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Cortical thickness index (CTI): Can it influence type of hip fracture in proximal femur?

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Abstract
Introduction: Proximal femur fractures account for mortality and morbidity in elderly population. Postmenopausal women, decreased physical work in urban population, estrogen deficiency can cause osteoporosis in Indian population. Osteoporosis can result in proximal femur fracture. Decreased oseoblastic response, in elderly population results in osteoporosis. Here by we intend to find the correlation between cortical thickness Index and type of fracture in proximal femur.
Null Hypothesis: Cortical Thickness Index cannot determine the type of proximal femur fracture
Materials and Methods: A retrospective study was carried out, over a period of 2 months. All patients admitted into hospital with proximal femur fractures into hospital were included into study. Radiological evaluation of Singh's Osteoporosis Index Grading, Cortical Thickness Index (CTI) in anterior-posterior (AP), and canal calcar ratio were calculated.
Results: 100 patients were included into study. 45 females and 55 males were present. Average age of patients in the study was 71 years. 31 Intracapsular (Neck of Femur) and 69 extra capsular (Intertrochanteric and Sub trochanteric) fractures were found. Average CTI (AP) was 0.53, and canal calcar ratio was 0.63.
Conclusion: There exists a Negative correlation exists between CTI (AP) and CC Ratio. Null Hypothesis remains rejected.

Keywords: Cortical thickness index (AP), canal to calcar ratio (CC ratio), osteoporosis, proximal femur fracture, intertrochanteric fracture, sub trochanteric fracture

Introduction

Cortical Thickness Index (AP) of femur represents the strength of bone at that region [1]. This can be used for estimating osteoporosis status and prediction of fracture risk status in the elderly population [2]. It has as good predictive value as Bone Mineral Density (BMD) [3]. Coming to osteoporosis, it is none other than blunted oseoblastic response in continued osteoclastic resorption. This osteoclastic response is due to continued mechanical stress on subchondral bone [4]. Osteoporosis has variable action on trabecular and cortical bone. Early stage of osteoporosis impacts trabecular bone, whereas later stages effects cortical bone [5]. there is increased incidence of cervical to trochanteric fracture ratio in post-menopausal women and elderly male population. Men have greater fracture threshold than women because of initial higher bone mass, greater postmenopausal bone loss and increased threshold at cervical site than trochanteric site [6].

There is variable response to osteoporosis in both trabecular (intertrochanteric) and cortical (neck and shaft of femur) area.

We here intend to find out whether
1. There exists any fracture pattern with cortical thickness index or canal calcar ratio
2. How CTI changes with age of the patient.

Null hypothesis

Cortical thickness index cannot determine the type of fracture happening in Individuals.

Materials and Methods

A retrospective study was carried out between November, 2019 to January, 2020.

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All the patients admitted into BIRRD (T) hospital with proximal femur fractures were included into study, after satisfying inclusion and exclusion criteria. The study involves only radiological evaluation of X-Ray and no direct interaction with patients.

Inclusion criteria
1. Patients with age >50 years
2. Patient without any other fractures
3. Patient with recent history of fall
4. Patients with X-Ray pelvis with both Hips with Anterio-Posterior at least 15cm of proximal femur visibility in X-Ray and internal rotation

Exclusion criteria
1. Patients of age <50 years
2. Patients with any other fractures other than proximal femur
3. X-Ray other than inclusion criteria, improper X-Ray
4. Malunion, nonunion in proximal femur fractures

We do have digital X-Rays stored in our databases which made our study easier. CTI (AP) and CC Ratio in AP view are calculated as shown in figure.
We used Singh's grading for osteoporosis in our study. We divided patients into osteoporosis and non-osteoporosis as follows.

Grade 1, 2, 3: Osteoporotic group
Grade 4, 5, 6: non osteoporotic group

Grade of osteoporosis was evaluated with two surgeons and radiologist and tabulated. Results tabulated and evaluated.

Statistical analysis
Pearson Correlation Calculator.

Observations and Results
There were 100 patients included in the study. There were 45 female and 55 male patients in all. Average age of patients in the study was 71 years. Average age in Intracapsular and extra capsular fractures were 68 and 72 years respectively. N all there were 52 fractures on right side (35 extra capsular, 17 intra capsular) and 48 fractures on left side (35 extra capsular, 14 intra capsular).

Table 1: Showing average CTI (AP) and CC Ratio in Male, Female, Total and Extra capsular (EC) and Intracapsular (IC)

No. of patients	female		male		total		
	EC	IC	EC	IC	EC	IC	total
	45		55		100		
	35	10	34	21	69	31	100
CTI(AP)	0.51	0.49	0.54	0.55	0.53	0.53	0.53
CC Ratio	0.64	0.65	0.62	0.62	0.63	0.63	0.63

Table 2: Showing correlation factor between the various fractures and Cortical Thickness Index (AP) and Canal Calcar Ratio

Parameters	R	P	P value significance
Cortical Thickness Index (AP) – Canal to Calcar Ratio (Intracapsular #)	-0.2478	0.04	$p<0.05$
Cortical Thickness Index (AP) – Canal to Calcar Ratio (Extracapsular #)	-0.4672	0.008	$p<0.05$
Cortical Thickness Index (AP) – Canal to Calcar Ratio (all types of #)	-0.3271	0.0008	$p<0.05$

Average CTI (AP) and CC ratio shows no difference in Intracapsular, extra capsular and total populations in this study. But co-relationship varies between variables in Intracapsular, extra capsular and total population. There is strong negative co-relation between CTI (AP) and CC ratio in extra capsular followed by total and Intracapsular respectively.
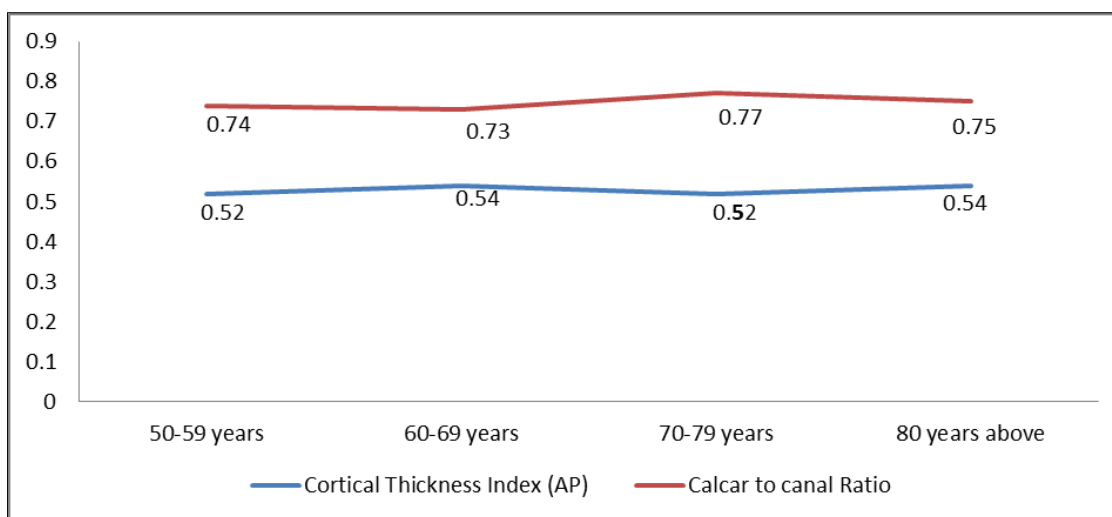
Fig 1: Line diagram showing trend in CTI (AP) and CC Ratio in various age groups

The graph above represents mild changes in trends of CTI (AP) and CC Ratio which are almost nil with increase in age of the patients.
We had 14 {extra-capsular (11)/Intra-capsular (3)} patients with grade 1, 54 (36/18) patients with grade 2, 25(18/7) patients with grade 3, and 7(4/3) patients with grade 4. We could not get any other grade 5 and 6 non-osteoporotic patients in the study.

Table 3: Singh's Grade of osteoporosis, Total, Extra-capsular, and Intracapsular with CTI (AP) and CC Ratio

Grade of Osteoporosis	Extra-capsular (CTI/CC)	Intra-capsular (CTI/CC)	Total (CTI/CC)
Grade 1	11 (0.79/0.5)	3 (0.51/0.86)	14 (0.5/0.8)
Grade 2	36 (0.76/0.54)	18 (0.54/0.74)	54 (0.54/0.75)
Grade 3	18 (0.74/0.54)	7 (0.49/0.7)	25 (0.53/0.73)
Grade 4	4 (o.71/0.52)	3 (0.59/0.66)	7 (0.55/0.69)
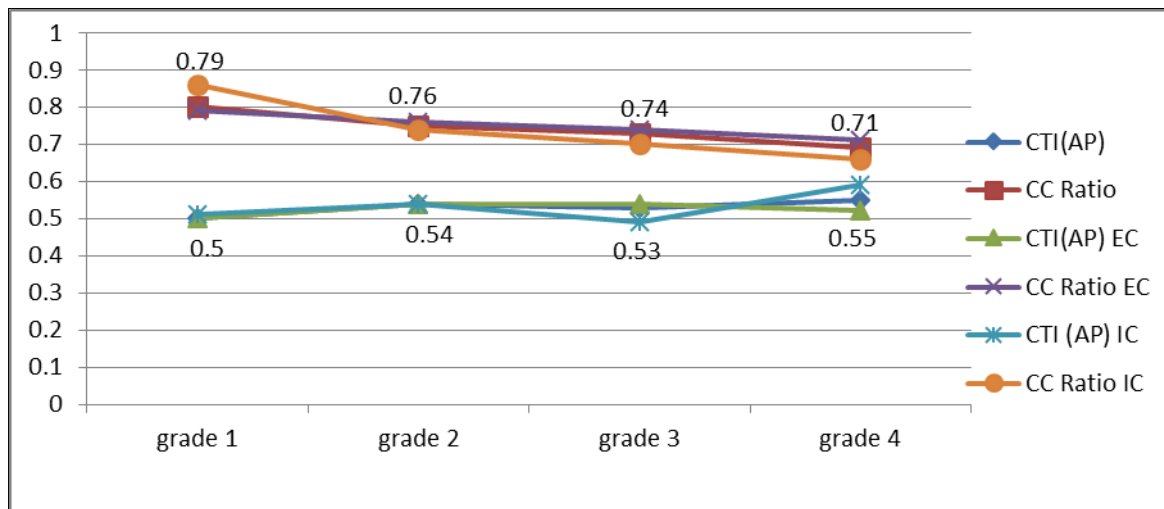
Fig 2: Shows Line diagrams of CTI (AP) and CC Ratio in Total, Intra-capsular, and Extra-capsular fractures in various Singh's Grades of osteoporosis.

Singh's Grade of Osteoporosis shows four grades in our study. Grade I refers severe osteoporosis which is in line with decreased cortical thickness index (AP) and increased with Canal-calcar ratio. Grade 4 represents borderline or non-osteoporotic patients which represents increased cortical thickness Index and decreased Canal-calcar ratio. This represents grade of osteoporosis and CTI (AP) follow same pattern, but they have negative relationship with CC Ratio.

Discussion
Average age of patients in our study was 71 years. Singh's osteoporosis grading (we used) shows variable pattern in the average age of the patient in comparison with Total, extra-capsular and intra capsular fractures. Grade 3 and below (osteoporosis) shows an average of 71, 72, 68 years respectively. Grade 4 and above (non-osteoporosis) shows 68, 71, 64 respectively. This shows direct relationship between age of patient and grade of osteoporosis.

Plate like, thicker, small separation, higher connectivity, high degree of anisometry are found in femoral neck trabecular bone. Similar findings are found in femoral trochanter region. Differences in microarchitecture, at that particular region of bone represents variability in bone loading in type and magnitude in particular [7].

Table 4: Shows comparison values of Mean CTI (AP) and CC Ratio in osteoporosis and non-osteoporosis groups in between my study and Kose *et al.* [8]

Group	Mean CTI		Mean CC Ratio	
	My Study	Kose *et al.* [8]	My Study	Kose *et al.* [8]
Osteoporosis	0.53 ± 0.08	0.43 ± 0.08	0.75 ± 0.11	0.74 ± 0.08
Non Osteoporosis	0.55 ± 0.06	0.51 ± 0.07	0.69 ± 0.10	0.68 ± 0.10

As per the data projected from above, we infer that our CTI (AP) and CC Ratio were in parallel and almost in line Kose et.al.[8] Kose *et al* used Bone Mineral Density (BMD) scan to differentiate between osteoporosis and non-osteoporosis patients with CTI (AP) and CC Ratio. We found similar CTI (AP) values in other studies like 0.5 (Sah *et al*. [9]) and 0.57 (Yun *et al*. [10]). Sample size in various studies varies like 92 (Kose *et al*.), 100 (Yun et.al) and 32 (Sah *et al*.) [8, 9, 10]. Studies have also found that radiologically, CTI values are in direct relation with T scores. CTI can be used as a reliable indicator of osteoporosis. This can in turn help surgeons to focus on osteoporosis evaluation and treatment, thereby decreasing hip fractures [9, 10]. Bone scan is costly investigation in major Metro cities of India [11]. The only difference is that these studies used BMD as standard for making out osteoporosis but we used Singh's Osteoporosis to differentiate the same. BMD scan is a costly investigation which is not available to most of Indian Population [11]. This is very far from the reach of local rural population (2/3 of Indian population being rural, with low economic status).

Proximal femur bone contains both cortical and cancellous bone. Outer layer of cortical bone is good enough to bear forces and movements of hip. While inner cancellous bone acts as shock absorber in walking and running [12]. Bone mass Index peaks in early adult life. Bone resorption accelerates from third decades of adult life. This resorption is further accelerated by post-menopausal state of women, occurs both trabecular and cortical bone [13]. In microstructure, osteoporosis in women is represented by decreased trabecular number, complete loss of trabecula. This is more destabilizing, resulting increased fractures in women at early stage. In men there is thinning of Trabecula [12].
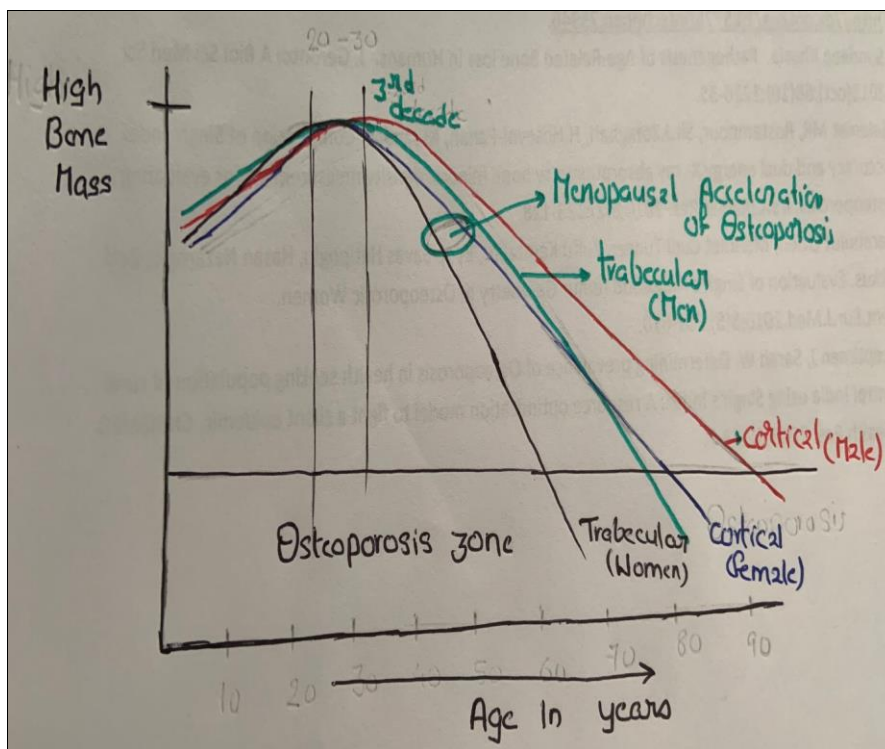
Pic 1: Representing the decrease in strength of bone (trabecular and cortical) in men and women with Age (representation of findings of Sundeep Khosla [13])
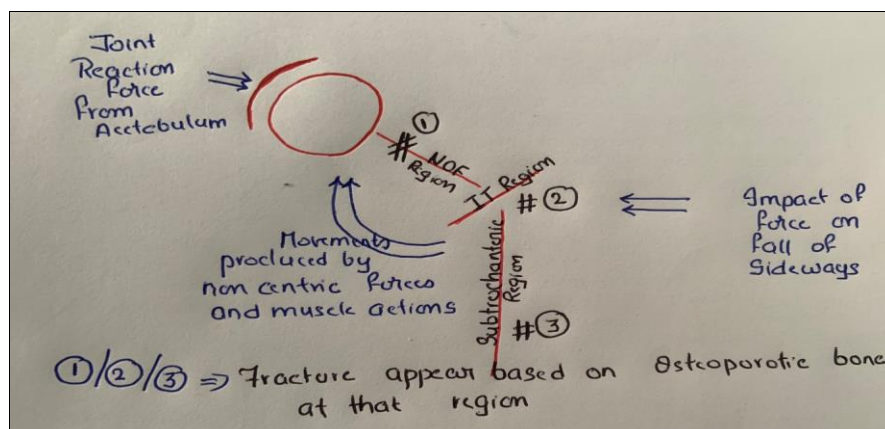
Pic 2: Showing Impact of fall and type of fracture (mechanism of fracture represented from Masoud Nasiri [12])

These findings we do infer that
1. Effect of osteoporosis on trabecular bone is more on comparison to cortical bone
2. Intertrochanteric region has more of trabecular bone. Neck of femur and Sub trochanteric femur has more cortical bone. Hence intertrochanteric fractures are more than Intracapsular fractures.

Coming to Age versus CTI, certainly CTI decreases with age. This varies because of many factors like sex, Menopausal status of women, rural and urban divide, sedentary and non-sedentary life style, working ability of patient, presence and absence of co-morbidities, mental status of patients, pre fracture mobility of the patients.

Singh's Index in our study was found to have direct co-relation with CTI (AP) and inversely related with CC ratio. The more osteoporosis severity, the more we can expect intertrochanteric fractures, in comparison to neck of femur.

We found CTI (AP) and CC Ratio were inversely related to each other in our study which is in line with other studies.

In the end we know some of the short comings of our study.

Sample size appears to be small, and a larger sample size could have delineated the relationship of CTI (AP), CC ratio and Singh's Index in a better way. Use of Bone Scan to delineate the osteoporosis woulb be better. Ours is a charity hospital, affording the needs of low-socioeconomic population, who cannot afford costly investigation. On other hand we believe that diagnosing of osteoporosis using Singh's Index with digital X-ray was found to have similar results as Bone Scan [14, 15, 16].

Conclusion
Osteoporosis through depends on age of patient, but intensity varies in person to person of same age dependent on sex, attainment of post-menopausal status of women, rural and urban population disparity, pre-operative mobility status of patient, co-morbidities of patient.

Singh's Index and CTI (AP) have direct correlation but are inversely related to CC ratio.

Low CTI (AP) values can alert the surgeon for evaluation and treatment of osteoporosis.

Null hypothesis remains rejected.

Yes low CTI (AP) values will have higher extra-capsular fractures than persons with high values with intra-capsular fractures.

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