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A Study of Morphometric Analysis of Proximal End of Femur and its Clinical Implications

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ABSTRACT

The parameters of proximal femur vary with age, gender, race, heredity, ethnicity and geographic factors. The knowledge of population specific parameters of femur is crucial in selection of proper size of implant for Total Hip Arthroplasty (THA) which in turn affect post-operative outcome. In present study, we measured parameters of proximal femur, analyzed any significant difference between two sides of body and compared with other ethnic populations of world. Around 80 dry human cadaveric femurs of unknown age and sex were studied to determine the morphology of the proximal end of femur. The measurements were taken using sliding Digital Vernier Caliper (with 0.01 mm precision), Goniometer and Osteometric board. Length of Femur (FL), Vertical Diameter of Head (VHD), Transverse Diameter of Head (THD), Femur Anterior Neck Length (FANL), Femur Neck Width (FNW), Femur Neck Thickness (FNT) and Femur Neck Shaft Angle (FNSA), were measured. Mean and standard deviations were calculated for all parameters. Unpaired t test applied to find any significant difference between two sides. We observed no significant difference between two sides. Pearson Correlation coefficient was used to analyze relationship between different parameter. We found high association between femur length and dimensions of head and neck. The data obtained from present study will provide population specific parameters of proximal femur. Such knowledge may help in proper designing and construction of hip prosthesis suitable for Indian population. It may contribute in better post-operative outcome by attaining good hip joint functionality.

INTRODUCTION

Femur is the longest and strongest bone of human body^[1]. It forms the skeleton of thigh and transmits body weight during standing, walking and running^[2]. It consists of proximal end, shaft and distal end. The proximal end has head, neck and two trochanters: greater and lesser. The head forms hip joint, the shaft is stout and anteriorly convex, while two condyles at the distal end forms the knee joint^[3]. The neck of femur is the commonest site of fracture at proximal end and in most cases it requires internal fixation with a variety of implants ranging from partially threaded screws to total hip arthroplasty^[4,5]. Total Hip Arthroplasty (THA) is the method of choice for treating diseases of hip of different etiology^[6]. The outcome of THA with regard to post-operative functionality is largely dependent on proper size and design of implant, besides skill of surgeon. Use of improperly designed and ill fitted implants results in non-fixation and breakage of implant followed by non-union, thereby increasing morbidity and cost of treatment^[7,8]. The anthropological parameters of bones depend on genetic and environmental factors such as age, sex, lifestyle, physique, locomotive forces encountered and their distribution on the bones. This leads to racial variations in parameters of bones among different population^[9,10]. Accordingly parameters of proximal femur also vary among different populations. Currently most of the implants used in Indian population are designed on the basis of morphometric data of western population. Use of properly designed implants based on morphometry of local population will help to avoid post-operative complications^[11]. Thus knowledge of parameters of proximal femur is crucial in planning of osteotomy and proper designing of implants preoperatively^[12]. Further they are useful in determining length of femur as well as stature and sex of an individual in forensic medicine and anthropology^[13,14]. The present study was designed to study the parameters of proximal femur in Gujarat and comparing the results with other ethnic populations across the world.

MATERIALS AND METHODS

The present study was conducted at the Department of Anatomy, SMIMER Medical College, Surat using bones available in departmental bone bank. Ethical approval was obtained from the Institutional Ethics Committee before the commencement of the study (SMIMER/IEC/OUT/No.53 dated 24/06/2024). Around 80 dry human cadaveric femurs of unknown age and sex were studied to determine the morphology of the proximal end of femur. The bones having any deformity particularly in the study area were excluded from the study. All measurements were taken using sliding Digital Vernier Caliper (with 0.01 mm precision),

Goniometer and Osteometric board. At first bones were divided into right and left on the basis of side. Then with lead pencil fixed points were marked on each bone to measure different parameters. All measurements were taken by a single author to avoid any inter observer error and each measurement was repeated thrice to avoid any intra observer error. Arithmetic average of the three readings was considered as the final reading for the study.

The Following Parameters were Measured:

- **Length of Femur (FL):** It was measured as the distance from the highest point of the head of femur to the lowest point of the medial condyle of femur after placing the femur in a position parallel to the surface of osteometric board so that shaft of femur remains internally rotated (**Fig. 1**).
- **Vertical Diameter of Head (VHD):** It was measured as the distance between most superior and inferior points on articular margin of head in vertical plane (**Fig. 2(a)**).
- **Transverse Diameter of Head (THD):** It was measured as maximum distance of femoral head on articular margin in horizontal plane (**Fig. 2(b)**).
- **Femur Anterior Neck Length (FANL):** It was measured as the distance between the base of head and mid-point of inter trochanteric line anteriorly (**Fig. 3(a)**).
- **Femur Neck Width (FNW):** It was measured as the diameter of the femoral neck in cranio-caudal axis (cc-axis) was measured as the distance in a straight line from the upper end to the lower end of the anatomical neck of the femur (**Fig. 3(b)**).
- **Femur Neck Thickness (FNT):** It was measured as the diameter of femoral neck in antero-posterior (sagittal) axis in a straight line from the front end to the rear end of the femur (**Fig. 3 (c)**).
- **Femur Neck Shaft Angle (FNSEA):** It was measured as the angle intersected between the long axis of the shaft of femur and the long axis of the neck of femur. Femoral shaft axis was considered as a vertical line from the tip of greater trochanter and femoral neck axis was drawn by joining the centre of head of femur and the midpoint of intertrochanteric line. NSA was measured in the frontal plane by means of goniometry (**Fig. 4**).

The data was tabulated in Microsoft Office Excel 2016 software (Microsoft Corporation). The results were tabulated and analyzed using descriptive statistics.

Statistical Analysis: Mean and standard deviation of each parameter were obtained using SPSS 29. To find difference of mean between two sides, unpaired 't' test was applied. Correlations between different parameters were obtained using Pearson's Index [Open Epi software].



Fig. 1: Measurement of Length of Femur (FL)



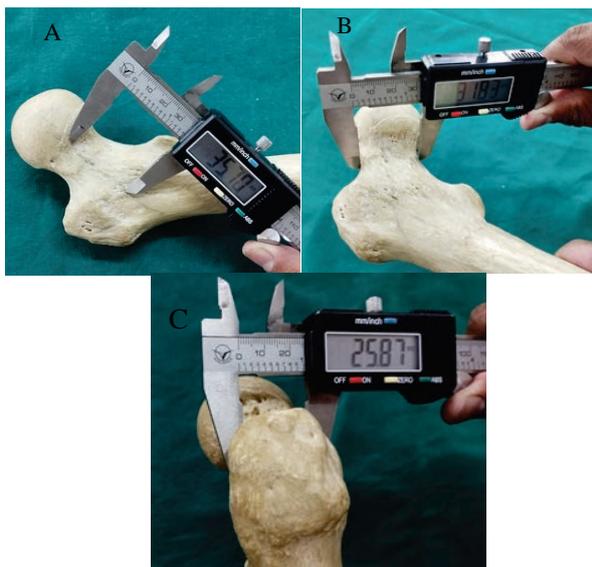
Fig. 4: Measurement of Femur Neck Shaft Angle (FNSA)



(a) Vertical Diameter of Head (VHD)

(b) Transverse Diameter of Head (THD)

Fig. 2: Measurements of Dimensions of Head of Femur



(a) Femur Anterior Neck Length (FANL)

(b) Femur Neck Width (FNW)

(c) Femur Neck Thickness (FNT)

Fig. 3: Measurements of Dimensions of Neck of Femur

RESULTS AND DISCUSSIONS

The mean and standard deviation all parameters are presented in (Table 1). Statistical analysis reveals no significant differences between right and left side for all parameters. Correlations between different parameters of femur are presented in (Table 2). We found a high correlation among length of femur, vertical diameter of head, transverse diameter of head and femur neck length. A comparative analysis of parameters of proximal femur among studies conducted in different regions of India is presented in (Table 3). The length of femur (FL) were 426.62 ± 15.82 , 435.1 ± 26.0 , 428.2 ± 28.7 , 446.2 ± 26.39 and 369.0 ± 41.1 ., femur anterior neck length (FANL) were 34.55 ± 3.78 , 29.75 ± 5.30 , 44.75 ± 8.09 , 36.3 ± 4.2 and 37.23 ± 4.65 ., femur neck shaft angle (FNSA) were 125.27 ± 2.54 , 125.96 ± 6.10 , 128.90 ± 4.49 , 137 and 123.5 ± 4.34 respectively in different studies^[15-19]. VHD were 39.60 ± 2.28 and 40.97 ± 3.46 while THD were 37.69 ± 3.99 and 41.74 ± 2.76 respectively^[15,16]. FNW reported to be 31.60 ± 2.32 , 33.02 ± 4.22 and 31.87 ± 2.91 while FNT were 26.47 ± 3.20 , 24.01 ± 3.05 and 24.90 ± 2.94 respectively^[15,17,19]. Various studies about parameters of proximal femur were conducted in other Asian countries^[20,21] as well as in other ethnic populations of the world^[22-26] (Table 4). R.C. Siwach *et al* compared the femoral parameters of Indian cadavers with those of western, Chinese and Hong Kong population^[19]. M.Y. Baharuddin *et al* concluded that femur in Malaysian population were generally smaller than western femur in many morphological parameters^[20]. H.J.Cho *et al* also reported the anatomic and geometric differences of femur in Korean subjects from Americans and Japanese^[27]. He suggested designing of new hip prosthesis for Asian population. E.B. De Sousa *et al* evaluated proximal femur parameters with Auto CAD 2000 in Brazilian population^[28]. Umer *et al* studied morphology of proximal femur in standardized antero-posterior pelvic radiographs in Pakistani population and suggested significant difference from

Table 1: Mean and Standard Deviation of All Parameters for Right and Left Sides, 'p' Value s/o Difference of Mean Between Two Sides

Parameters (mm)	Side	Number of Bones	Mean	Standard Deviation	'P' value	Mean±SD (Total n=80)
Length of Femur (FL)	Right	40	409.25	31.58	0.852	409.88±29.34
	Left	40	410.52	31.49		
Vertical Diameter of Head (VHD)	Right	40	40.66	4.04	0.244	40.15±3.53
	Left	40	39.63	3.73		
Transverse Diameter of Head (THD)	Right	40	39.99	3.60	0.563	39.75±3.28
	Left	40	39.52	3.66		
Femur Anterior Neck Length (FANL)	Right	40	30.99	5.27	0.103	30.0±4.68
	Left	40	29.01	5.45		
Femur Neck Width (FNW)	Right	40	28.10	2.60	0.065	28.80±2.35
	Left	40	29.49	3.72		
Femur Neck Thickness (FNT)	Right	40	23.59	2.48	0.988	23.59±2.11
	Left	40	23.59	2.94		
Femur Neck Shaft Angle (FNSA)	Right	40	124.35	3.68	0.108	124.99±2.56
	Left	40	125.62	3.32		

Table 2: Showing Correlation Between Different Parameters of Femur (R=0.8-1.0: High Correlation, R=0.6-0.79: Moderately High Correlation, R=0.4-0.59: Moderate Correlation., R=0.2-0.39: Low Correlation and R=0.1-0.19: Negligible Correlation., Values with * Mark are Statistically Significant p<0.05)

Parameters		FL	VHD	THD	FANL	FNW	FNT	FNSA
Length of Femur (FL)	Pearson Correlation - R	1	0.890	0.892	0.834	0.564	0.581	-0.067
	Significance 'p' value		<0.05	<0.05	<0.05	<0.05	<0.05	
Vertical Diameter of Head (VHD)	Pearson Correlation- R	0.89	1	0.925	0.82	0.598	0.665	-0.204
	Significance 'p' value	<0.05		<0.05	<0.05	<0.05	<0.05	
Transverse Diameter of Head (THD)	Pearson Correlation - R	0.892	0.925	1	0.790	0.584	0.730	-0.214
	Significance 'p' value	<0.05	<0.05		<0.05	<0.05	<0.05	
Femur Anterior Neck Length (FANL)	Pearson Correlation - R	0.834	0.82	0.790	1	0.552	0.365	-0.03
	Significance 'p' value	<0.05	<0.05	<0.05		<0.05		
Femur Neck Width (FNW)	Pearson Correlation - R	0.564	0.598	0.584	0.552	1	0.438	-0.282
	Significance 'p' value	<0.05	<0.05	<0.05	<0.05			
Femur Neck Thickness (FNT)	Pearson Correlation - R	0.581	0.665	0.730	0.365	0.438	1	-0.079
	Significance 'p' value	<0.05	<0.05	<0.05				
Femur Neck Shaft Angle (FNSA)	Pearson Correlation - R	0.067	-0.204	-0.214	-0.03	-0.282	-0.079	1
	Significance 'p' value	<0.05						

Table 3: Showing Comparison of Parameters of Present Study with Regional Studies Across India

Parameters (mm)	Present study (Mean±SD)	J.B. Contractor ^[15] (Mean±SD)	S.K. Sinha ^[16] (Mean±SD)	M.Verma ^[17] (Mean±SD)	S.M. Khan ^[18] (Mean±SD)	R.C. Siwach ^[19] (Mean±SD)
Population	South Gujarat	West Gujarat	Bihar	Delhi	South India	North India
Sample size	80	94	50	91	250	150
Type of study	Cadaveric bones	Cadaveric bones	Cadaveric bones	Cadaveric bones	Cadaveric bones	Cadaveric bones
Length of Femur (FL)	409.88±29.34	426.62±15.82	435.1± 26.0	428.2 ± 28.7	446.2±26.39	369.0±41.1
Vertical Diameter of Head (VHD)	40.15 ± 3.53	39.60 ± 2.28	40.97 ± 3.46	--	--	--
Transverse Diameter of Head (THD)	39.75 ± 3.28	37.69 ± 3.99	41.74 ± 2.76	--	--	--
Femur Anterior Neck Length (FANL)	30.0 ± 4.68	34.55 ± 3.78	29.75 ± 5.30	44.75 ± 8.09	36.3 ± 4.2	37.23 ± 4.65
Femur Neck Width (FNW)	28.80 ± 2.35	31.60 ± 2.32	--	33.02 ± 4.22	--	31.87 ± 2.91
Femur Neck Thickness (FNT)	23.59 ± 2.11	26.47 ± 3.20	--	24.01 ± 3.05	--	24.90 ± 2.94
Femur Neck Shaft Angle (FNSA)	124.99 ± 2.56	125.27± 2.54	125.96 ±6.10	128.90 ±4.49	137	123.5 ± 4.34

Table 4: Showing Comparison of Parameters of Present Study with Different Populations of World

Parameter (mm)	Present study (Mean±SD)	M.Y. Baharuddin ^[20] (Mean±SD)	K.J. Lin ^[21] (Mean±SD)	A. Tokpinar ^[22] (Mean±SD)	A. Unnanuntana ^[23] (Mean±SD)	T.M. Menezes ^[24] (Mean ±SD)	P.J. Rubin ^[25] (Mean ± SD)	O.I. Akinmoku ^[26] (Mean±SD)
Population	Indian	Malaysian	Chinese	Turkey	American & Caucasians	Brazilian	French	Nigerian
Sample size	80	120	100	30	200	29	32	56
Type of study	Cadaveric bones	CT reconstruction	Cadaveric bones	Cadaveric bones	Digital Photography	Cadaveric bones	Radiographic reconstruction	Cadaveric bones
Length of Femur (FL)	409.88 ± 29.34	--	--	--	--	--	443.6 ± 21.8	479.0± 21.0
Vertical Diameter of Head (VHD)	40.15 ± 3.53	M: 43.62 ± 3.05 F: 38.85 ± 2.17	45.4	Rt: 42.75 ± 6.14 Lt: 43.83 ± 4.03	52.09 ± 4.43	44.2 ± 4.4 43.8 ± 4.7	43.4 ± 2.6	--
Transverse Diameter of Head (THD)	39.75 ± 3.28	--	--	--	--	--	--	--
Femur Anterior Neck Length (FANL)	30.0 ± 4.68	--	--	Rt: 24.64 ± 4.95 Lt: 27.39 ± 4.24	--	25.5 ± 4.2	--	22.9 ± 3.9
Femur Neck Width (FNW)	28.80 ± 2.35	M: 28.88 ± 3.38 F: 25.95 ± 4.31	31.91	Rt: 29.88 ± 6.71 Lt: 31.99 ± 3.78	--	31.0 ± 3.5 25.0 ± 3.7	--	30.3 ± 2.9
Femur Neck Thickness (FNT)	23.59 ± 2.11	--	--	--	--	--	--	--
Femur Neck Shaft Angle (FNSA)	124.99 ± 2.56	M: 132.33 ± 3.44 F: 129.87 ± 3.95	129.88	--	132.69 ± 5.91	--	122.9 ± 7.6	130.8 ± 7.3

western population^[29]. These studies highlight the racial variations in parameters of proximal femur. Reddy *et al* concluded that a mismatched implant has strong correlation with increased risk of intraoperative fracture as well as postoperative complications, emphasizing the need to design the implants based on anthropometric and bio-mechanic data for a specific population in order to avoid complications^[30]. Besides importance in designing hip prosthesis, the dimensions of femoral head and neck have correlation with risk of fracture and osteoarthritis. El-Kaissai *et al*, in a

retrospective study on Caucasian postmenopausal women, found association between femoral neck dimensions with risk of fracture. He reported longer femoral neck in women with fracture hip than those without fracture. The risk of hip fracture has increased by 24% with every one mili meter increase in the thickness of femoral neck^[31]. Calis *et al* obtained a similar result in Turkish women, where the width and angle of femoral neck were significantly greater in patients with hip fractures^[32]. In male, neck thickness increases with age, which contributes to the

development of osteoarthritis by increasing cam impingement^[33].

CONCLUSIONS

Parameters of femoral head and neck are determinant in designing hip prosthesis. We have found high correlation between said parameters. As subdivisions of Indian population do not have specific implants designed for them, the data of current study may help in designing appropriately fit implants for the population. Further improved knowledge of the morphometric parameters of proximal femur will help orthopedicians during THA. As the study was conducted on dry cadaveric bones, we couldn't ensure that right and left sided femurs belonged to a particular individual. We also did not categorize the data for gender, but it will be noteworthy to observe any significant difference between genders.

Ethics Approval and Consent to Participate: Ethical approval was obtained from the Institutional Ethics Committee before the commencement of the study (SMIMER/IEC/OUT/No. 53 dated 24/06/2024).

List of Abbreviations:

FL: Length of Femur.,	VHD: Vertical
Diameter of Head.,	THD: Transverse
Diameter of Head.,	FANL: Femur
Anterior Neck Length.,	FNW:
Femur Neck Width.,	
FNT: Femur Neck Thickness.,	
FNSA: Femur Neck Shaft Angle	THA:
Total Hip Arthroplasty	

Conflicts of Interest: The authors declare that there is no conflict of interest regarding the publication of this paper.

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