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Innovative imaging approaches in intertrochanteric Hip fractures: A retrospective analysis of density assessment using CT, X-ray and DEXA

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Abstract

Intertrochanteric hip fractures in elderly patients are closely linked with underlying osteoporosis, making accurate bone quality assessment critical for both treatment planning and secondary fracture prevention. This study aimed to evaluate the feasibility of using computed tomography (CT) and X-ray as complementary or alternative tools to dual-energy X-ray absorptiometry (DEXA), with a focus on the contralateral (non-fractured) hip. A retrospective analysis was conducted on 48 elderly patients (33 females, 15 males) with unilateral intertrochanteric fractures. During the non-weight-bearing period, imaging of the opposite hip was reviewed. The cortical thickness index (CTI) was calculated from pelvic anteroposterior X-rays, proximal femoral density was quantified by CT in Hounsfield Units (HU), and T- and Z-scores were obtained from DEXA. Statistical relationships between demographic variables and bone parameters were analyzed with Pearson correlation, and interhip variability was explored. CTI, HU values, and DEXA-derived scores showed significant positive correlations, confirming consistency among the methods. Lower CTI and HU values were linked with advancing age and decreased bone mineral density (BMD). Age showed a negative correlation with CT mean, CTI, and total T-scores. Height was inversely correlated with Z-scores, while weight demonstrated negative associations with multiple parameters including T-scores, Z-scores, and CTI. Strong positive correlations were identified between CTI, CT mean, and densitometric scores. CTI derived from routine pelvic X-rays and HU values from CT scans can act as practical and widely available indicators of bone quality. When combined with or used in place of DEXA, these imaging parameters may improve preoperative planning, fracture risk stratification, and early osteoporosis recognition, particularly in centers where DEXA is limited or delayed.

Keywords: Intertrochanteric fractures, osteoporosis, computed tomography, dual-energy X-ray absorptiometry, cortical thickness index, bone density

Introduction

Intertrochanteric hip fractures represent a significant orthopedic challenge, particularly among elderly populations, where they are associated with considerable morbidity, mortality, and healthcare costs [1]. These fractures commonly result from low-energy trauma in the context of compromised bone quality, most notably osteoporosis, which reduces bone mineral density (BMD) and structural integrity. Beyond their immediate impact, intertrochanteric fractures can lead to prolonged hospitalization, loss of functional independence, and an increased risk of complications such as venous thromboembolism, infections, and secondary fractures [2]. Osteoporotic fractures are a major contributor to reduced quality of life in aging populations, emphasizing the critical importance of accurate bone quality assessment for fracture management and prevention strategies [3].

The standard imaging modality for evaluating BMD is dual-energy X-ray absorptiometry (DEXA), which provides precise measurements of BMD and is widely utilized in clinical and research settings for diagnosing and managing osteoporosis [4]. However, DEXA has limitations: it offers limited spatial resolution, lacks detailed anatomical information, and may not

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always be accessible in acute fracture settings [5]. Hsieh et al [6]. reported that 80% of patients aged 40 to 90 who underwent pelvic or spinal radiographs did not receive DXA testing. Consequently, if a method were developed to estimate fracture risk and determine hip mineral density using existing X-rays or CT scans without additional testing, it could eliminate the need for extra radiation exposure and reduce associated costs. In addition, while DEXA excels in BMD quantification, it does not provide insights into the structural and morphological characteristics of bone, which are critical for understanding fracture risk [7]. Conversely, CT, a modality routinely used for anatomical imaging and fracture evaluation, holds promise as an alternative or complementary tool for assessing bone density. CT provides high-resolution, three-dimensional imaging, enabling bone geometry and density assessment [8]. Despite these advantages, CT has yet to achieve widespread adoption for densitometry due to the absence of standardized protocols and its perceived inferiority to DEXA in measuring BMD. However, recent advancements in imaging technology, including innovations in magnetic resonance imaging-computed tomography, suggest that CT could evolve into a robust tool for assessing bone quality and fragility.

This retrospective study adds to the emerging body of evidence by comparing femoral neck bone density measurements obtained via CT and DEXA in the non-fractured hips of elderly patients with intertrochanteric fractures. The primary aim is to assess the feasibility and accuracy of CT as an alternative imaging modality for bone densitometry. In addition, by focusing on the healthy contralateral hip, the study highlights the importance of early identification of osteoporosis and implementing preventive measures to reduce the risk of subsequent fractures. The findings of this study are anticipated to contribute to the growing body of evidence supporting innovative imaging approaches in osteoporosis management. By exploring the potential integration of CT into clinical practice, the study aims to highlight the potential use of alternative imaging modalities such as CT and X-ray-derived CTI for bone quality assessment, especially in settings where DEXA is not accessible.

Material and Methods

This study is a retrospective analysis of archived medical records and radiological images. Ethical approval was obtained from the Non-Interventional Research Ethics Committee of our city hospital (Date: 19.12.2024; Decision No: 2024/6-16), covering the period between January 2019 and October 2024. All records were fully anonymized prior to data access to ensure confidentiality and adherence to ethical standards. Additionally, the Institutional Review Board (IRB) waived the requirement for informed consent, as the study involved only de-identified retrospective data. The study was conducted in accordance with the principles of the Declaration of Helsinki.

The study included patients who presented to the emergency department with complaints of simple falls and hip pain and were diagnosed with intertrochanteric femur fractures. Each patient's contralateral (non-fractured) hip was evaluated retrospectively using available pelvic anterior-posterior (AP) X-ray and computed tomography (CT) images. The cortical thickness index (CTI) was calculated only from X-ray images, while CT scans were used solely to quantify bone density in the proximal femur in Hounsfield Units (HU). CTI was not measured from CT images.

The primary aim was to investigate whether there is a correlation between the HU values obtained from CT (Figure 1) and the CTI calculated from X-rays (Figure 2), in order to determine whether CTI could provide preliminary insight into bone quality during preoperative planning. Furthermore, the study aimed to evaluate the potential of CT as a complementary tool to DEXA in assessing BMD (Figure 3) and whether it could reduce the need for additional imaging and radiation exposure in elderly patients with osteoporosis-related fractures.

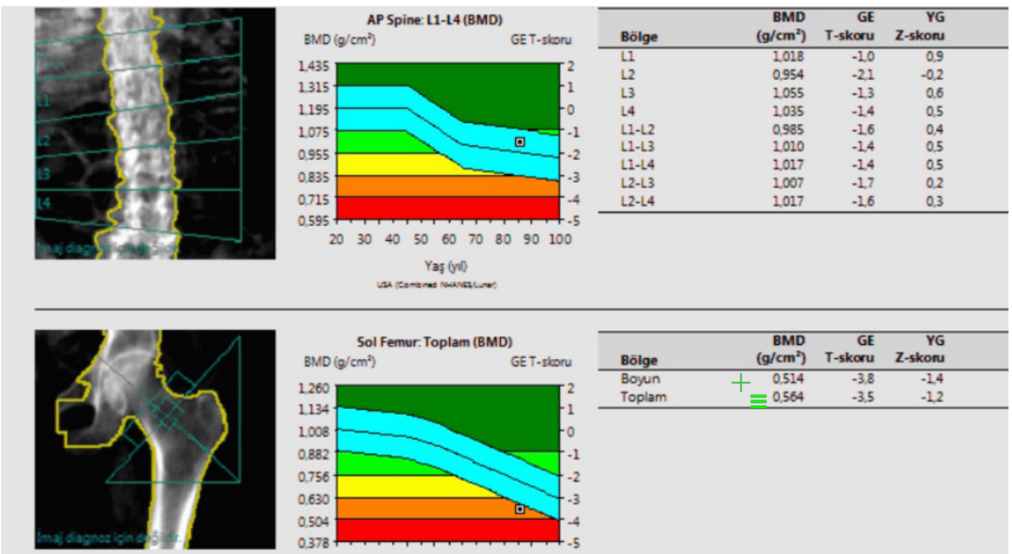

Figure 1. DEXA evaluation of the patient's vertebra and healthy hip at the time of admission with fracture

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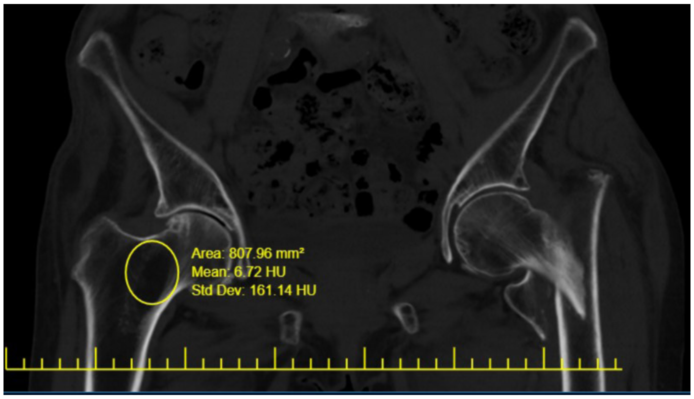

Figure 2. CT evaluation of the patient's healthy hip at the time of admission with fracture

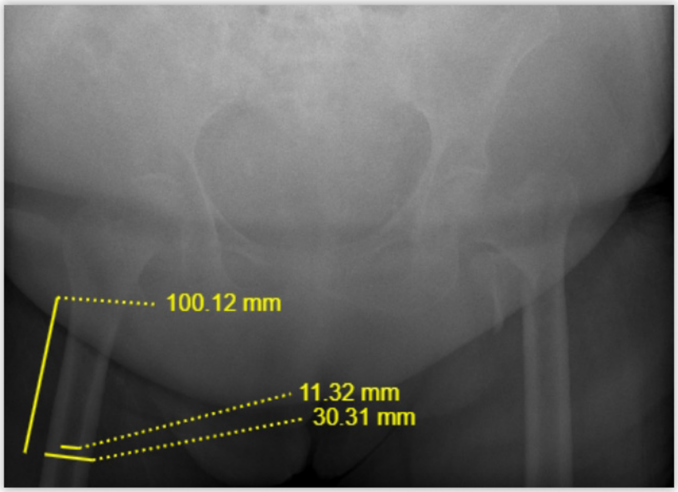

Figure 3. Sample measurement of cortical condition index (CTI) at the subtrochanteric level of the femur on AP X-ray of the pelvis. CTI = (Total width - Medullary width) / Total width

The required sample size was determined using G*Power version 3.1.9.4. Based on a previous similar study, a sample size of 46 participants was calculated to achieve 95% power with a significance level of α = 0.05 [9]. To account for possible exclusions, 50 patients were initially enrolled. After screening, two were excluded due to unrelated orthopedic conditions. As a result, 48 patients (33 female, 15 male) who met the inclusion criteria were included in the final analysis.

For each patient, BMD of the non-fractured hip was assessed using DEXA for T-scores, Z-scores, and BMD (g/cm²), and CT for HU-based quantitative analysis. The CTI values calculated from X-ray images were also included in the statistical comparisons with both CT and DEXA findings. Postoperative DEXA measurements were performed in a non-weight-bearing position to ensure consistency across patients. Demographic data were retrieved from patient records.

CTI

Calculating the CTI, a reference line is first drawn through the middle of the lesser trochanter, perpendicular to the long axis of the femur. A second line is then drawn parallel to the reference line, 10 cm distal. The diameters of the femoral diaphysis and the intramedullary canal are measured. The intramedullary canal diameter is subtracted from the femoral diaphysis diameter. The resulting value is then divided by the femoral diaphysis diameter, and the CTI is calculated [10].

Imaging

DEXA scan data were collected for unilateral femoral intertrochanteric, including T-scores, Z-scores, total scores, and BMD values measured in g/cm². CT scans were performed using multi-detector computed tomography (MDCT) systems following standard protocol settings. The raw data were reconstructed into axial images with a slice thickness and increment of 1.5 mm, using a bone convolution kernel and a field of view of 340 × 340 with a 512 × 512 matrix (SOMATOM Force or SOMATOM Edge, Siemens Healthineers, Munich, Germany). Regular calibration of the scanners was ensured using a phantom.

Statistical analysis

Data analysis was performed using the SPSS 22.0 software package. Kurtosis and Skewness values revealed that our data showed normal distribution (between - 2 and + 2). The student t-test determined the significant difference between independent groups. Statistically, $p<0.05$ values were considered significant. The obtained data are presented in tabular form as arithmetic mean±standard error (SD, (Minimum-Maximum). The Pearson correlation test was used to examine the relationships between parameters.

Results

In this study, the mean age of the 33 female participants was 80.33±7.83 years, with a mean height of 154.70±3.78 cm and a mean weight of 68.91±10.95 kg. Among the 15 male participants, the mean age was 74.33±12.56 years, with a mean height of 159.73±7.59 cm and a mean weight of 72.20±7.58 kg. Comparing the mean age of the groups ($p=0.50$), height ($p=0.60$) and weight ($p= 0.23$) no statistically significant differences were found.

All DEXA and CT scores evaluated between genders were higher in male participants; however, no statistically significant differences were observed (Table 1). When the participants' healthy right and left hips were compared, 26 participants had a healthy right hip, while 22 had a healthy left hip. The right hips exhibited more negative values for Neck T-scores, Total T-scores, Neck Z-scores, and Total Z-scores. Participants had Neck T-scores and Total T-scores less than -2.5 and were osteoporotic. Notably, the Total Z-scores for the right hip were higher than those for the left hip, and this difference was statistically significant ($p<0.05$). Additionally, the CTI values were found to be higher in the left hips compared to the right hips, and this difference was statistically significant ($p<0.05$), (Table 2).

A negative correlation was observed between participants' age and CT mean, CTI, and Total T-scores. Additionally, a significant negative correlation was found between age and Total T-scores. A significant negative correlation was identified between participants' height and Total Z-scores. Participants' weight showed a negative correlation with Total T-scores, Neck Z-scores, Total Z-scores, and CTI values. Furthermore, a highly significant negative correlation was noted between age and Total Z-scores. Positive significant correlations were observed between participants' Neck T-scores and Total T-scores, Neck Z-scores, Total Z-scores, and CTI values. Positive significant correlations were also identified between participants' Total T-scores and Neck Z-scores, Total Z-scores, CT mean, CTI, and Neck T-scores. Neck Z-scores showed positive significant correlations with Neck T-scores, Total T-scores, and Total Z-scores. Total Z-scores exhibited positive significant correlations with Neck T-scores, Total T-scores, Neck Z-scores, and CTI values. A positive significant correlation was found between participants' CT mean and Total T-scores. Finally, CTI values were positively and significantly correlated with Neck T-scores, Total T-scores, and Total Z-scores (Table 3).

Table 1. The relationship between gender and other variables

Bone Mineral Density (BMD) parameters	Group	N	X±SD	Min	Max	p
Neck T-scores	Female	33	-2.74±0.85	-4.1	-0.6	0.58
	Male	15	-2.88±0.67	-4.2	-1.8	
Total T-scores	Female	33	-2.89±0.6	-4.3	-1.5	0.98
	Male	15	-2.89±0.82	-4.1	-1.1	
Neck Z-scores	Female	33	-1.17±0.62	-2.4	0	0.05
	Male	15	-1.57±0.74	-3.3	-0.8	
Total Z-scores	Female	33	-1.16±0.6	-2.7	0.4	0.08
	Male	15	-1.5±0.64	-3.3	-0.8	
CT mean	Female	33	99±36.68	6.72	289.6	0.61
	Male	15	105.22±44.06	55.38	227.1	
CTI	Female	33	0.49±0.08	0.24	0.62	0.77
	Male	15	0.5±0.09	0.3	0.64	

X: mean; SD: standart deviation; Min: minimum; Max: maximum; CT: computed tomography; CTI: cortical thickness index

Table 2. The relationship of the intact hip side with other variables

Bone Mineral Density (BMD) parameters	Side	N	X±SD	Min	Max	p
Neck T-scores	Right	26	-2.93±0.89	-4.2	-0.6	0.17
	Left	22	-2.61±0.64	-4	-0.7	
Total T-scores	Right	26	-2.93±0.75	-4.1	-1.1	0.66
	Left	22	-2.85±0.57	-4.3	-1.5	
Neck Z-scores	Right	26	-1.45±0.64	-2.7	-0.1	0.07
	Left	22	-1.1±0.68	-3.3	0	
Total Z-scores	Right	26	-1.43±0.61	-3.3	-0.8	0.04*
	Left	22	-1.07±0.6	-2.7	0.4	
CT mean	Right	26	103.37±36.81	32.57	289.6	0.64
	Left	22	98.08±41.65	6.72	170.7	
CTI	Right	26	0.46±0.09	0.24	0.62	0.01*
	Left	22	0.52±0.06	0.41	0.64	

X: mean; SD: standart deviation; Min: minimum; Max: maximum; CT: computed tomography; CTI: cortical thickness index; *:p<0.05; **:p<0.01

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Table 3. Correlation of all values with each other

Parameters	Correlation Analysis	Age	Height	Weight	Neck T-scores	Total T-scores	Neck Z-scores	Total Z-scores	CT mean	CTI
Age	**r**	1	0	-0.18	-0.14	**-0.36***	0.01	0	-0.26	-0.09
	p		0.96	0.22	0.32	**0.01**	0.92	0.99	0.06	0.54
Height	**r**	0	1	**0.54****	-0.17	-0.13	-0.13	**-0.30***	0.07	0.07
	p	0.96		**0.001**	0.23	0.37	0.35	**0.03**	0.63	0.96
Weight	**r**	-0.18	**0.55****	1	-0.14	-0.14	-0.18	**-0.4****	0.03	-0.17
	p	0.22	**0.001**		0.34	0.31	0.21	**0.001**	0.81	0.24
Neck T-scores	**r**	-0.14	-0.17	-0.14	1	**0.79****	**0.40****	**0.63****	0.21	**0.28***
	p	0.32	0.23	0.34		**0.001**	**0.001**	**0.001**	0.15	**0.04**
Total T-scores	**r**	**-0.36***	-0.13	-0.14	**0.79****	1	**0.31***	**0.71****	**0.36***	**0.38****
	p	**0.01**	.37	0.31	**0.001**		**0.03**	**0.001**	**0.01**	**0.001**
Neck Z-scores	**r**	0.01	-0.13	-0.18	**0.40****	**0.31***	1	**0.56****	-0.06	0.12
	p	0.92	0.35	0.21	**0.001**	**0.03**		**0.001**	0.67	0.41
Total Z-scores	**r**	0	**-0.30***	**-0.4****	**0.63****	**0.71****	**0.56****	1	0.06	**0.44****
	p	0.99	**0.03**	**0.001**	**0.001**	**0.001**	**0.001**		0.65	**0.001**
CT mean	**r**	-0.27	0.07	0.03	0.21	**0.36***	-0.06	0.06	1	0.14
	p	0.06	0.63	0.81	0.15	**0.01**	0.67	0.65		0.31
CTI	**r**	-0.09	0	-0.17	**0.28***	**0.38****	0.12	**0.44****	0.14	1
	p	0.54	0.96	0.24	**0.04**	**0.001**	0.41	**0.001**	0.31	

CT: Computed tomography; CTI: Cortical thickness index; r: Pearson correlation; *:p<0.05; **:p<0.01

Discussion

This study evaluated the feasibility of using CT and X-ray–derived CTI as alternative or complementary tools to DEXA in assessing BMD in elderly patients with intertrochanteric hip fractures. Specifically, we investigated whether preoperative CT-based HU values and X-ray–derived CTI could provide predictive insight into bone quality. Our findings support the utility of these modalities in acute settings where DEXA access may be limited, aligning with prior studies identifying CTI thresholds (0.56 for males, 0.62 for females) as indicative of osteoporosis [16].

No statistically significant differences were found between genders in DEXA or CT measures, consistent with existing literature [17,18]. While males tended to have higher bone density values, the difference lacked clinical relevance, especially in small samples. Similarly, the absence of significant variation in age, height, or weight between sexes supports the internal consistency of our sample.

A notable observation was the interhip asymmetry in bone parameters. The left hips showed significantly higher CTI values and better T and Z scores, while the right hips exhibited more osteoporotic features. These differences may be explained by factors such as limb dominance, habitual load distribution, or microtrauma, as also suggested in previous anatomical studies [19,20].

Significant correlations were identified between demographic factors and bone health. Age was negatively associated with CT mean, CTI, and total T-scores; height with Z-scores; and weight with most bone metrics. These patterns reinforce the multifactorial nature of bone health decline and highlight the need to incorporate demographic data into risk prediction models [21–24].

Among all predictors, CTI stood out as a robust and easily accessible index correlating strongly with DEXA-derived T- and Z-scores. These results further support its integration into routine preoperative evaluations, especially when DEXA is not available [16,25].

Although DEXA remains the reference standard, its limitations in evaluating bone structure justify the use of additional tools. Imaging-based markers such as CTI and HU not only complement DEXA but may also serve as inputs for AI-driven screening systems in the future. Their utility is especially promising in time-sensitive decision-making environments.

CT and plain radiographs are frequently obtained as part of routine imaging in trauma patients. The reusability of these images reduces both costs and radiation exposure. Detecting low CTI or HU values during routine imaging may facilitate the earlier initiation of osteoporosis treatment, implementation of fall prevention strategies, and timely planning of physical therapy. These approaches require no additional imaging, making them practical, cost-effective, and time-efficient.

This study has limitations. The small sample size and retrospective design reduce generalizability. Confounding variables such as comorbidities, physical activity, and medication use were not evaluated. Larger, prospective studies are needed to confirm these findings and assess the longitudinal value of CT- and X-ray–based evaluations in osteoporosis management.

Conclusion

This study demonstrated that both the CTI calculated from pelvic X-rays and the HU values obtained from CT scans provide meaningful insights into bone mineral density in elderly patients with intertrochanteric hip fractures. The strong positive correlations observed between CTI, HU, and DEXA measurements support their utility as reliable indicators of bone quality. Additionally, the detected structural differences between the right and left hips highlight the need for individualized assessment in clinical decision-making. These findings suggest that CT and X-ray–based evaluations can serve as practical and accessible alternatives for osteoporosis risk assessment and treatment planning, particularly in settings where DEXA is not readily available.

Conflict of Interests
The authors declare that there is no conflict of interest in the study.

Financial Disclosure
The authors declare that they have received no financial support for the study.

Ethical Approval
The study was approved by the Local Ethics Committee and was conducted in accordance with the Helsinki Declaration (19.12.2024 date 2024/6- 16 number).

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