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Original Article

Correlation between bone mineral density of jaws and skeletal sites in an Iranian population using dual X-ray energy absorptiometry

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ABSTRACT

Background: The aim of the present study was to evaluate the relationship between the bone density of various regions of jaws and skeletal bones.
Materials and Methods: A total of 110 patients with a mean age of 55.01 ± 10.77 years were selected for the purpose of the present descriptive study. Dual X-ray Energy Absorptiometry (DXA) was carried out to determine bone mineral density (BMD) of the femur and lumbar vertebrae. Then all the subjects underwent DXA of the jaw bones and BMD values were determined at four jaw regions. Data were analyzed by SPSS 16 statistical software, and the correlation between the various BMD values was determined by Pearson's correlation coefficient.
Results: The results showed that 42.7% of females had normal BMD values in the femur, and in vertebrae, 20% were osteopenic and 37.3% suffered from osteoporosis, with statistically significant differences in the BMD values of the jaws between the three above-mentioned groups ($P < 0.001$). There was an increasing tendency toward osteopenia and osteoporosis with age. There was a positive correlation between BMD values of the femur and lumbar vertebrae and those of all the jaw regions under study ($P < 0.005$). There was a negative correlation ($P < 0.01$) between age and the BMD values of the femur, lumbar vertebrae and anterior maxilla.
Conclusion: The bone density of the maxilla and mandible and presence of osteoporosis or osteopenia in these bones might reflect the same problem in skeletal bones.

Key Words: Bone mineral density, dual X-ray energy absorptiometry, jaw bones, osteoporosis, skeletal bones

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INTRODUCTION

Different jaw regions exhibit different bone densities, which might be under the influence of various factors, including osteoporosis. Osteoporosis is the most common metabolic bone disorder, which is characterized by a decrease in bone mineral density (BMD) or changes in the bone microstructure. BMD is a medical term, which indicates the amount of material in each cm^3 of bone.[1] Studies have shown that after 60 years of age, almost ⅓ of the population is affected by osteoporosis, and it is twice more prevalent in females than in males.[2]

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The quality and quantity of jaw bones are two notable local factors in the definitive decision-making for placement, determination of type, and success rate of implants.[3] Studies have shown that the risk of implant failure in areas with low bone density (Type 4) increases compared to other bone types.[4-6] The systemic osteoporosis decreases the contact area between bone and the implant, although it does not result in definite implant failure. Knowledge about jaw regions with low bone density might assist in treatment planning and determination of implant prognosis.[7,8]

The hypothesis of relationship between osteoporosis and a decrease in the BMD of jaws was proposed for the 1st time in 1960.[9] Several studies have evaluated this relationship using the various radiographic and densitometry methods to determine the density of jaw bones to compare it with the BMD of skeletal sites. One of these tools used today is Dual X-ray Energy Absorptiometry (DXA), which is considered a gold standard in the diagnosis of osteoporosis.[1,10,11]

There is controversy over the relationship between osteoporosis of skeletal and density of jaw bones. In addition, it is not clear whether the quality and quantity of maxillary and mandibular bones decrease parallel with those of other bones or not.[12] Some studies have shown that there is a decrease in bone density of jaws in osteoporotic patients.[10,13] However, other studies have failed to show such a relationship.[14,15]

Given the importance of the presence or absence of such a relationship and considering the fact that no such studies have been carried out in Iran to date, the present study was undertaken to determine the correlation between the density of the lumbar vertebrae and femoral bones, and different regions of jaw bones in patients referring to the Bone Density Division of Baqyiatallah Hospital, Tehran, Iran, using the DXA technique in 2009-2010.

MATERIALS AND METHODS

The subjects in the present descriptive study consisted of 120 patients (10 males and 110 females) with a mean age of 55.01 ± 10.77 years, who had referred to the Bone Density Division of Baqyiatallah Hospital in Tehran, Iran, and needed DXA scan of skeletal bones (the femur and lumbar vertebrae), based on a request by their physicians; the subjects were also candidates to receive implants in some jaw regions. The subjects were selected using sequential sampling procedure. This study was approved by the Ethics Committee, and written consent forms were obtained from the patients undergoing DXA scan of the femur, lumbar vertebrae and jaws.

The patients' demographic data were collected, which included sex, height, weight, and menopause condition; these data were submitted to the scan machine and normal BMD values were determined for all patients. In addition, some other data regarding the patients, including the condition of their teeth, presence of systemic conditions, and use of any hormone medications with an effect on bone metabolism, and smoking, were recorded. Then DXA scan was carried out using the Hologic QDR-4500 machine (Hologic, Waltham, MA) to determine BMD values of the femur and lumbar vertebrae. The femoral neck and spine software programs of the scanner were used to scan the femur and vertebrae, respectively. The patients were positioned according to the criteria specified by the manufacturer during the procedures. The BMD of each subject was determined based on the following formula:

$$\text{T-score} = \frac{\text{Normal BMD-BMD of the subject}}{\text{Normal standared deviation}}$$

Based on WHO definition, if the T-score is greater than or equal to "−1", the subject has a normal bone density; a T-score between "−1" and "−2.5" is an indication of osteopenia and a T-score less than "−2.5" indicates osteoporosis.

Then all the subjects underwent jaw scans. The patient position was changed to semi-prone position during the jaw scan so that the right side of the body was toward the ceiling, the neck was a little extended and the head was laterally positioned to totally superimpose left and right jaws and to avoid superimposition of jaws on the cervical spine. DXA manufacturer's forearm subregion scan analysis was used for jaw scans. Jaw scans were carried out with the rectilinear motion of the scanner. In order to determine the BMD values of different regions of jaws square-shaped regions of interests were drawn on the scans to specify the body, ramus and anterior regions of the mandible and the anterior of the maxilla;[10] the BMD values of these specified regions were determined by the scanner [Figure 1]. All the scans and measurements were carried out by a well-trained operator and intra-examiner variability was also examined.

To analyze the BMD values, Pearson's correlation coefficient and ANOVA were used at 95% confidence interval. Statistical significance was defined at $\alpha = 0.05$.

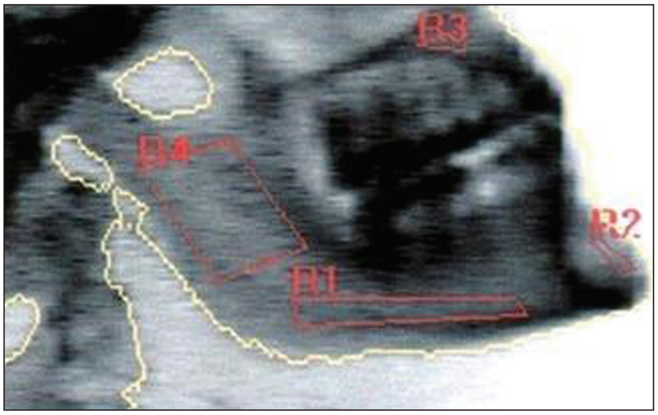

Figure 1: A sample of jaw scans and selection of the specific regions; R1: The body of the mandible; R2: The anterior mandible; R3: The anterior maxilla; R4: The ramus

RESULTS

In the present study, 120 subjects, 110 females and 10 males, were selected. Since the effect of sex on the variables under study was not the aim of the present study, no control was exerted on it, and the males were excluded from the study. Therefore, the results of the study were reported based on data obtained from 110 females. A total of 110 female patients, with an age range of 49-63 years took part in the present study; each group had a different mean age: Normal: 49.21 ± 68 years; osteopenic: 52.45 ± 9.2 years; osteoporotic: 63.02 ± 10.3. The demographic data of the 110 subjects in the present study are presented in Table 1.

Based on Table 1, the female subjects in the present study exhibited the following BMD categories in the femur region and vertebrae: 42.7 were normal; 20% were osteopenic and 37.3% were osteoporotic. The table shows that the majority of the patients were healthy, dentate, non-smoking and did not take any hormone medications affecting bone metabolism.

Mean BMD values in the different regions under study and age of the subjects are separately presented for the three normal, osteopenic and osteoporotic groups in Table 2.

According to Table 2, there were significant differences in the BMD means of different jaw regions between normal, osteopenic and osteoporotic females ($P < 0.001$); BMD values of different jaw regions decreased from normal to osteoporotic subjects, which was more prominent in the anterior region of the maxilla. There was a transition to osteopenia and osteoporosis with advancing age.

Table 1: Demographic data of patients, including BMD, presence or absence of teeth, conditions related to bone metabolism, use of hormone medications affecting bone metabolism, and smoking

Variable	Classification	Number	Percent
BMD	Normal	47	42.7
	Osteopenic	22	20.0
	Osteoporotic	41	37.3
Presence of teeth in anterior mandible	No	31	28.2
	Yes	79	71.8
Presence of teeth in the body of mandible	No	40	36.4
	Yes	70	63.6
Presence of teeth in anterior maxilla	No	30	27.3
	Yes	80	72.7
Disease	No	86	78.2
	Yes	24	21.8
Medication	No	76	69.1
	Yes	34	30.9
Smoking	No	104	94.5
	Yes	6	5.5

BMD: Bone mineral density

Table 3 presents the results of analysis between the density of vertebrae and the femur and also between those densities and the density of various jaw regions.

According to Table 3, there was a positive correlation between BMD values of the femur and vertebrae and BMD values of all the jaw regions under study ($P < 0.05$). In other words, BMD values in various regions of jaws are under the influence of age and osteoporosis in other body parts.

According to Table 4, there was a significantly negative correlation ($P < 0.01$) between age and BMD values of femur, vertebrae and anterior maxilla; in other words, anterior maxilla BMD value depends on the age and osteoporotic condition of the individual.

No significant relationship was observed between other variables under study, including presence or absence of teeth, smoking habits, diseases, use of hormone medications influencing bone metabolism, and the BMD values of different jaw regions ($P > 0.05$). No significant relationship was noted between these variables and the osteoporotic state of the individual and BMD values of different jaw regions.

Table 2: BMD values in the different regions under study and age of the subjects separately for the three normal, osteopenic and osteoporotic groups

Variable	Group	Mean ± SD	*P*	95% confidence interval for the means of the study population
Femoral BMD	Normal	0.965 ± 0.104	0.0001	0.935-0.996
	Osteopenic	0.838 ± 0.106		0.791-0.885
	Osteoporotic	0.737 ± 0.806		0.711-0.762
Vertebral BMD	Normal	1.055 ± 0.107	0.0001	1.023-1.086
	Osteopenic	0.937 ± 0.073		0.905-0.969
	Osteoporotic	0.747 ± 0.121		0.709-0.785
Anterior maxilla BMD	Normal	1.366 ± 0.432	0.0001	1.240-1.493
	Osteopenic	1.222 ± 0.406		1.042-1.402
	Osteoporotic	0.765 ± 0.299		0.670-0.859
Anterior mandible BMD	Normal	1.470 ± 0.271	0.0001	1.390-1.549
	Osteopenic	1.402 ± 0.345		1.249-1.555
	Osteoporotic	1.233 ± 0.300		1.118-1.308
Mandibular body BMD	Normal	1.386 ± 0.320	0.0001	1.292-1.480
	Osteopenic	1.400 ± 0.304		1.265-1.534
	Osteoporotic	1.032 ± 0.230		0.960-1.105
Mandibular ramus BMD	Normal	0.835 ± 0.223	0.0001	0.770-0.900
	Osteopenic	0.798 ± 0.226		0.697-0.898
	Osteoporotic	0.603 ± 0.173		0.548-0.657
Age	Normal	49.21 ± 6.846	0.0001	47.2-51.22
	Osteopenic	52.45 ± 9.267		48.35-56.56
	Osteoporotic	63.02 ± 10.398		59.74-66.31

BMD: Bone mineral density

Table 3: The results of Pearson's correlation coefficient test between BMD values of different regions

	Femoral BMD	Vertebral BMD	Ramus BMD	Mandibularbody BMD	Anterior mandibular BMD
Mandibular ramus BMD	0.21*	0.341*			
Mandibular body BMD	0.207*	0.299*	0.620*		
Anterior mandible BMD	0.23*			0.267*	
Anterior maxilla BMD		0.271*	0.383*	0.433*	0.236*

*$P < 0.05$, BMD: Bone mineral density

Table 4: The results of Pearson's correlation coefficient test between BMD values in different body parts and age (on the condition that the osteoporosis condition in females is the same)

	BMD of anterior maxilla	BMD of femur	BMD of vertebrae
Age	−0.350*	−0.266*	−0.294*

*$P < 0.01$; BMD: Bone mineral density

DISCUSSION

In the present study, DXA technique was used to evaluate the correlation between BMD values of different areas of jaws, lumbar vertebrae and femur in 110 female patients in Iran. The results showed a significant correlation between the BMD values of different regions of jaws (anterior maxilla, anterior mandible, body of the mandible, and the ramus) and the BMD values of the femur and vertebrae. In addition, there was a significant correlation between the densities of all the jaw bones, except for the ramus BMD values, which did not exhibit any significant correlation with the BMD of anterior mandible. In addition, in the present study, the relationship between age and the densities of skeletal and jaw bones was evaluated. The results showed a negative correlation between age and BMD values of femur, lumbar vertebrae and anterior maxilla.

Horner *et al.*[10] used the DXA technique to evaluate the bone densities of anterior mandible, mandibular body, mandibular ramus and skeletal sites and reported a significant correlation between the BMD values of the three mandibular areas and those of the femur, vertebrae and forearm bones, consistent with the results of the present study, despite the fact that in the present study, the majority of the subjects had teeth, but in the above-mentioned study all the subjects were edentulous. Therefore, it can be concluded that the presence or absence of teeth in the jaws has no effect on the correlation between BMD values of jaws and skeletal sites, which is a very valuable finding. Another difference between the two studies is the fact that in the present study anterior maxilla was evaluated, but the forearm was not evaluated.

Pluskiewicz *et al.*[9] evaluated the relationship between the BMD of the mandibular ramus and that of the femur using the DXA technique and reported a significant relationship between BMD of the mandibular ramus and that of the femur, which was confirmed by the results of the present study.

In another study, Nackaerts *et al*.[16] evaluated BMD values of mandibular and maxillary sites using intra-oral radiographic techniques in order to compare them with those of the skeletal bones determined by DXA technique and reported a moderate correlation between BMD values of maxillary and mandibular premolar areas and those of skeletal sites. Although, the use of intra-oral radiographic techniques are less sensitive and reproducible for the evaluation of the jaw bone BMD compared to the DXA technique, the results reported by Nackaerts *et al*. confirm the results of the present study.

Klemetti *et al.*[17] reported a significant correlation between BMD of the mandible determined by QCT (Quantitative Computed-tomography Technique) and those of the femur and vertebrae measured by the DXA technique, which is consistent with the results of the present study, although there are differences in the techniques used to measure BMD values of the mandible between the two studies.

Drage *et al*.[3] used the DXA technique to measure BMD values of a jaw regions (similar to the present study) in order to compare with those of the femur and vertebrae and reported a significant correlation between the mandibular ramus BMD and that of the mandibular body, which is consistent with the results of the present study. In that study, the only region of the jaws which showed a significant correlation with the femur and vertebrae was the mandibular ramus. However, in the present study, all the four jaw regions exhibited correlations with skeletal bones. The differences between the results of the two studies might be attributed to differences in population sizes; the study by Drage was carried out on 18 subjects, but the present study was carried out on 110 subjects, which increased the power of the study.

Cakur *et al*.[11] evaluated the density of the deepest portion of mandibular antegonial notch with the DXA and also the densities of skeletal bones and reported no correlation between mandibular and skeletal bone densities, which does not coincide with the results of the present study, in which a significant correlation was noted between the bone densities of various jaw regions and those of the skeletal bones. The discrepancies between the results of these two studies might be attributed to the fact that the results reported by Cakur *et al*. regarding the mandibular antegonial notch cannot be extended to the whole mandible (as opposed to the assumption of that study) and also to the technique used in the present study in which the bone density of each jaw region was separately evaluated; the method used in the present study yields more efficient results. Cakur *et al*. requested a panoramic view for patients in addition to the DXA scan of the mandible and evaluated MCI (Mandibular Cortical Index) factor on panoramic views in order to evaluate the relationship between the jaw and skeletal bones. In addition, the patients' positions in that study were different from those of the present study. Therefore, given the different patient positions and the use of different software programs for a similar study, the differences between the results of the two studies are justified. On the other hand, in the study carried out by Cakur a significant correlation was revealed between the densities of the femur and vertebrae, which is consistent with the results of the present study.

Naitoh *et al*.[18] used computed tomography (CT) scan technique to evaluate the width of the cortical bone at mental foramen area and the density of the mandible in order to compare it with density of vertebrae determined by DXA technique. They reported that the widths of buccal and lingual cortical plates and the BMD of cancellous bone at mental foramen area is weakly correlated with the density of vertebrae, which is not consistent with the results of the present study; the results of the present study showed a significant correlation between the mandibular body bone densities (around mental foramen area) with those of the femur and vertebrae. The differences between the results of the two studies might be attributed to the use of CT scan method to determine BMD values of the mandible, which is different from that used in the present study.

Given the limitations of the routine radiographic techniques in the diagnosis of the jaw bone density and low sensitivity of these techniques in relation to the changes produced and also considering the fact that evaluation of the condition and quality of two different bony regions using two different tools decreases the value and validity of the results, in the present study DXA technique was used to determine BMD values of both skeletal and jaw bones. DXA technique is the gold standard to evaluate BMD, and one of the strongest points of the present study was the fact that one technique was used for comparisons. Another positive aspect of the present study was the fact that all the scan procedures and analyses were carried out by one operator. In addition, contrary to the majority of studies which have only evaluated the mandibular BMD, in the present study the BMDs of both upper and lower jaws were evaluated in four regions and the correlation of each jaw with skeletal bones was evaluated.

We evaluated the correlation between age and bone mineral densities of skeletal and jaw bones and a negative correlation was observed between age and densities of the femur, vertebrae and anterior maxilla; this correlation might be explained by the similarities in the bony structures of maxilla and femur and the vertebrae because all these three areas have a cancellous structure.[19] In addition, it was demonstrated that there was a transition toward osteopenia and osteoporosis in females with age.

Given the fact that the majority of subjects in the present study were healthy, non-smoking, and dentate females who did not take any medications influencing bone metabolism, it appears a decrease in BMD values in these areas results from a correlation between the individual's osteoporotic condition and BMD values in jaw areas; as it was explained before, this correlation became more prominent with advancing age.

Some problems were encountered in carrying out the present study. One of the problems was a lack of access to a DXA software specifically designed for jaws; therefore, similar studies were used for help.[10,20] In addition, there was a need for an expertise in positioning the patients so that the two jaw sides would be completely superimposed on each other. Furthermore, it was difficult for some patients to remain still in the proper position, which is necessary to achieve correct and sharp images.

An important consideration is the fact that to date no such study has been carried out in Iran and the results of the present study might be extremely useful in treatment planning and prognosis determination given the prevalence of osteoporosis on one hand and ever-increasing demand for implant-based treatment modalities.

Considering the correlation between the density of skeletal and jaw bones in the present study it can be concluded that in case of osteoporosis or a decrease in the density of skeletal bones in patients, there is a concomitant decrease in the density of jaw bones, which might increase the risks involved in implant placement in various jaw regions or increase the odds of fractures in jaw bones. Of course, there are no definite contraindications for placement of implants in osteoporotic patients, but it is prudent to observe significant considerations in osteoporotic patients in the treatment plan for implants, especially in the maxilla because it consists of more cancellous bone. It is suggested that in future studies males and females be included with age groupings and the presence or absence of osteoporosis be evaluated with the BMD of various jaw regions.

CONCLUSION

There is a significant correlation between the densities of skeletal and jaw bones; therefore, the density of skeletal bones and the presence of osteoporosis or osteopenia in these bones might reflect the same situation in the maxilla and mandible.

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