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Comparison of Mandibular Bone Mineral Densities in Dentate and Edentulous Patients

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Abstract

Purpose: In contemporary implant dentistry, bone mineral density (BMD) of the jaws is a patient-associated prognostic factor. The aim of this study was to compare the mandibular body BMD of dentate and edentulous patients using the dual-energy X-ray absorptiometry (DXA) technique.
Materials and Methods: A total of 39 patients, 20 dentate and 19 edentulous, were included in this cross-sectional study. Mandibular body BMD was measured using the DXA technique. The variables were normally distributed; thus, the independent samples *t*-test was used for the determination of statistical significance between the dentate and edentulous groups (age, body mass index [BMI], DXA). Chi-square test was performed for identification of the gender differences between the groups. The Pearson correlation analysis was used to analyze the relationship between age, BMI, and mandibular body BMD. Note that $p < 0.01$ was accepted as the significance level.
Results: There was no statistically significant difference between the dentate and edentulous groups in matching variables (age, BMI, and gender) ($p > 0.01$). There was a statistically significant difference regarding the mandibular body BMD in the dentate and edentulous group ($p < 0.01$) controlling for age, gender, and BMI. The edentulous group patients had higher mandibular body BMD values (1.27 ± 0.31 g/cm^2) than those in the dentate group (0.94 ± 0.22 g/cm^2).
Conclusion: Comparison of the mandibular body BMD revealed that dentate patients had less dense bone than the edentulous patients. Further investigations are needed to determine the BMD of the jaws in different regions and for different systemic conditions.

In contemporary implant dentistry, many prognostic factors are related to bone quality and quantity. One of the patient-associated prognostic factors consists of the bone mineral density (BMD) of the jaws. It has been shown that BMD is affected by the physical muscle activity on skeletal bone,[1] which may suggest that dentate patients must have denser mandibular bone than edentulous patients due to greater bite force capability; however, the effect of physical muscle activity on alveolar bone is still in question. It was demonstrated that dentate patients have stronger masseter muscles and a smaller gonial angle than edentulous patients.[2] Despite these findings, BMD studies in the dental literature have presented conflicting results comparing the dentate and edentulous states of the mandible. Although some studies found a difference between dentate and edentulous patients' mandibular BMD,[3-6] others stated that mandibular BMD was similar.[7,8] The possible reason for controversial results in jaw bone density may originate from the differences between the study groups in regard to body mass index (BMI), age, or sex in the studies.

Because bone density has an impact on many dental procedures such as treatment planning, management and prognosis of osseointegrated dental implants, bone grafting and complete or partial denture prosthodontics, several studies have evaluated BMD changes in different clinical conditions.[9-14] Van Steenberghe et al[15] emphasized that it is logical that bone volume and quality are factors of relevance because the principle of osseointegration is based on intimate bone-to-implant contact achieved during healing and maintained over time, even under

Table 1 Demographics and clinical characteristics of the dentate and edentulous study groups (mean ± SD)

Groups	Age (mean ± SD) (years)	Gender (F/M)	BMD (g/cm^2)	BMI (kg/cm^2)
Dentate (n = 20)	51.05 ± 5.74	10/10	0.94 ± 0.22	28.82 ± 3.81
Edentulous (n = 19)	52.79 ± 5.23	10/9	1.27 ± 0.31*	28.27 ± 2.42
Total (n = 39)	51.90 ± 5.50	20/19	1.10 ± 0.31	28.49 ± 3.18

*Statistically significant ($p < 0.01$).

loading. It was also shown that surgical trauma and anatomical conditions are the most important factors for primary implant losses; jaw-bone quality, volume, and overload are major determinants for late implant failures.[16]

The aim of this study was to compare the mandibular body BMD of sex-, age-, and BMI-matched dentate and edentulous patients using the dual-energy X-ray absorbtiometry (DXA) technique.

Materials and methods

This cross-sectional study was performed as a joint collaboration between the Department of Nuclear Medicine, Department of Periodontology, and Department of Prosthodontics of Süleyman Demirel University. None of the study participants (40 to 65 years old) had any systemic disease that might influence BMD or metabolic or inflammatory bone disease, none had undergone dental surgical procedures except tooth extraction, and none were currently smokers (ex-smokers nonsmoking period >10 years). At the dental clinics, dental panoramic radiographs were taken to detect any pathological change, residual root, periodontal defects, and periapical pathology in the mandible. The exclusion criteria were having osteoporosis or osteopaenia diagnoses or receiving any osteoporosis treatment, medications that may influence the bone metabolism, regular alcohol consumption, having chronic periodontitis, a history of any surgical periodontal therapy and antibiotic, antiinflammatory, immunosuppressive or cytotoxic drug intake 3 months before the study.

The dentate patients were selected from the volunteer patients attending Süleyman Demirel University, Faculty of Dentistry, and Department of Periodontology. Patients having at least 20 natural teeth and all molar teeth in the mandible except for third molars were incorporated into the study. After designation of the dentate group (n = 20), the edentulous group was determined from existing patient files including 19 patients with matching age, sex, and BMI with the dentate group patients. To determine the sample size required for the study, a pilot study was performed, and the standard deviation of BMD values was calculated as 0.31 g/cm^2. The sample size of this study is calculated to detect a difference of 0.30 g/cm^2 between the BMD values of the groups at the 0.05 probability level with a power of 80%. Power analysis and sample size estimation were performed using a statistical program (Power and Precision™, Biostat, Inc., Englewood, NJ). The power analysis revealed that the required sample size was a minimum of 17 patients for each group. Minimum years of edentulism in the mandible to qualify for edentulous was >5 years. Edentulous patients wearing complete dentures with acrylic resin artificial teeth were included in the study. Patients who had gone through serial tooth extractions were not included to the study. The dentate and edentulous group patients were comparable with respect to age, gender, and BMI (Table 1). The study protocol was approved by the local Ethics Committee. Informed consent was obtained from all patients before their participation.

Mandibular BMD (g/cm^2) was measured using DXA (Norland XR-46; Norland Medical Systems Inc., Fort Atkinson, WI). BMD measurements were performed on the body of the mandible, which produces greater sensitivity and specificity compared with the ramus and the symphysis regions, as described by Horner et al.[17] Patients were positioned on their side with the neck extended to avoid the superimposition of cervical spine. The mandible was scanned in a rectilinear manner starting from 1 cm above the temporomandibular joint through the whole of the mandible on one side. The image of the contralateral side was superimposed. After DXA scan images were recorded and displayed on the computer monitor, manual analysis of these scans was carried out using rectangular customized regions placed over the body of the mandible extending from the anterior ramus to the parasymphyseal region. The size of the selected regions was adapted to conform to the shape of the mandible of each patient. BMD (g/cm^2) of the selected region was calculated by lumbar spine computer software. Mandibular DXA scans were analyzed by two independent investigators to minimize interobserver variations. These observers were experienced in mandibular BMD measurements, through three past mandibular BMD DXA studies. The reproducibility of the measurement system was assessed by repeating the analysis two times for 10 randomly selected images. No significant difference was noted between the measurement results ($p > 0.80$). The kappa scores (κ) for the assessment of intra- and interobserver agreement were higher than 0.85, implying satisfactory agreement between the observers. Thus, the mean of the measurement results for each patient was used for the determination of the mandibular body BMD value (SPSS for Windows version 15.0, SPSS Inc., Chicago, IL). The normality of the data distribution was examined using the Kolmogorov-Smirnov test. The variables were normally distributed; thus, the independent samples t-test was used for the determination of statistical significance between the dentate and edentulous groups (age, BMI, DXA). Chi-square test was performed for identification of gender differences between the groups. The Pearson correlation analysis was used to analyze the relationship between age, BMI, and mandibular body BMD; $p < 0.01$ was accepted as significant.

Results

The demographics and clinical characteristics of the study groups are illustrated in Table 1. The dentate and edentulous study groups were matched regarding age, BMI, and gender, as the aim of the present study was to compare the mandibular body BMD of dentate and edentulous patients controlling for age, sex, and BMI. Therefore, there was no statistically significant difference between the dentate and edentulous groups in matching variables ($p > 0.01$). There was a statistically significant difference regarding the mandibular body BMD in the dentate and edentulous group ($p < 0.01$). The edentulous group patients had higher mandibular body BMD values (1.27 ± 0.31 g/cm^2) than those in the dentate group (0.94 ± 0.22 g/cm^2). There was no correlation between BMI (kg/cm^2), mandibular body BMD (g/cm^2), and age.

Discussion

Previous publications demonstrate a positive correlation between BMD and bone quality.[18-20] Thus, mandibular body BMD may be important for the success of many dental procedures such as distraction osteogenesis, osteotomies, and hard-tissue grafting. The body of the mandible is also the location for implant placement, so the BMD measurements were performed on the body of the mandible, not the ramus. In this study, the authors tried to compose homogenous study populations with strict inclusion criteria to eliminate confounding factors that affect bone metabolism, such as age,[7,8] osteoporosis[21] and other systemic diseases,[22] smoking,[23] alcohol consumption, and hormone intake.[22] The distinguishing features of this study are that it was primarily designed to evaluate mandibular BMD using DXA on both male and female patients who were systemically healthy and had no risk factors for osteoporosis.

The existence of the teeth both in the maxilla and mandible may affect the muscle activity of the related site because of the difference of the occlusal forces between the dentate and edentulous jaws.[24] Because edentulism and the number of remaining teeth affect bone height and density,[25,26] special attention was paid to creating a standard dentate group as regards the tooth number of patients. Klemetti et al[24] indicated that muscle activity may strengthen the jawbone and create functional stress that prevents mineral loss. They also stated that physically active dentate patients may lose less mineral from the regions of the jaw bones where the muscles are attached. Functional stress, caused by the chewing muscles, is involved in maintaining BMD in edentulous regions of the mandible; however, according to the results of this study, edentulous patients had higher mandibular BMD values than the dentate group. The result of the present study may originate from the cortical bone of the edentulous mandible becoming denser to protect the edentulous jawbone from heavy occlusal forces.[27]

BMD is a medical term normally referring to the amount of mineral matter per square centimeter of bones. This medical bone density is not the real physical density of the bone, which would be computed as mass per volume. It is measured by a procedure called densitometry, often performed in the nuclear medicine or radiology departments of hospitals. In the DXA technique, two X-ray beams with differing energy levels are aimed at the patient's bones. When soft tissue absorption is subtracted out, the BMD can be determined from the absorption of each beam by bone. DXA is widely accepted as the gold standard method of clinical bone mineral measurements.[28]

In recent studies, correlations between mandibular BMD and other skeletal sites assessed by various techniques have been reported.[17,29-34] The methodology of measurement of mandibular BMD used in this study has been used in some recent investigations.[7,17,35] Devlin and Horner[7] suggested that BMD of the mandibular body of females decreases with age. Pluskiewicz et al[34] evaluated the mandibular BMD of 36 women and 6 men by DXA and reported that the mandibular BMD of women was lower than that of men. Kingsmill and Boyde[8] found that unlike other bones, the mandible may show an increase in density with age. Devlin and Horner[7] found no statistically significant difference between dentate and edentulous patients; however, in their study, the dentate and edentulous patients' ages were different from each other. It was also implied that the mandibular BMD of elderly women may be predicted by age, regardless of whether the patient is dentate or edentulous. Klemetti et al[3] showed that cortical bone density was higher in edentulous patients' buccal and lingual cortex; however, there was no correlation between BMI, age, and mandibular BMD in this study. The absence of correlation between BMI, age, and mandibular BMD may result from the small and similar sample groups of this study. BMD measurements were performed on the body of the mandible. BMD data of this area are most predictive of BMD in the hip, spine, and forearm, which produce greater sensitivity and specificity compared with the ramus and the symphysis regions as described by Horner et al.[17] Conflicting results from bone density studies that have similar sample and study designs may originate from a great variability of the measurement methods.[17,28,31-36] Even studies using the same method showed different results depending on one evaluator to the next.[17,34,36-41]

In this study, the mandibular body BMD was found to be 0.94 ± 0.22 g/cm^2 in the dentate group and 1.27 ± 0.31 g/cm^2 in the edentulous group. The results of this study were similar to the results by Devlin and Horner[7] (1.11 ± 0.3 g/cm^2) and Pluskiewicz et al[34] (1.221 ± 0.3 g/cm^2) but lower than the findings of the study conducted by Drage et al[42] (1.38 ± 0.39 g/cm^2). According to the results of this study, there was a statistically significant difference between the dentate and edentulous groups regarding BMD.

Some methodological problems were noted during the mandibular body BMD measurements. One error source was the superimposition of the contralateral side of the mandible. It was more prominent in the dentate group because the presence of teeth complicated the DXA image from recognizing the ideal superimposition.[21,22,43] For this reason, the clinician remained beside the patient to ensure that the scanning of the mandible was correct. In cases where an ideal superimposition was not achieved, the obtained BMD values could either be half of the real mandibular BMD values or artificially high because of the superimposition of other bony structures or teeth. Horner et al[17] emphasized that the poor precision of mandibular measurements may be improved with increasing practice because the operator becomes more familiar with the DXA technique. They also suggested that with increasing experience in positioning patients for mandibular DXA, it is likely that the incidence of errors would fall. In this study, the persons who performed the mandibular DXA imaging were experienced and had conducted three prior studies related to mandibular DXA.[21,22,43] In addition, the image was recorded onto a computer after the desired superimposition was observed on the screen. An ideal superimposition of the body of the mandible was obtained for all patients in this study.

Only quantitative computed tomography (QCT) is capable of differentiation and measuring all bone layers of the jawbone separately.[3] Although in past studies it was used for scientific research, recently, the use of QCT has been controversial for clinical human subject studies because the QCT radiation dose is very high. Thus, in this study, DXA was used because the reliability of the technique has been proven, and the radiation dose is low. The bearing area of the edentulous mandible is about half that of the maxilla, and residual ridge resorption seems to occur more often than in the maxilla.[44] Thus, the resorption process and confounding factors are more effective on the mandible than the maxilla. For this reason, only the mandible was evaluated in this study. In this study, it was also problematic to make dentate and edentulous study groups comparable regarding age and BMI. All of the edentulous patients were almost elderly, whereas the dentate patients were younger. Thus, small dentate and edentulous sample groups were recruited with regards to matching age and BMI.

In conclusion, on the basis of the sample size and controlling for age, sex, and BMI, a statistically significant difference between the dentate and edentulous patients in mandibular BMD was observed. Edentulous patients had a higher mandibular BMD than dentate patients. Longer healing time after surgery, selection of implant designs that assure stable bone-implant placement and primary fixation of self-tapping implants without countersink procedures before and during dental implant treatment may yield more favorable success rates for dentate patients in implant dentistry. Due to the finding of this study, further investigations are needed to determine the BMD of the jaws for different regions and systemic conditions related to implant dentistry.

Conclusion

Comparison of the mandibular body BMD revealed that dentate patients have less dense bone than edentulous patients controlling for age, sex, and BMI. Further investigations are needed to determine the importance of BMD and its relevance to implant dentistry.

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