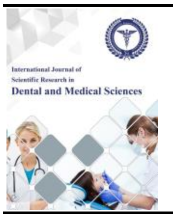

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The Ability of Cone Beam Computed Tomography to Predict osteopenia and Osteoporosis via Radiographic Density Derived from Cervical Vertebrae

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ABSTRACT

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

Results: Comparing all values of RD obtained from the first cervical vertebrae and second cervical vertebrae revealed a 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 99% and cut-off point (Cut-point) of it was 293, respectively. Also, the most accurate prediction of hip-related osteopenia was for the values of RD from the body of C2 so that the accuracy is88%, and the cut-off point is also 375.

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

1. Introduction

Osteoporosis (OP) is defined as a bone density-related disorder identified by the 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 critical health problems of most societies.[1] Most osteoporosis cases are seen in women (90%), especially in Asian and white women at higher risk. However, among American, African, and Latin American women, it is seen less.[2,3] Fracture due to osteoporosis has significant side effects, leading to an increased death rate so that 10-20 percent of women with Hip fracture die in the first year.[4] In epidemiological studies, it has been found that more than 10 million people over the age of 50 years in America have osteoporosis, and over 34 million people are at risk for this disease.[5] Among Iranian women over 50, approximately 28% are with osteoporosis, and 53% of cases have osteopenia.[6]

Definition based solely on bone mineral density (BMD) cannot include all risk factors for bone fractures and 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 sufficient on bone strength.[7, 8] 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.[9] For expressing a person's bone density, Respect to baseline, T-score criteria is used. The World Health Organization in 1994 defined osteopenia as a reduction of bone density with 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.[10]

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 defined by the recommendations of the World Health Organization Committee. The most specific 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 standard golden method and bone mass density can be measured anywhere in body by it,[11] in this method, the density of central bones such as vertebral column

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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, Cone-beam computed tomography. The technique has been known as a CT method in dentistry[12]. Since this technique was introduced in 1998, researchers have been widely welcomed, especially in dentistry.[13] This technique has many advantages so that it can provide 2D and 3D images with lower cost compared with the methods of computed tomography (CT). The spatial resolution of the CBCT technique is much higher than the old conventional CT devices at about 75 to 400 micrometers. Also, the required radiation dose in CBCT is much lower than the old methods of CT and is mainly dependent on the exposure parameters (FOVs: field of view)[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 osteoporosis in patients.[15] However, CBCT devices manufacturers have provided software to analyze the images created by this. This software contains the essential tools for the primary and straightforward analyses, including the multi-planar reconstruction, dimensional measurements, and radiographic density (RD) of bone. Therefore, the present research was designed to predict 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 who referred to the Dentistry faculty at Tabriz University of Medical Sciences, Iran.

2. Materials and methods

The current study with the 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 the hip. All the patients were between the ages 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 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 for 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 and the subjects with a history of densitometry in the last year. Were prepared using the DEXA scanner (Hologic QDR 4500/Acclaim, 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, by the WHO criteria and 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 C2using 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^2 with 0.2-mm voxel size and0.3-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 mentioned that all participants were protected against radiation using the lead apron. Like most devices, this device also includes essential 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 RD measurements 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.[16] These procedures resulted in a 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 in 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 middle of the den 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 primary value of RD for the area.

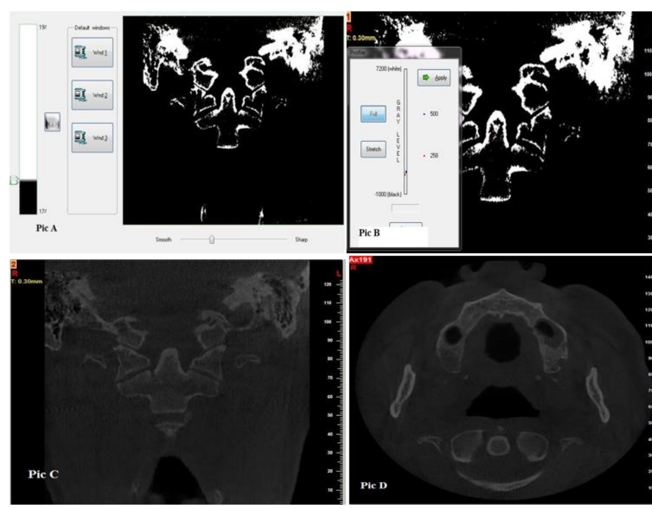

Figure 1. A)the adjustment process for image sharpness, window level and window wide; B)the reviewed areas under; C) the calculation of the values of RD in the dens; D) the coronal section passing through the middle of the den.

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 an appropriate follow-up test was used significantly. According to Levine's test, 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. The Kolmogorov-Smirnov test analyzed the normal distribution of data. The positive and negative predictive values (PPV, NPV), sensitivity, specificity, and cut-point were calculated for each area to predict the risk of osteoporosis and osteopenia accurately.

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. Table 1 shows 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

Group	Age
Healthy (n= 54)	49.6 (5.4)
Osteopenia(n= 35)	56.4 (6.9)
Osteoporosis (n=19)	61.4 (5.1)

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 the highest rate expectedly 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 intergroup mean difference, there was no statistically significant difference in RD values of the dens in both subjects with osteopenia and those with osteoporosis and between the whole group with osteopenia group (P-values are 0.804 and 0.119 respectively). The difference between 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]

Variables	Osteoporosis (19 persons)	Osteopenia (35 persons)	Healthy (54 persons)
Left lateral mass of C_1	229(31)	354(117)	413(72)
Right lateral mass of C_1	246(25)	339(106)	415(71)
Body of C2	221(20)	301(63)	409(57)
Dens of C2	517(79)	538(156)	599 (113)

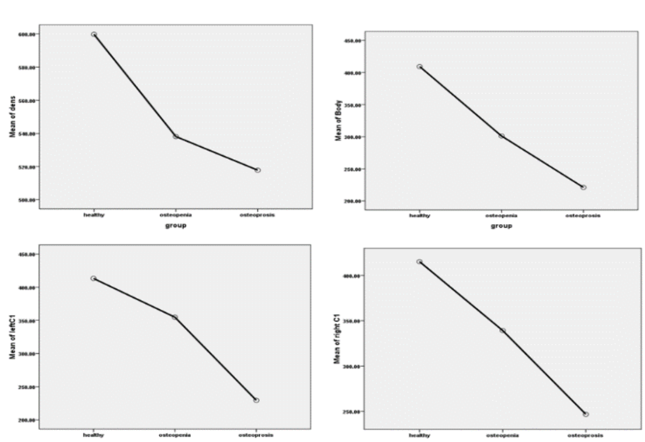

Figure 2 showed that all the values of RD Value had decreased from healthy people to people with osteoporosis, but this decline was less in the dens values. (The mean of RD values by separation of groups).

Table 3 provided the validity of RD's values for predicting the risk of osteopenia in the hip. As observed, the most accurate predictor for the osteopenia in the hip was related to the values of RD calculated for Body (88% with a cut-off point of 375), and the minimum level was seen for the dens (65% with a cut-off point of 533).

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. The maximum NPV was related to the values of the C1right lateral mass, with 77% probability 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

Area	Variable	Sen	AUC (95% CI)	Cut-off value	Spe	PPV	NPV
Lumbar spine	Left lateral mass of C_1	78%	0.72 (0.6-0.84)	357	78%	84%	69%
	Right lateral mass of C_1	85%	0.76 (0.63-0.88)	342	80%	86%	77%
	Body of C2	81%	0.88 (0.81-0.96)	375	92%	93%	75%
	Dens of C2	72%	0.65 (0.53-0.78)	533	66%	76%	60%

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 a cut-off point of 293), and the minimum level was also related to the dens (70% with a cut-off point of 528) (table 3).

PPV and NPV values show the probability of illness, in the positive case, and the 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. Also, 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

Area	Variable	Sen	AUC (95% CI)	Cut-off value	Spe	PPV	NPV
Lumber spine	Left lateral mass of C_1	88%	0.98 (0.96-1)	322	100%	100%	76%
	Right lateral mass of C_1	96%	0.97 (0.94-1.01)	300	100%	100%	90%
	Body of C2	98%	0.99 (0.99-1)	293	100%	100%	94%
	Dens of C2	75%	0.70 (0.57-0.83)	528	48%	80%	40%

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 fractures among fractures are the worst of them.[17, 18] Moreover, those surviving from the fracture have a severe disability, and their quality declines.[4] It has recently been found that painful vertebral fractures cause a 15% increase in mortality rate.

CBCT technique has been introduced for dentistry applications 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 a 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 the body area of the C2 can be used to predict the condition of osteopenia and osteoporosis in the hip. These findings can be considered 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, dentists can use these findings as a screening tool for early diagnosis before the occurrence of problems resulting from the progress of this sickness and without need to pay high costs and complications of use. The used software contains the tools for fundamental analysis of multi-planar reconstruction, dimensional measurement, RD calculation, and the calculation of the voxel's mean values.[19]

Among all RD values calculated by 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. Also, 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 the cervical vertebra and people prone to osteoporosis in the hip. Therefore, the Body of C2 is considered the best area for predicting the decline of BMD amounts in the hip. RD values about body sections of the second cervical vertebra were 293 and 375 in subjects prone to osteoporosis and osteopenia that may offer osteoporosis or osteopenia in the hip.

In a study, Imad Barngkgei et al. in 2014 assessed the ability of CBCT to predict osteoporosis. In this study, they compared the RD values of the whole bone area of the mandible with the T-score of the femoral neck and lumbar spine in postmenopausal osteoporotic women. The obtained results showed that RD values of mandible had the highest relation by T-score of the femoral neck and lumbar spine with a confidence coefficient of almost 0.5 and 0.6 for both areas, respectively. They concluded that osteoporosis of the femoral neck and lumbar spine could be predicted very accurately by the number of RD values about 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 values, that increased levels of noise and scattering beam, differences in levels of gray value between different CBCT devices, and various parameters in the same devices 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 the body part of the second cervical vertebra, which was more precise than the other parts.

Conflict of Interest

The authors declared that there is no conflict of interest.

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References

1. Consensus, N., Development panel on osteoporosis: prevention, diagnosis and therapy. Jama, 2001. 285(6): p. 785-795.
2. Riera-Espinoza, G., Epidemiología de la osteoporosis en Latino América. Salud pública de México, 2009. 51: p. s52-s55.
3. Johnell, O. and J. Kanis, Epidemiology of osteoporotic fractures. Osteoporosis international, 2005. 16(2): p. S3-S7.
4. Cummings, S.R. and L.J. Melton, Epidemiology and outcomes of osteoporotic fractures. The Lancet, 2002. 359(9319): p. 1761-1767.
5. Cooper, C., Epidemiology of osteoporosis. Osteoporosis International, 1999. 9(8): p. S2-S8.
6. Pajouhi, M., et al., Bone Mineral Density in 10 to75 Year-Old Iranian Healthy Women: Population Base Study. Iranian Journal of Public Health, 2004: p. 57-63.
7. Link, T.M., Osteoporosis imaging: state of the art and advanced imaging. Radiology, 2012. 263(1): p. 3-17.
8. Siu, W.S., L. Qin, and K.S. Leung, pQCT bone strength index may serve as a better predictor than bone mineral density for long bone breaking strength. Journalof bone and mineral metabolism, 2003. 21(5): p. 316-322.
9. Eastell, R., Treatment of postmenopausal osteoporosis. New England journal of medicine, 1998. 338(11): p. 736-746.
10. Organization, W.H., Assessment of fracture risk and its application to screening for postmenopausal osteoporosis: report of a WHO study group [meeting held in Rome from 22 to 25 June 1992]. 1994.

11. Lewiecki, E.M., et al., Official positions of the international society for clinical densitometry. The Journal of Clinical Endocrinology & Metabolism, 2004. 89(8): p. 3651-3655.
12. Nomura, Y., et al., Stability of voxel values from cone‐beam computed tomography for dental use in evaluating bone mineral content. Clinical oral implants research, 2013. 24(5): p. 543-548.
13. Mozzo, P., et al., A new volumetric CT machine for dental imaging based on the cone-beam technique: preliminary results. European radiology, 1998. 8(9): p. 1558-1564.
14. Bornstein, M.M., et al., Cone beam computed tomography in implant dentistry: a systematic review focusing on guidelines, indications, and radiation dose risks. International journal of oral & maxillofacial implants, 2014. 29.
15. Hua, Y., et al., Bone quality assessment based on cone beam computed tomography imaging. Clinical oral implants research, 2009. 20(8): p. 767-771.
16. Spin-Neto, R., E. Gotfredsen, and A. Wenzel, Standardized method to quantify the variation in voxel value distribution in patient-simulated CBCT data sets. Dentomaxillofacial Radiology, 2014. 44(2): p. 20140283.
17. Kasturi, G.C., D.X. Cifu, and R.A. Adler, A review of osteoporosis: Part I. Impact, pathophysiology, diagnosis and unique role of the physiatrist. PM&R, 2009. 1(3): p. 254-260.
18. Genant, H., K. Engelke, and S. Prevrhal, Advanced CT bone imaging in osteoporosis. Rheumatology, 2008. 47(suppl 4): p. iv9-iv16.
19. Naitoh, M., et al., Measurement of mandibles with micro focus x-ray computerized tomography and compact computerized tomography for dental use. International Journal of Oral & Maxillofacial Implants, 2004. 19(2).
20. White, S.C. and M.J. Pharoah, The evolution and application of dental maxillofacial imaging modalities. Dental Clinics of North America, 2008. 52(4): p. 689-705.
21. Barngkgei, I., I. Al Haffar, and R. Khattab, Osteoporosis prediction from the mandible using cone-beam computed tomography. Imaging science in dentistry, 2014. 44(4): p. 263-271.
22. Pauwels, R., et al., CBCT-based bone quality assessment: are Hounsfield units applicable? Dentomaxillofacial Radiology, 2014. 44(1): p. 20140238.