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Assessment of Mandibular Alveolar Bone Density in Osteoporotic Adults in Syria

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Abstract Objectives: Many studies indicated that reduction of skeletal bone mineral density (BMD) may lead to loss of the mandibular alveolar bone mass (MABM). Since osteoporosis is characterized with low bone mineral density, it may affect both maxilla and mandible. This study aims to evaluate the correlation between mandibular alveolar bone density (MABD) and bone mineral density (BMD), and to assess the use of intra-oral periapical radiographs in osteoporosis detection. Methods: Participants were patients attending periodontal clinic, Dentistry School, Damascus University then referred to the bone density unit at Al-Mowassat teaching hospital in Damascus to receive DEXA. Dual X-ray absorptiometry (DEXA) was done on Lumbar spine vertebrae (L2-L4) and femoral neck for each participant. They were classified into three groups: osteoporotic, osteopenic and normal (control) subjects. A periapical radiograph was taken for each participant using a standardized paralleling technique with an aluminum step wedge. MABD was measured using computerized software (Digora) to calculate MABD. Results: the number of the participants was 169 individuals (age= 42± 5.3 years), they were assigned as follows (Osteopenic 57, Osteoporotic 52, control 60). A significant positive correlation between MABD and BMD was found in osteoporotic group ($R = 0.527$ & $p < 0.01$). Also there were significant differences of MABD between osteoporotic group versus both osteopenic and normal groups .Conclusions: Mandible can be affected by osteoporosis. Intra-oral periapical radiographs using aluminum step wedge is considered one of the important and useful techniques for the detection of osteoporosis

Keywords Aluminum Step Wedge, Dual X-Ray Absorptiometry (DEXA), Mandibular Alveolar Bone Density (MABD), Osteoporosis

1. Introduction

Osteoporosis is a universal disease; World Health Organization considers it a priority health problem because it affects more than 20 million people (most of them are women) worldwide. It causes over 2 million bone fracture incident annually. Its treatment cost in United States was estimated to be 7- 10 billion dollars, whereas costs of indirect implications such as medical care and health insurance could rise to 18 billion dollars per year (1).

Osteoporosis is a silent, progressive, complex, chronic, and symptomless disease that affects bones of adults regardless of gender (2). Women after menopause are more affected; it is estimated that 33.33% of women and 12.5% of men over 50 years old are affected (3).

Osteoporosis causes reduced bone mineral density due to extensive loss of bone calcium which in turn is due to progressive deterioration of specific bone protein considered as calcium carrier (4).

Genetic factors play an important role in controlling and regulating bone mineral density (5). Other factors include: gender, family history, race, body structure, and conditions affecting bone metabolism such as: smoking, alcohol, maternity, sedentary life style, and some drugs (hormones, steroids) (5, 6, 7, 8, 9).

Osteoporosis may affect the structure of the alveolar bone the process that has high importance in dental sciences (10), therefore interfering with therapy in every sub-specialty especially tooth implantology.

Since studies were inconsistent regarding the involvement of the mandible in osteoporosis, the main question this study is trying to answer is: does osteoporosis affect mandible?

The second question is about the availability of a simple predictive technique that dentists could use to detect osteoporosis early in patients unknown to have it during the latent period.

Many investigators have evaluated the relation between osteoporosis and low bone density in the mandible (11, 12, 13, 14).

Most studies confirmed a strong relation between osteoporosis and mandiblular bone density which tends to be decreased in this disease (4, 11, 12, 14, 15, 16, 17, 18, 19, 20, 21).

Cao et al (13) studied mandibular bone density in lower central incisor region in 24 female rabbits with no ovaries. They noticed the rabbits developed osteoporosis in addition to the loss of bone mineral in the mandible.

Several methods have been developed for evaluating bone mass, including quantitative computed tomography(20), Single Photon Absorptiometry (4, 21), Dual Photon

Absorptiometry (22), and dual energy X-ray absorptiometry DEXA (11. 23). Unfortunately, these techniques involve special radiographic procedures and are relatively expensive.

Most dentists routinely take panoramic (11, 23, 24), intraoral radiographs (12, 15, 25, 26). If techniques to assess bone density using these radiographs can be refined and these radiographs are taken with an aluminum step-wedge in place, they might serve as a good screening tool for the detection of osteoporosis (12,18).

Hildebolt et al (15) used grey level values of plain X ray to detect color changes in alveolar bone density. These changes reflected modifications of skeletal bone mineral density (BMD) in general.

Dural et al (11) used panoramic radiographs of osteoporotic adolescents patients. They found that this method is economical and useful to detect the severity of osteoporosis, and there was a relation between mandibular and skeletal BMD.

Ishii et al (14) studied panoramic radiographs of 354 menopausal women to assess the resorption of alveolar bone and cortical width of the mandible. Femoral BMD were measured using DEXA technique. The results showed that panoramic technique may be useful in diagnosing mandible alveolar bone resorption as a mean to predict femoral osteoporosis in menopausal women.

Horner et al (4) used other diagnostic methods to detect mandible BMD in order to be used to predict osteoporosis. They used Single photon absorption SPA in 40 edentulous women who were subjected to DEXA imaging. A statistically significant relation was noticed between mandiblular BMD loss and BMD loss in other regions of the skeleton.

Mansour et al (24) found that panoramic indices (Mandibular Cortical Index MCI, Mental Index MI, and Panoramic Mandibular Index PMI) were positively correlated with t score and BMD of the lumbar spines.

The same conclusion was reached by Bodade and Mody who said that MCI is a useful tool for the screening of postmenopausal osteoporotic patients (23).

A study (12) used intraoral periapical imaging technique with aluminum step wedge as a predictive tool for osteoporosis. They assessed the mandiblular density in osteoporotic group after scanning their radiographs and performing computerized analysis using Digora software. They concluded that the described technique offered an early indication of osteoporosis, a simple, relatively not expensive, and harmless technique that could be used to follow up osteoporotic patients. They found a significant relationship between osteoporosis and reduced bone density of the mandible.

Not only using dental radiographs for the detection of osteoporosis was more economical than using of the standard techniques, but also minimized patient exposure to radiation.

Therefore, this study aims at assessing the relationship between Mandibular Alveolar Bone Density (MABD) and the skeletal BMD in addition to evaluating the potential of using periapical radiographs as a predictive indicator to detect osteoporosis.

2. Materials and Methods

The sample of this study included patients attending periodontal clinic, Dentistry School, Damascus University then referred to the bone density unit at Al-Mowassat teaching hospital in Damascus to receive DEXA. All participants should fulfill the following criteria:

- Gave Informed consent.
- Aged between 30 to 50 years old.
- Not affected by any systemic disease such as diabetes, cardiovascular conditions, or leukemia.
- Not affected by metabolic conditions that affect bones such as primary hyperparathyroidism, osteomalecia, rheumatoid arthritis, or multiple myeloma.
- Did not have long-term history of medications that affect bone metabolism, such as corticosteroids, antacids, or anti-convulsion.
- Neither smoker nor alcoholic.
- Had their lower right premolars present and not affected by deep pockets.
- Did not take protective (e.g. calcium or vitamin D) or replacement (e.g. bisphosphonates) therapy for osteoporosis.
- Did not have antibiotic therapy during the last 6 months.

Female participants: non pregnant- non menopausal, did not use replacement hormonal therapy.

Radiographs were taken to assess bone density of lumbar vertebra and left femur neck at the bone density unit, using dual energy X ray absorptiometry (DEXA), in order to measure the mineral content of the bone. Then, participants were assigned to three groups according to DEXA results and following WHO classification: the normal (control) group, the osteopenic group, and the osteoporotic group.

2.1. Radiographic Indicators of Skeletal BMD

We measured the bone density in vertebral bodies and left femur neck. The most important parameter that we adopted as indicator was T- score since it measures the number of standard deviation units (SD) between the individual BMD and that of young adult (18, 25, 27).

Osteoporosis as defined by the World Health Organization (WHO) is a condition where the bone mineral density (BMD) is 2.5 standard deviations (SDs) below the young normal. Osteopenia is defined as a BMD between (-1) and (-2.5) SDs (Table 1). According to WHO assessment, the patient is assigned a score that represents a comparison to the average young (25- 45years old) healthy adult of the same gender (T-score) or to the average healthy age and sex matched patient (Z-score). A one unit change in T-score corresponds to one SD difference in BMD from that in a young healthy individual of the same gender. Thus, osteoporosis corresponds to a T-score of (-2.5) or lower, whereas osteopenia corresponds to a T-score between (-1) and (-2.5).

The WHO classification of BMD which uses DEXA technique was adopted in this study:

Table 1. World Health Organization criteria for defining osteoporosis and osteopenia

Condition	Description
Normal	BMD≤1 SD below mean for a young healthy adult(T > -1.0)
Osteopenia	BMD>1SD but<2.5SD below the mean for a young healthy adult (-1.0 > T > -2.5).
Osteoporosis	BMD≥2.5SD below the mean for a young healthy adult (T ≤ -2.5).
Established osteoporosis	BMD≥2.5SD below the mean for a young healthy adult (T ≤ -2.5) with 1 or more fragility fractures
T score =1SD difference from the BMD in a young healthy adult of the same gender; BMD, bone mineral density; SD, standard diviation.	

2.2. MABD Indicators

For all participants we took three periapical radiographs between the two right premolars area using "AGFA dental film Speed E, Germany" that measures 2 (3×4 cm) along with Aluminum step wedge which was divided into 6 grades. Grade thickness ranged from 1 to 6 mm (figure (1)). Both the step wedge and the intraoral film were fixed on the film holder of the parallel technique apparatus during X-ray exposure. Exposure time was set to be 0.35 seconds for every participant. All Radiographs were developed automatically altogether using the same developer and fixer (Kodak).

Apical radiographs were then transformed into digital images using Sony camera (10.3 Mega pixels). They were entered to the computer using Adobe Photoshop 7.0 ME, and then colors were transformed to obtain grey scale images figure (2) which were introduced to Digora software(Windows version 1.15 Sordex Medical System Digora).

Digora calculated the density of region of interest (ROI) i.e. the chosen area in the alveolar bone between the two right lower premolars, figure (3).

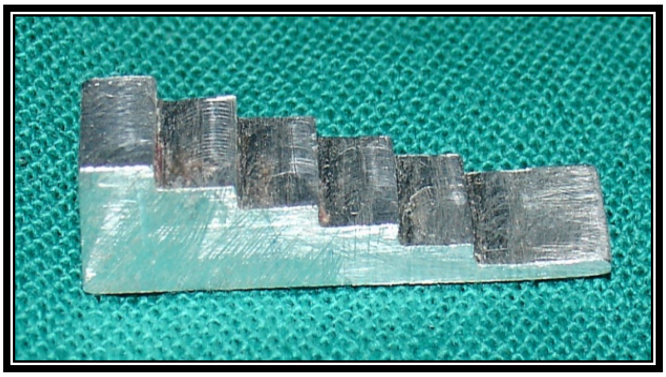

Figure 1. Aluminum step wedge

Using the same image, the density of aluminum wedge was calculated. The step I density is taken to be the density of step wedge immediately higher than the ROI density, and the step II density is taken to be immediately lower than the ROI density. That means the density of ROI is between step I and step II density.

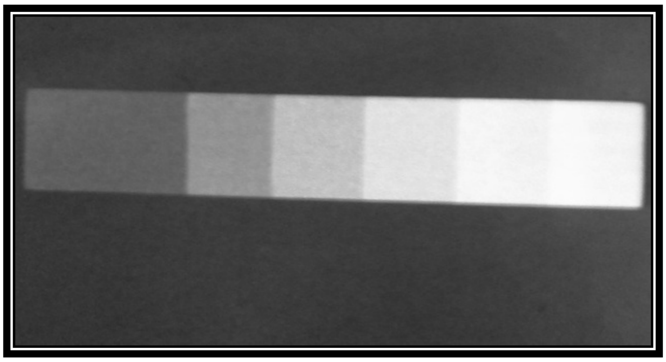

Figure 2. Radiograph of aluminum step wedge showing the radiological differentiation among various grades

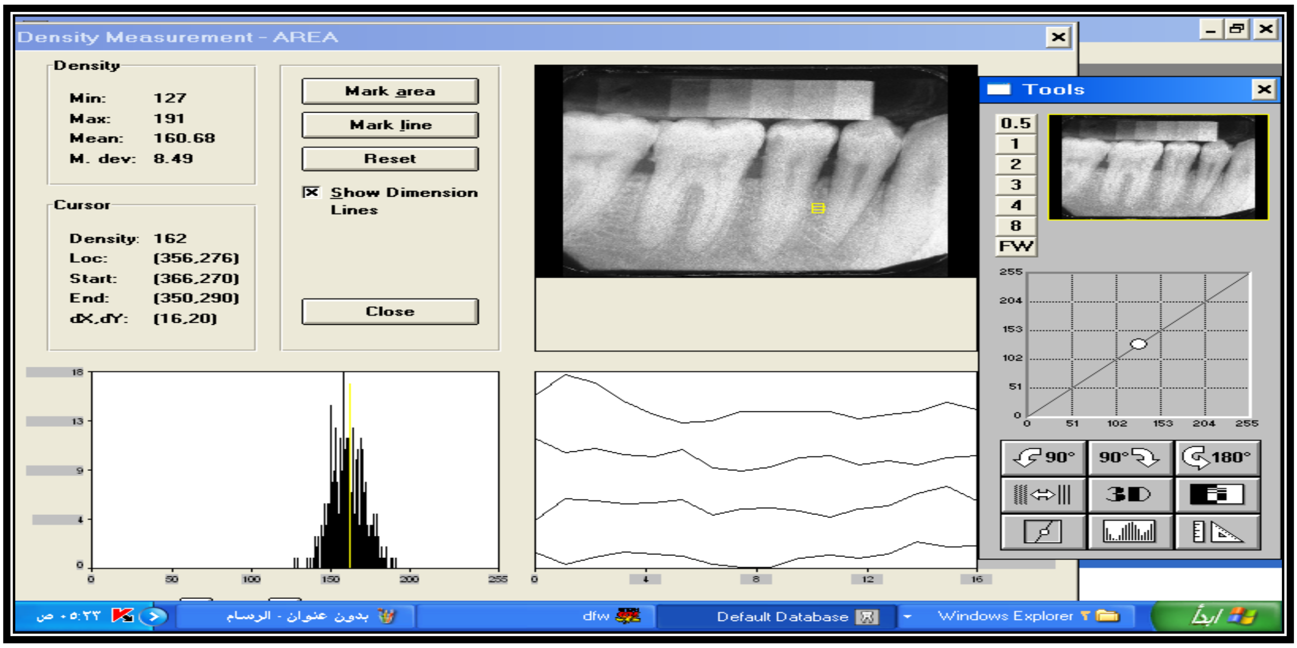

Figure 3, Digora software interface

Table 3. means and standard deviations (SD) of BMD and the equivalent alveolar density in the three groups

Group	Osteopenia		Osteoporosis		control		ANOVA test
	M	SD	M	SD	M	SD	
BMD_L	1.05 Δ O	0.07	0.84 # O	0.09	1.23 # Δ	0.11	S
BMD_F	0.93 Δ O	0.11	0.84 # O	0.12	1.08 # Δ	0.13	S
ATE	3.7 ΔO	0.82	3.09 # O	0.52	5.16 # Δ	0.6	S
T×D	0.48 Δ O	0.1	0.42 # O	0.07	0.64 # Δ	0.09	S
r Coefficient (BMD_L and ATE)	0.712 Strong direct		0.673 Strong direct		0.58 Moderate direct		
r Coefficient (BMD_F and ATE)	0.521 Moderate direct		0.684 Strong direct		0.636 Strong direct		
r Coefficient (BMD_L and T×D)	0.662 Strong direct		0.816 Very Strong direct		0.805 Very Strong direct		
r Coefficient (BMD_F and T×D)	0.372 Weak direct		0.55 Moderate direct		0.679 Strong direct		
r Coefficient (ATE and T×D)	0.847 Very Strong direct		0.849 Very Strong direct		0.738 Strong direct		

BMD_L: Lumbar BMD, BMD_F: femoral BMD, ATE: Aluminum equivalent thickness, T×D: thickness×density, r: Pearson coefficient, #: significant statistical difference between osteoporotic and control, O: significant statistical difference between osteoporotic and osteopenic, S: statistical significance among groups, Δ: significant statistical difference between osteopenic and normal, M:mean, SD:standard deviation

2.3. Ethical Considerations

Taking the informed consent from the participants was an integrated part of the methods. Syria has no ethical committee to deal with researches. We acquired the approval of the board of the Dentistry School, Damascus University as replacement of the ethical committee.

3. Results

We recruited 169 middle aged people (age= 42± 5.3 years) who fulfilled the inclusion criteria. They were assigned into three groups: the osteopenia, osteoporosis, and control group according to the results of lumbar vertebra bone mineral density (table 2):

1. Osteopenic group: 57 participants (29 male and 28 female); age= 41.9± 5.4 years.
2. Osteoporotic group: 52 participants (23 male and 29 females); age= 42.8± 4.9 years.
3. Control group: 60 (24 male and 36 female) participants with neither osteoporosis nor osteopenia; age= 41.3± 5.6 years.

Table 2. study groups, age groups, and mean ages

Group	patients	Female	Male	Mean age (Y)	Age group
Osteopenia	57	28	29	41.90± 5.4	30- 50 y
Osteoporosis	52	29	23	42.83± 4.9	
Control	60	36	24	41.30± 5.6	
Total	169	93	76	42.00± 5.3	

The results of the study were as follows:

1. The osteopenic group (57 patients): BMD_L (Lumbar BMD) was 1.05±0.07, BMD_F (Femoral BMD) was 0.93±0.11, ATE (Aluminum Thickness Equivalent) was 3.7±0.82, and T×D (Thickness by Density) was 0.48±0.1.
2. The osteoporotic group (52 patients): BMD_L was 0.84±0.09, BMD_F was 0.84±0.12, ATE was 3.09±0.52, and T×D was 0.42±0.07.
3. The control group (60 persons): BMD_L was 1.23±0.11, BMD_F was 1.08±0.13, ATE was 5.16±0.6, and T×D was 0.64±0.9.

There was a very strong relationship between BMD_L and T×D in the osteoporotic and control groups (r coefficient 0.816 and 0.805 respectively), and between ATE and T×D in the osteopenic and osteoporotic groups (r coefficient 0.847 and 0.849 respectively).

A strong relationship existed between BMD_L and ATE in the osteopenic and osteoporotic groups (r coefficient 0.712 and 0.673 respectively), between BMD_F and ATE in osteoporotic and control group (0.684 and 0.636 respectively), between BMD_L and T×D in the osteopenic group (r coefficient 0.662), between BMD_F and T×D in the control group (r coefficient 0.679), and between ATE and T×D in the control group (r coefficient 0.738).

A moderate relationship existed between BMD_L and ATE in the control group (r coefficient 0.58), between BMD_F and ATE in the osteopenic group (r coefficient 0.521), and between BMD_F and T×D in the osteoporotic group (r coefficient 0.55). Table 3 summarizes these results.

4. Discussion

The results showed that correlation of both BMD indicators (ATE and T×D) with BMD_L is stronger that those with BMD_F. Taking into consideration that correlation between ATE and T×D was almost perfect through the whole sample, they can be used as strong indicators reflecting each other and reflecting BMD_L, BMD_F, and MABD. This fact suggests that MABD (expressed as ATE and T×D) is reduced significantly in osteoporotic and osteopenic individuals comparing with normal, thus the mandible could be affected by osteoporosis and osteopenia.

Osteoporosis is the reduction of bone mass and deterioration of its structure leading to increased fragility and fracture risks (30, 31). Therefore it is considered a priority health problem in middle and old ages especially in women.

Because skeletal BMD changes may accompany the altered density of other bones such as alveolar bone (19, 31, 32), this study aimed to assess the relation between BMD and MABD, and validate the use periapical radiograph in detecting osteoporosis. While skeletal BMD was assessed using DEXA, MBMD was assessed through the periapical radiograph with aluminum step wedge technology.

DEXA has high accuracy in detecting skeletal BMD including cases of osteoporosis and osteopenia (2, 33, 34, 35, 36, 37).

Horner et al in 1996 (4) evaluated DEXA usage in detecting mandible conditions. They suggested that DEXA accuracy in convenient bone locations is higher than that in mandible due to the difficulty encountered in implementation in the later situation. This difficulty is due to the impression of both mandible ends on one radiograph, and to the limitation of its use (available only for edentulous). This study chose to use the body of mandible between the two premolars since it is free of muscular tendons impressions and its BMD has good relevance to the skeletal BMD (3, 10).

The best location to detect osteoporosis is the apical half interdental part of mandibular alveolar bone. Thus the periapical radiograph is superior to the bitewing radiograph (25, 38), and the panoramic radiograph (4)

This justified our use of the periapical radiograph technique (based on grey scale values) instead of the bitewing technique and panoramic technique.

The main source of error in the periapical radiograph is the developing procedures (12, 39). This problem was overcome by using the aluminum step wedge. The standard aluminum step wedge is of high importance since its density and thickness are well known, and it has homogenous radiographic density. It also helps the developing process because it measures the density of the studied grade, it has similar radiological absorption and interactional properties to the bone (18, 28, 39, 40, 41), and it appears with alveolar bone in the same periapical radiograph. Therefore it provides standardized density of the scanned bone.

This study demonstrated a very strong correlation between MABD (expressed as ATE) with BMD_L ($r = 0.847$, $p<0.05$), and with BMD_F ($r = 0.771$, $p<0.05$). Therefore, osteoporosis could be seen as a risk factor for reduced MABD i.e. mandible can be affected with osteoporosis. Intraoral radiograph technology using ATE could be useful in detecting skeletal osteoporosis. It is an easy, simple, and harmless method. The assessment of radiological mandibular density may as well be used as diagnostic tool to predict osteoporosis. These results support those of Elsawaf et al 2005(12) and Jonasson et al 2001(25) who studied the relation between skeletal BMD and MABD in osteoporotic adults. Most studies evaluated the relationship between skeletal and jawbone BMDs in old osteoporotic women (18, 19, 36, 42, 43, 44, 45, 46), Changes in spine and femur BMD with aging can be found in both sexes at advanced ages (47). Also, there are few studies probing the relationship between osteoporosis and mandibular body. The present study which investigated these relationships in adult osteoporotic men and women generated results demonstrating that a reduced skeletal BMD may be associated with alteration in the mandibular body density. Density assessment of mandibular bone between premolars regions in intraoral periapical radiographs is a potential method to identify subjects at risk of having osteoporosis. As step-wedges are not routinely used in clinical settings, this technique can be helpful in screening osteoporotic patients.

Study limitations: there were few limitations to this study; the sample was a small one (169 participants), the participants were mainly from Damascus and neighboring areas, and it was hospital based study rather than general population study.

4. Conclusion

Our results indicate a strong correlation between osteoporosis and low MABD. The periapical imaging technique with aluminum step wedge could be useful in detection of osteoporosis, and could be used to monitor osteoporosis in high risk patients. The advantages of using dental radiographs are that they are simple, already available, and of low cost.

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