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Original Research Article

To Determine the Effect of Ageing on Cortical Thickness Index (CTI) and Canal Flare Index (CFI) of Long Bones in Indian Population at a Tertiary Healthcare: A Comparative Study in Two Age Groups I.E. 19-40 Years and 41-Above Using AP Radiograph of Hip

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Abstract

Aim: the aim of the study was to measure cortical thickness index (CTI) and canal flare index (CFI) on an anteroposterior radiograph of femur in normal Indian population of age group 19-40 years and effect of ageing on these parameters.

Methods: A cross-sectional hospital-based study included 684 patients conducted at department of Radiology, in a tertiary healthcare centre under BMC from 1st December 2021-30th November 2022.

Results: In the present study, out of 342 participants in group I, maximum 203 (86.5%) were referred due to pain and out of 342 in group II, maximum 154 (45.0%) were referred due to pain. This difference was found to be statistically significant. In the present study, out of 342 participants in group I, 4 (1.2%) were diabetic and out of 342 in group II, 33 (9.6%) were diabetic. In the present study, out of 342 participants in group I, no one hypertensive and out of 342 in group II, 30 (8.8%) were hypertensive. This difference of diabetes, history of addiction and hypertension were found to be statistically significant. In our study, mean CTI in 18-40 years age was found to be 0.53±0.07 (95% CI-0.52-0.53) and mean CTI in >40 years age was found to be 0.50±0.12 (95% CI-0.48-0.51). In our study, mean CFI in 18-40 years age was found to be 4.3±0.71 (95% CI-4.2-4.37) and mean CFI in >40 years age was found to be 3.8±0.92 (95% CI-3.7-3.9). This difference was found to be statistically significant.

Conclusion: We found a significant statistical difference in the values of CTI among males and females of the same age group. We also found statistically significant effects of ageing in

the values of CTI among both sexes. We also found statistically significant difference in the values of CFI among each sex of same and different age groups.

Keywords: Osteoporosis, Bone density, Hip fractures, Retrospective studies, Diagnosis

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Introduction

Cortical bone contains Haversian systems (osteons), which are composed of a central Haversian canal surrounded by osseous tissue in a concentric lamellar pattern. The thickness of the cortex is due to the subperiosteal deposition of bone. The periosteum becomes thicker, more vascular, and more active with age. On radiographs, cortical bone appears radio-opaque (white) as the outermost layer of bone. In the absence of underlying pathology, the periosteum is poorly visible on radiographs. Dual-energy x-ray absorptiometry (DEXA) is used to estimate bone density and bone insufficiency at various places (e.g., lumbar spine, femoral neck, distal radius). [1] On computed tomography (CT), cortical bone appears radio-opaque (white). CT scans detect fractures more easily than radiographs. There are few mobile protons in the outermost layer of the cortex. As a result, in all pulse sequences except those with ultrashort-TE4 it has low signal (hypointense i.e., black).

On Magnetic Resonance imaging (MRI), the normal periosteum is not visible generally. However, it may identify periosteal reactions earlier than on radiography. On T2-weighted scans of the cortex, fracture lines, particularly stress fractures, appear hyperintense. Osteoporosis is characterised by an impairment of both structural properties and bone quality, and predisposes the patient to an increased risk of fragility fracture. [2] The skeletal sites most affected by a fragility fracture are the femoral neck, proximal humerus, vertebrae, wrist, and ankle.

Femoral neck fractures in the older population are associated with high mortality, morbidity, and social dependence. [1,3] Its incidence is predicted to rise owing to ageing populations. Surgical delay increases short-term and long-term mortality. [4]

Bone quality of the femur represents a major determinant in the choice of therapeutic options and durability of total hip replacement. The most used radiographic parameter to assess bone status is the cortical thickness index (CTI). CTI of the proximal femur can be considered a reliable parameter that can easily be measured on standard anteroposterior radiographs. The Cortical Thickness Index (CTI) of the femur shows the bone strength in that location. [5] This can be used to estimate osteoporosis status and predict fracture risk status in the general population. [6] It is just as accurate as Bone Mineral Density (BMD). [7] The early phases of osteoporosis have an influence on trabecular bone, whereas the later stages have an impact on cortical bone. [8-9] Women have a smaller fracture threshold than men due to lesser initial bone mass and more postmenopausal bone loss. [10] Osteoporotic fractures occur more at cervical level of femur than intertrochanteric region.

Cortical thickness index can serve as an easy and reliable screening tool to predict the local bone status when quantitative bone mineral density (BMD) measurements are not available. It can therefore serve as a rapid screening tool in fragility fractures to identify patients requiring further diagnosis or treatment of osteoporosis. [11] CTI has showed

correlation and the ability to predict nBMD and FRAX at a statistically significant level in the general elderly population, especially females. [12] Cortical thickness index (CTI) correlates significantly with bone mineral density (BMD) except in patients with proximal femoral fracture. Hence it is not recommended as a parameter to assess the BMD of the proximal femur in geriatric patients with hip fractures. [13]

Thus the aim of the study was to measure cortical thickness index (CTI) and canal flare index (CFI) on an anteroposterior radiograph of femur in normal Indian population of age group 19-40 years and effect of ageing on these parameters.

Materials and Methods

A cross-sectional hospital-based study included 684 patient conducted at department of Radiology, in a tertiary healthcare centre under BMC from 1st December 2021-30th November 2022.

Inclusion criteria:

1. Patients undergoing antero-posterior hip radiographs in the Institute on Outpatient basis and Indoor patient basis.
2. Age-19 years and above.
3. Gender- both male and female.
4. High impact trauma patients.
5. Postmenopausal women.

Exclusion criteria:

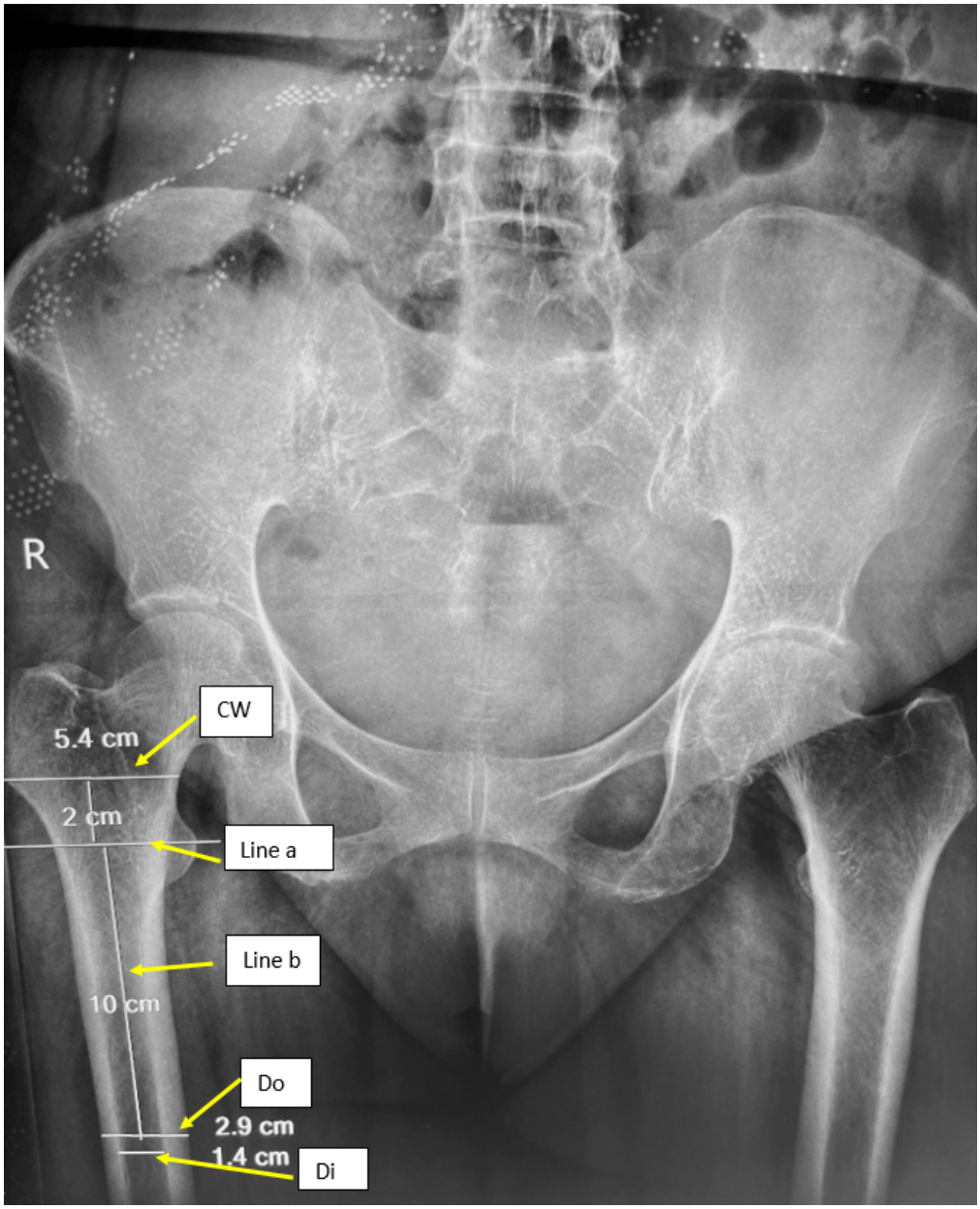
1. Age- less than 19 years.
2. Bed ridden patients.
3. On medications causing osteoporotic changes like steroids.
4. Benign bone tumors such as osteoid osteoma.
5. Malignant bone lesions involving bone of interest.
6. Malignancies causing paraneoplastic syndromes.
7. Infective pathology involving the bone of interest.
8. Previous fracture involving bone of interests.

Measurements:

CTI is defined as the ratio of the femoral diaphyseal diameter (outer diameter [Do]) minus the intramedullary canal diameter (inner diameter [Di]) to the femoral diaphyseal diameter. These diameters were measured 10 cm below the midpoint of the lesser trochanter, as described by

Dorr et al. [14] Noble et al. [15] described CFI as a parameter for morphologically classifying the proximal femur. It was defined as the ratio of the intracortical width of the femur at a point 20 mm proximal to the lesser trochanter (canal width) and at the canal isthmus. For consistent measurement, we identified the canal isthmus at 10 cm below the mid lesser trochanter, as defined by Yeung et al. [16]

Measurement of cortical thickness index (CTI) and canal flare index (CFI) on an anteroposterior radiograph was done using a similar method as Yeung et al. (Reference Figure 1).



Do: outer diameter (the shaft's outer diameter at 10 cm below the lesser trochanter)

Di: inner diameter (the shaft's inner diameter at 10 cm below the lesser trochanter, measured at the same level as Do)

CW: canal width (the canal width measured at 2 cm above Line a)

Line a: drawn perpendicular to the femoral shaft through the middle point of the lesser trochanter.

Line b: 10-cm line drawn perpendicular to Line a, used to identify the shaft's inner and Do measurement levels.

$$CTI = \frac{Do - Di}{Do}$$

$$CFI = \frac{CW}{Di}$$

Representative image: Measurement of cortical thickness index (CTI) and canal flare index (CFI) on an anteroposterior radiograph of a 55-year female patient with nonspecific back pain

Do: outer diameter (the shaft's outer diameter at 10 cm below the lesser trochanter)

Di: inner diameter (the shaft's inner diameter at 10 cm below the lesser trochanter, measured at the same level as Do)

CW: canal width (the canal width measured at 2 cm above Line a)

Line a: line drawn perpendicular to the femoral shaft through the middle point of the lesser trochanter.

Line b: 10-cm line drawn perpendicular to Line a, used to identify the shaft's inner and Do measurement levels.

CTI= Do-Di i.e.,2.9-1.4= 0.51

Do 2.9

CFI= CW i.e., 5.4= 3.85

Di 1.4

Statistical analysis:

Data analysis was done using licensed SPSS software version 21.0 (Chicago, Illinois). An Independent t-test was used to compare the continuous variable, and a chi-square test was used for categorical variables. A p-value <0.05 will be considered statistically significant.

Results

Table 1: Patient characteristics

Indications	Group I		Group II		p-value
	Count	%	Count	%	
Ankle varus	5	1.5%	0	0.0%	0.0001
Fall	1	0.3%	87	25.4%	
Tubercular arthritis	12	3.5%	23	6.7%	
Fournier's gangrene	4	1.2%	0	0.0%	
Fracture	103	30.1%	67	19.6%	
Missing IUD	10	2.9%	0	0.0%	
Pain	203	59.4%	154	45.0%	
Postural abnormality	0	0.0%	4	1.2%	
Scoliosis	4	1.2%	0	0.0%	
Stiffness of joints	0	0.0%	7	2.0%	
Total	342	100.0%	342	100.0%	
Diabetes					
No	338	98.8%	309	90.4%	0.0001
Yes	4	1.2%	33	9.6%	
Hypertension					
No	342	100.0%	312	91.2%	0.0001
Yes	0	0.0%	30	8.8%	
History of addiction					
No	342	100.0%	312	91.2%	0.0001
Alcoholic	4	1.2%	27	7.9%	
Smoker	8	2.3%	14	4.1%	
Menopause					
NA	198	57.9%	180	52.6%	0.008
No	144	42.1%	81	23.7%	
Yes	0	0.0%	81	23.7%	

In the present study, out of 342 participants in group I, maximum 203 (86.5%) were referred due to pain and out of 342 in group II, maximum 154 (45.0%) were referred due to pain. This difference was found to be statistically significant. In

the present study, out of 342 participants in group I, 4 (1.2%) were diabetic and out of 342 in group II, 33 (9.6%) were diabetic. In the present study, out of 342 participants in group I, no one hypertensive and out of 342 in group II, 30 (8.8%) were hypertensive. In the present study, out of 342 participants in group I, 4 (1.2%) had history of alcohol drinking and 8 (2.3%) had smoking history and out of 342 in group II, 27 (7.9%) had history alcohol drinking history and 14 (4.1%) were smoker. This difference was found to be statistically significant. This difference of diabetes, hypertension, history of addiction were found to be statistically significant. In the present study, out of 144 female participants in group 1, no one achieved menopause and out of 162 female participants in group 2, 81 (23.7%) achieved Menopause. This difference was found to be statistically significant.

Table 2: Descriptive analysis of CTI score between both group

GROUP I		
Mean		0.5285
95% Confidence Interval for Mean	Lower Bound	0.5205
	Upper Bound	0.5364
5% Trimmed Mean		0.5294
Median		0.5100
Std. Deviation		0.07456
Minimum		0.36
Maximum		0.67
Range		0.31
GROUP II		
Mean		0.4979
95% Confidence Interval for Mean	Lower Bound	0.4863
	Upper Bound	0.5094
5% Trimmed Mean		0.5017
Median		0.5100
Std. Deviation		0.10844
Minimum		0.21
Maximum		0.71
Range		0.50

In our study, mean CTI in 18-40 years age was found to be 0.53±0.07 (95% CI-0.52-0.53) and mean CTI in >40 years age was found to be 0.50±0.12 (95% CI-0.48-0.51). This difference was found to be statistically significant.

Table 3: Descriptive analysis of CFI score between both group

GROUP I		
Mean		4.2954
95% Confidence Interval for Mean	Lower Bound	4.2194
	Upper Bound	4.3714
5% Trimmed Mean		4.2689
Median		4.0700
Std. Deviation		0.71451
Minimum		2.57
Maximum		6.76
Range		4.19

GROUP II		
Mean		3.8002
95% Confidence Interval for Mean	Lower Bound	3.7025
	Upper Bound	3.8980
5% Trimmed Mean		3.7772
Median		3.7500
Std. Deviation		0.91887
Minimum		2.04
Maximum		5.90
Range		3.86

In our study, mean CFI in 18-40 years age was found to be 4.3±0.71 (95% CI-4.2-4.37) and mean CFI in >40 years age was found to be 3.8±0.92 (95% CI-3.7-3.9). This difference was found to be statistically significant.

Discussion

The Cortical Thickness Index (CTI) of the femur shows the bone strength in that location. [17] Studies in the past have shown considerable correlation between the CTI values and risk assessment of osteoporotic fractures. It is just as accurate as Bone Mineral Density (BMD). [18] Hence CTI values can be used to estimate osteoporosis status and predict fracture risk status in the general population. [11] CTI of the proximal femur can be considered a reliable parameter that can easily be measured on standard anteroposterior radiographs.

Bone quality of the femur also serves as a major determinant in the selection of therapeutic options for osteoporotic fractures and durability of total hip replacement. The early phases of osteoporosis have an influence on trabecular bone, whereas the later stages have an impact on cortical bone. [8,9] Osteoporotic fractures occur more at cervical level of femur than intertrochanteric region and are more common in females as compared to males of same age.

There are several studies in the literature which have compared the effectiveness of CTI in predicting the bone strength, but no study gave reference threshold for asymptomatic general adult Indian population. This study is centred towards filling the lacunae in the literature, as there is significant variation in bone densities based of demographic and geographic characteristics.

Cortical bone thickness is affected by various parameters such as chronically deranged functioning of liver or kidney (i.e., in CLD patients/ CKD patients); hence in our study we excluded these patients. It is also affected by diseases which impaired blood supply to these organs such as diabetes and hypertension, hence diseases like these can act as effect modifiers so care was taken to exclude these as well. Few pharmacological agents also have direct role on loss of cortical bone such as long-term steroids intake, hence were excluded from the study.

Sah et al. [19] suggested CTI ≤ 0.4 on a lateral hip radiograph as the threshold. However, their population sample included all postmenopausal osteoarthritic females undergoing hip replacement. Patterson et al. [20] proposed distal tibial cortical thickness value of 3.5 mm as the threshold value with 100% SEN and 100% negative predictive value. [21]

Limitations

- The internal and external rotation of the femur due to pain or other patient related factors may affect the CTI and CFI measured on the anteroposterior radiographs. But this was eliminated in our study with proper positioning of

the patient and excluding the rotated radiographs.

- Most of the patients were recruited from the department of orthopaedics which may have incorporated selection bias in the study.
- The normal value range of CTI and CFI calculated for group I, lacks representative data of the general population within a geographic area as we have included subjects visiting the hospital.

Conclusion

Cortical thickness is a good indicator of bone strength. This fact is backed up by many studies in the literature. It can be measured using several CT- based techniques and conventional radiography. The range of CTI calculated in our study for the age group 18-40 years is 0.53±0.07 (95% CI-0.52-0.53), and for the age group >40 years is 0.50±0.12 (95% CI-0.48-0.51). We found a significant statistical difference in the values of CTI among males and females of the same age group. We also found statistically significant effects of ageing in the values of CTI among both sexes. We also found statistically significant difference in the values of CFI among each sex of same and different age groups.

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