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# MANDIBULAR RADIOMORPHOMETRY USING CONE BEAM COMPUTED TOMOGRAPHY FOR PREDICTING OSTEOPOROSIS IN POSTMENOPAUSAL WOMEN

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## *ABSTRACT*

**Purpose**: This study evaluated the potential use of the computed tomography indices (CTI) on cone beam CT (CBCT) images for an assessment of the bone mineral density (BMD) in postmenopausal osteoporotic women.

**Materials and Methods**: Ninety postmenopausal women were enrolled as the subjects. The BMD of the lumbar vertebrae, femur and forearm were calculated by dual energy X-ray absorptiometry (DXA) using a DXA scanner. The CBCT images were obtained from the bilateral mental foramen region using a Kodak ™ 9500 Cone Beam 3D Dental CT system. The axial, sagittal, and coronal images were reconstructed from the block images using Carestream™ software. The radiomorphometric indices were computed tomography mandibular index superior (CTI(S)), computed tomography mandibular index inferior (CTI(I)), and computed tomography cortical index (CTCI), and computed tomography mental index (CTMI: inferior cortical width). The relationship between the CT measurements and BMDs were assessed and the intra-observer agreement was determined.

**Results**: The results of CBCT indices showed a significant difference among the three studied groups for CTI scores. The mean values of CTMI and CTCI showed higher values in control than in osteopenic and osteoporotic groups and the differences were highly significant ($p < 0.001$) among the three studied groups. The current study revealed that, mandibular indices on CBCT may help in predicting and detecting osteoporosis.

## INTRODUCTION

Osteoporosis is a skeletal disease characterized by a low bone mass, deterioration of the bone structure, and an increased risk of bone fracture(1). According to the World Health Organization (WHO), osteoporosis is the second most common health problem after heart and vascular diseases. Because of the silent nature of this disease, it may not be diagnosed until fractures occur. Although, bone loss occurs with aging after approximately 30 years, the lifetime risk from osteoporotic fracture over the age of 50 years is approximately 40% in women and 13% in men. This difference might be due to the more rapid decrease in oestrogens level in women compared to men of the same age range(2). The early detection of osteoporosis might possibly improve the prognosis as well as the quality of patients' life. When patients suspected for having osteoporosis are evaluated, detection of the disease, assessment of bone mass and identification of fracture risk are important goals. Many steps may be involved including medical history, physical examination, and bone density test. The National Osteoporosis foundation (NOF) recommended a bone density by a

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central Dual Energy X-ray Absorptiometry (DEXA) machine to diagnose osteoporosis[3].

Dental radiographs are usually taken to diagnose conditions affecting the teeth and jaws. Therefore, these radiographs may offer an opportunity as a screening tool for osteoporosis. Panoramic mandibular index (PMI) on panoramic radiograph has been used to assess the mandibular bone quality. Cone beam Computed Tomography (CBCT) in dentistry has become popular and is commonly utilized for diagnosis and treatment planning. This imaging technique can allow the clinician to evaluate the patient's osseous structures in three dimensions without interferences of overlying structures. In the literature there are few studies that used CBCT to predict osteoporosis. Koh and Kim [4] was the first one who proposed the term CTI, following by other studies [5-10].

## SUBJECTS AND METHODS

**Subjects selection:** Ninety female patients with age range between 51-70 years were selected from those who attended Outpatient Clinic in the Department of Oral Medicine, Periodontology, Oral Diagnosis, and Oral Radiology, Faculty of Dental Medicine, Al-Azhar University, Cairo, (Boys). Those patients were cases indicated for imaging with CBCT to aid in their dental diagnosis and/or treatment. The patients were referred for DEXA screening to assess their bone mineral density and weather if they have or do not have osteoporosis. Radiomorphometric analysis on CBCT was performed blindly (two separate examiners performed the analysis for each patient).

**Exclusion criteria:** Patients have a history of systemic disorders affecting bone architecture such as diabetes and renal disorders, hormonal replacement therapy, Corticosteroid use within the last 3 months, traumatic fracture or habitual smoking

### Examination procedures

**1-Evaluation of bone mineral density (BMD) measurements:** All patients were referred to the Department of Rheumatology and Physical Medicine, El-Hussein University Hospital for measuring bone mineral density (BMD) by using DEXA of lumbar vertebrae (AP spine), the left femoral neck bone as well as the left forearm, using the direct digital densitometer*. Patients were classified into three groups, according to the T-score as defined by WHO [11], a value of BMD above -1 standard deviation (SD) of the young adult mean was defined as normal, between -1 and -2.5 SD as low bone mass or osteopenia, and below -2.5 SD as osteoporosis. Once with respect to the lumbar T-score and the other time, with respect to the femoral neck T-scored. The least value was considered in the analysis.

**II- Cone Beam Computed Tomography (CBCT) Imaging:** CBCT images were obtained for all patients using Kodak ® 9500 Cone Beam 3D Machine**. Images were acquired in a single 360 degree rotation around the patient's head. For CBCT scanning, the occlusal plane of the jaw was positioned horizontally to the scanning plane and the midsagittal plane was cantered. The used acquisition protocol was 10 mA, 90 Kvp, slice thickness 0.1 mm, voxel size of 200 $\mu$.

### Radiomorphometric indices measurements:

Three radiomorphometric indices were evaluated on the CBCT images. The terms of the indices utilized in this study were modified from the Ledgerton's classification[12] on panoramic images to be compatible with CBCT images[4]. CBCT images were obtained for all patients. Four radiomorphometric indices evaluated on the CBCT images; CTCI is the type of the mandibular inferior cortex of the mandible, it was evaluated from reformatting panoramic view obtained after slice preparation. The morphology of mandibular inferior cortex was visually examined distally from the mental foramen

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bilaterally and was classified using Klemetti classification [13] as follows; type 1: the endosteal margin of the inferior cortex is smooth on both ends (figure 1A), type 2: the endosteal margin shows semilunar defects or appears to form endosteal cortical residues (figure 1B), type 3: the endosteal margin is obviously porous with dense endosteal (figure 1C). residues CTMI is the mandibular cortical width at the mental foramen region (figure 2), CTI(S) is the ratio of the thickness of the mandibular cortex to the distance from the superior margin of the mental foramen to the inferior border of the mandible (figure 2), and CTI (I) computed tomography mandibular index (inferior), which was the ratio of the inferior cortical width to the distance from the inferior margin of the mental foramen to the inferior border of the mandible (figure 2).

**Statistical analysis:**

In this cross sectional study, power analysis indicated that 90 subjects for treatment modality would be sufficient to demonstrate statistical significance at the $p < 0.05$ level with a power of (at least) ≥ 80%. This was calculated according to the following equations: $n = Z_{1-\alpha/2}^{2} \times p(1-p) / d^2$ where p (Expected proportion in population based on previous studies) = 6 % and d = 0.05. Data were analysed using Statistical Program for Social Science (SPSS) version 20.0 for Windows (SPSS, Inc., Chicago, IL, USA) Quantitative data were expressed as mean ± standard deviation (SD). Qualitative data were expressed as frequency and percentage. For each patient CBCT Images were interpreted bilaterally and blindly (by two separate examiners). The measurements were carried out twice, by each examiner almost at 2 weeks interval.

## RESULTS

Patients were classified into three groups, according to the T-score. Accordingly, 29 of subjects (32.2%) were normal with T-score < -1, 20 (22.2%) had osteopenia with T-score ranging from - 2.5 to -1 and 41 (45.6%) had osteoporosis with T-score > -2.5. There were good intra and inter-observer agreements as well as no statistically significant differences among the measurements of each and both observers (twice at two weeks' interval). Using Pearson Correlation Coefficient (r) test among DEXA and different indices, the values were statistically significant with R-CTMI ( $r = 0.630$, $p < 0.001$), L-CTMI ($r = 0.557$, $p < 0.001$), R-CTI(S) ($r = 0.494$, $p < 0.001$), L-CTI(S) ($r = 0.492$, $p < 0.001$), R-CTI(I) ($r = 0.438$, p 0.005) in a decreasing order, while L-CTI(I) ($r = 0.393$. p 0.012) failed to reach the level of significance (table 1).

**TABLE (1)** Correlation between T-score and other parameters using Pearson Correlation Coefficient (r) test.

| Parameter | T-score | |
|---|---|---|
| | **R** | **p-value** |
| R-CTMI | **0.630** | <0.001 |
| R-CTI(S) | 0.494 | <0.001 |
| R-CTI(I) | 0.438 | 0.005 |
| R-CTCI | **-0.785** | <0.001 |
| L-CTMI | **0.557** | <0.001 |
| L-CTI(S) | 0.492 | <0.001 |
| L-CTI(I) | 0.393 | 0.012 |
| L-CTCI | **-0.812** | <0.001 |

From the Receiver Operating Characteristic curve (ROC) curve that determines the sensitivity and specificity of the measured parameters, the results of the Area Under Curve (AUC) revealed that CTMI (right or left) are the most accurate indices to predict osteoporotic cases (AUC = 0.987, 0.992 respectively) compared to other measured mandibular indices. For right CTMI osteoporosis may be predicted if the measure is ≤ 3.7 with sensitivity of 94.44 and specificity of 95.45, while, for the left CTMI osteoporotic may be predicted if the measure ≤ 3.6 with sensitivity of 100.0 and specificity of 95.45 (figure 3)

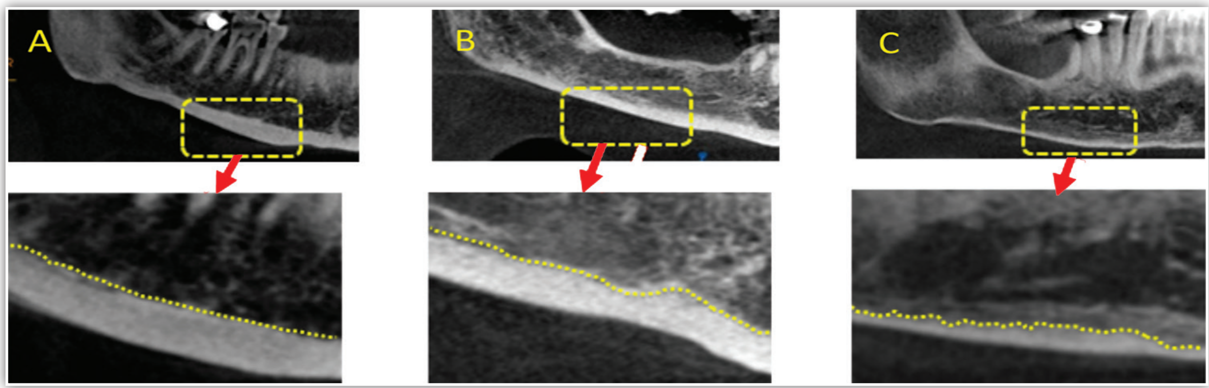


Figure 1: Reformatting panoramic view showing CTCI; A: type 1, B: type 2, and C: type 3.

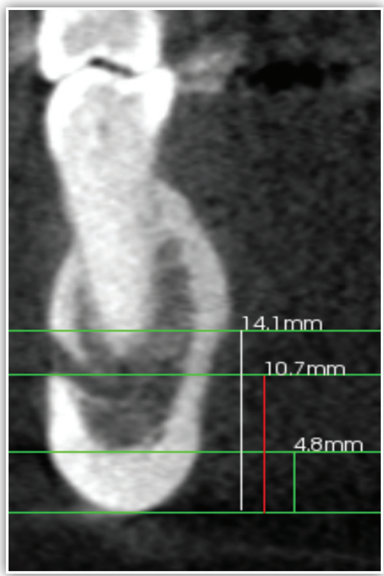


Fig. 2: Non orthogonal coronal section showing lines drawn to measure CTMI (green line 4.8 mm), CTCI (S) [green line/white line = 4.8/14.1= 0.34], and CTCI (I) [green line/red line = 4.8/10.7= 0.45].

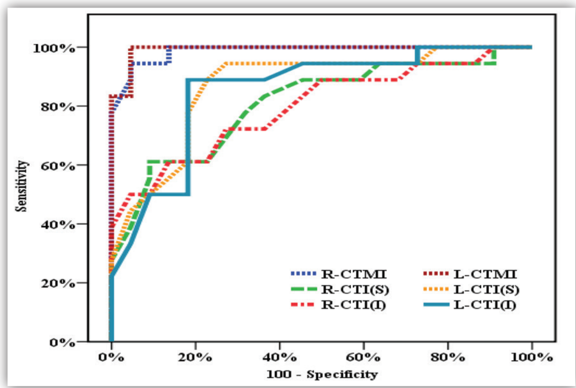


Fig. (3) ROC curve for indices analysis to predict osteoporosis.

## DISCUSSION

Because of its silent nature, osteoporosis may not be diagnosed until bone fractures occur. Although, bone loss occurs with aging after approximately 30 years, the lifetime risk from osteoporotic fracture over the age of 50 years is approximately 40% in women and 13 % in men. Regarding to the results of CTMI, this study was in agreement with the studies of Gungor et al.[7] Mostafa et al.[8], Brasileiro et al.[9], and Geibel et al.[10]. Gungor et al. [7] used cross-sectional CBCT images, such as the current study, to evaluate CTMI and demonstrated that the CTMI measurements in the osteoporosis group (2.76 mm) were lower than those in the osteopenia (3.42 mm) and normal groups (3.62 mm). However, in contrast to the results of the present study, these differences were not significant only when comparing osteopenia with the control patients. The differences in the results may be explained on the basis that Gungor et al.[7] did not evaluate post-menopausal women and the normal group age range (over 30 years) was considerably less than the age range of the patients evaluated in the present study (over 50 years). The results of our study match almost completely with those of the other mentioned authors. On the other hand Koh and Kim[4] found that the mean value of the CTMI in the osteoporosis group (2.33 mm) was lower than that in the normal patients (3.22 mm), but there was no significant correlation in both groups. These researchers did not include a third osteopenic group. In the present study, the patients with low BMD were divided into osteopenia and osteoporosis patients, and the mean values of CTMI in the osteopenia and osteoporosis groups (4.08 and 2.93 mm, respectively) were lower than those in the normal group (5.10 mm). In contrast to Koh and Kim[4], the results were statistically significant ($p < 0.001$). The difference in sample size (21 in each group) may explain the discrepancy in the results of the two studies.

The results of CTCI in the present study totally agree with all previous studies of Koh and Kim[4], Gomes et al.[5], Beatriz et al.[6], and Mostafa et al.[8], who recorded a significant difference in CTCI measurements between normal and low BMD (osteopenia or osteoporosis). These researches comprised differences in sample size, age range of patients' numbers of studied groups and brands of CBCT machines. However, all agreed for the importance and sensitivity of CTCI as an indicator of decreased BMD and validity in prediction and detection of osteoporosis. These results together with the results of the current study may support that; the osteoporotic changes could mainly affect the cortical bone of the mandible. The results of CTI(S) in the present study agree with the study of Koh and Kim[4], Gungor et al.[7], Mostafa et al.[8], Brasileiro et al.[9], and Geibel et al.[102] who found a significant difference in CTI(S) measurements between normal and osteoporotic patients. However, 44some differences in the degree of sensitivity of CTI(S) for detecting osteoporosis exist among these studies and the current one, which may be accounted for differences in sample size, field of view and age range of patients in different studied groups. Finally, the results of CTI(I) in the present study agree with those in the study of Koh and Kim [4], Mostafa et al. [8] and Geibel et al. [10] who found a significant difference in CTI(S) measurements between normal and osteoporotic patients. However these studies did not include osteopenic group. Both studies of Gungor et al. [7] and Brasileiro et al. [9] included osteopenic groups in their evaluation of mandibular indices as predictors for osteoporosis. The results of CTI(I) in the present study agree with the study of Gungor et al. [7]. This agreement is achieved although, he used different voxel size (0.30 mm) compared to that which was used in our study (0.20 mm). However, they used same sample size (90 patients), and different, but close mean age (52.67 ± 8.61 for the osteopenic group) of patients as that in the present study (58.99 ± 5.97). On the contrary, the disagreement of significance of CTI(I) between this study and that of Brasileiro et al.[9] who used patient with almost the same mean age (over 50 years) may be attributed to the less sample size (60 postmenopausal women) compared to that in the present study (90 postmenopausal women. It is obvious from the results of this study and previous ones that CBCT can offer an idea about BMD through careful examination and analysis of mandibular indices. This is especially of great importance in patients at high risk of diseases with silent nature as osteoporosis.

## CONCLUSION

The current study revealed that, mandibular indices on CBCT may help in predicting and detecting osteoporosis. Of these indices, Computed Tomography Cortical Index (CTCI) and Computed Tomography Mental Index (CTMI) seem to be more reliable as they best predicted and correlated with femoral neck, lumbar vertebrae, and forearm T-scores.

## RECOMMENDATION

Further studies on different CBCT machines with small voxel size are strongly recommended for better visualization of the mandibular cortex and alveolar bone. Further studies with larger sample size are recommended to support the results of the current study.

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