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Bone Quality Assessment Using Cone Beam Computed Tomography of the Mandible in Correlation to Dual Energy X-Ray Absorptimetry

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Abstract: *Cone beam computed tomography (CBCT) of the mandible allows accurate assessment of the maxillofacial anatomic relationships in 3D and as we know any decrease in the body bone quality can affect jaw bones, therefore this study was performed to evaluate the efficacy of mandibular CBCT in assessing bone quality in postmenopausal women and to correlate it to the Dual energy x-ray(DEXA). Based on the DEXA results, twenty four patients were classified into osteoporotic (test) and non-osteoporotic (control) groups. CBCT examination was done as part of surgical treatment. The computed tomography mandibular index superior (CTIS), the computed tomography mandibular index inferior (CTII), the computed tomography mental index (CTMI), and the computed tomography average trabecular bone density (CTBD) were measured and correlated to T-Score measured by DEXA. There were significant differences between the control and test groups in all indices. There was significant positive correlation between CBCT indices, CTBD and T-score. CTIS, CTII, CTMI and CTBD on the CBCT images can be used for assessing bone quality and so can detect presence of osteoporosis in post menopausal women visiting the dental clinic.*

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I. Introduction

Osteoporosis is usually characterized by reduced bone mass and high risk of fractures of unknown cause and therefore it is considered to be a great challenge to public health worldwide[1]. Moreover patients suffer deterioration of the bone structure and increased bone fragility[2]. It is considered a priority health problem because over 20 million people worldwide, most of them women, are affected by osteoporosis. It causes over 2 million bone fracture incidents annually. Women after menopause are more commonly influenced by osteoporosis[3]. The problem concerning osteoporosis is that no manifestations of the disease are apparent until a fragility fracture occurs. That’s why; massive concern exists within the medical community for developing accurate early detection [4].

The World Health Organization (WHO) in 1994 performed a new epidemiological definition of osteoporosis and osteopenia, depending on measurements of bone mineral density (BMD) expressed in Standard Deviation units called T-scores. Normal patients are those having T-score at −1.0 and above, while osteopenic patients are those having T-score between −1.0 and −2.5 and finally Osteoporosis patient are those with T-score at or below −2.5[5].

Osteoporosis is classified into a primary and secondary disease. Primary osteoporosis considered to be the most common form and includes two types: in postmenopausal women “postmenopausal” osteoporosis or in older men and women “senile” osteoporosis as human bones density decreases and their porosity increases over the age of 40 years old[6]. There is intimate relationship between reproductive hormone deficiency and the development of postmenopausal osteoporosis [7].

The term “secondary” osteoporosis refers to bone loss occurring in patients with underlying clinical diseases, such as hyperparathyroidism or cushing disease[7].

The impact of osteoporosis on the jawbones has been widely studied [6]. Osteoporosis may involve the alveolar bone and change its structure, the process that has big significance in dentistry. It has been reported that osteoporosis results in decreased mass of jaw bone and altered mandibular structure, especially that of the inferior border (mandibular lower cortex) [8], this may interferes with implant placement and other dental procedures [3].

The jaw bones density can be assessed using intraoral and panoramic radiographs, cone beam computed tomography (CBCT), quantitative computed tomography (QCT), and dual energy X-ray absorptiometry (DEXA). DEXA is known as the standard clinical method for diagnosing those with low (BMD)

[2]. However; BMD testing, using DEXA, for all suspected women is not available in many countries. Moreover, many post-menopausal woman visit dental clinic more frequently for dental caries and periodontitis treatment than to visit a medical clinic for detection of osteoporosis [9].

The width of the inferior mandibular cortex and a subjective evaluation of cortical porosity are measured on panoramic radiographs were previously used to diagnose osteoporosis [2].

Nowadays all oral maxillofacial professionals use CBCT in many clinical applications, especially for its minimum radiation in comparison to multi-slice computerized tomography, moreover Misch [11]used CBCT to classify cancellous bone density for dental implant treatment planning into five grades by correlation to a range of Hounsfield units (HU); D1: >1250 HU, D2: 850 to 1250 HU, D3: 350 to 850 HU, D4: 150 to 350 HU, D5: <150 HU. Furthermore Naitoh et al. [12] observed a high correlation between voxel values in CBCT and BMDs of multisectional computed tomography (MSCT). Also, they reported that voxel values measured from mandibular cancellous bone on CBCT could be used to predict the bone density.

Such radiographs have several advantages as higher requirement need for dental treatment planning, and less full body radiation exposure, so it would be useful to know whether radiographic alterations in mandible could have a role in identification of osteoporosis. It would allow the dentist to discover such patients, alter the treatment plan and refer such patients to the specialists for instant management [13].

Therefore, to evaluate the efficacy of mandibular CBCT images for the assessment of bone quality in postmenopausal women, three CBCT indices and average trabecular bone density (CTBD) were measured and correlated with T-Score as detected by DEXA scan.

II. Materials and Methods

This study was carried out on twenty four postmenopausal females patients with age above 45 years selected from the outpatient of Department of Oral Medicine, Periodontology, Oral Diagnosis, and Oral Radiology, Faculty of Dentistry, Alexandria University. An approval was obtained from the ethics committee at the faculty of dentistry, Alexandria University and all patients were asked to sign an informed consent before the commence of the study.

Study design: The study was performed on twenty four postmenopausal females patients with age above 45 years old.

Study location: Clinic of the Department of Oral Medicine, Periodontology, Oral Diagnosis, and Oral Radiology, Faculty of Dentistry, Alexandria University. The study was accepted by the committee of Ethics, Faculty of Dentistry, Alexandria University. All the procedures of the study and its aim were explained to the participants.

Study duration: January 2017 to January 2018

Sample Size: 24 patients

Sample calculation; A sample of 24 patients[14] was required to estimate an average difference at computed tomography mandibular index superior (CTIS) measures between nonosteoporotic and osteoporotic patients = 0.07mm [2], SD = 0.05mm for both (based on DEXA scan as standard), using alpha error = 0.05 provided a study power of 80%.

The sample was selected randomly using simple random sample technique and sample size was calculated using Med Calc software version 12.6.1 (Ostend, Belgium).

Subjects and selection method: The Patients who participated in this study were those of age over 45 years, indicated for CBCT for dental surgical procedure. All 24 selected patients were evaluated according to bone mineral density (BMD) of the lumbar vertebrae (L1-L4) which was calculated using a DEXA scanner (LUNAR Prodigy machine, USA). The height and weight were measured at the time of DEXA scanning.

The twenty four patients were classified into two groups, according to the T-score defined by the World Health Organization (WHO) [15] into two groups:

Group 1: Control group consisted of thirteen patients classified as non osteoporotic with respect to bone mineral density (BMD) (T-score>-2.5);

Group 2: Test group consisted of eleven patients classified as osteoporotic with respect to bone mineral density (BMD) (T-score<-2.5).

Inclusion criteria:

1- Patients age range over 45

2 -Postmenopausal women.

3-Women with history of amenorrhea for at least five years .

4- Patients indicated for CBCT for dental surgical procedures.

Exclusion criteria:
1-Patients suffering from metabolic bone diseases (hyper,hypoparathyroidism, Paget disease, osteomalacia,……).
2-Patients with any systemic disease that affect bone metabolism
3-History of smoking or tobacco use
4-history of using any drug that affects bone metabolism within the past 6 months [(8)].

Procedure methodology:
CBCT images: CBCT images of the mandible were obtained using I-CAT machine (Imaging science International, 2nd generation, Hatfield, PA, USA). Scans were set at 120 kV, 37 mA, 26.9 seconds, voxel size of 0.25 mm and field of view 16x6cm.
Radiologist specialist in head and neck and maxillofacial imaging with 5 years experience blind about the results of DEXA, performed the measurement which were repeated after two weeks.
Slice selection
Using the multiplanar reformation screen (MPR) using On Demand software (Cyber med Inc, Korea) axial images with a slice thickness of 0.1mm were selected and the mental foramen was detected by scrolling through sequential slices. The slice which showed and provided the widest mesiodistal dimension of the mental foramen clearly was used.
Four indices were assessed on the CBCT images in addition to the computed tomography average trabecular bone density (CTBD). As CBCT was utilized in this research, the terms of the indices used were proposed as a result of a modification of Ledgerton's classification for panoramic images [2,16].
The indices were:
1- The computed tomography mandibular index (superior) CTIS: which calculate the ratio of the width of inferior cortical to the distance from the superior margin of the mental foramen to the inferior border of the mandible. CTIS is related to the panoramic mandibular index(PMI). The PMI is a radiomorphometric index presented by Benson et al. [17] and is the ratio between the thickness of mandibular cortical bone and the distance from the superior margin of the mental foramen to the inferior border of the mandible CTIS =W/S.
2- The computed tomography mandibular index (inferior) CTII: is the ratio of the width of inferior cortical to the distance from the inferior margin of the mental foramen to the inferior border of the mandible CTII=W/I.
3- The computed tomography mental index (CTMI):, is the width of inferior cortical of the mandible and symbolized the mental index (MI) as reported by Ledgerton et al.[16] (CTMI=W).

Steps of measurements
Using the axial view at the mental foramen region, the Y-axis (arrow) has been changed to be tangent to the outer border of mandible (Figure 1).

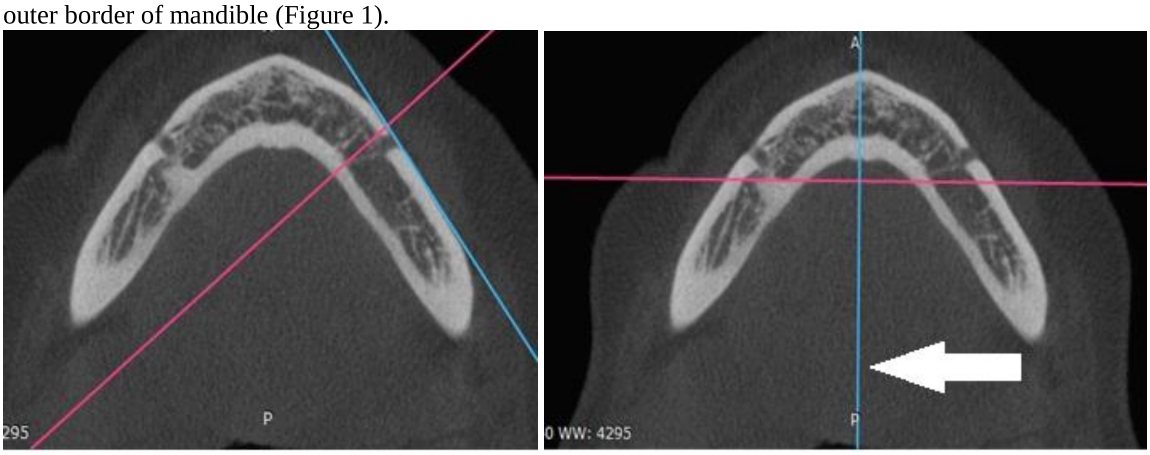


Fig.1: Slice adjustment in axial view

On the coronal view the same Y-axis has been moved to the bisecting position of the bucco-lingual width of the mandibular body and it has been changed simultaneously in the axial view (Figure 2).

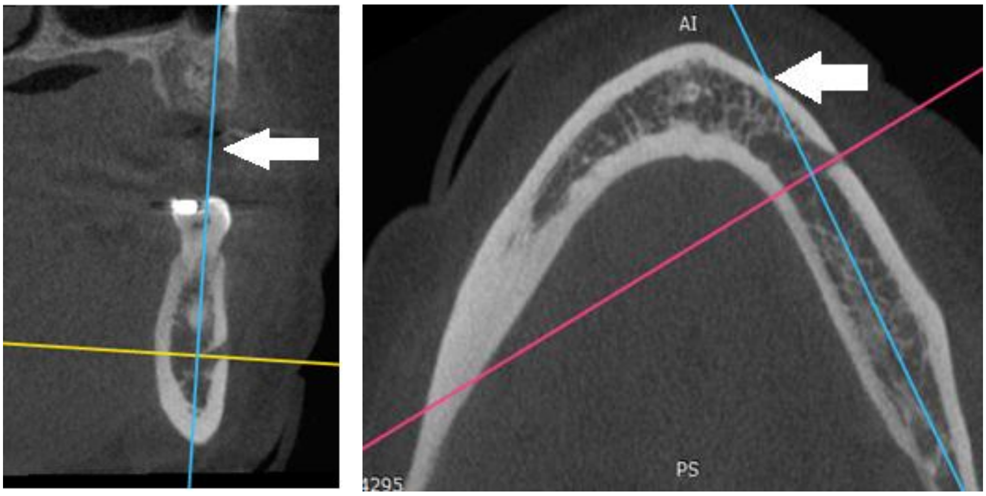


Fig. 2: Slice adjustment in coronal view .

On the sagittal view, the Z-axis (arrow) has been moved to be parallel with the inferior border of the mandible (Figure 3).

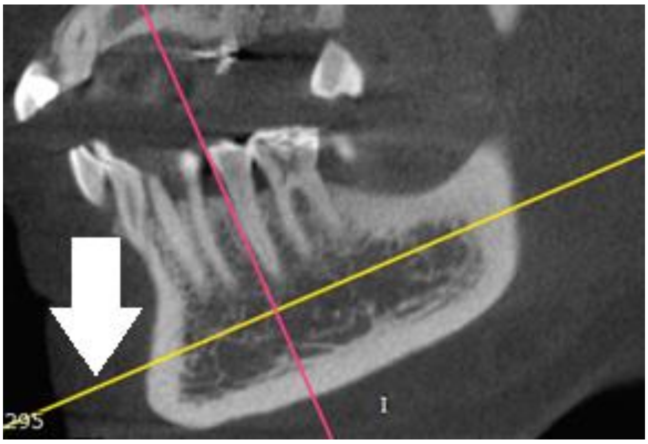


Fig. 3: Slice adjustment in sagittal view.

Measurements were taken from the coronal view where distance "S" was measured from the mental foramen superior margin to the mandible inferior border, distance "I" was measured from the mental foramen inferior margin to the mandible inferior border ,and distance "W" was measured as representing the inferior cortical width of the mandible. (Figure 4).

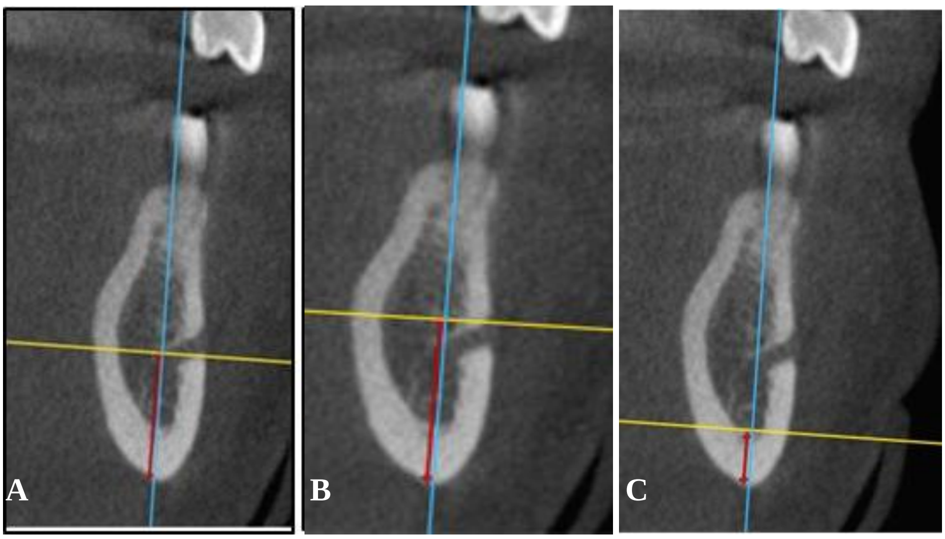


Fig. 4: CBCT indices measurements.

4- **The computed tomography average trabecular bone density (CTBD):** Using the obtained cross-sectional cut at the mental foramen area, the average trabecular bone density was obtained at both sides right and left using the ROI measuring tool [18]. Cross-sectional slice thickness and measured area size was standardized in all cases. (Figure 5)

Fig.5: Average trabecular bone density measurement D4 bone density according to Misch classification.

Each participant was identified with a bone category according to Misch bone density classification by correlation to a range of Hounsfield units[11,19,20].

Statistical analysis

Data were fed to the computer and analyzed using IBM SPSS software package version 20.0. (IBM Corp, Armonk, NY, USA). The CBCT indices and CTBD were described using range (minimum and maximum), mean, standard deviation and median. Significance of the obtained results was evaluated at the 5% level. Differences were analyzed using t-test.

III. Results

This study was carried out to evaluate the efficacy of mandibular CBCT images for the assessment of bone quality in postmenopausal female patients over 45 years old selected randomly from the outpatient clinic at the department of Oral Medicine, Periodontology, Oral Diagnosis, and Oral Radiology, Faculty of Dentistry, Alexandria University.

I. Clinical data of the subjects

In the present study, 24 post menopausal female patients were recruited and were divided into 2 groups according to the T-score defined by the World Health Organization (WHO):

Group 1(Control): comprised non osteoporotic patients and included two subgroups:

- Normal patients with T-score >-1
- Osteopenic patients with (−1 >T-score> −2.5).

Group 2(Test): Comprised Osteoporotic patients with (T-score < -2.5).

Table no. 1 shows the demographic data of the recruited patients of the two groups regarding age.

Table (1): Descriptive analysis of the studied groups according to age

	Control		Test Osteoporotic (n=11)	F	P
	Normal (n= 6)	Osteopenia (n= 7)			
Age (years)					
Min. – Max.	45.0 – 56.0	47.0 – 65.0	52.0 – 68.0		
Mean ± SD.	49.50 ± 4.37	56.0 ± 7.21	57.73 ± 5.66	3.390	0.079
Median	49.0	59.0	56.0		

F,p: F and p values for **ANOVA test**

II. Radiographic examination

1. DEXA scanning

Table no.2 shows the descriptive analysis of the two studied groups according results of DEXA scan.

Table (2): Descriptive analysis of the studied groups according to different parameters of DEXA scanning

	Control (Non osteoporotic)		Test Osteoporotic (n=11)
	Normal (n= 7)	Osteopenia (n= 6)	
AP spine(T-score)			
Min. – Max.	-0.70 – 0.90	-1.90 - -1.10	-3.30 - -2.10
Mean ± SD.	0.20 ± 0.69	-1.49 ± 0.28	-2.74 ± 0.44

Median	0.25	-1.40	-2.80
AP spine BMD (g/cm^2)			
Min. – Max.	1.09 – 1.29	0.95 – 1.04	0.64 – 0.98
Mean ± SD.	1.21 ± 0.09	1.0 ± 0.03	0.85 ± 0.12
Median	1.21	1.01	0.84

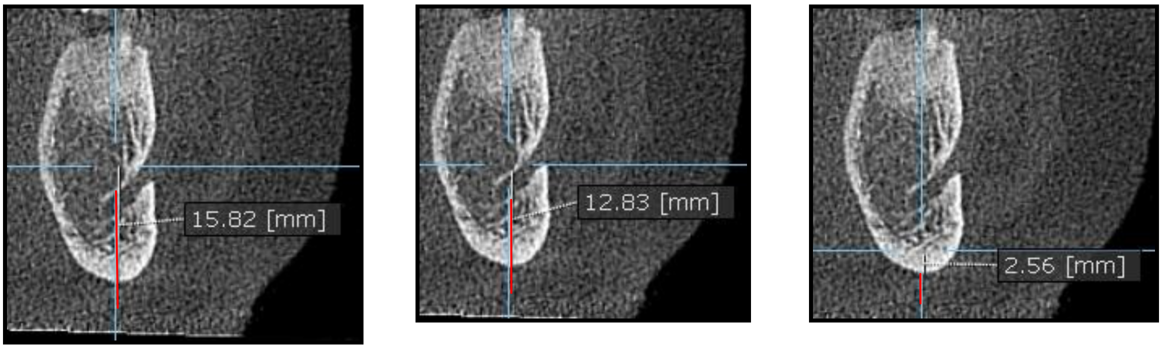
2. CBCT indices and CTBD

Table no.3 illustrates comparison between the two studied groups according to CBCT indices and CTBD. On comparing the studied groups, a statistically significant difference was detected between the non osteoporotic and osteoporotic groups regarding CTIS, CTII and CTMI ($p<0.05$). The osteoporotic group showed lower mean values than the osteoporotic group(figure 6). Concerning the CTBD the difference between the two groups was not a statistically significant although the non-osteoporotic group showed higher mean values than the osteoporotic group.

Table (3): Comparison between the two studied groups according to CBCT indices.

CBCT	Control (n= 13)	Test osteoporosis (n=11)	t	p
CTI (S)				
Median (Min. – Max.)	0.27(0.22–0.35)	0.19(0.16–0.29)	3.748*	0.001*
Mean ± SD.	0.27±0.04	0.20±0.04		
CTI (I)				
Median (Min. – Max.)	0.32(0.26–0.40)	0.25(0.20–0.32)	3.853*	0.001*
Mean ± SD.	0.33±0.05	0.26±0.04		
CTMI				
Median (Min. – Max.)	4.0(3.50–5.20)	3.44(2.69–4.50)	2.854*	0.009*
Mean ± SD.	4.12±0.53	3.44±0.63		
CTBD				
Median (Min. – Max.)	466.7(161.0–822.3)	247.4(134.2–602.0)	2.057	0.052
Mean ± SD.	490.4±210.5	325.7±175.6		

t, p: t and p values for **Student t-test** for comparing between the two groups
*: Statistically significant at $p \leq 0.05$



S CTIS=CTMI/S   *I* CTII=CTMI/I   CTMI

Fig. 6: CPCT indices of an osteoporotic case in coronal view

3. Correlation between CBCT indices and DEXA

Table no. 4 shows the correlation between CBCT indices, CTBD and T-Score.
Computed tomography mental index showed strongest positive correlation with T-score of lumbar spine in both non osteoporotic and osteoporotic group and the correlation was statistically significant followed by CTIS which showed also moderate positive correlation in non osteoporotic group and strong positive correlation in osteoporotic group but only the test group correlation was statistically significant. Concerning the CTII, it showed least positive correlation with T-score of lumbar spine in both non osteoporotic and osteoporotic groups and it was not statistically significant. However there was a statistically significant strong positive correlation between the three indices and T-Score in total patient number of the two groups.
Regarding the CTBD Table 4 showed a statistically significant strong positive correlation between it and the T-Score in the two groups and also in the total patient number including the two groups.

Table (4): Correlation between CBCT indices, CTBD and T-Score obtained from Dexa measurement in each group

	CBCT							
	CTI (S)		CTI (I)		CTMI		CTBD	
	r	p	r	p	r	p	r	p
Control (n= 13) AP spine (T-Score)	0.462	0.112	0.414	0.205	0.706*	0.007*	0.751*	0.003*
Osteoporosis (n=11) AP spine (T-Score)	0.673*	0.023*	0.598	0.052	0.851*	0.001*	0.983*	<0.001*
Total cases (n= 24) AP spine (T-Score)	0.853*	<0.001*	0.847*	<0.001*	0.856*	<0.001*	0.746*	<0.001*

r: Pearson coefficient
*: Statistically significant at $p \leq 0.05$

IIII. Discussion

Osteopenia and osteoporosis affect many aged individuals and might not be discovered until symptoms or fractures occur. Therefore, it is better to detect this disease early to maximize the retention of bone mass, decrease the risk of fracture, and avoid possible complications in those patients[21].

The silent nature of this disease makes its diagnosis more difficult. Therefore, all medical professionals should participate in early diagnosis of this disease [15].

As various portions of body bones are affected by osteoporotic bone loss, the jaws also are included[21]. Researchers have reported a correlation between BMD in the mandible and that in hip and spine [22]. It is also evident that the reduction of skeletal BMD can modify the mandibular shape; increasing the possibility that osteoporosis may be accompanied with specific changes in the form of this bone [21].

It was reported that postmenopausal women presented with thin or eroded form in the cortex of the mandible and lower BMD values [23].

Mandibular radiomorphometric indices measured on panoramic radiographs were proved to be one of the preliminary tools for osteoporosis diagnosis [24].

However, detection of the thickness of lower mandibular cortex in panoramic radiographs has certain limitations which is the difficulty of accurately locating the mental foramen and mandibular cortex border .These limitations may be mastered by CBCT, because tomographic images can accurately identify the mental foramen [25,26].

In the current study CBCT was evaluated as a tool as it provides three-dimensional images associated with high resolution. It also allows the qualitative and quantitative evaluation of osseous structures [4]. And the results gained were compared to those resulted from using the DEXA scan, which is considered to be the basic diagnostic tool for diagnosing osteoporosis [27,28]. Based on DEXA results, the two groups comprising the osteoporosis group and the non osteoporosis control group were defined.

Our results showed a highly significant difference between both groups for CTIS, CTII, CTMI scores and CT BD ($p<0.05$). Also noted that the mean values of these indices showed higher values in the non-osteoporotic group than in the osteoporotic group.

Our results are simillar to those obtained from the few studies that could be found in the dental literature that investigated these indices using CBCT. A study by Koh and Kim [2]who were the first to evaluate CBCT as a low-BMD predictor, showed that there was a significant difference between the control and test groups regarding CTIS and CTII, CTMI and the computed tomography cortical index (CTCI). Moreover, these indices showed increased mean values in healthy rather than in osteoporotic group.

Another study was done by Mostafa et al. [7] where they showed similar results in their study, significant differences for the CTCI, CTMI and CT mandibular index (CTI) (that corresponds to CTIS in our study) between the non osteoporotic and osteoporotic groups were found, whereby the non osteoporotic group showed increased mean values than the osteoporotic one.

Furthermore, a similar study was done by Güngör et al. [27]. They found that the paired comparison of osteoporosis and osteopenia groups and of the osteoporosis and control groups showed significant differences in all indices measurements (CTIS, CTII and CTMI), while on comparing the osteopenia to the control group there were no significant differences in index measurements. Their findings indicated that in the osteopenia, no changes in the jaw indices were apparent, whereas osteoporosis, significant differences were recognized in the indices measurements.

In this study we compared the control group (including both normal and osteopenia patients) to osteoporosis group only as we found no changes in jaw bones in osteopenia group.

Similarly in a study by Brasileiro et al. [26] DEXA was performed, and the patients were divided into normal, osteopenia, and osteoporosis groups, according to the World Health Organization (WHO) criteria. Cross-sectional images were used to assess the computed tomography indices. Mean CTMI, CTIS and CTII values were lower in the osteoporosis group than in osteopenia and normal patients ($p < 0.05$).

In our study regarding correlation between CBCT indices and T-score calculated by DEXA a high significant positive correlation was found between CTMI and lumbar spine T-score (p=0.007), (r=0.7)in control group and (r=0.8) in osteoporosis group ;while CTIS showed moderate positive correlation (r= 0.4) in control group and (r=0.6) in osteoporosis group only. CTII showed least positive correlation with T-score of lumbar spine(r=0.4) in control group and (r=0.5) in osteoporotic group.

This can be explained by the fact that CTMI is a direct measurement index which measure the thickness of mandibular cortex, while other indices (CTIS and CTII) are ratios and subsequently depend on the anatomical location of mental foramen in the mandible.

In our study, DEXA was performed at lumbar vertebrae (spine) as the rate of bone changes and bone loss is the central skeleton usually predict the presence of osteoporosis, fracture risk, and the need for treatment [29].

This can be explained by the fact that sites abundant with trabecular bone, like the vertebrae, are usually influenced earlier after the menopause and to a higher degree than other sites with abundant cortical bone such as the femoral neck. [30].Therefore, in osteoporosis evaluations, the measurement of vertebral BMD is preferred in postmenopausal females (as in our study) while calculations of the femoral head BMD is favored in individuals over 70 years [27.]

Corresponding results were reported by Güngör et al. [27] showing positive correlation between vertebral BMD and CTMI and CTI(S) and CTI (I).

However, the study done by Mostafa et al. [4] showed a highly significant positive correlation between all indices and lumbar spine BMD detected by DEXA (T-score). This significant correlation could be as result of larger sample size used in their previous study.

As a result of limited studies using CBCT for the assessment of radiomorphomertic indices and average trabecular bone density for osteoporosis detection and their correlations with BMD assessed by DEXA, we compare our study results to the results of similar studies that used panoramic images.

Studies that evaluated the correlation between panoramic mandibular index (PMI) in panoramic radiography (that corresponds to both CTIS and CTII in CBCT) and BMD showed controversial results. Some authors reported a significant correlation between PMI and BMD as Singh et al. [31] and Passos et al. [32]. The former found that mean BMD scores increased significantly with increasing PMI ($p < 0.05$) so, significant correlations between PMI and DEXA BMD were obtained. Also Passos et al. [32] observed that the mandibular cortical width (MCW corresponding to CTMI in CBCT) presented a significant positive correlation at both of the sites (left femur and lumbar spine) and that the PMI correlated with lumbar spine only.

However, others did not find this correlation such as Damilakis and Vlasiadis [33] who found weak correlations between mandibular cortical width (MCW) and BMD values and no correlation between PMI and BMD. Moreover, they concluded that MCW was better than PMI ratio in its power to differentiate women with osteopenia or osteoporosis from healthy subjects. These conflicting results could be due to different populations under studies on one hand and different machines applied in the studies on the other.

This study signified the importance of the CBCT in the detection of changes in BMD and demonstrated that CBCT is an effective tool in the detection of osteoporosis. Where, a positive correlation was detected between T-score values as detected by DEXA and CTBD measured by CBCT in both osteoporotic and non osteoporotic group postmenopausal women.

This result came along with different studies which proved a positive correlation between measurements of T-score values as assessed by DEXA and mandibular density values as assessed by CBCT. They concluded that osteoporosis could be predicted with a high accuracy from the radiographic density value of the mandibular body performed by CBCT [27,15].

Furthermore, Guerra et al. [34] systematically reviewed the literature concerning the ability of CBCT images to identify individuals with low BMD; concluding that, radiographic density obtained from CBCT is an efficient tool to differentiate between osteoporotic patients and normal persons .

However, some researches compared DEXA derived BMD values and the CBCT-derived density for the mandible and found no correlation.[35, 36] .However, these few researches have used different CBCT devices and voxel sizes. Some investigators have proved that the trabecular bone measurements, and consequently the image quality, depend on technical parameters, as, the amperage ,unit itself, tube voltage and the voxel size [37]. They proved that, the smaller the voxels, the higher the spatial resolution and therefore the sharper the images [38].

V. Conclusion

Therefore based on this study results we concluded that using the CBCT indices measured in this study in addition to CTBD considered to be an effective for assessing bone quality and so can detect presence of osteoporosis in post menopausal women visiting the dental clinic.

Conflict of interest

No potential conflict of interest relevant to this article was reported.

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