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ORIGINAL ARTICLE

The relationship between panoramic radiomorphometric indices and the femoral bone mineral density of edentulous patients

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Abstract

Objectives To determine the relative efficacy of panoramic radiomorphometric indices in detecting osteoporosis, and optimal thresholds for referral for osteoporosis investigation in edentulous patients.

Methods Forty-nine edentulous patients, age 41–78 years, were divided into normal and osteopenic/osteoporotic groups according to femoral bone mineral density. Panoramic radiographs were obtained to determine the mandibular cortical index (C1, normal; C2, mild; and C3, severe erosion of mandibular cortex), mental index (cortical thickness in the mental foramen region), and panoramic mandibular index (ratio of thickness of the mandibular cortex to distance between the inferior margin of the mental foramen and the inferior mandibular cortex). Results were compared using a chi-squared test and Student's *t*-test.

Results Categories C1 and C3 were more frequent in the normal and osteopenic/osteoporotic groups, respectively ($p = 0.007$). The mean mental index and panoramic mandibular index values were significantly lower in the osteopenic/osteoporotic group than in the normal group ($p = 0.002$ for mental index, $p = 0.019$ for panoramic mandibular index). The sensitivity and specificity were 71.4% for the mandibular cortical index. The area under the receiver operating characteristic curve enabled moderately accurate identification of patients with osteoporosis using the mental index and less accurate identification using the panoramic mandibular index.

Conclusions The mandibular cortical index and mental index are better than the panoramic mandibular index for identifying patients with osteoporosis. Within the limits of this study, edentulous male or female patients in category C3 with a mental index <3.5 mm should be referred for further osteoporosis investigation.

Keywords Osteoporosis · Panoramic radiography · Mandibular cortical index · Mental index · Panoramic mandibular index

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Introduction

Osteoporosis, the most common metabolic bone disease, is characterized by low bone mass, microarchitectural weakening leading to bone fragility, and increased fracture risk [1–3]. Bone loss starts at about 35 years of age and continues at different rates throughout life [3]. The jaw bones can be affected by systemic disease, medical treatment, or local bone diseases that can result in the loss of all of the teeth. After tooth extraction, the jaws undergo continuous alveolar ridge atrophy with the use of full dentures [3, 4]. Several investigators have stated that osteoporosis results in reduced jaw bone mass and altered mandibular structure, especially of the inferior border [5–7].

Panoramic radiographs are widely used for routine examinations, especially for edentulous patients before the construction of a complete denture [3, 8]. It would be very useful to know whether radiographic changes in the mandible indicate skeletal osteopenia and might aid in the detection of osteoporosis. Panoramic radiomorphometric indices, including the mandibular cortical index (MCI), mental index (MI), and panoramic mandibular index (PMI), have been used to assess bone quality and detect osteoporosis [9–15]. Using panoramic radiographs, Klemetti et al. [11] developed the MCI to classify the porosity of cortical bone as follows: C1, an even, clear endosteal cortical margin; C2, the endosteal margin has semilunar defects or forms one to three endosteal cortical residues; and C3, the cortical layer forms many endosteal cortical residues and appears porous. The MI is the mandibular cortical width measured at the mental foramen region, as described by Ledgerton et al. [13]. The inferior PMI, which was initially described by Benson et al. [16], is the ratio of the thickness of the mandibular cortex to the distance between the inferior margin of the mental foramen and the inferior mandibular cortex. Several studies have investigated the relationship between panoramic radiomorphometric indices and skeletal bone mineral density and report that the efficacy of panoramic indices for diagnosing osteopenia/osteoporosis is low to moderate [3, 10, 13].

Dual-energy X-ray absorptiometry (DEXA) is a technique that enables fast, noninvasive, and highly precise measurement of bone mineral density (BMD). In daily clinical practice, DEXA is the most useful method for assessing BMD in the vertebrae, femoral neck, and forearms [1, 17].

Although a few studies have evaluated changes in the MCI, MI, and PMI in males or females [13, 18, 19], no study has determined the relative efficacy of all three indices for detecting osteoporosis. Therefore, this study evaluated whether the MCI, MI, and PMI are useful for identifying patients with osteoporosis and determined the optimal MI and PMI thresholds for referral for osteoporosis investigation.

Materials and methods

The study group consisted of 49 edentulous patients (18 males, 31 females; age range 41–78 years, mean age 60.2 ± 11.04) who were examined in the Ankara University Faculty of Dentistry Oral Diagnosis and Radiology Department. Patient age, gender, menopause, and systemic conditions were recorded. The criteria for selecting the subjects were as follows: edentulous maxilla and mandible and using two full dentures; no history of serious diseases affecting oral bones; all women had a natural menopause; and no previous fractures. None of the women were on hormonal replacement therapy or taking calcitonin, bisphosphonates, or fluorides, but may have been taking low doses of calcium or vitamin D.

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Femoral bone mineral density measurements

Bone mineral density at the left femoral neck was determined using DEXA (Hologic Discovery A, Hologic, Bedford, MA, USA). Scans were performed by the same experienced technicians. The patients were divided into three skeletal mineral density groups based on DEXA measurements of the femoral neck according to the WHO criteria: normal (T-score > -1; $n = 28$), osteopenic (T-score from -1 to -2.5; $n = 16$), and osteoporotic (T-score < -2.5; $n = 5$). Given the small number of osteoporotic patients, they were combined with osteopenic patients into one group ($n = 21$).

Panoramic measurements

All panoramic images were taken with a PM 2002 CC Proline machine (Planmeca, Helsinki, Finland) by a single operator. The position of the head was standardized as much as possible. Linear measurements were made using digital calipers on panoramic radiographs after correction for 20% magnification, to better simulate the clinical situation. Two oral radiologists (with 12 and 6 years of clinical experience, respectively) independently determined the MCI (Fig. 1), MI, and PMI (Fig. 2).

Intraobserver and interobserver agreement

One observer, with 12 years of clinical experience, served as the main observer, and intraobserver reliability was estimated between measurements performed one month apart. To determine intraobserver reliability, all subjects were reassessed and the distances were re-measured. To determine interobserver reliability, all subjects were evaluated by two observers. The kappa value was calculated for the MCI classification and the intraclass correlation coefficient (ICC) was calculated for MI and PMI. Kappa > 0.75

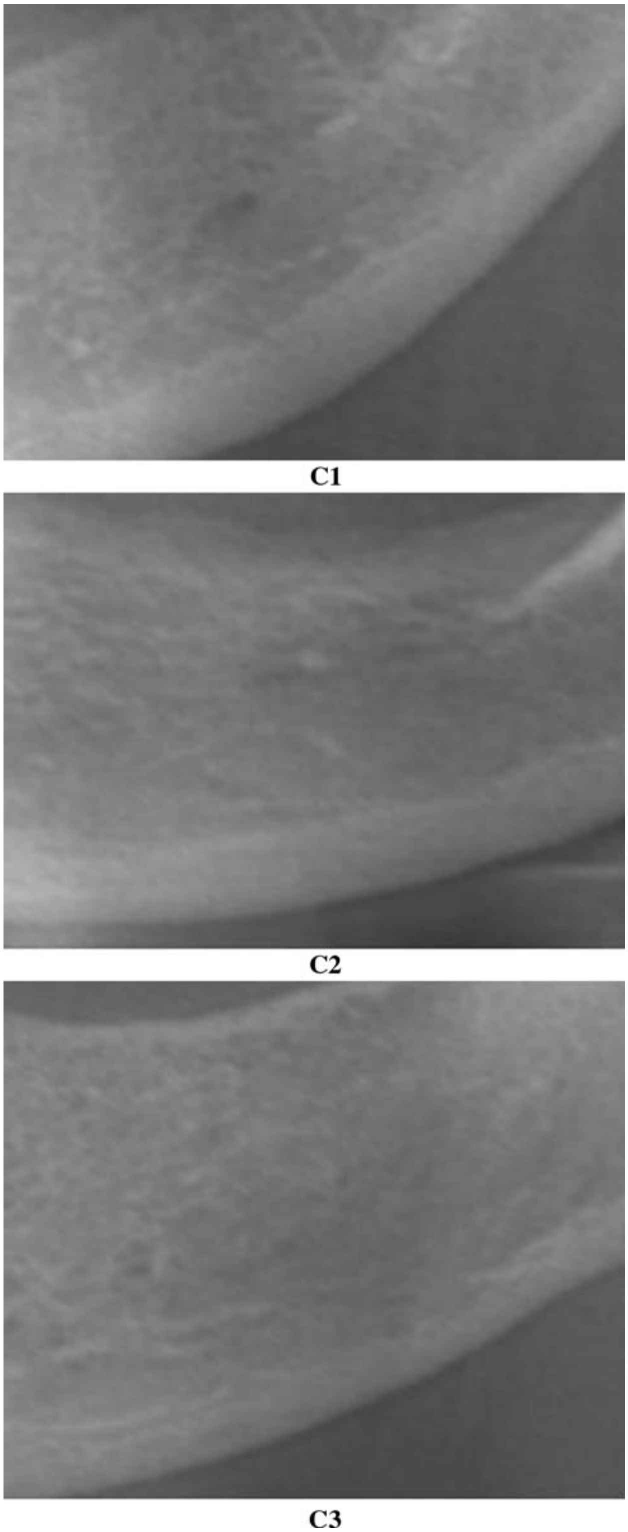

Fig. 1 Examples of categories C1, C2, and C3 of the mandibular cortex index

was considered excellent agreement whereas kappa < 0.40 was considered poor agreement and intermediate values were considered good agreement [20].

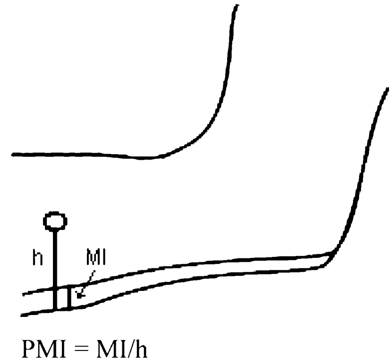

Fig. 2 The measurements used to determine the MI and PMI

Statistical analysis

Variables in the normal and osteopenic/osteoporotic groups were compared using the chi-squared test and Student's *t*-test.

The Lehmann family of receiver operating characteristics (ROC) curve analysis, which adjusts for covariates [21], was used to clarify whether patients with femoral osteoporosis could be identified accurately using the MI and PMI. For tests (normal and osteopenia/osteoporosis) that yield continuous data, for example the MI and PMI, the cut-off threshold was shifted systematically over the measurement range and observed pairs of sensitivity and (1 − specificity) were established for each different operating point. Based on these observed pairs, the ROC curve was obtained and the area under the ROC curve (AUC) was calculated. The results were classified as non-informative (AUC = 0.5), less accurate ($0.5 < \text{AUC} < 0.7$), moderately accurate ($0.7 < \text{AUC} < 0.9$), highly accurate ($0.9 < \text{AUC} < 1$), and perfect (AUC = 1), as defined elsewhere [8]. In addition, the AUCs of the MI and PMI were compared.

For the MCI, the sensitivity and specificity were calculated. To obtain the sensitivity and specificity values for the MCI classification, categories C2 and C3 were combined.

Results

All possible readable observations were included in the analysis. For the MCI, the kappa values showed excellent intraobserver and good interobserver agreement (0.830 and 0.708, respectively). For the MI and PMI, the ICC values indicated excellent intraobserver (0.812 and 0.775, respectively) and good interobserver (0.724 and 0.692, respectively) agreement.

The distributions of patient age, gender, menopause condition, systemic disease, medications, the MCI

Table 1 The distributions of patient age, gender, menopause condition, systemic disease, medications, the MCI classification, and the mean MI and PMI values for normal and osteopenic/osteoporotic patients

	Normal	Osteopenic/ osteoporotic	*p* value
Age (years) (mean ± SD)	54 ± 11	65.5 ± 10	0.000
Gender			
Female	16 (52%)	15 (48%)	0.305
Male	12 (67%)	6 (33%)	
Menopause			
Postmenopausal	5 (26%)	14 (74%)	0.000
Premenopausal	11 (92%)	1 (8%)	
Systemic disease			
Present	4 (50%)	4 (50%)	0.71
Absent	24 (59%)	17 (41%)	
Medication			
Present	4 (50%)	4 (50%)	0.71
Absent	24 (59%)	17 (41%)	
MCI			
C1	20 (77%)	6 (23%)	0.007
C2	7 (41%)	10 (59%)	
C3	1 (17%)	5 (83%)	
MI (mm) (mean ± SD)	3.9 ± 1.0	2.9 ± 1.1	0.002
PMI (mean ± SD)	0.33 ± 0.09	0.26 ± 0.1	0.019

classification, and the mean MI and PMI values between the normal and osteopenic/osteoporotic groups are summarized in Table 1. The mean age of the osteopenic/osteoporotic patients was significantly greater than that of the normal group ($p = 0.000$), whereas there were no significant differences in gender, systemic disease, or medications between the two groups. There were significantly more postmenopausal females in the osteopenic/osteoporotic group ($p = 0.000$). Whereas C1 category was more frequent in the normal group, C3 category was more frequent in the osteopenic/osteoporotic group ($p = 0.007$). The mean MI and PMI values in the osteopenic/osteoporotic group were significantly less than in the normal group ($p = 0.002$ for MI, $p = 0.019$ for PMI). Because age differed between the normal and osteopenic/osteoporotic patients in the univariate analysis, it was considered a covariate. Its effect was evaluated using the Lehmann family approach, but was not found to be statistically significant ($p = 0.4344$ for MI, $p = 0.9390$ for PMI).

The cut-off value was 3.5 for the MI and 0.30 for the PMI. The AUC for identifying patients with osteoporosis was 0.743 for the MI (95% confidence interval (CI): 0.59–0.896), and 0.67 for the PMI (95% CI: 0.51–0.83; Fig. 3). The AUC for the MI was moderately accurate, whereas the AUC for the PMI was less accurate. Furthermore, the difference between the AUCs for the MI and PMI was not statistically significant ($p = 0.09$). For the MCI, the sensitivity and specificity were 71.4%.

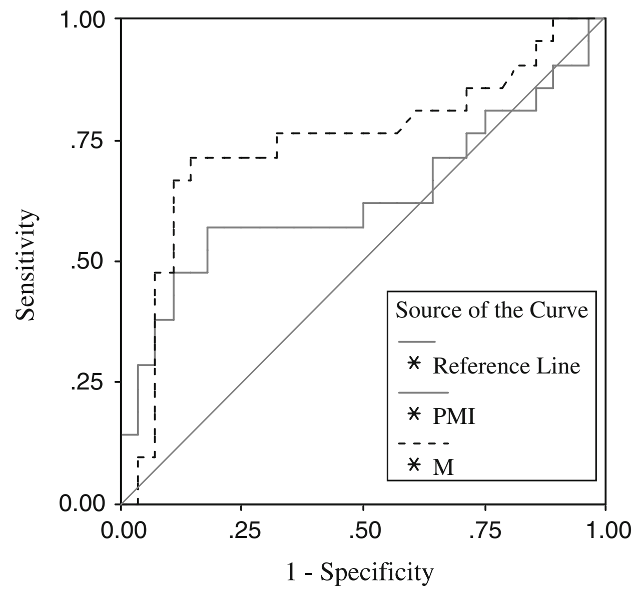

Fig. 3 The receiver operating characteristics (ROC) curves for identifying patients with osteoporosis using the MI and PMI

Discussion

Osteoporosis is a degenerative disease that primarily affects postmenopausal women, although older men are also affected [22]. Osteoporotic fractures are a health burden worldwide, resulting in reduced physical activity, increased risk of mortality, and increased medical costs [12]. Therefore, health-promotion strategies should focus on identifying subjects at high risk of fracture. Because most elderly individuals have more opportunities to visit a dental clinic than to visit a medical clinic for diagnosis of osteoporosis, it is important to determine the relationship between panoramic radiomorphometric indices and skeletal bone mineral density.

Diagnosis of osteoporosis in the jaws requires the development of a set of population-based, gender-related and age-related bone morphometric values corresponding to the method used. Although many studies have focused on this topic [2, 3, 5, 8, 10, 12–15, 22], few [18, 19, 22–24] have evaluated changes in the MCI, MI, or PMI for both males and females separately and together. Furthermore, this is the first report to examine whether edentulous male and female patients with osteoporosis can be identified accurately by use of the MI, PMI, and MCI.

There are published data on problems with the repeatability of radiomorphometric indices [3]. Most authors have concluded that MCI or PMI assessments have limited repeatability, which might limit their usefulness in clinical practice [3, 10, 20]. By contrast, excellent intraobserver and interobserver agreement for MCI assessments has been noted [13]. In this study, the intraobserver and interobserver agreement were good to excellent. The highest agreement was achieved for the MCI and the lowest for the PMI. This is accordance with previous studies [3, 19].

Our study showed that whereas there were statistically significant differences in age, menopause condition, and the MCI, MI, and PMI between patients with and without osteoporosis, there were no significant differences in gender, systemic disease, or medications. Horner et al. [14] concluded that epidemiological publications used simple factors such as age, gender, weight, and age at menopause to predict the likelihood of a patient having osteoporosis. However, these factors do not have sufficient sensitivity to prescreen patients accurately. Cortical width and porosity on dental panoramic radiographs have been shown to be potentially useful assessment methods [15, 22]. Therefore, this study used the panoramic MCI, MI, and PMI radiomorphometric indices to evaluate an individual's risk of osteoporosis.

The mandibular cortical index is a simple three-point index with fairly good reproducibility; category C3 indicates a substantially greater risk of osteoporosis than category C1 [15]. Many observers have found this index to be a useful method for screening for osteoporosis [2, 7, 11, 25]. Similarly, category C3 occurred significantly more in the osteopenic/osteoporotic group in this study ($p = 0.007$). In addition, the sensitivity and specificity were both 71.4% for the MCI and classed as moderately accurate. The results of this study suggest that the MCI is useful for identifying subjects with osteoporosis. In the literature, only a few studies [2, 3, 12, 15, 22] have reported the sensitivity and specificity of the MCI. Nakamoto et al. [2], Taguchi et al. [12], and Halling et al. [22] demonstrated that the assessment of mandibular cortex patterns is a reliable method for identifying osteopenia/osteoporosis, whereas other reports [3, 15] concluded that the cortical porosity was a poorer predictor of osteoporosis.

The cortical bone in the mental region was significantly thinner in individuals with osteoporosis. This result was expected and concurs with previous studies [3, 8, 10, 12, 14, 15, 26]. The AUC for identifying patients with osteoporosis using the MI was 0.743 (95% CI: 0.59–0.896), and classed as moderately accurate. The cut-off value of the MI was 3.5 mm in our study. Similarly, recent studies [14, 15] revealed that patients with the thinnest mandibular cortices ($\leq$3 mm) should be sent for further osteoporosis investigation. Recently, Devlin and Horner [27] reported that the cortical width at the mental foramen region was of low to moderate accuracy for detecting reduced skeletal bone density at the femoral neck, lumbar spine, or forearm (AUC = 0.73, 95% CI: 0.618–0.830) in 74 Caucasian women aged 43–79 years. Similarly, Ishii et al. [8] concluded that the AUC for identifying postmenopausal women with osteoporosis using the MI was 0.779 (95% CI: 0.713–0.844). Therefore, patients with osteoporosis may be identified, with sufficient diagnostic efficacy, by using the MI.

Watson et al. [28] found no differences in the mean PMI between normal and osteoporotic women aged 54–71 years (0.38 and 0.37, respectively). In addition, Drozdzowska et al. [3] studied 30 healthy, postmenopausal edentulous women divided into normal, osteopenic, and osteoporotic groups and found no significant difference in the mean PMI (0.34, 0.43, and 0.37, respectively). By contrast, Klemetti et al. [29] found weak but significant correlations between the PMI and BMD of the femoral neck and spine measured using DEXA in 355 women. In our study, the mean PMI values of patients with and without osteoporosis were 0.33 and 0.26, respectively, and the difference was statistically significant ($p = 0.019$). Compared with the MI, the AUC for identifying patients with osteoporosis using the PMI was 0.67 (95% CI: 0.51–0.83), which was classified as less accurate. This implies that both women and men with osteoporosis cannot be identified accurately using the PMI. In addition, Horner and Devlin [10] suggested that the PMI has no significant advantage over the MI, whereas Drozdzowska et al. [3] concluded that the PMI might be used as an indicator of bone mineral changes when PMI values deviate markedly from the mean PMI of the population. In our study, the cut-off value of the PMI was 0.30, which concurs with a previous report [19].

Our study has limitations. The sample size was small; the patient population included only edentulous individuals; and there were few osteoporotic and male patients. We are planning to study a bigger group of dentate and edentulous patients of both genders and a larger proportion of osteoporotic individuals.

In conclusion, this study demonstrated that edentulous patients with osteoporosis may be identified with sufficient diagnostic efficacy by use of the MCI and MI, but not by use of the PMI. Within the limits of this study, edentulous males or females in category C3 with MI < 3.5 mm should be referred for further osteoporosis investigation.

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