RESEARCH

Assessment of bone mineral density in the jaws and its relationship to radiomorphometric indices

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Objectives: The aim of this study was to evaluate maxillary, mandibular and femoral neck bone mineral density using dual energy X-ray absorptiometry (DXA) and to determine any correlation between the bone mineral density of the jaws and panoramic radiomorphometric indices.

Methods: 49 edentulous patients (18 males and 31 females) aged between 41 and 78 years (mean age 60.2 ± 11.04) were examined by panoramic radiography. Bone mineral density (BMD) of the jaws and femoral neck was measured with a DXA; bone mineral density was calculated at the anterior, premolar and molar regions of the maxilla and mandible.

Results: The mean maxillary molar BMD (0.45 g cm^{-2}) was significantly greater than the maxillary anterior and premolar BMD (0.31 g cm^{-2} , $P < 0.05$). Furthermore, the mean mandibular anterior and premolar BMD (1.39 g cm^{-2} and 1.28 g cm^{-2} , respectively) was significantly greater than the mean mandibular molar BMD (1.09 g cm^{-2} , $P < 0.01$). Although BMD in the maxillary anterior and premolar regions were correlated, BMD in all the mandibular regions were highly correlated. Maxillary and mandibular BMD were not correlated with femoral BMD. In addition, mandibular cortical index (MCI) classification, mental index (MI) or panoramic mandibular index (PMI) values were not significantly correlated with the maxillary and mandibular BMDs ($P > 0.05$).

Conclusions: The BMD in this study was highest in the mandibular anterior region and lowest in the maxillary anterior and premolar regions. The BMD of the jaws was not correlated with either femoral BMD or panoramic radiomorphometric indices.

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Introduction

Bone mineral density (BMD) is the amount of bone tissue in a certain volume of bone.¹ Assessment of jaw BMD may be considered useful, or even necessary, in many clinical situations such as oral and/or systemic diseases, implant planning, therapeutic evaluation and follow-up.² BMD varies throughout regions of the jaws and may be affected by many factors including osteoporosis.³ In recent literature several approaches have been introduced to measure mandibular and skeletal BMD.^{1,4}

The relationship between mandibular and skeletal BMD has received increasing attention over the past few years, and most studies have shown a good correlation between these parameters.^{5–8} Dental radiographs, especially panoramic images, have been used to predict patients with low BMD.^{8–11} Most studies have focused on the thickness and integrity of the inferior border of the mandible. The appearance of the mandibular cortical porosity (mandibular cortical index (MCI)),¹⁰ measurement of the mandibular cortical width at the mental foramen region (mental index (MI))¹² and the ratio of the thickness of mandibular cortex to the distance between the inferior margin of mental foramen and the inferior mandibular cortex (panoramic mandibular index (PMI))¹³ have been used to assess bone quality and to observe the

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signs of osteoporosis.^{5,12–14} Some authors have concluded that panoramic radiomorphometric indices are significantly correlated with mandibular BMD.^{5–7}

Dual energy X-ray absorptiometry (DXA) is a common investigation in the diagnosis of osteoporosis. In clinical daily practice DXA is the most useful method for BMD assessment in the vertebrae, femoral neck and forearms.^{3,15} DXA measurement of BMD of the jaws was first described in 1993.¹⁶ To the authors' knowledge, no study comparing the maxillary BMD, measured by DXA, and panoramic radiomorphometric indices has been published, whereas such comparisons with mandibular BMD measurements have been demonstrated in a few studies.^{5–7} Therefore, the aims of this study were to assess maxillary, mandibular and femoral neck BMD using DXA, and to investigate whether there is any correlation between BMD of the jaws and panoramic radiomorphometric indices.

Materials and methods

The participants in this study were 49 healthy edentulous patients (18 males and 31 females) aged 41–78 years (mean age 60.2 ± 11.04 years). Patient age, gender, menopausal state and systemic conditions were recorded. The criteria for selecting the patients 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. 19 female patients were post-menopausal. None of the women were on hormone replacement therapy or taking calcitonin, bisphosphonates or fluorides, but they may have been taking low doses of calcium or vitamin D. Any patients who were unwilling or unable to undergo the slight discomfort necessary for accurate positioning for the DXA scan of the jaws were excluded from the study. Panoramic radiographs and DXA scans of the femur, maxilla and mandible were obtained.

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Committee of the Ankara University Faculty of Dentistry. All subjects provided informed consent.

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 a digital calliper and a clear plastic acetate sheet superimposed on panoramic radiographs after correction for 20% magnification (to better simulate the clinical situation). Two oral radiologists (with 12 years and 6 years of clinical experience) assessed the following measurements independently:

1. MCI refers to the inferior mandibular cortical thickness and is categorized into three groups according to the criteria described by Klemetti *et al.*¹⁰ C1 = the endosteal margin of the cortex is even and sharp on both sides; C2 = the endosteal margin shows semilunar defects (lacunar resorption) and/or seems to form endosteal cortical residues on one or both sides; and C3 = the cortical layer forms heavy endosteal cortical residues and is clearly porous (Figure 1).
2. MI is the measurement of the cortical width at the mental foramen region and is assessed according to the technique described by Ledgerton *et al.*¹² Accordingly, the mental foramen was identified and a line was traced that passed perpendicular to the tangent of the lower border of the mandible and through the centre of the mental foramen. The cortical width was measured at this point. It was not possible to measure MI in two of the patient radiographs and these two patients were excluded from the study (Figure 2).
3. The inferior PMI as described by Benson *et al.*¹³ is the ratio of the thickness of mandibular cortex to the distance between the mental foramen and the inferior mandibular cortex (Figure 2).

Figure 1 The C1, C2 and C3 classification of the mandibular cortex index (MCI)

Figure 2 Mental index (MI) and panoramic mandibular index (PMI = MI/h) measurement

Bone mineral density measurements

The DXA scans of the jaws and femoral neck were performed on a Hologic Discovery A (Hologic Inc., Bedford, MA) device. Scans were performed by the same experienced technician. Before undergoing jaw scanning, patients were positioned supine and acrylic blocks were used to prevent superimposition of the jaws. A laser dot indicating the starting point of the scan was then positioned between the patient's eyebrows and continued through the maxilla and mandible to the mandibular symphysis.¹⁷ A "scout view" was obtained and the patient was adjusted. To measure the maxillary and mandibular BMD, rectangular customized regions of interest (ROI) were placed by one clinician using the DXA manufacturer's subregions scan analysis software to include the selected sites and then the computer software automatically calculated the ROI area. The shape and size of the ROIs were altered to conform to the shape of the bone images of each patient. Three ROIs were selected for the mandible: anterior of the ramus mandible (molar region), anterior mandible and middle of these two regions (premolar); and three for the maxilla: anterior maxilla, posterior maxilla, which consisted of posterior alveolus plus the hard palate shadow,³ and middle of these two regions (premolar). BMD at the left femoral neck was also determined.

Intra- and interobserver agreement

1 observer, with 12 years of clinical experience, served as the main observer and intraobserver reliability was estimated between the measurements performed 1 month apart. For the intraobserver reliability, all patients were reassessed and the distances were remeasured. For the interobserver reliability all patients were evaluated by the two observers. The kappa value

was calculated for MCI classification and intraclass correlation coefficient (ICC) was calculated for MI and PMI. Values > 0.75 were considered to indicate excellent agreement, < 0.40 poor agreement and intermediate values good agreement.⁶

Statistical analysis

The Statistical Package for the Social Sciences (SPSS 12.0, Chicago, IL) was used for the statistical analysis of the data. Differences between the BMD at the various sites were investigated using paired *t*-test (maxillary anterior, maxillary molar, mandibular premolar and femur) and Mann-Whitney *U*-test (maxillary premolar, mandibular anterior and mandibular molar). The influence of age on BMD at the various sites was investigated using Spearman's rho correlation. Pearson's correlation coefficient was used to investigate the relationship between the jaw BMD and femur BMD. The relationship between maxillary and mandibular BMDs and the radiographic measurements (MCI, MI and PMI) was also assessed by calculation of Pearson's correlation coefficients. The significance level was $P < 0.05$.

Results

For MCI, kappa values showing intraobserver and interobserver agreement were excellent and good (0.830 and 0.708, respectively). For MI and PMI, ICC values indicating intraobserver and interobserver agreement were excellent (0.812 and 0.775, respectively) and good (0.724 and 0.692, respectively).

Patients were divided into three skeletal mineral density groups based on DXA measurements of the femoral neck according to the World Health Organization (WHO) criteria: normal group, T-score > -1 ($n = 28$); osteopenic group, T-score ranging from -1 to -2.5 ($n = 16$); and osteoporotic group, T-score < -2.5 SD below above value ($n = 5$). Owing to the small number of osteoporotic patients in this study one group was formed by combining them with the osteopenic patients ($n = 21$). The mean femoral neck BMD value was 0.87 ± 0.11 g/cm² in the normal group and 0.64 ± 0.08 g/cm² in the osteopenic/osteoporotic group; the difference was statistically significant ($P < 0.01$). The mean BMD values (with standard deviations) of the maxillary and mandibular bone sites are given in Table 1. No significant differences were observed between the normal and osteopenic/osteoporotic groups for the maxillary and mandibular BMD values. The mean age of the patients in the normal and osteopenic/osteoporotic groups was 53.96 and 65.52 years, respectively. Only the BMDs of the femur and maxillary molar region were significantly correlated with the age of the patients ($R = 0.63$, $P < 0.01$; $R = 0.33$, $P < 0.05$, respectively).

Table 1 The mean bone mineral density (BMD) and standard deviation (SD) of the maxillary and mandibular bone sites

Bone site	Normal		Osteopenic/osteoporotic		All patients	
	Mean BMD	SD	Mean BMD	SD	Mean BMD	SD
Maxillary anterior	0.32	0.14	0.30	0.13	0.31	0.13
Maxillary premolar	0.31	0.12	0.32	0.15	0.31	0.13
Maxillary molar	0.45	0.17	0.46	0.14	0.45	0.15
Mandibular anterior	1.40	0.32	1.38	0.40	1.39	0.36
Mandibular premolar	1.33	0.27	1.24	0.36	1.28	0.31
Mandibular molar	0.99	0.24	1.19	0.42	1.09	0.33

The mean maxillary molar BMD (0.45 g/cm²) was significantly greater than the maxillary anterior and premolar BMDs (0.31 g/cm², $P < 0.05$). Furthermore, the mean mandibular anterior and premolar BMD (1.39 g/cm² and 1.28 g/cm², respectively) was significantly greater than the mean mandibular molar BMD (1.09 g/cm²) ($P < 0.01$). The maxillary BMD at all sites was significantly lower than the mandibular BMD at all sites ($P < 0.01$). Whereas BMD in the maxillary anterior and premolar regions were correlated, BMD in the mandibular anterior, premolar and molar regions were all highly correlated (Table 2). In addition, maxillary and mandibular BMDs were not correlated with femoral BMD ($P > 0.05$). Although female patients had significantly lower mandibular anterior and premolar BMDs ($P < 0.05$, $P < 0.01$, respectively) than male patients, the mandibular molar BMD and the maxillary BMD at all sites were not different between the genders.

The distribution of MCI classification, the mean MI and the PMI values are summarized in Table 3. Although the C1 and C2 categories are seen significantly more often in males, the C3 category was seen significantly more often in females ($P < 0.05$). However, there was no difference in MI and PMI values between genders. MCI classification, MI or PMI values were not significantly correlated with the maxillary and mandibular BMDs ($P > 0.05$). The sensitivity and specificity values were 0.67 and 0.64 for PMI and; 0.71 and 0.86 for MI, respectively. For MCI, both sensitivity and specificity values were 0.71.

Discussion

Osteoporosis, a generalized reduction in the amount of bone tissue, is a major health problem for middle-aged and elderly patients.⁵ This reduction in bone tissue is associated

with an increased risk of fractures, pain and consequently morbidity for patients. Considerable effort has been expended in identifying methods of detecting individuals with osteoporosis at an early stage. Jaw BMD measurements are applicable in many clinical situations to assess bone tissue. BMD measured by DXA in the mandible has been shown, in a number of studies,^{5-7,16,18-21} to be positively correlated with that in the lumbar spine, femoral neck and forearm.⁵⁻⁷ However, there have only been two studies to measure maxillary BMD with DXA.^{3,21} Surveys have shown that implant therapy in the maxilla has a significantly higher clinical failure rate than that in the mandible, and the regional differences in maxillary BMD may be partly responsible.³ Therefore, the aims of this study were to evaluate the maxillary, mandibular and femoral neck BMD obtained using DXA and to determine any correlation between the BMD of the jaws and panoramic radiomorphometric indices.

The problems associated with age-related skeletal osteopenia have received much attention as the human skeleton undergoes a continuous physiological decrease in bone mass with advancing age. Bone loss starts at about the age of 35 and continues at different rates throughout life.⁷ Changes in bone structure related to age differ according to site.³ In the present study only the BMD of the femur and maxillary molar region was significantly correlated with the age of the patient. This finding was interesting because other studies have demonstrated that the mandibular body and the anterior maxilla BMD³ and the BMD of the ramus²¹ are significantly related to age. However, the findings of the present study are based on a relatively small number of elderly patients, and it is possible that the relationship between age and BMD at other jaw sites would be stronger if a larger population over a greater age range was examined.

Only two previous studies have examined maxillary BMD using DXA.^{3,21} Although these studies included

Table 2 Pearson correlation coefficients (r values) between the mean bone mineral density (BMD) measurements at the maxillary and mandibular sites and femur

Bone site	Maxillary anterior	Maxillary premolar	Maxillary molar	Mandibular anterior	Mandibular premolar	Mandibular molar	Femur
Maxillary anterior	1.0	0.28*	0.03	0.02	0.10	0.19	0.059
Maxillary premolar		1.0	0.34	0.84	0.15	0.07	0.05
Maxillary molar			1.0	0.05	0.04	0.07	0.08
Mandibular anterior				1.0	0.78**	0.58**	0.02
Mandibular premolar					1.0	0.67**	0.01
Mandibular molar						1.0	0.07

*Correlation is significant at the 0.05 level (two-tailed)

**Correlation is significant at the 0.01 level (two-tailed)

Table 3 The distribution of mandibular cortical index (MCI) classification, the mean mental index (MI) and panoramic mandibular index (PMI) values in normal, osteopenic/osteoporotic and all patients

	Normal	Osteopenic/ osteoporotic	All patients
MCI			
C1	20 (77%)	6 (23%)	26
C2	7 (41%)	10 (59%)	17
C3	1 (17%)	5 (83%)	6
MI (mm)			
(mean $\pm$ SD)	3.9 $\pm$ 1.0	2.9 $\pm$ 1.1	3.4 $\pm$ 1.0
PMI			
(mean $\pm$ SD)	0.33 $\pm$ 0.09	0.26 $\pm$ 0.10	0.30 $\pm$ 0.10

only females³ or a small patient population (18 patients)²¹ they found that the BMD of the mandible was significantly greater than that of the maxilla. Similarly, the present study revealed that the maxillary BMD at all sites was significantly lower than the mandibular BMD at all sites. Furthermore, the mean maxillary molar BMD was significantly greater than the maxillary anterior and premolar BMD in this study. However, other studies³ have shown that the BMD of the anterior maxilla is significantly greater than that of the posterior maxilla. Differences between the two studies may depend on tooth extraction time, complicated tooth extraction or scanning technique.

There appears to be a correlation between mandibular BMD and the BMD of other skeletal sites,^{7,18,19,21} but this finding was not confirmed in the present study. The present results indicated that maxillary and mandibular BMD were not correlated with femoral BMD. Drage *et al*²¹ revealed that BMD only of the ramus mandible was significantly correlated with the BMD of skeletal sites. In the present study the different size of ROI selection and measurement of the specific area (anterior, premolar and molar regions of maxilla and mandible) may have affected the results.

In their study, Drozdowska *et al*⁷ evaluated the correlation between the panoramic-based mandibular

indices and mandibular BMD in 30 post-menopausal edentulous women. They found that, although MCI correlated significantly with mandibular BMD measured with DXA, MI and PMI were not correlated. Horner and Devlin⁵ showed that both MCI and PMI were significantly correlated with mandibular BMD. In contrast to these previous reports, we conclude that MCI, MI and PMI are not correlated with mandibular BMD. MCI, MI and PMI were also not correlated with maxillary BMD; however, no comparison with results from other authors is possible due to the lack of published data.

Although there are published data about the problems with repeatability of panoramic radiomorphometric indices,⁵⁻⁷ most authors conclude that the efficacy of these indices in diagnosing osteoporosis is sufficient.^{10-12,17,22} In this study, the intra- and interobserver agreement was good to excellent. The highest agreement was achieved for the MCI and the lowest for the PMI.

Limitations of the study include the small sample size, the fact that only edentulous individuals were sampled and the small number of osteoporotic patients with T-score < -2.5. The authors are planning to study a larger group of dentate and edentulous patients of both genders and to include a larger proportion of osteoporotic individuals.

In conclusion, the BMD in this study was highest in the mandibular anterior region and lowest in the maxillary anterior and premolar regions. There was no significant difference in maxillary and mandibular BMD values between normal and osteopenic/osteoporotic groups. The BMD of the jaws was not correlated with either femoral BMD or panoramic radiomorphometric indices.

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References

1. Celenk C, Celenk P. Relationship of mandibular and cervical vertebral bone density using computed tomography. *Dentomaxillofac Radiol* 2008; **37**: 47-51.
2. Nackaerts O, Jacobs R, Horner K, Zhao F, Lindh C, Karayianni K, *et al*. Bone density measurements in intra-oral radiographs. *Clin Oral Investig* 2007; **11**: 225-229.
3. Devlin H, Horner K, Ledgerton D. A comparison of maxillary and mandibular bone mineral densities. *J Prosthet Dent* 1998; **79**: 323-327.
4. Lindh C, Obrant K, Petersson A. Maxillary bone mineral density and its relationship to the bone mineral density of the lumbar spine and hip. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2004; **98**: 102-109.
5. Horner K, Devlin H. The relationship between mandibular bone mineral density and panoramic radiographic measurements. *J Dent* 1998; **26**: 337-343.
6. Horner K, Devlin H. The relationships between two indices of mandibular bone quality and bone mineral density measured by dual energy X-ray absorptiometry. *Dentomaxillofac Radiol* 1998; **27**: 17-21.
7. Drozdowska B, Pluskiewicz W, Tarnawska B. Panoramic-based mandibular indices in relation to mandibular bone mineral density and skeletal status assessed by dual energy X-ray absorptiometry and quantitative ultrasound. *Dentomaxillofac Radiol* 2002; **31**: 361-367.
8. Dutra V, Devlin H, Susin C, Yang J, Horner K, Fernandes AR. Mandibular morphological changes in low bone mass edentulous females: evaluation of panoramic radiographs. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2006; **102**: 663-668.
9. Devlin H, Karayianni K, Mitsea A, Jacobs R, Lindh C, van der Stelt P, *et al*. Diagnosing osteoporosis by using dental panoramic radiographs: The OSTEODENT project. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2007; **104**: 821-828.
10. Klemetti E, Kolmakov S, Kroger H. Pantomography in assessment of the osteoporosis risk group. *Scand J Dent Res* 1994; **102**: 68-72.
11. Taguchi A, Tsuda M, Ohtsuka M, Kodama I, Sanada M, Nakamoto T, *et al*. Use of dental panoramic radiographs in identifying younger postmenopausal women with osteoporosis. *Osteoporos Int* 2006; **17**: 387-394.

12. Ledgerton D, Horner K, Devlin H, Worthington H. Radiomorphometric indices of the mandible in a British female population. *Dentomaxillofac Radiol* 1999; **28**: 173–181.
13. Benson BW, Prihoda TJ, Glass BJ. Variations in adult cortical bone mass as measured by a panoramic mandibular index. *Oral Surg Oral Med Oral Pathol* 1991; **71**: 349–356.
14. Halling A, Persson GR, Berglund J, Johansson O, Renvert S. Comparison between the Klemetti index and heel DXA BMD measurements in the diagnosis of reduced skeletal bone mineral density in the elderly. *Osteoporos Int* 2005; **16**: 999–1003.
15. von Wowern N. General and oral aspects of osteoporosis: a review. *Clin Oral Investig* 2001; **5**: 71–82.
16. Corten FG, van't Hof MA, Buijs WC, Hoppenbrouwers P, Kalk W, Corstens FH. Measurement of mandibular bone density ex vivo and in vivo by dual-energy X-ray absorptiometry. *Arch Oral Biol* 1993; **38**: 215–219.
17. Gulsahi A, Paksoy CS, Yazicioglu N, Arpak N, Kucuk NO, Terzioglu H. Assessment of bone density differences between conventional and bone-condensing techniques using dual energy X-ray absorptiometry and radiography. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2007; **104**: 692–698.
18. Horner K, Devlin H, Alsop CW, Hodgkinson IM, Adams JE. Mandibular bone mineral density as a predictor of skeletal osteoporosis. *Br J Radiol* 1996; **69**: 1019–1025.
19. Pluskiewicz W, Tarnawska B, Drozdowska B. Mandibular bone mineral density measured using dual-energy X-ray absorptiometry: relationship to hip bone mineral density and quantitative ultrasound at calcaneus and hand phalanges. *Br J Radiol* 2000; **73**: 288–292.
20. Drozdowska B, Pluskiewicz W. Longitudinal changes in mandibular bone mineral density compared with hip bone mineral density and quantitative ultrasound at calcaneus and hand phalanges. *Br J Radiol* 2002; **75**: 743–747.
21. Drage NA, Palmer RM, Blake G, Wilson R, Crane F, Fogelman I. A comparison of bone mineral density in the spine, hip and jaws of edentulous subjects. *Clin Oral Impl Res* 2007; **18**: 496–500.
22. Taguchi A, Asano A, Ohtsuka M, Nakamoto T, Suei Y, Tsuda M, et al. Observer performance in diagnosing osteoporosis by dental panoramic radiographs: results from the osteoporosis screening project in dentistry (OSPD). *Bone* 2008; **43**: 209–213.