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Original Research Article

Anthropometric analysis of proximal femur in south Indian population: A computed tomography-based study

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Abstract

Background: Intramedullary devices are the most popular mode of management for unstable intertrochanteric femur fractures. These implants have been designed based on geometric studies of proximal femur of western population which varies from other ethnic groups.
Objective: This study is aimed to measure proximal femur parameters in south Indian population using computed tomography (CT).
Methodology: A descriptive anatomical study, conducted by measuring proximal femoral parameters using computed tomography scans which were available in the Department of Radio-diagnosis, S. Nijalingappa Medical College and Hospital and Research Centre, Bagalkot. Parameters assessed are-Neck Width(NW), Canal width at Lesser trochanter anteroposterior (CW-LT AP), Canal width at lesser trochanter mediolateral (CW-LT ML), Neck Shaft Angle (NSA), Head Size (HS), Horizontal Offset (HO), Vertical Offset (VO), Greater trochanter to lesser trochanter distance (GT-LT) and Trochanteric region width (TRW).
Results: The mean parameters observed were as follows: NW 29.48 ± 2.51mm (range 25-35.1mm), NSA 130.01° ± 4.80° (range 121°-138°), canal width at lesser trochanter anteroposterior (CW-LT AP) 14.93 ± 2.34mm (range 10.1-21.4mm), canal width at lesser trochanter mediolateral (CW-LT ML) 13.18 ± 1.96mm (range 9.75-18.5mm), head size (HS) 45.03 ± 2.77mm (range 40.24-49.91mm), vertical offset (VO) 41.78 ± 9.84mm (range 33.8-58.6mm), horizontal offset (HO) 34.56 ± 2.86mm (range 27.9-38.4mm), Greater trochanter to lesser trochanter distance (GT-LT) 64.24 ± 6.33mm (range 56.3-82mm), trochanteric region width (TRW) 45.34 ± 3.47 (range 38.9-55.4mm).
Conclusion: Greater trochanter to lesser trochanter is less and needs reduction in length of proximal segment height of PFN nails for south Indian population. Similarly diameter of proximal segment of PFN nail has to be further reduced for south Indian population.

Keywords: Anthropometric analysis, Proximal femur, Computed tomography

Introduction

Intertrochanteric femur fractures are very common fractures which orthopaedicians encounter. These are more common in elderly population (>65yrs). Since the advent of intramedullary devices for these fractures, intramedullary fixation has been very popular and most sought method of fixation of unstable intertrochanteric femur fracture and subtrochanteric femur fracture.

The aim of any surgical procedure in proximal femur is to obtain stable and well-functioning hip joint. The common implants used in the proximal femur are dynamic hip screw, proximal femoral nail, cancellous screws and replacement arthroplasty. Since the parameters of proximal femur morphometry for Indian population is lacking, the data about proximal femur geometry for the Western population are utilized in prosthetic designing. With no other available option, the same implants designed for the Western population is used for Indian patients.

Siwach and Dahiya compared the parameters of the femurs of Indian cadavers with those of Western and Hong Kong Chinese population [1]. They observed that the implants were oversized and their angles and orientations have a mismatch, which can presumably lead to complications such as splintering and fractures [1]. Pathrot *et al*. using cephalomedullary nails suggested design modifications for Indian population with lesser neck width (NW) [2].

The geometry of the proximal femur is determined by genetic and environmental factors such as age, race, sex and lifestyle [1, 3, 4]. It is also vital to match the dimensions of the implant closely with those of native femur to prevent complications resulting from mismatch could be aseptic loosening, improper load distribution, and discomfort [5, 6].

This study is aimed to measure proximal femur parameters in south Indian population of a district Bagalkot in north Karnataka using computed tomography (CT).

Materials and Methods

A descriptive cross-sectional study was conducted in the Department of Orthopaedics and data was collected from the Department of Radio- Diagnosis, S. Nijalingappa Medical College and Hanagal Shri Kumareshwar Hospital and Research Centre Bagalkot, by using CT scan images of the patients undergoing CT KUB for unrelated disease. A total of 30 adult individuals (17 males and 13 females) were included for the study. The CT images of adult individuals having normal hip and pelvic architecture without any obvious fracture and deformity were included; and having history of any hip surgery, deformities and preexisting hip pathology were excluded from the study.

Neck width (NW), Canal width at Lesser trochanter anteroposterior (CW-LT AP), Canal width at lesser trochanter mediolateral (CW-LT ML), neck shaft angle (NSA), head size (HS), vertical offset (VO), horizontal offset (HO), GT to LT distance(GT-LT), trochanteric region width (TRW) were measured by lines and angles drawn in CT images.

Neck width (NW)

A perpendicular line to the neck axis at the narrowest part of the femoral neck is measured [Figure 1].

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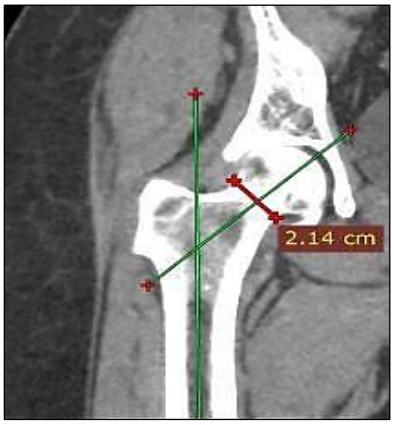

Fig 1: Neck width

Canal width at lesser trochanter

Canal diameter measured at the mid-level of lesser trochanter both anteroposterior (CW-LT AP) and mediolateral (CW-LT ML) in axial cuts. [Figure 2]

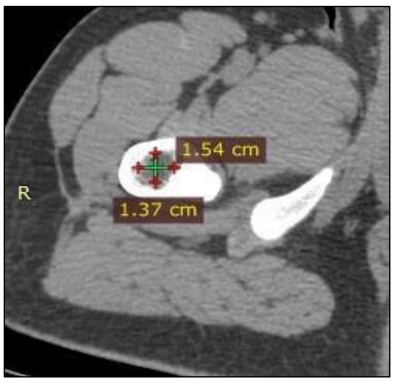

Fig 2: Canal with at lesser trochanter

Neck-shaft angle (NSA)

It is the angle subtended between the long axis of the femur and the long axis of the neck of the femur [Figure 1a]. Femoral shaft axis is a line drawn by extending through two equidistant points from the mediolateral surface of femoral shaft in the center of the medullary canal. Neck axis is drawn by joining the two points equidistant from the superior and inferior surface of femoral neck.11 [Figure 3].

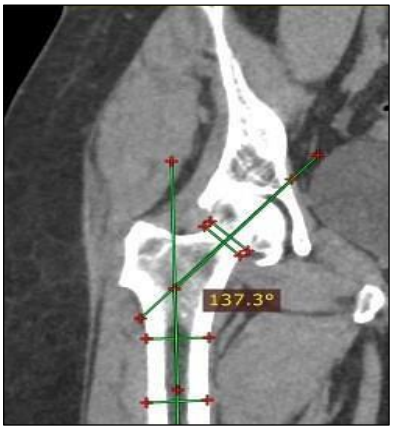

Fig 3: Neck shaft angle. Head size (HS)

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A perfect circle is drawn over the spherical femoral head, and circle diameter then calculated [Figure 4].

Horizontal offset (HO)

Horizontal offset or simply femoral offset is the horizontal distance from the center of rotation of femoral head to a line bisecting the long axis of shaft of femur [7]. Two lines were drawn-one along the center of femoral head, another along the middle of the femoral medullary canal. The measured distance between the two lines gives the HO. [Figure 4]

Vertical offset (VO)

Vertical offset or femoral head position is the vertical distance from the center of femoral head to the tip of lesser trochanter [8]. [Figure 4].

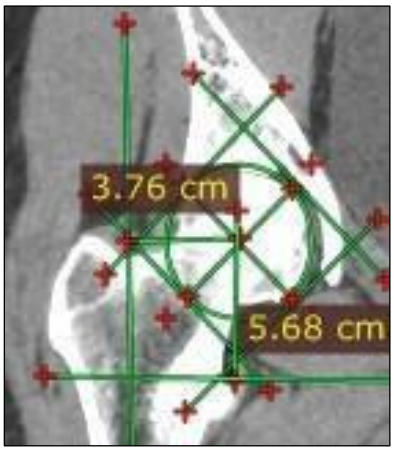

Fig 4: Horizontal and Vertical offset

Greater trochanter to lesser trochanter distance (GT-LT)

Perpendicular line is drawn to femoral axis at GT tip level and lower border of LT. Distance is measured between these two levels which gives trochanteric region height [Figure 5].

Fig 5: Greater trochanter to lesser trochanter distance and trochanteric region width measurement

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Trochanteric region width (TRW)

Perpendicular line is drawn to femoral axis at GT tip level and lower border of LT. Distance is measured between these two levels which gives trochanteric region height. Following which two perpendicular lines drawn to the previous two lines, one each at base of LT and GT flair and distance is measured between these lines for trochanteric region width [Figure 5].

All the scans available in the department were taken for the study. Data was collected and entered in Microsoft excel. Point estimate at 95% Confidence Interval was calculated along with frequency and proportion for binary data. The collected data was analyzed by using the Statistical Package for the Social Sciences version 19 (SPSS 19.0) for descriptive statistical analysis. P value was calculated to find the level of significance and p value <0.05 was considered as significant.

Statistical analysis

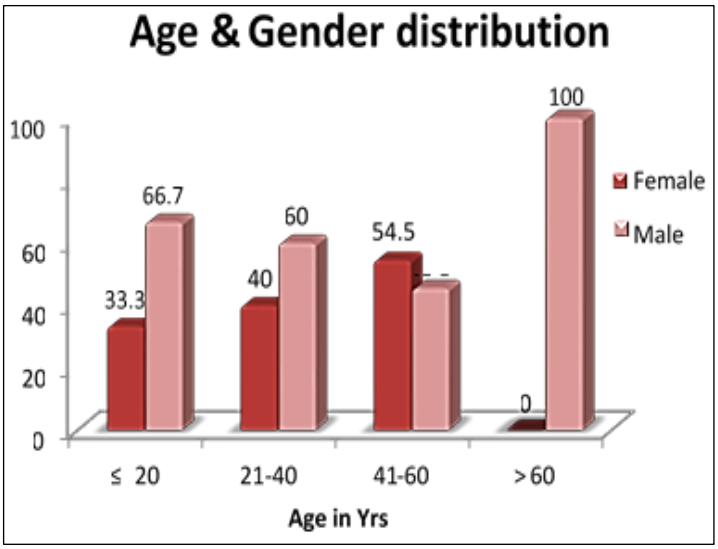
Sample size estimation was done using OpenEPi Software Version 2.3.1. At 95% confidence level, α(two-tailed) = 0.050 and at 95% confidence level. Where Zα = standard table value for 95% CI =1.96. Based on previous study Sengodan VC, *et al*., Mean and SD of Femoral head diameter was found to be 44.1±2.45. At 10 percent relative precision Sample size is calculated using the formula, n=2Zα2 σ2/d2.Sample size estimated is 27 which is rounded off to 30.

Results

Age and Gender: There were 30 patients (17 males and 13 female) with mean age of 38.93years (39yrs in male and 38.85 in female).

Table 1: Age distribution and percentage

Age in Yrs	Female			Male	Total
	Count	%	Count	%	
≤ 20	1	33.3	2	66.7	3
21-40	6	40	9	60	15
41-60	6	54.5	5	45.5	11
> 60	0	0	1	100	1
Total	13	100	17	100	30



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Neck width

The mean value of the NW in our study was 29.48 mm. Among the male, it ranged from 28 to 35.10 mm, and for the female, it was from 25 to 30.30 mm. The mean value was 30.93 mm among male, and it was 27.58 mm among females. Statistical analysis was done; the *P* value was statistically significant (0.001).

Medullary canal width at lesser trochanter

The mean value of the medullary canal diameter at the level of lesser trochanter anteroposterior (CW-LT AP) and mediolateral (CW-LT ML) in our study was 14.93mm and 13.18mm respectively. CW-LT AP among males and females, range was 10.1-21.40mm and 11.3-16.2 mm, respectively. CW-LT ML among males and females, range was 9.75-18.5mm and 11.6- 15.5mm respectively.
The mean value of CW-LT AP among male and female was 15.06mm and 14.77 mm respectively. The mean value of CW-LT ML among male and female was 13.26mm and 13.07 mm respectively. Statistical analysis was done; the *P* value was statistically insignificant.

Neck-shaft angle

The mean value of the NSA in our study is 130.01°. Among male and female, the range of NSA was 121°-137° and 123°-138°. The mean value was 130.66° in male and 129.15° in females. Statistical analysis was done; the *P* value was statistically insignificant.

Vertical offset

The mean value of the VO was 41.78 mm. Among males, it ranged from 39-56.5 mm and for the females 33.80-58.60 mm. The mean value for the males was 41.37 mm, and for the females, it was 42.32 mm. Statistical analysis was done; the *P* value was statistically insignificant.

Horizontal offset

The mean value of the HO was 34.55 mm. Among males, it ranged from 35 to 27.90-38.40 mm and for the females 27.90-37.20 mm. The mean value for the males was 35.97mm and for the females, it was 32.70mm mm. Statistical analysis was done; the *P* value was statistically significant (0.001).

Femoral head diameter

The mean of the value of the femoral HD in our study was 45.02 mm. The mean femoral HD among male and female was 46.66 and 42.88 mm, respectively.
The values ranged from 42.75 to 49.91 mm among male and 40.24-48.05 mm in female. Statistical analysis was done; the *P* value was statistically significant (0.001).

Greater trochanter to lesser trochanter distance (GT-LT)

The mean value of the Greater trochanter to lesser trochanter distance was 64.24 mm. Among males, it ranged from 56.50-82 mm and for the females 56.30-68.60 mm. The mean value for the males was 66.10 mm and for the females, it was 61.81 mm. Statistical analysis was done; the *P* value was statistically insignificant.

Trochanteric region width

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The mean value of the Trochanteric region width was 45.34 mm. Among males, it ranged from 38.90-55.40 mm and for the females 39.70-46.80 mm. The mean value for the males was 66.10 mm, and for the females, it was 61.81 mm. Statistical analysis was done; the *P* value was statistically significant (0.03).

Table 2: Overall mean values

	CW-LT AP	CW-LT ML	NSA	NW(mm)	HS(mm)	VO(mm)	HO(mm)	GT-LT(mm)	TRW(mm)
Mean	14.93	13.18	130.01	29.48	45.03	41.78	34.56	64.24	45.34
Std. Deviation	2.34	1.96	4.80	2.51	2.77	9.84	2.86	6.33	3.47
Minimum	10.1	9.75	121	25	40.24	33.8	27.9	56.3	38.9
Maximum	21.4	18.5	138	35.1	49.91	58.6	38.4	82	55.4
N	30	30	30	30	30	30	30	30	30

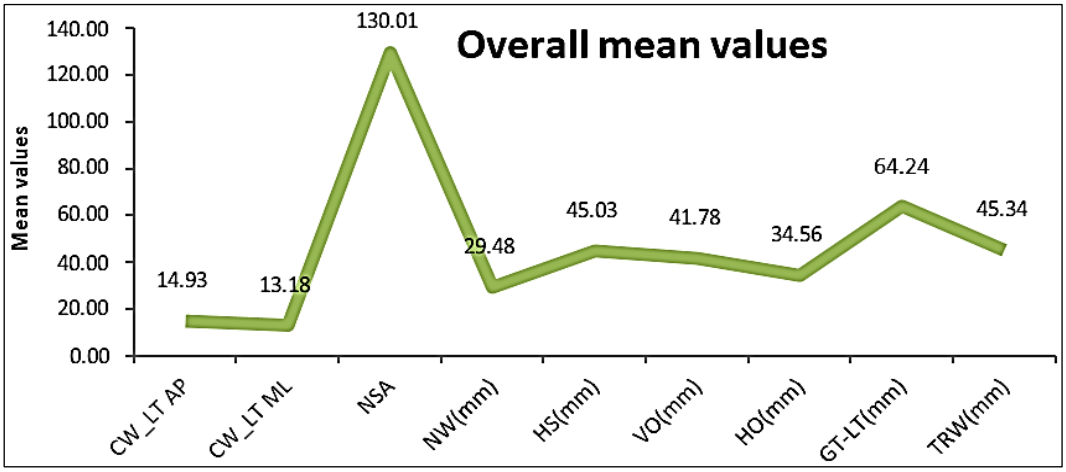
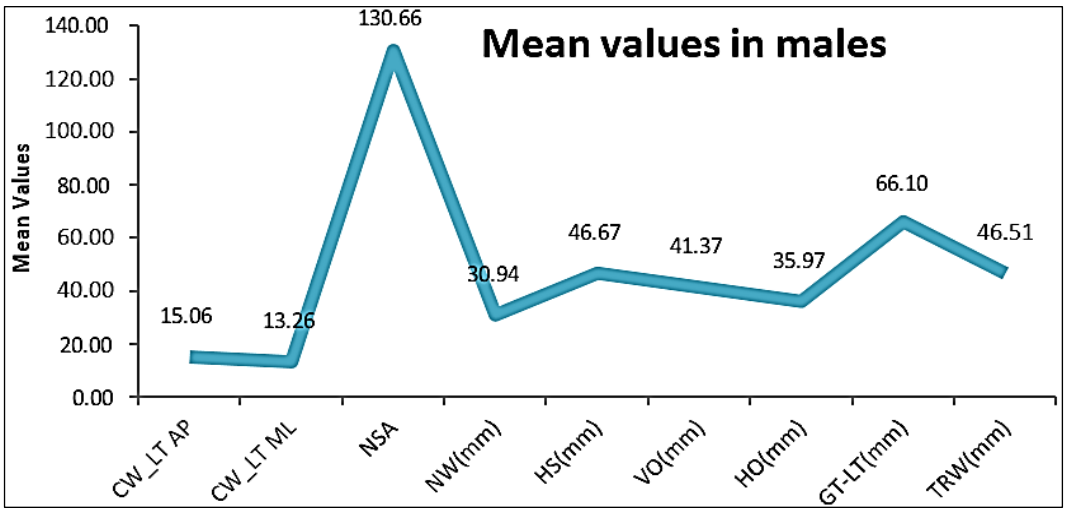


Table 3: Statistical analysis of proximal femoral parameters of our study

	NW (mm)	CW- LT (mm) AP	CW- LT (mm) ML	NSA (mm)	HS (mm)	VO (mm)	HO (mm)	GT-LT (mm)	TRW (mm)
Male	30.93±	15.06±	13.26±	130.66	46.66	41.37±	35.97±	66.10±	46.50±
	1.99	2.90	2.41	±5.05	±1.86	11.52	1.98	7.16	3.96
Female	27.58±	14.77±	13.07±	129.15	42.88	42.32±	32.70±	61.81±	43.81±
	1.74	1.38	1.23	±4.5	±2.27	7.50	2.83	4.14	1.93
p-value	0.001	0.74	0.79	0.39	0.001	0.3	0.001	0.06	0.03
t-value	4.9	0.33	0.26	0.68	5.04	1.09	3.64	1.93	2.2



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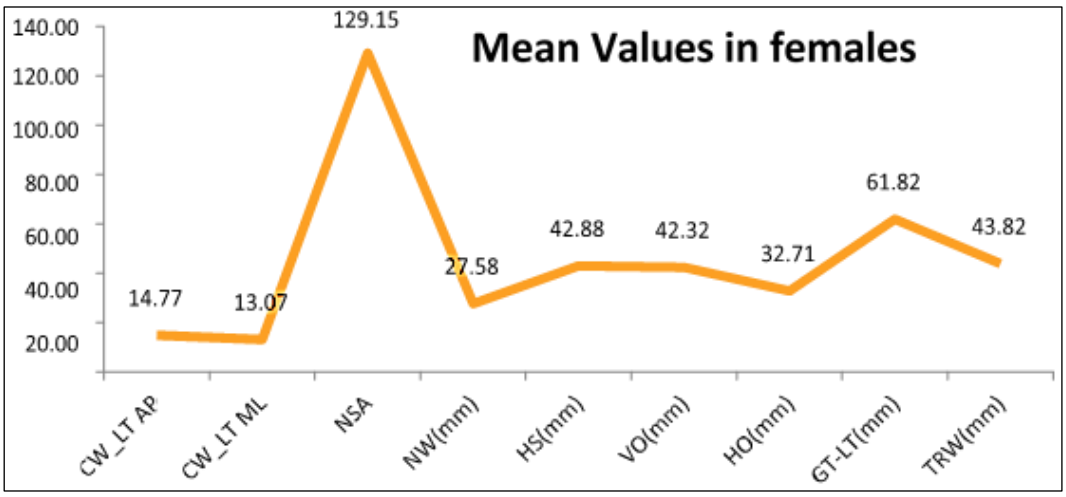

Discussion

Knowledge of the anatomical parameters of the bony components of the hip joint will provide better understanding of anatomical construct and also idea regarding implant design for particular population [9]. The lifestyle and the social customs of the Indian population differ from that of the Western population.

The hip joints of the Indian population is different from their Western counterparts since our population is more apt to floor level activities with increased external rotation of the hip [9].

Differences in the parameters of bone and anatomical variations of the hip joint do exist among different races. The development of computed tomography has helped in further detailed anatomic study of the hip Joint [9].

Various anthropometric studies of proximal femur were done among which Husmann *et al*. [10] and Noble *et al*. [11] used plain radiographs in their study**,** whereas CT scan was used by Rubin *et al*. [12] and Mahaisavariya *et al*. [13] According to Rubin *et al*., CT scan values were more accurate than plain radiographs [12].

In a study conducted by Rubin *et al*. in Swiss population, the femoral HD was 43.4 mm [10]. A study among the Caucasian population by Noble *et al*., the femoral HD was 45.9 mm [9]. In our study, we attained femoral HD measurement of 45.09mm (range 40.24-49.91 mm). Femoral HD value among South Indian population was more while comparing our study with similar studies done in New Delhi by Rawal *et al*. [5] and in Swiss population by Rubin *et al*. [12] [Table 4].

Femoral neck forms an angle with the shaft which is usually 125°-135° in normal adult called neck shaft angle. Functional significance of this angle is that the displacement of femoral shaft away from the pelvis facilitates freedom of hip joint mobility [14]. The results of our study with respect to NSA were compared with Western studies [5, 11, 12]. The NSA of the Western studies was less than our study results (130.01) [Table 4]. Our study was also compared with other Indian studies [4, 6]. The NSA among South Indian population was more than Rawal *et al*. study done in New Delhi [5] [Table 4] and Northeastern study done by Saikia *et al*. [9].

The NSA in males were found more than females which was statistically insignificant in our study [Table 3]. Available cephalo cervical diaphyseal angles in proximal femoral nail are 130° and 135°. In our study, NSA ranges from 121° to 138°. Hence, a routine proximal femoral nail may not replicate the original NSA following surgical fixation in all patients.

Table 4: Comparative analysis of morphometry of hip joint reported in different studies

	Indan studies		Western studies					
Parameters	**Present**	**Rawal**	**Ravichand**	**Saikia**	**Rubin**	**Husmann**	**Mahaisav**	**Noble**

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	study	*et al.* [5]	ran *et al.* [14]	*et al.* [9]	*et al.* [12]	*et al.* [10]	ariya *et al.* [13]	*et al.* [11]
Sample size	n =30	n = 98	n = 578	n = 104	n = 32	n = 310	n = 108	n = 80
Neck width (mm)	29.48 ± 2.51	-	30.99	-	-	-	-	-
Medullary canal diameter at the lesser trochanter (mm)	ML	14.93±2.34	-	-	-	27.9±3.6	-	-
	AP	13.18±1.96	-	-	-	-	-	-
Neck-shaft angle (°)	130.1±4.79	124.42±549	126.55	139.5±7.5	122.9±7.6	129.2±7.8	128.04±6.14	125.4
Femoral head diameter (mm)	45.02±2.77	45.41±3.66	-	-	43.4±2.6	-	43.98±3.47	45.9
Horizontal offset (mm)	34.55± 2.86	40.23±4.85	-	-	47±7.2	40.5±7.5	-	-
Vertical offset (mm)	41.78±9.83	52.33±7.19	-	-	56.1±8.2	57.3±8.1	48.94±4.95	-
GT-LT	64.24±6.33	-	-	-	-	-	-	-
TRW	45.34±3.47	-	-	-	-	-	-	-

Maintaining the leg length (VO) and HO helps to preserve proper hip biomechanics and improves overall postsurgical patient satisfaction [15, 16]. The horizontal and vertical femoral offsets in our study were 34.55 (range 27.9-38.4 mm) and 41.78 mm (33.80-58.6), which were much lower than the values observed by Western studies of Rubin *et al.* [12], Husmann *et al.* [10] Our study results when compared with a similar Indian study conducted in New Delhi by Rawal *et al.* [5] revealed that HO and VO were less in our study population [Table 3].

In our study, the mean value of medullary canal diameter measured at the level of lesser trochanter in anteroposterior and mediolateral was 15.05mm and 14.76mm respectively among male population [Table 3]. In female population, the mean values were 13.26mm and 13.06mm respectively [Table 3]. In total mean value of medullary canal diameter measured at the level of lesser trochanter in anteroposterior and mediolateral in our study is 14.93mm and 13.17mm, when compared to a similar Indian study Ravichandran *et al.* [17] the mediolateral canal diameter at the level of lesser trochanter is less.

The proximal femoral nail antirotation (PFNA) was introduced by the Arbeitsgemeinschaft fur Osteosynthesefragen (AO)/Association for the Study of Internal Fixation group in 2004 [18, 19]. for unstable intertrochanteric femur fracture fixation [3]. Despite the wide use of PFNA and satisfactory outcomes with low major complication rates, lateral cortex impingement in Asian patients has been reported [20]. Then Asian version that is PFNA-II was introduced in 2008 which was designed to accommodate Asian anatomic characteristics:

1. The proximal nail diameter was reduced from 17 mm to 16.5 mm.
2. The mediolateral angle was reduced from 6° to 5°.
3. A flat proximal lateral surface was adapted to avoid impingement of the femoral lateral cortex.
4. 105 mm in proximal segment length [21].

The standard length of proximal segment in PFNAII is 105mm which is more than the mean value of GT to LT distance measured in our study which is 64.23mm. This might lead to nail protrusion and causes soft tissue irritation, pain and disturbance in daily activity.

In our study mean value of trochanteric region width was found to be 45.34mm. Mean TRW in male and female are 46.5mm and 43.81mm. p value is found statistically significant. Trochanteric region width in females is lea than males.

Macheras *et al.* [22] retrospectively reviewed 108 unstable pertrochanteric fractures treated with PFNA or PFNA-II and concluded that PFNA-II could avoid lateral cortex impingement while providing fast and stable fixation of unstable pertrochanteric fractures.

Normally, a minimum of three cancellous screws was necessary, while fixing the fracture neck of femur. The diameter of cancellous screw is 6.5 mm. The lowest value of the NW in our study was 25mm; hence, fixation with three screws will be practically difficult. Cephalomedullary nail study done by Pathrot *et al.* also suggested design modifications for Indian population with lesser NW [2].

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Medullary canal width at lesser trochanter in both anteroposterior and mediolateral in our study are less compared to western population (Rubin *et al*.) [12]. Proximal diameter of PFNA-II is 16.5mm which is more than mean values of canal width at lesser trochanter, hence needs further reduction of proximal segment diameter in PFN to avoid complications like splintering and fracture site distraction.

The mean value of the proximal femoral CW-LT AP, CW-LT ML, NW, NSA, HD, HO, VO, GT-LT, TRW of male are found to be higher than female and NW, HS, HO, TRW are statistically significant [Table 3].

Conclusion

Proximal femoral parameters of south Indian population vary from westeren population and other Indian population studies. In our study we found that the greater trochanter to lesser trochanter distance is significantly less and needs reduction in length of proximal segment height of PFN nails for south Indian population to avoid nail impingement. Similarly diameter of proximal segment of PFN nail has to be further reduced for south Indian population.

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