMD in the hip but not in the lumbar spine region. According to Govindraju and Chandra [14], significant difference was seen between females and males for PMI values. Shakeel et al. [23] demonstrated a positive correlation between PMI and BMD. Bajoria et al. [7] demonstrated that the mean PMI in younger individuals was 0.69 and in older individuals it was 0.64. The mean PMI in males was 0.73 whereas in females it was 0.58. The authors also showed that PMI decreased with age and was smaller in women than in men. In contrast, some studies have not shown significant results of correlation between PMI and BMD. Damilakis and Vlasiadis [35] compared PMI and MCW and demonstrated that MCW showed the best performance for the prediction of patients with low BMD compared to PMI. Passos et al. [24] observed difference statistically significant in MCW between osteopenia or osteoporosis women and normal women. Similar results were found by Bhatnagar et al. [9]. The authors demonstrated a significant correlation between MCW and BMD and no significant difference was found in PMI. Panoramic radiograph showed 58% specificity and 73% sensitivity in assessing osteoporosis. Govindraju and Chandra [14] showed that PMI were higher in patients classified as C1 and C2 and they gradually decreased in the C3 category.

In a recent study, Vijay et al. [22] evaluated indexes that are not usually assessed such as, GA, AA, AD, AI, besides the MI and MCI. The results revealed that AA e AD were significantly greater in normal patients when compared with low bone mass individuals (osteoporotic and osteopenic patients). However, AI could diagnose only four of twenty three patients with osteoporosis, probably due to the continuous remodeling in the mandibular cortex with age, dental status and gender. Bajoria et al. [7] demonstrated that AI and GI had lower values in females when compared to males. Geary et al. [36] found that GA and AA were not significantly different between normal and low bone mass patients. Shakeel et al. (2015) showed positive correlation between AA and Tscore in female patients, but not in males patients. Savic and Pavicin [34] showed significant correlation between AI and BMD in the hip but not in the lumbar spine, but GI did not show statistically significant correlation with BMD in both regions. Gaur et al. [11] evaluated panoramic radiographies of 40 postmenopausal women and assessed MI, PMI, GI, AI and a qualitative index, MCI, and showed significant reductions in mean values in the osteoporotic group compared to normal and osteopenic groups in MI, PMI and GI. No significant correlation was seen between AI and low BMD. Ardakani et al. [37] evaluated the cortical thickness of the mandibular angle of 60 patients (40 females and 20 males). The mean cortex thickness of the mandible angle on the right and left sides were 0.99 ± 0.34 mm and 0.98 ± 0.3 mm, respectively. The results indicated that there is no significant relationship between mandibular angle cortex thickness in osteoporotic patients compared to patients with a normal BMD, suggesting that this index is not a suitable tool for screening patients for a low BMD. Shakeel et al. [23] showed positive correlation between MA and T-score in male patients, but not in female patients. In Table 1 is listed the indexes of the dental panoramic radiograph evaluated in the studies about low bone mineral density according to the search in PubMed database from 2010 through November 2015.

In conclusion, it was verified that visual and morphometric indices measured in dental panoramic radiography could be considered a useful tool to predict low BMD and risk of osteoporosis, especially in postmenopausal female patients. In this way, being an exam routinely requested in dental offices, the dentists had an important role in screening patients with low BMD and referring them properly for bone densitometry for osteoporosis investigation.

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