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Radiomorphometric Indices of the Mandible as a Screening Tool for Osteoporosis

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ABSTRACT

Introduction: Osteoporosis is the most common metabolic bone disease and is characterized by an increased risk of bone fractures. Early detection of osteoporosis is necessary to prevent hip fractures later in life. We evaluated changes in mandibular radiomorphometric indices in post-menopausal women using Dual Energy X-Ray Absorptiometry (DXA) to assess their association with Osteoporosis.

Materials and Methods: Nine radiomorphometric indices and the number of mandibular teeth on dental panoramic radiographs were evaluated in 85 post-menopausal women at age 45-74. DXA measured bone mineral density (BMD) at the lumbar spine. BMD values were categorized as normal (T-score greater than -1.0), indicative of osteopenia (-1.0 T-score<-2.5), or osteoporosis (T-score<-2.5) according to the World Health Organization classification.

Results: The AA, AI and MI were significantly smaller in individuals with low bone mass (p<0.05). The AD was significantly larger in osteoporotic individuals (p<0.05) and the comparison of MCI among the three subgroups of MBD showed significant differences. There was no significant difference between the three categories of skeletal bone status for PMI, M/M Ratio, GA and the number of mandibular teeth.

Conclusion: Osteoporotic individuals are more likely to have altered inferior cortex and antegonial region morphology and thickness than non-osteoporotic individuals. The smaller AI and larger AD were strongly associated with lower bone mass. Clinical relevance: In this study, we provided a model to assess the risk of osteopenia or osteoporosis in dental panoramic radiography.

Keywords: Osteoporosis; Panoramic radiography; Mandible; Bone mineral density.

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Introduction

Osteoporosis is considered as the most significant health problem of middle-aged women coinciding with menopause. Osteoporosis manifestations include generalized decrease in bone mass and deterioration of bone microarchitecture. The prevention of disease is of great importance as the pathologic fractures resulting from the disease are a serious health and economic issue [1,2]. As an established gold standard, Dual-Energy X-ray Absorptiometry (DXA) has remained a reliable method for calculating bone mineral density (BMD) [3]. This test is recommended for post-menopausal women for early diagnosis of osteoporosis. However, as DXA is not widely available in many countries, it is not truly practical for all postmenopausal women to undergo this examination [4].

In order to diagnose and treat dental disorders such as dental caries and periodontal diseases, panoramic radiographs are routinely taken [5]. On the other hand, the earliest suggestion of a correlation between osteoporosis and oral bone loss was made in 1960 [6]. In several studies, the correlation between bone mineral density (BMD) and mandibular densitometric [7,8] and morphometric indices was evaluated [8,9]. Additionally, various methods such as Dual Photon Absorptiometry (DPA), Quantitative Computed Tomography (QCT), and Dual Energy X-ray Absorptiometry (DXA) have been employed to assess the relationship between changes in BMD and the jawbones [10]. This study aimed to evaluate changes in radiomorphometric indices in the mandible of osteopenic and osteoporotic postmenopausal women to assess whether these indices can be used as a screening tool.

Materials and Methods

Study Sample

This descriptive–analytic study was based on 85 postmenopausal Iranian women varying in age from 45 to 74 years (Table 1). All the subjects had lumbar spine densitometry by the order of their medical specialist and a panoramic radiograph that their dentist ordered. Patients with a history of hyper and hypoparathyroidism, osteomalacia, renal osteodystrophy, osteogenesis imperfecta, cancers with bone metastasis and significant renal impairment were excluded due to possible changes in bone metabolism. Also, all subjects were non-smokers and had no background of alcohol consumption. Every patient entered the study with consent and all their information remained confidential.

Antero-posterior DXA scan was performed using Medilink osteocore bone densitometer (serial number 810, 1990, France) for measuring BMD at the lumbar spine. BMD values were categorized as normal (T-score greater than -1.0), indicative of osteopenia (-1.0 T-score<-2.5), or osteoporosis (T-score<-2.5) according to the World Health Organization classification [11].

Radiographic Measurements

A panoramic radiograph was used to evaluate radiomorphometric changes in the mandible. Panoramic images were created using the panoramic machine (Proline model 2002, Helsinki, Finland). All the radiographies were prepared by an Oral and Maxillofacial radiologist in order to control the technical errors. Two dentists independently and without knowledge of the results of the bone density of patients measured continuous mandibular radiomorphometric indicators using a digital caliper type of 0.01mm and conveyor, then the data were recorded on appropriate forms. After all data were obtained, all procedures were repeated after 2 weeks.

All measurements were taken on both the left and right sides and were not corrected for the magnification inherent in panoramic radiography.

Radiomorphometric indices were determined based on panoramic radiographs.

Gonial Angle (GA)[12].

Antegonial Angle (AA) [13].

Antegonial Depth(AD) [12].

Antegonial Index (AI) [13,14].

Mental Index (MI) [13-15].

Panoramic Mandibular Index (PMI)[7,16].

Mandibular crest resorption degree (M/M ratio)[16].

Mandibular Cortical Index (MCI)[17].

Number of mandibular teeth

Eight of the variables were continuous and one of them, MCI, was categorical data (Figure.1-4).

Statistical Analysis

The Shapiro-Wilk test is used to evaluate the normality of numerical variables. Data were expressed as mean (±SD) or frequency and percentage for analysis of quantitative variables. Paired T-test and analysis of variance were used to compare means. The chi-square test or Fisher's exact test was used to determine the relationship between qualitative variables. The degree of agreement between two observers' measurements was determined by Cohen's kappa coefficient (ĸ) values with 95% confidence intervals. Sensitivity and specificity were reported for mandibular radiomorphometric. The correlation between the right and left sides was computed with the Pearson correlation coefficient. The local research Ethics committee approved this study. Informed consent was obtained from all 85 participants.

Results

Of the total 85 samples, based on the results of BMD in the lumbar spines (L2-L4), 33 individuals were normal (38.8%), 39 cases were osteopenic (45.9%), and 13 cases were osteoporotic (15.3%). According to the obtained data, each variable was analyzed separately for the three groups (Table 2). Osteoporotic individuals had significantly smaller AA, antegonial and MI than those of the normal patients ($p<0.05$) (Table 3). Also, AA was significantly smaller for osteoporotic individuals compared with osteopenic individuals, and AI was significantly smaller for osteopenic individuals compared with normal individuals ($p<0.05$). On the other hand, AD was significantly larger for osteoporotic individuals compared to normal individuals. Notable decrease was observed in MI and AI with aging ($p<0.05$). No significant difference was observed between the three BMD categories for PMI, M/M ratio, GA and number of mandibular teeth ($p<0.05$) compared with individuals with normal bone status.

Since inter-observer agreement for variables was good to excellent, data obtained by one of the observers were evaluated. Weighted kappa was calculated as 0.68 for inter-observer agreement with a 99% confidence interval. After the analysis of quantitative variables, in order to assess the mandibular cortical index , the frequency of mandibular inferior cortex morphology based on Klemetti and colleagues was calculated in the studied groups (Figure.). In the normal group, 19 cases (57.6%) were classified as C1, 14 cases (42.4%) were classified as C2, and C3 was not detected in this group. In the osteopenia group, there were 15 patients (30.8%) C1, 23 cases (59.0%) C2 and one case (2.6%) C3. The results showed that with the changes of BMD from normal to osteopenia and then osteoporosis, the morphology of the inferior cortex of the mandible changes from C1 to C2. Statistical test revealed a significant difference between the MCI of normal, osteopenic, and osteoporotic groups. ($P=0.022$) The chi-square test and the Fisher test separately found that this difference between normal and osteoporotic individuals is significant. The sensitivity and specificity of the MCI Index, evaluated in healthy cases and osteopenic and osteoporotic patients, are 63.46% and 57.57%, respectively. With regard to the meaningfulness of age between the groups, the effects of aging on mandible radiomorphometric indicators were assessed separately (Table 3). For this purpose, patients were divided into three groups based on age. First group: 45-54 years (38 cases), the second group 55-64 years (36 cases) the third group was older than 65 years (n=11). Based on the obtained results, only AI reduction and reduction in the number of remaining teeth in the three groups showed significant differences. Likewise, by every decrease in AI per unit, subjects were 0.84 times more likely to be osteoporotic. Figure 1. Categories of cortical morphology in the lower mandible of three groups by Klemetti.

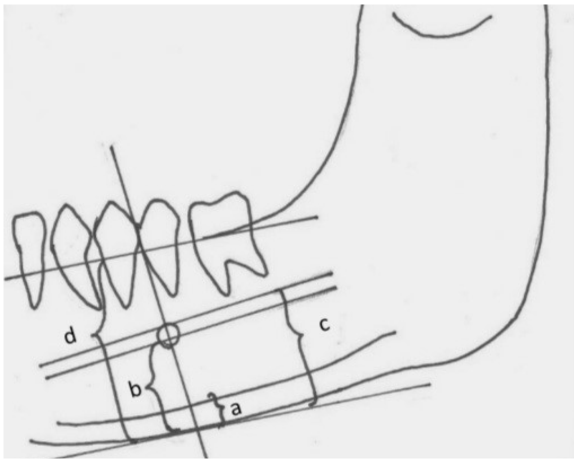

Figure 1. Measurements on the panoramic radiography. cw:a. PMI:a/b. M/M:d/c.

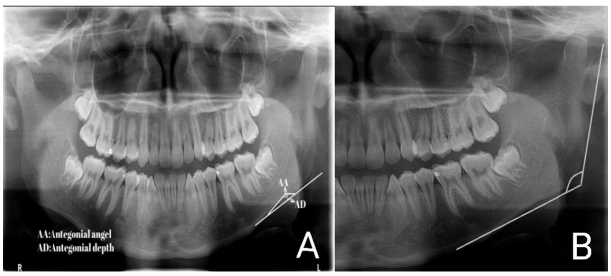

Figure 2. Measurements on the panoramic rediography. A: antegonial depth and antegonial angle, B: gonial angle.

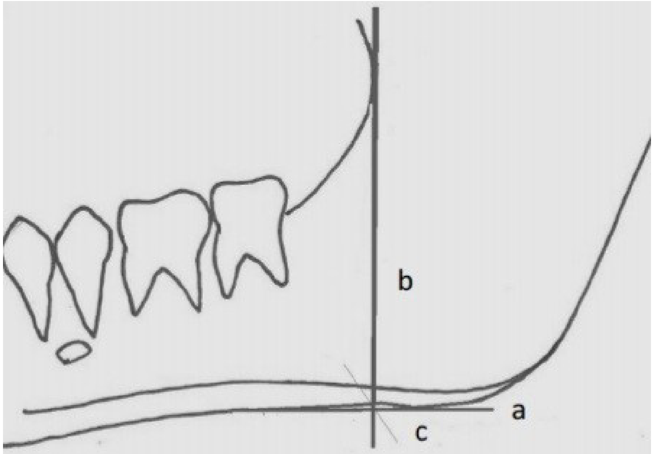

Figure 3. Measurements on the panoramic radiography for antigonial index.

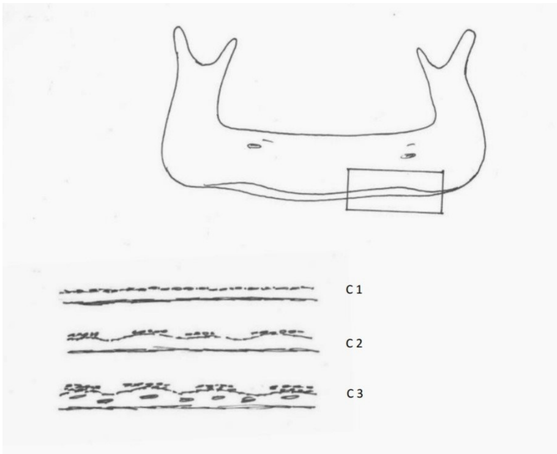

Figure 4. Classification of Cortex morphology.

Table 1. Characteristics of the sample.

Characteristics		*N*	*%*
Age(years)	*45-54*	*38*	*44.7*
	55-64	*36*	*42.3*
	64+	*11*	*12.9*
Bone status	*Normal*	*33*	*38.8*
	Osteopenia	*39*	*45.9*
	Osteoporosis	*13*	*15.3*

Table 2. Sample distribution by MCI category in three BMD categories.

	Cortical index		
	C1 1	*C1 2*	*C1 3*
Normal	*19 (57.6)*	*14 (42.4%)*	*0*
Osteopenia	*15 (38.5%)*	*23 (59%)*	*1 (2.6%)*
Osteoporosis	*4 (30.8%)*	*6 (46.2%)*	*3(23.1%)*

Table 3. Means and standard deviations for continuous variables in three BMD categories.

Index	Normal (n=)	Osteopenia (n=)	Osteoporosis (n=)	P value
M/M (in dentulus patient)	2.35±0.30	2.29±0.30	2.34±0.30	0.852
M/M (In edentulous patient)	1.98±0.36	1.83±0.41	1.86±0.28	0.510
MI	7.76±0.82	4.39±0.88	3.90±0.87	0.10
AI	3.9±0.59	3.23±0.68	3.09±0.61	0.000
AA	169±5.07	167.5±5.07	162.53±5.63	0.000
GA	125.4±5.7	124.2±6.8	124.04±7.48	0.669
AD	1.63±0.94	2.03±0.93	2.68±0.94	0.005
PMI	0.341±0.06	0.332±0.07	0.331±0.11	0.866
Teeth	8.27±4.68	6.49±5.07	5.85±5.19	0.199
Age	53.67±5.29	57.18±6.64	61.00±7.56	0.002

* SD=Standard Deviation.

Table 4. Coefficients of intra- and inter-observer agreement.

	Gonial angel	MI	AI	Antegonial angle	Antegonial depth	PMI	Teeth	M/M
Intraobserver agreement	0.99	0.85	0.82	0.98	0.98	0.95	1	0.95
Interobserver agreement	0.98	0.92	0.87	0.91	0.95	0.76	1	0.92

Table 5. The overall accuracy of the model in predicting subjects having osteoporosis.

	Chi- square	df*	Significance
Model	29.372	2	0.001
Block	29.372	2	0.001
Step	7.85	1	0.005

Confidence interval: 99%, P= 0.05.
*degrees of freedom.

Discussion

This study aimed to evaluate the relationship between various mandibular indices and low BMD and to develop an equation that might be applied in assessing the probability of osteoporosis in certain patients. BMD of the lumbar spine was used as the gold standard in defining patients with low BMD. However, the only truly reliable gold standard measure of BMD is bone biopsy. The DXA offers the best means of obtaining accurate information in vivo [18]. By 2030, the world population of menopausal and postmenopausal women is expected to increase to 1.2 billion, with 47 million new cases each year [19,20]. Some investigators reported that mandibular indices could be used in screening for osteoporosis [15,21]. Panoramic radiography is still used as a routine diagnostic tool in dental treatments of the population prone to OP (the elderly). In contrast, Gomes et al. have indicated no significant difference between cone-beam computed tomography (CBCT) and panoramic technique in patients with low BMD [22]. Kingsmill and Boyde studied the variability in the anatomy of mandibles of individuals between 19 to 96 years and cross-sectional slices of the dry mandibles in London in 1998 and measured cortical width from the radiography of those slices they concluded that unlike other bones, the mandible may show no increase in apparent density with age, implying that the mandible may not be suitable for evaluating osteoporosis status. They found no relationship between radiographic cortical thickness and age [23]. Taguchi et al studied the mandibular bone density of 44 women who were in different postmenopausal stages using topograms of skull and CT images of mandible in Hiroshima in 1995 and reported that BMD of the mandibular cortical bone had greater correlation (r=0.73) with lumbar trabecular bone mineral density in recent postmenopausal group than in long-term postmenopausal group (r=0.46) [18]. In this study, we were unable to show any relation between low BMD and mandibular indices such as PMI, M/M ratio, GA, and number of mandibular teeth, as in Yasar and Akgunulu studies [16]. However, we have found that mandible also undergoes a change in shape during osteoporotic involution. This way, mandibular shape analysis may be a powerful diagnostic tool for screening patients at increased risk of osteoporosis. The AA was significantly larger in normal individuals compared with those of low bone mass, and this difference was not affected by age. Also, the AD was significantly greater in osteoporotic individuals when compared to individuals with normal bone mass. These results suggest that AA and AD may be suitable for predicting low bone mass, as both measurements exhibited resorptive patterns in the antegonial region in individuals with low bone mass.

The resorption in the antegonial region may be associated with muscle function, which tends to preserve bone at its point of insertion. The antegonial region may be more sensitive to bone resorption because of the reduced number of muscle fiber insertions when compared to the gonial region. The thickness of the cortical bone in the antegonial and mental region was significantly smaller in those with low bone mass. This result was already predicted and agrees with the previous studies [16,24]. However, both indices were significantly smaller in older patients. The previous study also found that AI decreased with age [25-28]. Therefore, these indices may not be suitable for assessing low BMD. On the other hand, Durra et al. showed another interaction between AI and MI and dental status, suggesting that these indices may have limited use in predicting individuals with decreased BMD [13]. In Nemati et al.'s study in Iran in 2016, significant differences were observed in the number of teeth lost among the osteoporotic, osteopenic, and control groups. This finding confirms that the mean number of teeth lost in osteoporotic patients was greater than in normal and osteopenic groups [29]. However, in this study, the number of mandibular teeth did not show differences among the three categories of skeletal bone status (p>0.05). One possible explanation for these findings could be the limitation in sample selection, and as a result of the fact that most of the individuals with a normal BMD were younger and most of the individuals with low BMD were older. Similar to the present study, Johari et al. found no statistically significant difference in the number of teeth lost among the three groups [30]. Further studies using samples with a narrow age range should investigate the potential influence of age on these parameters. One of the most common studies on parameters of mandibular bone in relation to osteoporosis is the porosity of the mandibular cortical bone (MCI). Some investigators have found an association between MCI and osteoporosis [15,17,29,31]. Valerio et al. stated that MCI can be used to identify postmenopausal females with low bone densities [32], and Munhoz et al. demonstrated that MCI is inversely associated with bone mineral density [33]. Still, in some other studies, MCI showed no significant difference between normal and osteoporotic groups [34-36].

In the study conducted by Çacur et al., no significant result was observed between BMD obtained in the densitometry of the jaw and that obtained in the hip and lumbar spine. This fact may be due to the difference in measurement methods, as they evaluated the BMD of the jaw using DXA, rather than panoramic images, and also did not use overlapping images of both sides of the jaw [8]. On the other hand, research by YaŞar and Akgünlü on 48 postmenopausal women demonstrated no significant differences between non-osteoporotic and osteoporotic patients for the panoramic mandibular index (PMI) and the number of mandibular teeth [16]. Although these results were similar to those in our study, the samples included in that study were significantly younger than ours.

In this study, MCI showed a statistically significant difference in the osteoporotic and non-osteoporotic individuals with a good agreement in inter-observer reliability (k=0.68) and an excellent agreement in intra-observer reliability (k=1). The risk of low BMD in Cl 2 category was 2.07 times that of Cl 1, with a 95% confidence interval. The number of mandibular teeth showed the highest intra-observer reliability, while the antegonial and mental indices exhibited the worst reliability. The least inter-observer reliability was related to PMI and AI, respectively. Obtaining high agreement in measuring gross structure, such as counting teeth, is easier than obtaining high agreement in measuring in millimeters because in these measurements, the visual perception of the human eye and brain should also be taken into consideration.

The linear measurements have greater observer dependency, and another factor is that X-ray film is measured by hand. There is a limitation in the repeatability of panoramic measurements. This limitation must be considered when using these measurements for assessing osteoporosis risk.

Conclusion

Some indices revealed differences between osteoporotic individuals and healthy individuals. AI, AD, AA, and MCI could be considered as predicting indices for individuals at risk of osteoporosis. The results also demonstrate that aging is a determining factor in the thickness of the inferior mandibular cortex in the mental and antegonial region, so this point should be considered while evaluating panoramic radiographs in healthy older individuals. According to the result of this study, an equation for determining the probability of being affected by osteoporosis in an individual is generated as follows:

z=5.4+0.8 AD-1.8 AI.

PV=1/ (1+e −z).

Finally, it is concluded that women with low BMD are likely to have resorption in the antegonial region and cortical borders and an increase in porosity degree of the inferior mandibular cortex. Unfortunately, access to patients' mandible densitometry was not possible, and this may be considered a significant limitation in this study. It is recommended that future studies incorporate mandible densitometry into their research methodology and investigate its association with osteoporosis.

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Conflict of Interest

There is no conflict of interest to declare.

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