



**A PROFILE OF QUANTITATIVE COMPUTED TOMOGRAPHY BONE  
MINERAL DENSITY OF PATIENTS PRESENTING FOR CT STUDIES OF ABDOMEN**

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**ABSTRACT**

**Introduction:** Osteoporosis is characterized by reduced bone mass, disruption of bone architecture resulting in increased bone fragility and increased fracture risk. As I have not put this sentence in the introduction part below and I haven't put reference for this, kindly remove this sentence. Osteoporosis is diagnosed when the bone mineral density (BMD) is less than or equal to 2.5 standard deviations below that of a young adult reference population which is translated as a T-score. The most widely used technique for measurement of BMD is dual energy x-ray absorptiometry (DXA) which is non-invasive, rapid, accurate, easy to use and safe. Quantitative Computed Tomography (QCT) has advantages that it provides a true volumetric measurement of bone density and separate measurement of metabolically active trabecular and cortical bone density is possible. **Aims and objectives:** To determine the BMD in cortical & cancellous bones of lumbar vertebrae using QCT technique in patients  $\geq 50$  years of age and to compare the BMD of lumbar spine measured by QCT with DXA. **Material and Methods:** The present study is cross-sectional study done in 75 patients of  $\geq 50$  years of age at department of Radiodiagnosis and Imaging, BPKIHS, Dharan, Nepal. Informed consent was taken from all patients. Mid vertebral scan of L1-L4 vertebrae along with calibration phantom was done and mean BMD of trabecular, cortical bone and T-score was calculated. The DXA scan was also done in the same patient. DXA scan was analysed and results were obtained in absolute values ( $\text{g}/\text{cm}^2$ ), in T-score and in Z-score on the basis of WHO defined criteria. The data collected were recorded as per structured Pro forma and entered in the Excel data sheet and SPSS 16 software programme to analyze the data. The collected data was analysed using Chi square test and Pearson correlation coefficient. **Results:** We studied BMD of 75 subjects by both QCT and DXA. The mean age of our study subjects was  $66.72 \pm 11.28$  (range 50 – 87) years with male: female ratio 0.56:1. The maximum numbers of patients were in age group 60-69 years, Maximum patients were with normal BMI. The mean cortical BMD by QCT was  $365.40 \pm 74.54$  (range 184-532), trabecular BMD was  $96.01 \pm 39.25$  (range 13-213), QCT T-score  $-3.62 \pm 1.42$  (range -6.2-0.8) and DXA T-score was  $-2.31 \pm 1.08$  (range -4.5-0.5). We found good correlation between DXA and QCT ( $r=0.621$  and  $p < 0.0001$ ) to differentiate between normal and osteoporotic cases. **Conclusion:** We concluded that both QCT and DXA can be used to measure BMD and differentiate normal and osteoporotic patients and the difference between the two techniques is not statistically significant.

**KEYWORDS:** Osteoporosis, BMD, DXA, QCT.

**INTRODUCTION**

Bone mineral density (BMD) is the most important determinant of bone fragility used to evaluate osteoporosis.<sup>[1,2]</sup> Osteoporosis is characterized by reduced bone mass and disruption of bone architecture, resulting in increased bone fragility and increased fracture risk.<sup>[3]</sup> According to the National Osteoporosis Foundation of USA, by 2035, India and China will have the maximum number of Persons with osteoporosis in

the world.<sup>[4]</sup> Osteoporosis is diagnosed when the bone mineral density is  $\leq 2.5$  Standard deviations (SD) below that of a young adult reference population. This is translated as a T-score. The World Health Organization (WHO) has established the following diagnostic guidelines.<sup>[5]</sup>

- T-score -1.0 or greater is "normal"
- T-score between -1.0 and -2.5 is "low bone mass" (or "osteopenia")

- T-score -2.5 or below is “osteoporosis”

The most widely used technique, nowadays, for measurement of BMD is dual energy x-ray absorptiometry (DXA) which is non-invasive, rapid, accurate, easy to use and safe.

Quantitative Computed Tomography (QCT) is another well-recognized technique for the measurement of BMD in the lumbar spine and forearm which provide a true volumetric measurement of bone density and separate measurement of trabecular and cortical bone density. Recent developments in CT have also allowed three-dimensional (3-D) volumetric BMD (vBMD) analysis together with texture analysis of the proximal femur. The limitation of QCT is its slightly higher radiation dose than DXA but a low dose technique could be used<sup>[6, 7]</sup> with a dose of approximately 90  $\mu$ Sv which is favorable as compared to other X-ray based investigations performed in patients with osteoporosis.<sup>[7]</sup>

There have been various studies published in which a single slice mean QCT *T*-score equivalent to a DXA *T*-score of -2.5 have been derived, but currently it is judged that these *T*-scores derived from QCT are not equivalent to *T*-scores derived from DXA *T*-scores.<sup>[8]</sup> It is suggested that subjects with BMD below 80 mg hydroxyapatite/cm<sup>3</sup> could be classified as osteoporotic and those with BMD between 80 and 120 mg/cm<sup>3</sup> as osteopenic.<sup>[9]</sup>

In this study, we calculated the QCT BMD in relation to age and gender in persons (age  $\geq$ 50 years) of eastern part of Nepal and compared the two methods of BMD measurement, the QCT and DXA.

#### AIMS AND OBJECTIVES

1. To determine the BMD in cortical and cancellous bones of lumbar vertebrae using QCT technique in patients  $\geq$ 50 years of age.
2. To compare the BMD of lumbar spine measured by QCT with DXA.

#### MATERIAL AND METHODS

This is a cross-sectional study on 75 patients at the Department of Radiodiagnosis and Imaging, B P Koirala Institute of Health Sciences (BPKIHS) over the period of one year (January 2011 to December 2011). All patients of  $\geq$ 50 Years of age referred from various departments for the CT studies of abdomen were included. Patients with fracture at measurement site, those patients in whom DXA examination was not performed recently were excluded.

Non-contrast CT was done on ECLOS 16, HITACHI, Japan, with the calibration phantom B-MAS (the phantom provided by the manufacturer). The patient was positioned supine, so that the patient's lumbar vertebrae

was positioned over the calibration phantom. Patient's hips were flexed to reduce the curvature in the lumbar vertebra. The gap between the patient and the calibration phantom, if any, was filled with the included knee crutch pad in order to avoid the beam hardening effects.

A lateral scanogram provided localization of the axial scans in the vertebral mid planes of four lumbar vertebrae (L1–L4). A midvertebral 10 mm thickness slice was acquired parallel to the vertebral endplates at 120 kVp and 80 mA. Calibration of the CT image was achieved by a simultaneous scanning of a calibration phantom containing various inserts of hydroxyapatite-equivalent material. Two different regions of interest (ROIs) in trabecular and cortical bone of the lumbar vertebra representing a cross-section through the mid vertebra was placed to determine BMD of each vertebra (L1-L4) expressed in hydroxyapatite-equivalent units (mg/cm<sup>3</sup>) for cortical and trabecular bone of L1 to L4 separately and from these values mean cortical and trabecular BMD of L1-L4 was calculated. From this average trabecular BMD value, *T*-score was calculated with the formula (patients BMD- Reference BMD) divided by standard deviation. BMD was also measured with Osteocore DXA scanner installed in Orthopaedic OPD section of our institute.

DXA scanner was maintained according to the manufacturer's recommendations including the performance of daily quality control calibrations. The region of interest was the L1- L4 vertebral bodies. The scout scan started about 2 cm above the lowest point of the rib cage and extended to 2 cm below the iliac crest. DXA scan was analysed according to the manufacturer's instructions and results were obtained in absolute values (g/cm<sup>2</sup>), in *T*-score and in *Z*-score on the basis of WHO defined criteria.

The data obtained by both the scans were then entered in Microsoft Excel data sheet. SPSS 16 software was used to analyse the data. Mean, standard deviation, range and quartiles were calculated where necessary. Chi square test was applied to compare categorical data and correlation between BMD and anthropometric parameters like height, weight & BMI were made by Pearson correlation coefficient.

#### RESULTS

A total of 75 patients of age  $\geq$ 50 years presenting for the CT studies of abdomen were included. Fourty eight (64%) were females and rest were males. The age and sex distribution of the patients is shown in figure 1.

The mean age of the study population was 66.72 + 11.28 years (range 50 to 87). Anthropometric data of different age group is summarised in the table 1.

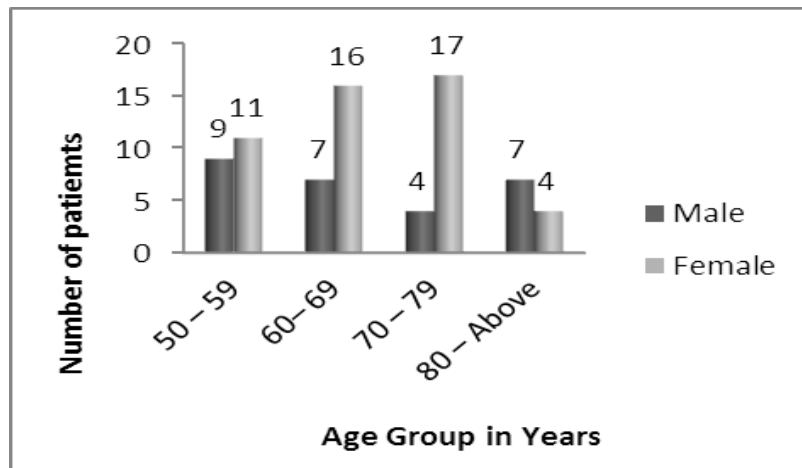


Figure 1: Age and sex distribution of study population.

Table 1: Anthropometric data of study population.

Parameters	N =75	Females (n=48)	Males (n= 27)
Mean age $\pm$ SD (Range) Years	66.72 $\pm$ 11.28 (50 – 87)	66.96 $\pm$ 10.41 (50-85)	66.3 $\pm$ 12.87 (50-87)
Height $\pm$ SD (Range) Cm	149 $\pm$ 7.98 (130-167)	145 $\pm$ 6.60 (130-156)	156.26 $\pm$ 4.40 (149-167)
Weight $\pm$ SD (Range) Kg	52.99 $\pm$ 7.47 (40-71)	52.38 $\pm$ 7.45 (40-70)	54.07 $\pm$ 7.54 (47-71)
BMI $\pm$ SD (Range) Kg/m <sup>2</sup>	23.99 $\pm$ 4.1 (17.31-38.41)	25.0 $\pm$ 4.09 (17.31-38.41)	22.20 $\pm$ 3.52 (19.36-31.98)

Mean height was 149  $\pm$  7.98, male had slightly more average height and weight than females. The mean BMI was 23.99  $\pm$  4.1. The mean BMI was higher in females than males. Forty three (57.33%) had normal BMI, 23 (30.66%) were overweight and 8 (10.66%) were obese and 1 patient (1.33%) was underweight. The mean and range of cortical and trabecular BMD, calculated CT T-score and DXA T-score is presented in the table 2.

Table 2: Average BMD of study population measured by QCT and DXA.

Average cortical BMD $\pm$ SD (Range)	353.76 $\pm$ 73.48 (184-532)
Average Trabecular $\pm$ SD (Range)	94.42 $\pm$ 36.59 (18-171)
CT T-Score Mean $\pm$ SD (Range)	-3.68 $\pm$ 1.32 (-6.8-0.73)
DXA T-Score Mean $\pm$ SD (Range)	-2.31 $\pm$ 1.08 (-4.5-0.5)

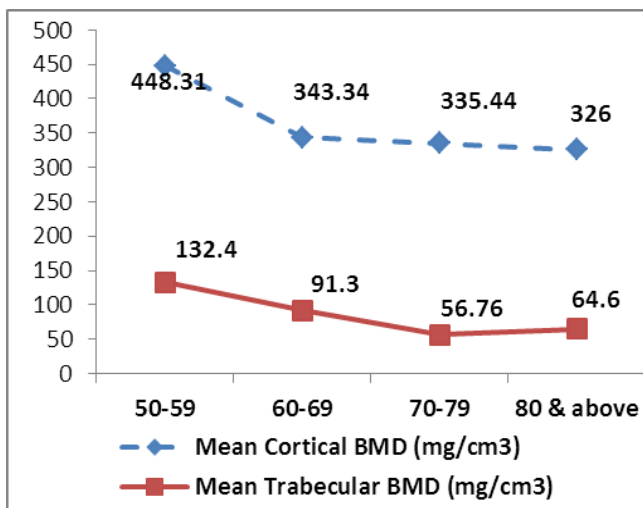
The mean cortical density of L1-L4 vertebra measured by QCT was 355  $\pm$  73.48 mg/cm<sup>3</sup> (range 184-532 mg/cm<sup>3</sup>). Similarly, the trabecular density was 94.42  $\pm$  36.59 (range 18-171). Trabecular BMD by QCT and BMD by DXA along with T-score among various age groups is presented in table 3.

With increasing age, the mean BMD by both QCT as well as DXA decreased except in age group 80 years and above, which is slightly more than the previous decade by QCT which can be explained by more number of male patients in this age group who had more BMD than females. The mean value of cortical and trabecular BMD by QCT in female population is shown in table 4 and figure 2.

In female population, there is decrease in average BMD after every decade except the trabecular density in the 80 years & above age

Table 3: BMD results in different age group by QCT and DXA.

Modality	Parameter	Age in Years (50-59)	Age in years (60-69)	Age in years (70-79)	Age in years (80 & Above)
QCT	Trabecular BMD Mean $\pm$ SD(Range) in mg/cm <sup>3</sup>	137.92 $\pm$ 35.87 (91-213)	93.22 $\pm$ 22.77 (38-147)	67.35 $\pm$ 25.61 (37-121)	80.36 $\pm$ 31.20 (18-118)
	T-Score Mean $\pm$ SD(Range)	-2.08 $\pm$ 1.34 (-3.68-0.82)	-3.71 $\pm$ 0.84 (-5.64--0.60)	-4.62 $\pm$ 0.82 (-5.64--0.60)	-4.32 $\pm$ 1.1 (-6.38- -2.9)
DXA	BMD Mean $\pm$ SD(Range) in gm/cm <sup>2</sup>	0.92 $\pm$ 1.34 (0.59-1.29)	-0.77 $\pm$ 0.43 (0.50-0.96)	0.73 $\pm$ 0.53 (0.51-1.06)	0.62 $\pm$ 0.88 (0.39-0.83)
	T-Score Mean $\pm$ SD(Range)	-1.22 $\pm$ 1.77 (-3.7 $\pm$ 1.4)	-2.50 $\pm$ 1.20 (-4.8—1.0)	-2.91 $\pm$ 1.12 (-4.8—1.0)	-3.745 $\pm$ 1.04 (-5.5- -2.5)



The decreasing trend of trabecular as well as cortical bone mineral density in male patients is shown in table 5 and figure 3.

It was observed that in male population in every decade, there is decrease in average BMD of both trabecular as well as cortical density except the trabecular density in the 70-79 years age.

Figure 2: Line diagram showing decreasing trend of cortical and trabecular BMD in female population.

Table 4: Mean age, cortical and trabecular BMD by QCT in females.

Age group in years	Nos.	Mean age in Years	Mean Cortical BMD (mg/cm <sup>3</sup> )	Mean Trabecular BMD (mg/cm <sup>3</sup> )
50-59	11	51.63	448.31	132.40
60-69	16	65.06	343.34	91.73
70-79	17	74.94	335.44	56.76
≥ 80	4	82.75	326	64.62

Table 5: Mean age, cortical and trabecular BMD by QCT in males.

Age group in years	Nos.	Mean age in Years	Mean Cortical BMD (mg/cm <sup>3</sup> )	Mean Trabecular BMD (mg/cm <sup>3</sup> )
50-59	9	52.33	374.88	140.83
60-69	7	62.42	339.84	96.60
70-79	4	74.25	330.56	112.31
≥ 80	7	83.57	313.92	77.25

group which is more than that of 60 -69 years age group which may be due to small number of patients i.e. only 4 patients in 70-79 years age group.

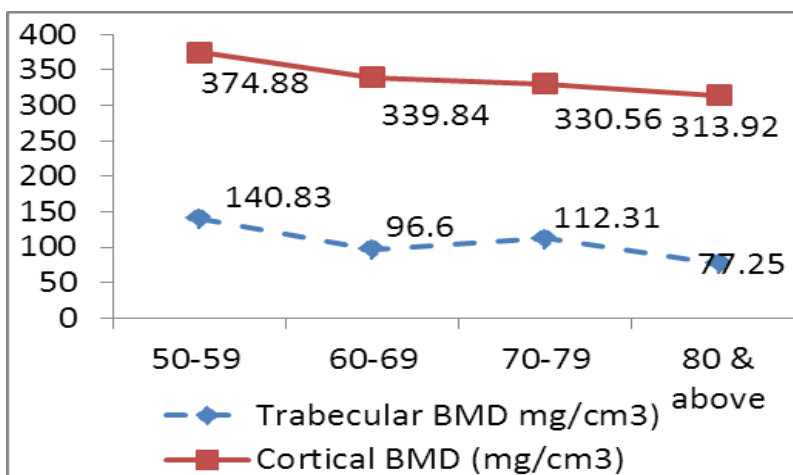


Figure 3: Trend of cortical and trabecular BMD in male population.

It has been observed that the decrease in slope of trabecular BMD with age is steeper than that of cortical BMD.

**Table 6: Normal and steoporotic & osteopenic by QCT and DXA.**

ModalityPPp	QCT by calculated T- Score	QCT by cut off value	DXA by T-score	p-value
Osteoporotic and Osteopenic	70 (93.33%)	64 (85.33%)	67 (89.33%)	0.28
Normal	5 (6.66 %)	11 (14.66%)	8 (10.66 %)	

Majority of patients (93.33 %) were diagnosed as osteoporotic by QCT and (89.3 %) by DXA scan. Maximum number of cases were shown to be osteoporotic by QCT when T-score of -2.5 and -1 are

used to define the osteoporotic and osteopenic respectively in both the genders though there is no significant difference between the methods used.

**Table 7: Pearson correlation coefficient and significant level of various parameters with BMD by various methods.**

Correlation		Average Trabecular BMD by QCT	Calculated CT T-score	DXA T-score	Average BMD by DXA
Age	r- value	-0.718	-0.740	-0.591	0.714
	p-value	<0.001	<0.001	<0.001	<0.001
Height	r- value	0.166	0.82	0.211	0.174
	p-value	0.154	0.484	0.069	0.135
Weight	r- value	0.181	0.174	0.445	0.399
	p-value	0.121	0.135	<0.001	<0.001
BMI	r- value	0.060	0.107	0.217	0.203
	p-value	0.609	0.361	0.062	0.081

BMD is negatively and significantly correlated to the age ( $r = -0.718$  to  $-0.740$  for QCT and  $-0.591$  to  $-0.714$  for DXA;  $p = <0.001$ ) and it is positively correlated with

height, weight and BMI. BMD values by both the methods were positively and significantly correlated.

**Table 8: Measurement of agreement by various methods of BMD**

Correlation	QCT TRAB Vs DXA	QCT TRAB Vs QCT T-score	QCT T-Score Vs DXA T-score
r-value	0.621	0.991	0.488
P-value	<0.001	<0.001	<0.001

## DISCUSSION

Present study was carried out to find the BMD in cortical and cancellous bones of lumbar vertebrae using QCT technique in patient's  $\geq 50$  years of age and to compare the BMD of lumbar spine measured by QCT with BMD measured by DXA. The mean age of our study population was  $66.7 \pm 11.28$  with slight female preponderance, which is similar to the study by Hasan D. et al.<sup>[10]</sup>

As compared to study done by Hasan D. et al.<sup>[10]</sup> in Turkish population, our study revealed slightly higher mean cortical density measured by QCT in 5<sup>th</sup>, 6<sup>th</sup> and 7<sup>th</sup> decade in female and male population but the values of trabecular BMD which mainly reflects turnover in bone metabolism are comparable.

In a study from San Francisco, Ettinger B et al.<sup>[11]</sup> showed post-menopausal females aged  $53 \pm 4$  showed mean BMD of  $117 \pm 27$  which is lower than mean BMD of

132.40 among 50-59 years females in our study though above mentioned study purely targeted females whereas in our study data from both genders were collected. Moreover, the sample size in our study was small. More local studies targeting both pre and post-menopausal women are needed.

Trabecular bone in the spine changes more rapidly after menopause than any other region, including total spinal bone.<sup>[12, 13]</sup> Because of this, more bone is lost as measured by QCT in the early after menopause, but then this rate slows down after about age 60-65, while bone loss as measured by DXA in the spine, hip, or forearm occurs more gradually but continues well into the 70's. In our study, rate of decline in CT T-score or trabecular BMD value is maximum in age group 50-69 years. Thereafter, it has declined at lesser rate. Furthermore, it was observed that at early post menopause, there is large difference between the T-scores of QCT and DXA. The difference between the T-score is maximum at this group

than other age groups.

If the T-score for the mean BMD of the population reaches -2.5, that means one-half of the population is osteoporotic who are at high risk of fracture. This happens at about age 60-62 for QCT and lateral spine DXA, age 75 for PA spine DXA and forearm, and age 88 for hip.<sup>[14]</sup> Similarly, we found that the mean T-score of < -2.5 was seen in the age group 60-69 years by QCT of lumbar spine and 70-79 years by DXA.

This study showed positive correlation of height, weight and BMI with the BMD. Weight of the subjects showed significant positive correlation with the bone density ( $p < 0.001$  and  $r = 0.445$ ) by DXA similar to other studies.<sup>[11, 15, 16]</sup> This has been attributed to physiological factors (increased body weight causing increased mechanical forces on bone or more body fat increasing circulating estrogen levels). However, this study however showed positive but statistically insignificant correlation of weight with BMD by QCT compared to previous studies which showed body weight to be associated with greater trabecular BMD.<sup>[13, 14]</sup> A direct comparison between QCT and DXA<sup>[17]</sup> showed that for postmenopausal patients classified as clinically obese, the average T-score by PA-DXA was 1.45 units higher in obese patients than in age and height matched controls, while the QCT T-scores did not differ between the groups. However, other researchers have shown similar effects with different systems.<sup>[18]</sup> Similar to study by Ebbesen N.<sup>[19]</sup> among patients of same age groups, our study showed a decrease in bone density by QCT with age.

Our study showed that QCT diagnosed more cases of osteoporosis as compared to DXA which is similar to a study by Bansal SC et al<sup>[20]</sup> done in India in a population of 165 subjects. In our study QCT diagnosed 93% of subjects to be osteoporotic as compared to 89% by DXA which is more than that of a study done by Bansal et al.<sup>[20]</sup> The more number of elderly patients in our study can explain this observation. We included all the suspected cases of osteoporosis in whom DXA was done and compared the DXA with QCT, we found a good correlation between DXA and QCT ( $r=0.621$  and  $p < 0.0001$ ). We found that age had better correlation with QCT T-score than DXA T-score ( $r=0.74$  Vs.  $0.59$  and  $p$  value  $< 0.001$ ) similar to study by Gugliemi G. et al.<sup>[21]</sup>

This study showed the correlation between DXA and QCT ( $r = 0.621$  and  $p < 0.001$ ) when absolute values in  $\text{mg}/\text{cm}^3$  and  $\text{mg}/\text{cm}^2$  were assessed. Similarly, there was a correlation between T-score of both DXA and QCT ( $r = 0.448$  and  $p$  value  $< 0.001$ ). Ebbesen N.<sup>[19]</sup> also found Lateral DXA bone mineral densities (BMD) were correlated with QCT densities in both females ( $r=0.68$ ,  $p < 0.00001$ ) and males ( $r=0.53$ ,  $p < 0.00001$ ), but females had constantly lower DXA BMDs than males at a given QCT density.

Ebbesen N. et al<sup>[19]</sup> observed that the females had the highest densities in the younger decades and males had the highest densities in the oldest decades. In our study, as we have not included the younger study subjects our study revealed low density in the females with both QCT as well as DXA. As in study by Bansal S C et al (20), our study showed that both the modalities confirm the direct correlation between age and osteoporosis and the risk of prevalence of osteoporosis increases across all age groups with increasing age. But QCT has been found to be more efficacious than DEXA scan in the diagnosis of osteoporosis i.e. QCT helps discriminate between normal subjects and those with osteoporosis better than DXA-lateral and XA-AP.<sup>[22]</sup>

#### LIMITATIONS

This study was done in hospital setting with small sample size in whom osteoporosis was suspected and do not reflect the real scenario in general population. Our results may be influenced by definition for osteoporosis for QCT which is not universal. With the available QCT scanner, the study of only lumbar spine was possible to assess BMD whereas with the DXA scanner apart from lumbar spine peripheral sites and hip could also be measured to assess the BMD. Hence, we could do this study only in lumbar spine to accurately compare the findings of these two modalities in the same region.

#### CONCLUSION

We concluded that both QCT and DXA can be used to measure BMD, and as QCT can separately measure trabecular as well as cortical density, it can discriminate between normal subjects and those with osteoporosis better than that with DXA. However, the difference was not found to be statistically significant and there was good correlation between the two techniques. So, further multicenter study encompassing wider age group of normal population from different parts of Nepal with larger sample size should be carried out to get more acceptable and definitive conclusions on bone mineral density of our population as literature in this part is lacking on the particular subject.

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