Original Article

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Dentistry Section

Comparative Analysis of Linear and Angular Measurements on Digital Orthopantomogram with Calcaneus Bone Mineral Density

MOHAMMED KAMRAN SHAKEEL[1], MARIAPPAN JONATHAN DANIEL[2], SUBRAMANIAM VASUDEVAN SRINIVASAN[3], RAMADOSS KOLIYAN[4], JIMSHA VANNATHAN KUMAR[5]

ABSTRACT

Background: Bone remodeling is a continuous and complex process which occurs throughout life. Radiomorphometric and radioangular indices on the orthopantomogram are the predictors of bone remodeling associated with mandible. Bone mineral density is the amount of calcified tissue in a certain volume of the bone.

Materials and Methods: Fifty normal healthy individuals within the age range of 25-55 years were included in the study. Linear measurements including mandibular cortical width (MCW) and panoramic mandibular index (PMI); and angular measurements including mandibular angle (MA) and antegonial angle (AGA) were recorded. Quantitative ultrasound bone mineral density (BMD) scan of the heel bone (calcaneus) of the same patient were also performed.

Results: In our study, for both males and females, antegonial angle (AGA) had highest correlation with calcaneus bone mineral density. In the age group of less than 35 years, PMI in males, and AGA in females had highest correlation. In the age range of more than 35 years, MA in males and AGA in females had highest correlation.

Conclusion: There is a correlation between the mandibular bone remodelling changes and calcaneal bone mineral density in case of elder subjects and thus these parameters may be used as an inexpensive alternative screening method to assess the bone mineral density and identify individuals at risk for osteoporosis and fractures and also for dental treatment planning.

Keywords: Antegonial, Osteoporosis, Radiomorphometric, Remodeling

INTRODUCTION

Bone mineral density (BMD) is the amount of calcified tissue in a certain volume of the bone. Assessment of mandibular bone mineral density may be considered useful or even necessary, in many clinical situations [1]. Findings of histomorphometric and microradiographic studies show that both cortical and trabecular bone tissues of the mandible undergo changes [2]. This, together with the characteristics of the anatomical structure of the mandible as well as the sufficient thickness of its cortical bone, accounts for the use of the mandible to determine changes in BMD [3]. It is therefore no coincidence that panoramic radiography and radiomorphometric indices used by odontologists for examining the mandible have attracted the clinician`s attention. Panoramic radiomorphometric indices (mandibular cortical width, MCW; panoramic mandibular index, PMI) and radioangular indices (mandibular angle, MA; antegonial angle, AGA) serve as diagnostic criteria that help to select elderly patients with suspected changes in bone mineral density for further BMD testing [4].

Quantative ultrasound (QUS) is a promising alternative peripheral technique which is able to assess bone density, its structure, accumulated fatigue, and changes in cortical and trabecular architecture. Because of its low cost, portability and lack of exposure to hazardous ionizing radiation, it is becoming popular. Although various sites can be analysed by QUS, the only recognized site for the clinical use of QUS in osteoporosis management is the heel. The reason for this recognition is the trabecular composition of the calcaneous bone with flat, homogenous and parallel external surfaces. Using heel as the analysis site, researchers have been able to differentiate healthy individuals from individuals with fractures; have detected alterations related to age and menopause; and have been able to identify individuals susceptible to fracture [5].

The major limitation associated with QUS and calcaneum as an index for BMD is the paucity of supporting scientific literature. Also, in the studies which have used calcaneum as a site for BMD, the study sample consisted of menopausal women [6], which is not the case in our study. Further, lumbar spine and femur have been used as preferred sites for BMD in the previous literature [7]. However, for lumbar spine and femur as the sites, the gold standard is DEXA [8] but it is associated with risk of radiation exposure [9].

With this background, an attempt was made to assess the correlation and comparison between mandibular bone remodeling changes by radio-morphometric and radio-angular measurements and calcaneal bone mineral density as an alternative method to assess bone mineral density to identify the individuals at risk for osteoporosis and fractures, and also for dental treatment planning.

MATERIALS AND METHODS

Fifty normal healthy individuals (25 males and 25 females) within the age range of 25-55 years, who reported to the Department of Oral Medicine and Radiology for dental treatment and were indicated for digital orthopantomography, were selected for the study. Patients with metabolic diseases e.g. hyperparathyroidism, hypoparathyroidism, hyperthyroidism and diabetes mellitus and other systemic diseases as well as patients taking drugs which may affect bone metabolism e.g. glucocorticoids, aluminium containing antacids, furosemide, bisphosphanate, calcium, vitamin A, vitamin D and antiepileptics were excluded from the study. For all 50 patients, linear (MCW and PMI) and angular (MA and AGA) measurements as well as Quantitative Ultrasound Bone mineral density scan reports were obtained separately.

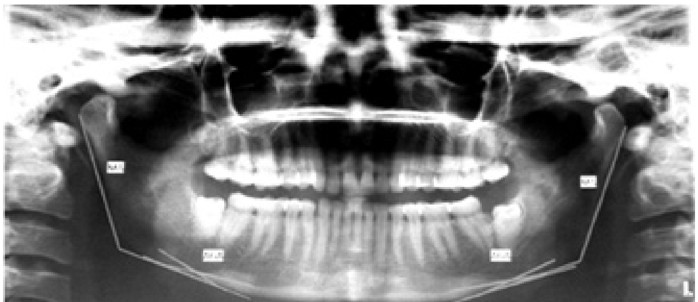
Panoramic radiographic measurements

Panoramic radiography examination was performed using a ProMax (Planmeca OY, 00880 Helsinki, Finland) panoramic radiography machine unit with inbuilt Dimaxis 3 software (64 KVp; 6 mA; and 18 secs). Radio-morphometric and radio-angular measurements were recorded by the inbuilt Dimaxis 3 software (Planmeca Dixi 3, Planmeca Oy, Helsinki, Finland) for image analysis. For every patient, two linear (MCW and PMI) and two angular (MA and AGA) measurements were obtained by calculations based on the mean of both right and left sides.

MCW was calculated by measuring the mandibular cortical thickness on the line perpendicular to the tangent drawn along the inferior border of mandible at the middle of the mental foramen (normal value: > 3.1 mm). PMI was calculated by obtaining the ratio of the mandibular cortical thickness measured on the line perpendicular to the bottom of the mandible, at the middle of the mental foramen, and the distance between the inferior mandibular cortex and the bottom of the mandible (normal value: > 0.3) [4]. The mandibular radio-morphometric measurements have been depicted in [Table/Fig-1].

For calculating MA, two lines were traced on panoramic radiographs. One line was traced tangential to the posterior border of ramus and the condyle; the second line was traced tangential to the inferior most points at the gonial angle and the inferior border of the mandible. MA was formed at the intersection of these two tangential lines, and was measured on both the right and left sides of the mandible. For calculating AGA, two lines were traced parallel to the antegonial region. These two lines intersected at the deepest point of the antegonial notch to form AGA [10]. The mandibular bone radioangular measurements have been depicted in [Table/Fig-2].

[Table/Fig-1]: Orthopantomogram revealing radiographic presentation of mandibular cortical width (MCW) and panoramic mandibular index (PMI)



[Table/Fig-2]: Orthopantomogram revealing radiographic presentation of mandibular angle (MA) and antegonial angle (AGA)

Quantitative ultrasound bone mineral density measurements

QUS bone mineral density (BMD) scan of the heel bone (calcaneus) of the same patient was performed using GE Healthcare Lunar Achilles ExpressTM machine (GE Healthcare, Madison, WI, USA) and Stiffness Index (SI), T-Score and Z-Score were obtained. The "T" score represents the individual's SI above or below a reference "young adult" mean and is expressed in standard deviation (SD) units. Output of the QUS machine contains a graph having three different zones of different color: green, yellow and red. The bottom of the green region marks one standard deviation (-1 SD) below the mean "young adult" value. The yellow region represents the range from -1 to -2.5 SD. The red region represents values below -2.5 SD. Fracture risk increases continuously as the SI values decrease. The "percentage young adult" expresses a individual`s stiffness index value as a percentage of the "young adult" mean for women aged 20 to 35 years. Among three parameters, T- score is more reliable to predict bone mineral density so in this study we chose T- score to correlate bone remodeling changes in mandible.

Achilles QUS system measurements were performed with the individual seated, with one foot placed on the foot positioner, and the heel surrounded by warm water encapsulated between inflated membranes. A transducer on one side of the heel converts an electrical signal into a sound wave, which passes through the water and the individual`s heel. A transducer at a fixed distance on the opposite side of the heel receives the sound wave and converts it to an electrical signal that is analysed.

To compare and correlate the radio-angular measurements, sample was divided into two separate groups: male and female groups with each group having 25 study subjects. Further, both groups were divided into patients less than 35 years of age and patients more than 35 years of age. According to literature [11], bone metabolism is a continuous process consisting of osteoblastic as well as osteoclastic processes. In the first phase of life, bone deposition predominates, and in the second phase, osteoclastic activity predominates. The reference age mentioned in the literature varies from 30 years to 40 years. In the present study, the mean age of these two age groups i.e. 35 years, was considered.

STATISTICAL ANALYSIS

Comparison and analysis of the data were performed using the data accumulation and analysis software packages Statistica 5.5, Excel 2000, and SPSS 13.0 (SPSS Inc., Chicago, IL, USA). The sample volume was selected randomly during the study. The dependence of the attributes was evaluated by applying Pearson's linear regression (correlation coefficient, r). The verification of the statistical hypotheses was performed using the following significance denotations: $P<0.05$ (significant), $p<0.01$ (highly significant), and $p<0.001$ (especially significant); p denotes the marginal level of significance in the verification of hypotheses.

RESULTS

In the case of male patients, for MCW (0.2743), PMI (0.5629) and MA (0.3429), there was a positive correlation with T-score while AGA (-0.6352) had a negative correlation [Table/Fig-3]. Negative correlation signifies that with increase of T-score, AGA decreases. In the case of female patients, for MCW (0.4597), PMI (0.4691) and AGA (0.5055), there was a positive correlation with T- score while MA (-0.4033) had a negative correlation [Table/Fig-3].

In the case of male patients less than 35 years of age, for MCW (0.3920), PMI (0.5941) and MA (0.2016), there was a positive correlation with T- score while AGA (-0.3482) had negative correlation [Table/Fig-4]. In the case of female patients less than 35 years of age, for MCW (0.3983), PMI (0.2962) and AGA (0.6314), there was a positive correlation with T- score while MA (-0.5589) had negative correlation [Table/Fig-4].

In the case of male patients more than 35 years of age, a positive correlation was observed for MCW (0.5760), PMI (0.5997) and MA (0.8285) with T- score while AGA (-0.6032) revealed a negative

Correlation for male patients					
	T-Score	MCW	PMI	MA	AGA
T-Score	1.0000	0.2743	0.5629	0.3429	-0.6352
MCW		1.0000	0.9370	0.2399	-0.3728
PMI			1.0000	0.3119	-0.3403
MA				1.0000	0.2939
AGA					1.0000
Correlation for female patients					
	T-Score	MCW	PMI	MA	AGA
T-Score	1.0000	0.4597	0.4691	-0.4033	0.5055
MCW		1.0000	0.9020	-0.5711	0.5936
PMI			1.0000	-0.5616	0.2398
MA				1.0000	-0.2766
AGA					1.0000

[Table/Fig-3]: Correlation of mandibular cortical width (MCW), panoramic mandibular index (PMI), mandibular angle (MA), antegonial angle (AGA) and T-Score in male patients (n=25) and female patients (n=25).

Correlation for male patients					
	T-Score	MCW	PMI	MA	AGA
T-Score	1.0000	0.3920	0.5941	0.2016	-0.3482
MCW		1.0000	0.8151	-0.2101	-0.2261
PMI			1.0000	0.2876	0.2639
MA				1.0000	0.4106
AGA					1.0000
Correlation for female patients					
	T-Score	MCW	PMI	MA	AGA
T-Score	1.0000	0.3983	0.2962	-0.5589	0.6314
MCW		1.0000	0.9536	-0.6305	0.5889
PMI			1.0000	-0.5087	0.5528
MA				1.0000	-0.4425
AGA					1.0000

[Table/Fig-4]: Correlation of mandibular cortical width (MCW), panoramic mandibular index (PMI), mandibular angle (MA), antegonial angle (AGA) and T-Score in male patients (n=15) and female patients (n=14) less than 35 years of age

correlation [Table/Fig-5]. For female patients more than 35 years of age, a positive correlation was observed for MCW (0.4545), PMI (0.6169) and MA (0.5249) with T-score while AGA (-0.5155) revealed a negative correlation [Table/Fig-5].

When both the groups, male and female, were compared separately by paired t-test, it was observed that there was no statistically significant difference between the two groups [Table/Fig-6].

Correlation for male patients					
	T-Score	MCW	PMI	MA	AGA
T-Score	1.0000	0.5760	0.5997	0.8285	-0.6032
MCW		1.0000	0.9196	0.6440	-0.8328
PMI			1.0000	0.4486	-0.8341
MA				1.0000	-0.6217
AGA					1.0000
Correlation for female patients					
	T-Score	MCW	PMI	MA	AGA
T-Score	1.0000	0.4545	0.6169	0.5249	-0.5155
MCW		1.0000	0.8417	-0.3819	0.5295
PMI			1.0000	-0.5707	-0.4389
MA				1.0000	0.6166
AGA					1.0000

[Table/Fig-5]: Correlation of mandibular cortical width (MCW), panoramic mandibular index (PMI), mandibular angle (MA), antegonial angle (AGA) and T-Score in male patients (n=10) and female patients (n=11) more than 35 years of age

Observation	Males		Females		*t*-value	*p*-value
	Mean	Standard Deviation	Mean	Standard Deviation		
T-Score	-0.53	1.23	-0.07	1.21	-1.29	0.2048
MCW	4.38	0.79	4.09	1.19	0.96	0.3414
PMI	0.29	0.08	0.29	0.08	0.10	0.9204
MA	117.67	7.17	121.08	4.95	-1.90	0.0637
AGA	159.38	5.25	161.68	3.56	-1.76	0.0849

[Table/Fig-6]: Comparison of male and female groups by paired t-test

All t-values are stastically non-significant (p>0.05)

DISCUSSION

During an individual's life, the morphologic changes undergone by the mandible are thought to be influenced by dental status and age of the patient [12]. The resorption of mandibular bone tissue as well as the morphological-dimensional changes in cortical bone, both typically observed in elderly individuals, is largely attributable to age related reduction in bone mineral density. Analyses conducted over the last few decades have proven a relationship between mandibular bone mineral density, alveolar bone height, tooth loss, and changes in general skeletal bone mineral density [13]. Changes in bone mineral density are diagnosed based on the changes detected in cortical bone thickness and integrity in the mandibular base, which is an important symptom of osteoporosis [14]. Dutra et al., conclusively demonstrated that cortical bone thickness changes in the mandibular base are characteristic of individuals with osteoporosis, and increasing bone porosity results in decreasing bone mass [15,16]. Changes in mandibular bone and skeletal osteoporosis share multiple risk factors, such as age, menopause, race, smoking, diet low in calcium, certain medications, as well as genetic factors such as family history of osteoporosis [17]. A comparative analysis of similar studies has been mentioned in [Table/Fig-7] [1,18-24].

Osteoporosis is relatively common systemic bone pathology. The characteristic microscopic alterations in osteoporosis include deterioration of bone tissue and scarce bone mass, which results in clinical manifestations of increased bone fragility and increased susceptibility to fractures [25]. Bone is a dynamic structure and is characterized by simultaneous processes of bone formation by osteoblasts and bone resorption by osteoclasts [15]. This dynamic biological nature of bone turnover ensures constant replacement of old bone with new bone [26].

Author name and year	Number of patients and mean age	Imaging modality used	Parameters calculated	Result
Klemetti E et al., 1993 [18]	355 women of mean age 52	DEXA	PMI	PMI can be used as an indicator of bone mineral changes when the PMI values deviate markedly from the mean PMI of the population.
Taguchi A et al., 1996 [19]	124 women of mean age 53.7 years	Dual energy QCT	MCI	Osteoporotic women can be accurately identified with high accuracy using the status of the mandibular inferior cortex on panoramic radiograph.
Horner K et al., 1998 [20]	40 men of mean age 65 years	DEXA	MCI, PMI	Positive association in detecting BMD between DEXA and panoramic radiograph.
Cakur B et al., 2009 [21]	80 women of mean age 54.9 years	DEXA	MCI	MCI did not correlate significantly with DEXA measurements in determining BMD.
Gulsahi A et al., 2010 [21]	49 edentulous patients	DEXA	MCI, MI and PMI	The BMD of the jaws was not correlated with either femoral BMD or panoramic radiomorphometric indices.
Dagistan S et al., 2010 [22]	40 males	DEXA	MCI,MI,PMI and AGI	MI, PMI and AGI values as radiomorphometric indices were found to be smaller among male patients with osteoporosis, compared with normal patients.
Devi BKY et al., 2011 [23]	40 post-menopausal women	DEXA	PMI, AGI	PMI had a better efficacy in identifying postmenopausal women with osteoporosis in comparison with AI.
Rati G et al., 2014 [24]	50 post-menopausal women	DEXA	MCI	Significant correlation between results obtained by MCI and BMD of the lumbar vertebrae.

[Table/Fig-7]: Comparative analysis of previous studies on linear and angular measurements
DEXA: Dual-energy X-ray absorptiometry; QCT: Dual-energy quantitative computed tomography; PMI: panoramic mandibular index; MCI: mandibular cortical indices; MI: mental index; AGI: antegonial index; BMD: Bone Mineral Density

Reduced bone mineral density (BMD), and thus the development of osteoporosis, is more pronounced in postmenopausal women than in other patients. The exceptionally progressive phase of bone destruction, which occurs in women during the period of 5 to 10 years following menopause, is associated with the dramatic drop in estrogen levels [27,28]. Various bones are analysed in studies on bone mineral density in postmenopausal women. A number of studies have revealed a significant positive correlation between BMD of the mandible and that of the most frequent sites of osteoporosis, namely the lumbar spine, the femoral neck, and the forearm [29,30].

The present study sought to assess BMD of the mandible by the use of panoramic radiography as a diagnostic method, primarily due to the fact that mandibular bone mineral density is a parameter closely associated with alveolar bone resorption and early tooth loss. However, the patient with systemic diseases affecting bone metabolism are a subject of further studies and thus were not analysed in this study.

Overall, our analysis suggests that determining BMD of the mandible (based on panoramic radiographs) and comparing it with BMD of the calcaneus (measured by quantitative ultrasound) is expedient for several reasons. As panoramic radiographic examinations are convenient and informative, and are common in odontological practice, we expect this study to serve as an impetus for the advancement of diagnostic and clinical collaboration between dental practitioners and other medical professionals in predicting low general skeletal BMD. For instance, our research findings indicate that the use of panoramic radiography for assessing bone mineral density of the mandible also allows for determining general skeletal bone mineral density loss in elderly female patients. These measurements, coupled with criteria such as other clinical risk factors and/or family history of osteoporosis, could therefore prove to be a promising instrument in the assessment of risk for skeletal osteoporosis [31].

In this study, we observed that BMD and different parameters assessed do not correlate overall. This may be attributed to the reason that the present study included patients spread over a broad age range and belonged to a diverse socio-economic stratum. These findings are in agreement with the study done by Gulsahi et al., [1]. Also, in our study for both male and female groups, AGA had highest correlation with BMD. This finding can be attributed to the effect of masticatory forces on mandibular bone remodeling at antegonial region. On the contrary, MCW in case of male group and MA in case of female group had lowest correlation. Our study illustrates that in case of age range less than 35 years; there was a week correlation between BMD and linear and angular parameters in comparison to older age group, probably because osteoclastic activity and hormonal changes in females become significant after 35 years of age.

Although the calcaneus is a classic example of a weight-bearing bone, it is noteworthy that the mandible is likewise loaded, with occlusal force being the most direct origin of that load. Therefore, examining the functionally as well as metabolically active sites of the calcaneus and the mandible in tandem is essential for an in-depth understanding of changes in bone turnover. Whereas reduced calcaneal BMD is firstly reflected in its trabecular area, and only later in its cortical component, mandibular BMD loss manifests itself through the decrease in its cortical thickness.

This study is unique, as we have taken normal healthy individuals of broader age range (25-55 years) while in the past other studies have included mostly female patients with osteoporosis in the age range of more than 40 years (post menopausal period), so we have tried to generalize this study for routine healthy dental patients.

LIMITATIONS

Limitations of the study could be the small sample size and if we could take the age and sex matched samples for the study then we could have got more consistent results. Further, another limitation of the study could be manual calibration of radiographic indices that depends on the observer`s skill. Also, the present study did not make use of the automated designed software which are available in the market and have the ability to exclude the need of manual calibration and thus, can make the study results more consistent.

CONCLUSION

From the findings of the present study, it can be concluded that there exists a correlation between the mandibular bone remodelling changes and calcaneal bone mineral density in case of older people and thus these parameters may be used as an inexpensive alternative screening method to assess the bone mineral density and identify individuals at risk for osteoporosis and fractures, and also for dental treatment planning.

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PARTICULARS OF CONTRIBUTORS:
1. Post Graduate Resident, Department of Oral Medicine and Radiology, Mahatma Gandhi Postgraduate Institute of Dental Sciences, Pondicherry, India.
2. Professor and Head, Department of Oral Medicine and Radiology, Mahatma Gandhi Postgraduate Institute of Dental Sciences, Pondicherry, India.
3. Associate Professor, Department of Oral Medicine and Radiology, Mahatma Gandhi Postgraduate Institute of Dental Sciences, Pondicherry, India.
4. Associate Professor, Department of Oral Medicine and Radiology, Mahatma Gandhi Postgraduate Institute of Dental Sciences, Pondicherry, India.
5. Assistant Professor, Department of Oral Medicine and Radiology, Mahatma Gandhi Postgraduate Institute of Dental Sciences, Pondicherry, India.

NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:
Dr. Mohammed Kamran Shakeel,
Post Graduate Resident, Department of Oral Medicine and Radiology,
Mahatma Gandhi Postgraduate Institute of Dental Sciences, Pondicherry-605006, India.
Email: kamranshakeel36@gmail.com

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