The Ability of Cone Beam Computed Tomography to Predict Osteopenia and Osteoporosis via Radiographic Density Derived from Cervical Vertebrae

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Abstract

**Background and aim:** Osteoporosis (OP) is defined as a bone density-related disorder identified by reduction of the microstructure quality of bone with increased fracture risk. The current study aimed to evaluate the ability of cone beam computed tomography (CBCT) imaging method to predict osteoporosis and osteopenia using values of Radiographic Density (RD) derived from cervical vertebrae.

**Materials and methods:** This study was a descriptive-cross sectional study conducted on 54 research units suffering from osteopenia and osteoporosis in the hip, aged 42-72 years. Finally, the values of RD from the lateral mass of the first cervical vertebra on both right and left side and dens of the second cervical vertebra were calculated by NNT viewer software.

**Results:** Comparing the all values of RD obtained from the first cervical vertebra and second cervical vertebra revealed statistically significant difference between the three groups (P-value <0.05). It was also found that the most accurate prediction of osteoporosis was related to the values of RD from body of C2 so that the accuracy equals to 99% and cut-off point (Cut-point) of it was 293 respectively. In addition, the most accurate prediction of hip-related osteopenia was for the values of RD from the body of C2 so that the accuracy is 88% and cut-off point it is also 375.

**Conclusion:** According to the findings of this study, osteoporosis and osteopenia status can be predicted through RD value amounts related to body part of the second cervical vertebra, which were more precise compared to the other parts.

1. Introduction

Osteoporosis (OP) is defined as a bone density-related disorder identified by low density of the bone mass, degeneration of the bone structure and increase of the risk of bone fracture that is one of the most important health problems of most societies. Most cases of osteoporosis is seen in women (90%), especially in Asian and white women who are at greater risk. However, among American, African, and Latin American women, it is seen less. Fracture due to osteoporosis has significant side effects leading to increased rate of death, so that 10-20 percent of women with Hip fracture die in the first year. In epidemiological studies, it has been found that more than 10 million people over the age of 50 years in America suffer from osteoporosis and over 34 million people are at risk for this disease. Among Iranian women over 50, approximately 28% are with osteoporosis and 53% of cases have osteopenia. Definition based solely on bone mineral density (BMD) cannot include all risk factors for bone fractures and any of microstructural changes. Bone quality cannot be obtained simply based on BMD, because in addition to it, the quality of bone structures (mechanically) and geometric indexes (size, shape and macrostructure) are effective on bone strength. According to the new definition, osteoporosis is said to bone loss and bone microstructure quality loss that results in increased fragility rate of bone and elevated risk of fracture. For expressing a person’s bone density, Respect to baseline, T-score criteria are used. The World Health Organization in 1994 defined osteoporosis as reduction of bone density with a T-scores between -1 and -2.5, as well as osteoporosis as reduction of bone density with T-scores less than or equal to -2.5. Due to improved diagnostic methods during the past decade, there has been the possibility that the disease is diagnosed before a fracture occurs. The base of diagnosis is to measure the BMD that is defined by the recommendations of World Health Organization Committee. The most confident and most common way used to do it, is to measure the BMD by the Dual Energy X-ray Absorptiometry (DEXA) technique. Although, this method is a golden
standard method and bone mass density can be measured anywhere in body by it.\textsuperscript{[11]} In this method, density of central bones such as vertebral column and hip is mostly measured. However, most researchers believe that, this technique is not cost effective and not always possible because of the difficulty and high cost of DEXA as a screening method. So other methods should be used to assess bone density that can be applicable, cheap and have acceptable results.

In recent years, CBCT (Cone Beam Computed Tomography) technique has been known as a CT method in dentistry.\textsuperscript{[12]} Since this technique was introduced in 1998, it was widely welcomed by researchers, especially in the field of dentistry.\textsuperscript{[13]} This technique has many advantages, so that it has the ability to provide 2D and 3D images with lower cost compared with the methods of computed tomography (CT). Spatial resolution of CBCT technique is much higher than the old conventional CT devices at about 75 to 400 micrometers. In addition, required radiation dose in CBCT is much lower than old methods of CT and is largely dependent on the exposure parameters (FOVs: field of view).\textsuperscript{[12,14]} Moreover, the CBCT offers data to assess bone quality however, few studies have used this technique for assessing osteoporosis. For example, some studies using CBCT images of the jaw at evaluating the osteoporosis in patients.\textsuperscript{[15]} However, CBCT devices manufacturers have provided several software to analyze the images that created by this. This software contains the essential tools for the simple and main analyses, including the multi-planar reconstruction, dimensional measurements and radiographic density (RD) of bone. Therefore, the present research was designed for the prediction of osteopenia and osteoporosis of people in the hip area by the values of RD obtained from the first cervical vertebrae and second cervical vertebrae of the patients whom referred to the Dentistry Faculty of Tabriz University of Medical Sciences, Iran.

2. Materials and methods

The current study with cross-sectional design was conducted during 2014 to 2015 on 54 research units suffering from osteopenia and osteoporosis in the hip to evaluate the association between the values of RD obtained from C1 and C2 with the total T-score of hip. All the patients were between the age ranges of 42 to 72. Furthermore, 54 healthy individuals with the T-scores of ≥-1 were selected as the control. An endocrinologist collaborated and supervised on the implementation of all study processes. Exclusion criteria were the history of thyroid diseases, diabetes, alcohol consumers, cigarettes and drugs which affect BMD, bone disease except osteoporosis, and history of any lumbar spine and femoral neck fracture. Moreover, no study-related extra cost was obtained from the participants and X-ray-related damage was avoided. Therefore, the CBCT images from those requiring stereotype preparation for dental therapy as well as the subjects with history of densitometry in the last year were prepared using the DEXA scanner (Hologic DEXA, USA) at Sina hospital after providing relevant details and obtaining informed consent under the supervision of the Ethics Committee of the University. This device was calibrated daily according to the manufacturer’s instructions at last, the individuals were assigned in the three groups, including the patients with osteopenia and osteoporosis and the control, in accordance with the WHO criteria as well as total T-score obtained from the hip, as follows:

- T-score ≥-1 healthy group
- 1>T-score >-2.5 group with osteoporosis
- T-score ≤-2.5 patients with osteoporosis

At last, the study continued to evaluate the association between the values of RD from C1 and C2 using T-scores of the hip. A New tom VGI (QR, Verona, Italy) was used to take CBCT images, at amorphous silicon flat panel detector with 86-μSv effective dose in the zoom FOV of 12*15 cm\textsuperscript{2} with 0.2-mm voxel size and 0.3-mm focal spot size, with the aid of 110-kV/1-20-mA rotating anode at the 18-s scan time and 360 rotations for taking images. A pulsed emission is used in the system. It should be noted that the X-ray source is activated in the system only when needed, in contrast to other systems. The automatic program is applied for all exposure factors. After taking the required images, they were explored under NNT viewer version 2.17 software in the190B 19-inch LCD screen (Philips, Eindhoven, Netherlands) having16-bit 1024 × 1024 resolution in a dim light room lacking windows. It should be mentioned that all participants were protected against radiation using lead apron. Like most devices, this device also includes basic tools such as tools for RD analysis, measurements of dimension and multidimensional reconstruction. A distilled water was applied to test the RD homogeneity between scans to achieve no difference in the measurements of RD between various scans; the repeated step was observed during the scanning for all subjects. Based on the bit depth of the instrument, the difference in water RD values, obtained from measurement techniques offered by Spin-Neto et al., shows that intermediate densities can be homogeneous.\textsuperscript{[16]} These procedures resulted in homogeneous density of various scans and increased validity of our research. The window width (17%) and level (15%) were applied to record the values of RD, providing black and white images. Figure 1(A) exhibits the adjusted sharpness for achieving smooth images. As shown Figure 1(B, C), in the values of RD from the lateral mass of the first cervical vertebra (C1) on both right and left side and dens and body of the second cervical vertebrae (C2) were calculated by NNT viewer software. According to Figure 1(D), the coronal section passing through the dens middle was chosen and explored in the 175% magnification. Five sites (four in the margins and one in the center) were selected from these areas to measure the values of RD. Finally, the mean value of RD was regarded as the main value of RD for the area.

![Figure 1](image1.png)

Figure 1. A) the adjustment process for image sharpness, window level and window wide; B) the reviewed areas under; C) the calculation of the values of RD in the dens; D) the coronal section passing through the dens middle.

Data analysis with statistical methods:

Our data were described by descriptive statistics of mean ± standard deviation (SD). One-way analysis of variance (One-way ANOVA) was applied to compare the values of RD between the study groups and appropriate follow-up test was used significantly. Tukey’s post hoc test was used for the
significant results according to Levine’s test, and Games-Howell post hoc test for the non-significant results according to Levine’s test. The normal distribution of data was analyzed by Kolmogorov-Smirnov test. The positive and negative predicative values (PPV, NPV), the sensitivity, specificity and cut-point were calculated for each area predicts accurately the risk of osteoporosis and osteopenia.

3. Results
Table 1 shows the profile of age related to the three study groups, and Table 2 classifies the descriptive information concerning the values of RD for the three study groups. According to the Table 1, it shown that the mean age of the group with osteoporosis had the maximum value (61.4 years) and healthy subjects had the lowest average (49.6).

Table 1: Comparing the mean age of patients (n=108) between the three studied groups.

<table>
<thead>
<tr>
<th>Group</th>
<th>Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Healthy (n= 54)</td>
<td>49.6 (5.4)</td>
</tr>
<tr>
<td>Osteopenia(n= 35)</td>
<td>56.4 (6.9)</td>
</tr>
<tr>
<td>Osteoporosis (n=19)</td>
<td>61.4 (5.1)</td>
</tr>
</tbody>
</table>

Data have been expresses as mean ± standard deviation
All numbers have been rounded.

In Table 2, the values of RD calculated for C1 and C2 had been represented separately based on healthy individuals group, groups of those with osteoporosis and those with osteopenia (according to T-score of the hip). These values related to the control group had expectedly the highest rate and in patients with osteoporosis had the lowest value. Comparing the values of RD showed significant differences among the three groups (P-value <0.05). Finally, by reviewing the inter group mean difference, it had been determined no statistically significant difference just in RD values of the dens in both subjects with osteopenia and those with osteoporosis and between healthy group with osteopenia group (P-values are 0.804 and 0.119 respectively). In addition, the difference among other variables in all studied groups was significant statistically (P-value <0.05).

Table 2: The values of RD calculated for the three studied groups [presented as mean ± standard deviation].

<table>
<thead>
<tr>
<th>Variables</th>
<th>Osteoporosis (19 persons)</th>
<th>Osteopenia (35 persons)</th>
<th>Healthy (54 person)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left lateral mass of C1</td>
<td>229(31)</td>
<td>354(117)</td>
<td>413(72)</td>
</tr>
<tr>
<td>Right lateral mass of C1</td>
<td>246(25)</td>
<td>339(106)</td>
<td>415(71)</td>
</tr>
<tr>
<td>Body of C2</td>
<td>221(20)</td>
<td>301(63)</td>
<td>409(57)</td>
</tr>
<tr>
<td>Dens of C2</td>
<td>517(79)</td>
<td>538(156)</td>
<td>599 (113)</td>
</tr>
</tbody>
</table>

Figure 2 showed that all the values of RD Value had decrease from healthy people to the people with osteoporosis, but this decline was less in the dens values. (The mean of RD values by separation of groups).
Table 3 provided the validity of the values of RD for predicting the risk of osteopenia in hip. As it was observed, the most accurate predictor for the osteopenia in hip was related to the values of RD calculated for body (88% with cut-off point of 293), and the minimum level was seen for the dens (70% with cut-off point of 528).

Table 3 displays the maximum PPV related to body of C2 (93%) and this means that 93% if the patients whose test’s result was positive by these measures will be sick. In addition, the maximum NPV was related to the values of the C1 right lateral mass, with 77% probability that showed that, if the test result was negative, the probability of being healthy was 77%.

Table 3: Validity of the values of RD in the prediction of osteopenia.

<table>
<thead>
<tr>
<th>Area</th>
<th>Variable</th>
<th>Sen</th>
<th>AUC (95% CI)</th>
<th>Cut-off value</th>
<th>Spe</th>
<th>PPV</th>
<th>NPV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lumbar spine</td>
<td>Left lateral mass of C1</td>
<td>78%</td>
<td>0.72 (0.6-0.84)</td>
<td>357</td>
<td>78%</td>
<td>84%</td>
<td>69%</td>
</tr>
<tr>
<td></td>
<td>Right lateral mass of C1</td>
<td>85%</td>
<td>0.76 (0.63-0.88)</td>
<td>342</td>
<td>80%</td>
<td>86%</td>
<td>77%</td>
</tr>
<tr>
<td></td>
<td>Body of C2</td>
<td>81%</td>
<td>0.88 (0.81-0.96)</td>
<td>375</td>
<td>92%</td>
<td>93%</td>
<td>75%</td>
</tr>
<tr>
<td></td>
<td>Dens of C2</td>
<td>72%</td>
<td>0.65 (0.53-0.78)</td>
<td>533</td>
<td>66%</td>
<td>76%</td>
<td>60%</td>
</tr>
</tbody>
</table>

Table 4 provided the validity of RD values for predicting the risk of osteoporosis. It was revealed that most accurate predictor of the osteoporosis was related to the values of RD calculated for the body of C2 (99 % with cut-off point of 293), and the minimum level was also related to the dens (70% with cut-off point of 528) (Table 3).

PPV and NPV values, respectively, show the probability of illness, in the positive case, and probability of healthiness, if the results were negative. According to the findings, the maximum PPV (100%) was related to left and right lateral masses of C1 as well as body area of the C2 and it means that, 100 percent of tested subjects with positive results via these measures would be sick. In addition, the highest negative predictive value is related to the body area of the C2 with the probability of 94% showed that if the test result is negative, the probability of being healthy was 94%.

Table 4: Validity of the values of RD in the prediction of osteoporosis.

<table>
<thead>
<tr>
<th>Area</th>
<th>Variable</th>
<th>Sen</th>
<th>AUC (95% CI)</th>
<th>Cut-off value</th>
<th>Spe</th>
<th>PPV</th>
<th>NPV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lumbar spine</td>
<td>Left lateral mass of C1</td>
<td>88%</td>
<td>0.98 (0.96-1)</td>
<td>322</td>
<td>100%</td>
<td>100%</td>
<td>76%</td>
</tr>
<tr>
<td></td>
<td>Right lateral mass of C1</td>
<td>96%</td>
<td>0.97 (0.94-1.01)</td>
<td>300</td>
<td>100%</td>
<td>100%</td>
<td>90%</td>
</tr>
<tr>
<td></td>
<td>Body of C2</td>
<td>98%</td>
<td>0.99 (0.99-1)</td>
<td>293</td>
<td>100%</td>
<td>100%</td>
<td>94%</td>
</tr>
<tr>
<td></td>
<td>Dens of C2</td>
<td>75%</td>
<td>0.70 (0.57-0.83)</td>
<td>528</td>
<td>48%</td>
<td>80%</td>
<td>40%</td>
</tr>
</tbody>
</table>

4. Discussion

Osteoporosis fractures may occur in any area of the body except the face and typical locations for this fracture are hip, spine, humerus and forearm. Morbidity and mortality associated with hip fracture among fractures is the worst of them.[17, 18] Moreover, those surviving from the fracture suffer from a severe disability and quality of their life declines.[19] It has recently been found that painful vertebral fractures cause 15%increase mortality rate.

CBCT technique has been introduced for dentistry application since about one and half decades ago, in which 2D and 3D images are provided with lower cost compared with the methods of computed tomography. If small FOV is used, the radiation dose is comparable with panoramic pictures. This may explain why this technique is used widely in dentistry.[19, 20]

According to the results of the present study, the values of RD related to body area of the C2 can be used to predict condition of osteopenia and osteoporosis in the hip. These findings can be considered as an important step in the cooperation between health organizations, health and care in the diagnosis of osteoporosis or osteopenia. Using RD values of CBCT images, and having appropriate diagnosis reasons, dentist can use these findings as a screening tool for early diagnosis, before occurrence of problems resulting from progress of this sickness and without need to pay high costs and complication of use. The used software contains the tools for basic analysis of multi-planar reconstruction, dimensional measurement, RD calculation, and calculation of the mean values of voxel.[19]

Among all values of RD calculated in accordance with CBCT images obtained from the cervical vertebra, RD amount of the body area of the C2 and the Right lateral mass of the C1 were the best predictors for people prone to osteopenia. In addition, according to results obtained, the values of RD calculated for the body area and the Left C1 derived from CBCT were best
for predicting osteoporosis status that these values could predict osteoporosis in cervical vertebra and people prone to osteoporosis in hip. Therefore, body of C2 is considered as the best area for the anticipating decline of BMD amounts in hip. RD values pertaining to body Section of the second cervical vertebra were 293 and 375 in subjects prone to osteoporosis and osteopenia that may offer presence of osteoporosis or osteopenia in hip.

In a study, Imad Barngkgei et al in 2014 assessed the ability of CBCT to prediction of osteoporosis. In this study, they compared the RD values of the whole bone area of the mandible with T-score of femoral neck and lumbar spine in postmenopausal osteoporotic women. The obtained results showed that, RD values of mandible had a highest relation by T-score of femoral neck and lumbar spine with confidence coefficient of almost 0.5 and 0.6 for both areas, respectively. The concluded that, osteoporosis of femoral neck and lumbar spine can be predicted very accurately by the amount of RD values pertaining to the body area in the mandible.21) Given that few studies about the validity of the RD values of CBCT images had been conducted and various results of the investigation have been made, some conditions can reduce the reliability of the values of RD results, that increased levels of noise and scattering beam, differences in levels of gray value between different CBCT devises and various parameters in same devises are some of them.22)

5. Conclusion
According to the findings of this study, osteoporosis and osteopenia status can be predicted through RD value amounts related to body part of the second cervical vertebra, which were more precise compared to the other parts.

Conflict of Interest
The authors declared that there is no conflict of interest.

References