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Original Research Article

Quantitative Assessment of Lumbar Vertebral Bone Mineral Density Using 120 kV MDCT Compared with HU-Derived QCT Measurements

Article History:

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Abstract: ***Introduction***: Osteoporosis is a systemic skeletal disorder characterized by decreased bone mass and microarchitectural deterioration, resulting in increased fracture risk, particularly in the vertebral column (1). Early identification of low bone mineral density (BMD) is essential for timely intervention and prevention of fragility fractures (2). Dual-energy X-ray absorptiometry (DXA) remains the clinical standard for BMD assessment; however, its limitations—including two-dimensional measurement, inability to distinguish trabecular from cortical bone, and restricted accessibility in certain clinical settings—have prompted the exploration of alternative imaging modalities (3). ***Materials and Methods*** This prospective observational study was conducted at the Department of Radio-Diagnosis, Teerthanker Mahaveer Hospital & Research centre, Moradabad, Uttar Pradesh, India-244001 between 2024 and 2025. Ethical clearance was obtained from the Institutional Ethics Committee (Ethical No: PM/ETHICAL/2024/018). The study population comprised patients undergoing routine whole abdomen and lumbar spine CT imaging for various clinical indications. Patient demographic data including age and sex, along with mean Hounsfield Unit values at lumbar vertebral levels L1–L5, were recorded for analysis. ***Results*** The study included 385 participants, of whom 199 (51.7%) were females and 186 (48.3%) were males, indicating a nearly balanced distribution of sex as illustrated in Figure 1 and the overall mean age of the study population was 50.01 ± 13.35 years. ***Conclusion*** The present study demonstrates that lumbar vertebral bone mineral density (BMD) estimated from routine 120 kV multidetector computed tomography (MDCT) using HU-based conversion formulas shows a very strong monotonic association with QCT-derived BMD across all lumbar vertebral levels (L1–L5). Bland–Altman agreement analysis revealed a small, consistent positive bias, with MDCT-derived BMD slightly overestimating QCT-derived values. The mean differences between the two methods ranged from 2.42 mg/cm³ at L5 to 5.93 mg/cm³ at L3, with narrow and clinically acceptable limits of agreement. Despite the presence of a minor systematic difference, the magnitude of bias was small relative to the overall BMD values and showed no evidence of proportional bias across the measurement range.

Keywords: Osteoporosis, Bone Mineral Density (BMD), Computed Tomography (CT) Attenuation / Hounsfield Units, Quantitative Computed Tomography (QCT), Opportunistic Osteoporosis Screening

INTRODUCTION

Osteoporosis is a systemic skeletal disorder characterized by decreased bone mass and microarchitectural deterioration, resulting in increased fracture risk, particularly in the vertebral column (1). Early identification of low bone mineral density (BMD) is essential for timely intervention and prevention of fragility fractures (2). Dual-energy X-ray absorptiometry (DXA) remains the clinical standard for BMD assessment; however, its limitations—

including two-dimensional measurement, inability to distinguish trabecular from cortical bone, and restricted accessibility in certain clinical settings—have prompted the exploration of alternative imaging modalities (3). Quantitative computed tomography (QCT) offers volumetric assessment of trabecular and cortical bone, providing a more precise evaluation of vertebral BMD (4). However, dedicated QCT requires specific calibration phantoms and additional radiation exposure, limiting its routine clinical use (5). In contrast, routine multidetector computed tomography (MDCT), commonly performed for various abdominal, thoracic, or spinal indications, provides Hounsfield Unit (HU) values that correlate with bone mineral density (6). HU-based conversion formulas enable opportunistic estimation of BMD from standard CT scans without additional imaging or radiation, offering a practical approach for large-scale screening and retrospective analyses (7). The lumbar spine, comprising vertebrae L1 to L5, is a clinically significant site for osteoporosis assessment due to its high trabecular content and susceptibility to osteoporotic fractures (8). Previous studies have demonstrated a strong correlation between HU-derived BMD and QCT measurements, suggesting that routine MDCT may serve as a reliable surrogate for QCT in evaluating vertebral bone quality (9,10). Despite these advances, comparative analyses of BMD derived from routine 120 kV MDCT versus HU-based QCT estimations remain limited, particularly in standardized protocols assessing the full lumbar spine (6). Therefore, the present study aims to perform a quantitative assessment of lumbar vertebral bone mineral density using 120 kV MDCT compared with HU-derived QCT measurements, evaluating the correlation, agreement, and potential utility of routine MDCT in opportunistic osteoporosis screening.

MATERIALS AND METHODS

This prospective observational study was conducted at the Department of Radio-Diagnosis, Teerthanker Mahaveer Hospital & Research centre, Moradabad, Uttar Pradesh, India-244001 between 2024 and 2025. Ethical clearance was obtained from the Institutional Ethics Committee (Ethical No: PM/ETHICAL/2024/018). The study population comprised patients undergoing routine whole abdomen and lumbar spine CT imaging for various clinical indications. Patient demographic data including age and sex, along with mean Hounsfield Unit values at lumbar vertebral levels L1–L5, were recorded for analysis. All CT scans were performed using a uCT 780 160-slice MDCT scanner with a 120 kV tube voltage. Regions of interest (ROIs) were placed centrally within the trabecular portion of each vertebral body, avoiding cortical margins, vertebral endplates, and any focal lesions, to obtain mean HU values. BMD estimates were derived using two established equations: QCT-based BMD was calculated using the formula QCT = 17.8 + 0.7 × HU, while MDCT-derived BMD was estimated using BMD_MDCT = 0.78 × HU (mg/mL), which demonstrates a strong correlation with quantitative CT measurements ($R^2 = 0.92$, $P < 0.001$) at 120 kV tube voltage. Data were systematically tabulated for each vertebral level (L1–L5) and analyzed to assess lumbar spine BMD using both methods. Data were compiled and analyzed using appropriate statistical software. Continuous variables were expressed as mean ± standard deviation. Correlation between QCT-derived and MDCT-derived BMD values at each lumbar vertebral level was assessed using Spearman's rank correlation coefficient. Since both BMD measurements were derived from identical CT attenuation values using linear conversion equations, correlation coefficients were expected to be high. Therefore, Bland–Altman agreement analysis was additionally performed to evaluate systematic bias and limits of agreement between the two methods. A p value <0.05 was considered statistically significant.

RESULTS

Demographic Characteristics:

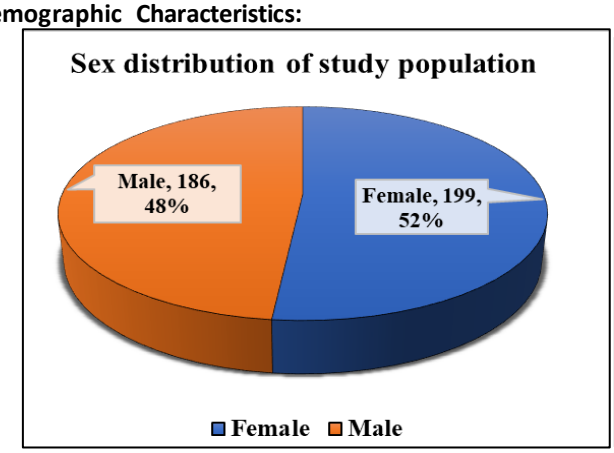

Figure 1. Sex distribution of study population

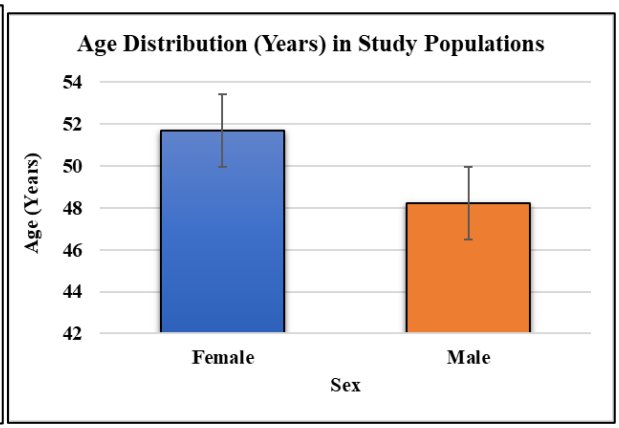

Figure 2. Age distribution of study population

The study included 385 participants, of whom 199 (51.7%) were females and 186 (48.3%) were males, indicating a nearly balanced distribution of sex as illustrated in **Figure 1** and the overall mean age of the study population was 50.01 ± 13.35 years. Female participants had a higher mean age (51.68 ± 13.16 years) compared to males (48.22 ± 13.36 years) as display in **Figure 2 .**

Distribution of CT Attenuation and Bone Mineral Density Across Lumbar Vertebrae

Mean CT attenuation (HU) and corresponding BMD values derived from QCT and MDCT demonstrated a consistent pattern across lumbar vertebrae L1–L5. Both QCT-derived and MDCT-derived BMD showed a similar vertebral distribution, with higher BMD values observed at L5 compared with upper lumbar levels. MDCT-derived BMD values were slightly lower than QCT-derived BMD across all vertebral levels, indicating a small systematic difference between the two methods while preserving comparable variability, as reflected by similar standard deviations as given in Table 1 and illustrate **Figure 3.**

Table 1. Mean ± SD of CT Attenuation and BMD at Lumbar Vertebrae (L1–L5)

Vertebra	CT Attenuation (HU) Mean ± SD	QCT-Derived BMD (mg/cm³) Mean ± SD	MDCT-Derived BMD (mg/cm³) Mean ± SD
L1	157.47 ± 55.64	128.03 ± 38.95	122.83 ± 43.40
L2	154.92 ± 56.15	126.24 ± 39.30	120.84 ± 43.80
L3	148.37 ± 52.19	121.66 ± 36.53	115.73 ± 40.71
L4	151.01 ± 59.73	123.50 ± 41.81	117.78 ± 46.59
L5	192.25 ± 47.86	152.38 ± 33.50	149.96 ± 37.33

Values are expressed as mean ± standard deviation (SD). CT attenuation was measured in Hounsfield units (HU). QCT-derived and MDCT-derived bone mineral density (BMD) values are reported in mg/cm³. Measurements were obtained at lumbar vertebral levels L1–L5.

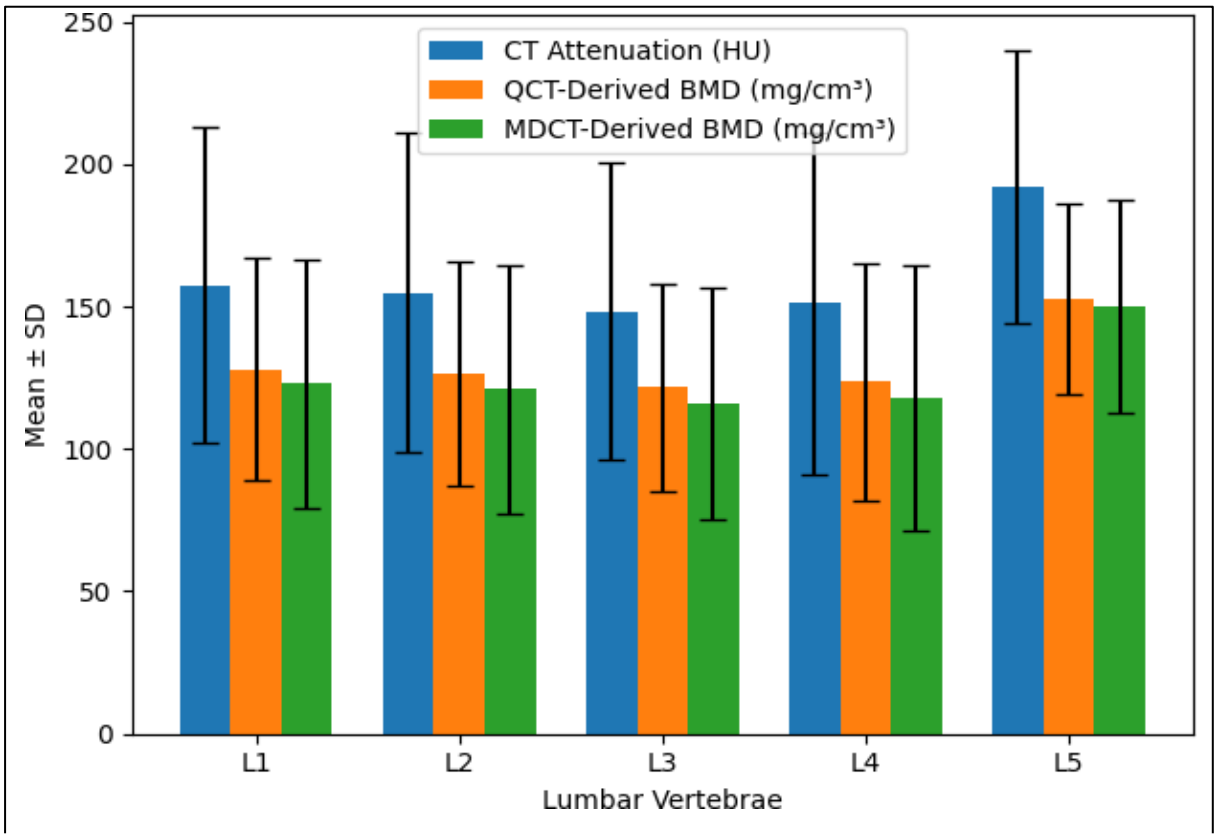

Figure 3. *Comparison of CT Attenuation Values and QCT- and MDCT-Derived Bone Mineral Density Across Lumbar Vertebrae (L1–L5). Grouped bar chart showing mean ± standard deviation of CT attenuation values (Hounsfield Units), QCT-derived bone mineral density (BMD), and MDCT-derived BMD across lumbar vertebrae L1–L5. Error bars represent one standard deviation. QCT-derived BMD was used as the reference method for comparison.*

Correlation Analysis

Spearman correlation analysis demonstrated a perfect positive monotonic correlation between QCT-derived BMD and MDCT-derived BMD at all lumbar vertebral levels (L1–L5), with correlation coefficients of r = 1.00 ($p < 0.001$) for each corresponding vertebra. This finding reflects the fact that both BMD estimates were derived from the same CT attenuation values using established conversion equations as given in Table 2.

Table 2. Correlation Between QCT- and MDCT-Derived BMD at Lumbar Vertebrae

Vertebra	QCT-Derived BMD (mg/cm³) Mean ± SD	MDCT-Derived BMD (mg/cm³) Mean ± SD	Spearman r	p-value
L1	128.03 ± 38.95	122.83 ± 43.40	1.00	<0.001**
L2	126.24 ± 39.30	120.84 ± 43.80	1.00	<0.001**
L3	121.66 ± 36.53	115.73 ± 40.71	1.00	<0.001**
L4	123.50 ± 41.81	117.78 ± 46.59	1.00	<0.001**
L5	152.38 ± 33.50	149.96 ± 37.33	1.00	<0.001**

*Spearman's rank correlation coefficient (r) was used to assess the monotonic association between QCT-derived and MDCT-derived bone mineral density (BMD) measurements at each lumbar vertebral level. All correlations were statistically significant at the 0.001 level. p < 0.001 indicates strong positive correlation. **Correlation is significant at the 0.001 level (two-tailed).*

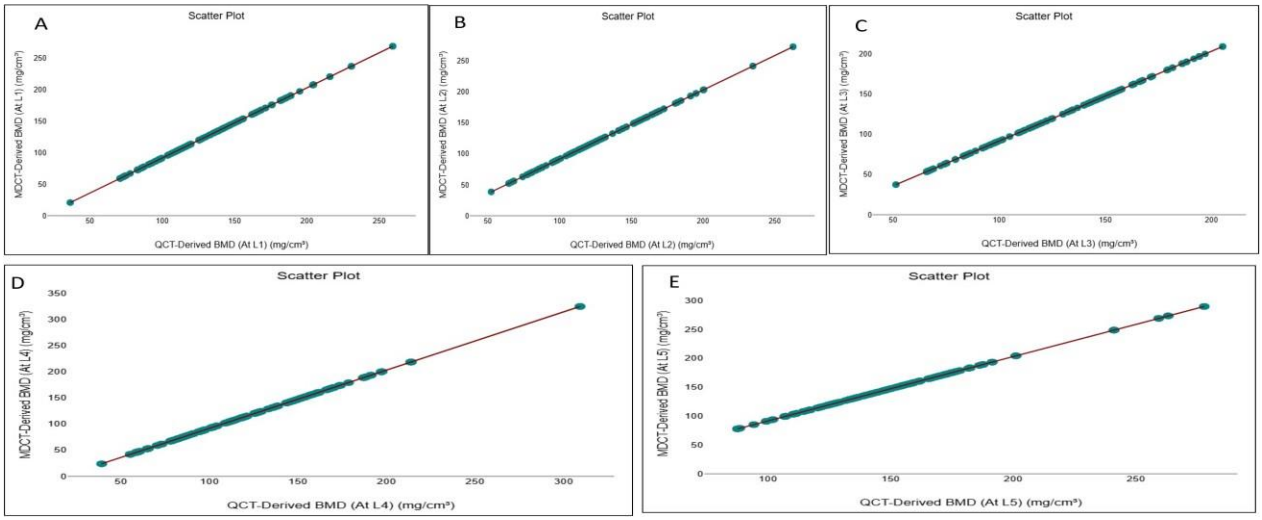

***Figure 4*. Scatter plots showing correlation between QCT-derived and MDCT-derived bone mineral density (BMD) at lumbar vertebrae L1–L5.** *Scatter plots demonstrate the relationship between QCT-derived and MDCT-derived BMD measurements at lumbar vertebral levels (A) L1, (B) L2, (C) L3, (D) L4, and (E) L5. Each point represents an individual vertebral measurement. Solid lines indicate the line of best fit. Spearman's rank correlation analysis showed a perfect positive correlation (r = 1.00, p < 0.001) at all vertebral levels, reflecting a consistent monotonic relationship between the two methods*

Bland–Altman Agreement Analysis Between MDCT- and QCT-Derived BMD

Bland–Altman analysis demonstrated a small positive mean bias between MDCT- and QCT-derived BMD across all lumbar vertebrae, indicating a slight underestimation of BMD by MDCT. The mean bias ranged from 2.42 mg/cm³ at L5 to 5.93 mg/cm³ at L3. The 95% limits of agreement were relatively narrow, with most measurements lying within these limits, suggesting acceptable agreement between MDCT- and QCT-derived BMD measurements as illustrated in **Table 3.**

Table 3: Bland–Altman Agreement Analysis Between MDCT- and QCT-Derived BMD

Vertebra	Mean BMD (mg/cm³)	Bias (MDCT − QCT)	95% Limits of Agreement (mg/cm³)
L1	125.43 ± 41.17	5.20 ± 4.45	−3.52 to 13.92
L2	123.54 ± 41.55	5.41 ± 4.49	−3.39 to 14.21
L3	118.70 ± 38.62	5.93 ± 4.18	−2.26 to 14.12
L4	120.64 ± 44.20	5.72 ± 4.78	−3.65 to 15.09
L5	151.17 ± 35.42	2.42 ± 3.83	−5.09 to 9.93

Values are expressed as mean ± standard deviation (SD). Bias represents the mean difference between MDCT- and QCT-derived bone mineral density (BMD) measurements (MDCT − QCT). The 95% limits of agreement were calculated as bias ± 1.96 × SD of the differences, indicating the range within which 95% of the differences between the two methods are expected to lie. BMD values are reported in mg/cm³.

DISCUSSION

The present study evaluated lumbar vertebral BMD derived from routine 120 kV MDCT and compared it with QCT-derived BMD using validated HU-based conversion formulas. Our findings demonstrated a strong monotonic correlation between MDCT- and QCT-derived BMD across all lumbar vertebral levels (L1–L5) with good agreement on Bland–Altman analysis, indicating only a small systematic bias. These results suggest that MDCT-derived BMD can serve as a reliable surrogate for QCT-derived measurements in clinical practice. Spearman correlation analysis demonstrated a near-perfect positive correlation between the two methods, consistent with findings by **Andresen et al. (2025)** (11), who reported that HU values from native lumbar CT scans can be reliably converted into quantitative BMD (correlation coefficient 0.98, $p < 0.001$). Bland–Altman analysis in our study revealed a small, consistent positive bias (approximately 2–6 mg/cm³), which is clinically negligible. These findings are comparable to **Schwaiger et al. (2014)** (12), who demonstrated that conversion of routine MDCT to QCT-equivalent BMD reliably differentiated patients with and without osteoporotic fractures and predicted incidental fractures and screw loosening after spondylosis. Our results also align with **Deevi et al. (2025)** (13), who reported mean lumbar BMD of 149–152 mg/cm³ in younger adults (20–39 years), with HU thresholds correlating with osteopenia and osteoporosis defined by reference standards. Additionally, **Simion et al. (2024)** (14) highlighted segmental variations of BMD along the spine, emphasizing the importance of individualized assessment, which our study corroborates with higher cranial vertebral BMD compared with caudal segments. The clinical implication of these findings is significant. Given the widespread availability of MDCT and its routine use in abdominal and spinal imaging, MDCT-based BMD estimation can provide an opportunistic, non-invasive tool for early osteoporosis screening without additional radiation exposure or dedicated scanning protocols. However, consistent scan parameters, standardized ROI placement, and awareness of the small systematic bias are essential to ensure reliable interpretation.

CONCLUSION

The present study demonstrates that lumbar vertebral bone mineral density (BMD) estimated from routine 120 kV multidetector computed tomography (MDCT) using HU-based conversion formulas shows a very strong monotonic association with QCT-derived BMD across all lumbar vertebral levels (L1–L5). Bland–Altman agreement analysis revealed a small, consistent positive bias, with MDCT-derived BMD slightly overestimating QCT-derived values. The mean differences between the two methods ranged from 2.42 mg/cm³ at L5 to 5.93 mg/cm³ at L3, with narrow and clinically acceptable limits of agreement. Despite the presence of a minor systematic difference, the magnitude of bias was small relative to the overall BMD values and showed no evidence of proportional bias across the measurement range. These findings indicate good agreement between MDCT-derived and QCT-derived BMD measurements. Therefore, MDCT-based BMD estimation may serve as a feasible alternative for opportunistic assessment of lumbar bone density in routine clinical CT examinations, particularly when dedicated QCT is not available. However, given the observed systematic bias, MDCT-derived BMD should be interpreted with appropriate caution and standardized acquisition protocols.

Ethics approval and consent to participate: The study was approved by the Institutional Ethics Committee of Teerthanker Mahaveer University College of Paramedical Sciences (Ethical Approval No: PM/ETHICAL/2024/018). Written informed consent was obtained from all participants prior to data collection.

Consent for publication: All authors have consented to the publication of this manuscript and any associated data.

Availability of data and materials: The datasets generated and analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests: No

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Authors' contributions:

- **Raushan Kumar:** Conceptualization, data collection, data analysis, manuscript drafting.
- **Prof. (Dr.) Rajul Rastogi :** Supervision, methodology, review, and editing of the manuscript.

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