



PROXIMAL FEMORAL GEOMETRY IN SOUTH INDIANS AND ITS CLINICAL IMPLICATIONS WITH BILATERAL VARIATIONS

Anatomy

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ABSTRACT

Background and aims: The knowledge of proximal femoral geometry is of utmost importance for designing the best femoral implants. Fractures of proximal femur involving the neck and trochanters are quite common. The increase in osteoarthritis cases in India is high. The final management in both the cases is total hip replacement with femoral implants. These implants are designed for western population whose constitutional and biomechanical factors vary from South Indian population. Race, climate, heredity and geographical areas have strong influence over the anthropometric parameters of bone. Hence this study is carried out to analyze the dimensions of proximal femora in South Indians and compare the results with the dimensions of available femoral implants and the available data from different regions including bilateral variations in unpaired femora.

Materials and methods: 50 Right and 50 Left dry human femora along with commonly used implants such as DHS PFN, Cancellous screws were studied. The parameters of proximal femora studied are NSA, Length of neck, Height of neck, width of neck and vertical diameter of the head of femora. Dimensions obtained were measured according to standard anthropometric guidelines and compared with the implants and the available data from different regions.

Result: Significant variations were seen in the obtained dimensions between proximal femoral parameters, implants and the available data. NSA has shown significant variations in unpaired femora with 127.70 in left femora and 125.70 in right femora.

Conclusion: Present study concludes that significant differences were found between the dimensions of South Indian proximal femora and the available data from different regions indicating ethnic variations. The bilateral variations of NSA are seen in unpaired femora. Therefore implants designed which are available in standard sizes mismatch South Indian femora. This study enlightens the Orthopaedic surgeons and Biomechanical engineers.

KEYWORDS

Femur, Implants, Fracture, Dimensions, Geometry, NSA (neck shaft angle), DHS (Dynamic Hip screw), PFN (Proximal femoral nail).

INTRODUCTION

The morphology of the proximal femur, specifically the relationships among the head, neck and proximal shaft has been the subject of interest and debate in orthopaedic literature¹. The proximal femur in humans is subjected to a large variety and magnitude of forces during day to day activities². Operations on the proximal femur are one of the commonest in orthopaedic surgical practice as fractures of femur involving the neck and trochanters are quite common. The aim of these surgeries is to remove pathology and restore anatomy to normal as far as possible.³ The rise in the geriatric population in India will increase the morbidity due to osteoarthritis. Total hip replacement is the most common, permanent and effective surgical procedure available for the treatment of osteoarthritis of the hip joint.⁴ The morphology of proximal femur is a topic of extensive research. The hip joint is one of the most commonly replaced joint⁵ Orthopaedicians and Radiologists use the normal range and mean of the NSA in the diagnosis and treatment of the diseases of hip. The neck shaft angle is important clinically for the diagnosis, treatment and follow up of fractures of neck of the femur, trochanteric fractures, slipped upper femoral epiphysis, developmental dysplasia of the hip and neuromuscular disorders of the lower extremity⁶. Most of the textbooks mention the average NSA as 125° and according to Gray's Anatomy average NSA is 135°⁷. In early infancy, the NSA is about 150 degrees, in childhood about 140 degrees, in adults about 125°, and in the elderly about 120°⁸. NSA has been studied by many workers like Kate, Hoagland, Noble PC, Ravichandran, BR. Rawal, Isaac and many others.

The basic purpose of this study is to collect the data on people of South India, whose built, physique, habits, genetic makeup and personal lifestyles are different from Western countries, whose data base regarding anthropometry of proximal femur is available.

It is mandatory that the design and dimensions of the femoral component should match the anatomy of the femur to avoid complications like avascular necrosis, malunion, nonunion and intraoperative complications⁶. The common implants used for the surgical treatment of proximal fractures include DHS, PFN, Cancellous screws, TFN, etc.^{6,9&10}.

Review of literature showed scarcity in information of proximal

femoral dimensions like neck shaft angle, width of neck, height of the neck, length of neck and vertical diameter of head in South Indian population. Hence this study is carried out to analyze the dimensions of proximal femora in South Indians and compare the results with the dimensions of the femoral implants which are being commonly used as per Western standards and also the bilateral differences in obtained dimensions are analyzed.

Material and Methods

50 right and 50 left femora are collected from the departments of Anatomy Government Medical college Nizamabad and Kakatiya Medical College Warangal were utilized for this study. Commonly used implants such as DHS, PFN, Cancellous screws were obtained from the Orthopaedic Departments of Government General Hospital Nizamabad and Mahatma Gandhi Hospital Warangal (photo.1). Their dimensions are tabulated in table no.1



photo.1 Common implants-Cancellous screw, DHS plate, PFN



Photo.2. Determination of axis of neck



Photo.3 Determination of axis of shaft

Neck shaft angle is angle made by the axis of anterior neck of femur with axis of the shaft of femur. The neck shaft angle is measured according to the guidelines given by Singh and Basin 1968^{6,11}. The axis of the neck or column is determined by a thread dividing the anterior surface of the neck into two equal halves (Photo.2). The axis of the shaft is determined by a thread which extends in the mid sagittal plane over the anterior surface of the bone from the upper end of the oblique line of condyles (Photo.3). In case of strongly developed torsion, take only the axis of upper shaft into consideration. This angle is measured by using Goniometer (photo.4)^{6,11}.

The length of the neck is measured along long axis of neck. Anterior neck length is measured as a distance between the base of head and mid point on the intertrochanteric line (Photo.5). Posterior neck length is measured as distance between the base of head and mid point of intertrochanteric crest. It is measured by using Vernier calipers⁶.

The height of the neck or superoinferior diameter of the neck measures the least distance between the upper and lower margins of the neck (photo.6)¹¹. Anteroposterior diameter or width of the neck measures the distance

between the anterior and posterior surfaces of neck taken at right angle to the vertical diameter¹¹. These are measured by using Vernier callipers. The vertical diameter of head of femur measures the straight distance between highest and deepest points of head (photo.7). It is measured by using Vernier Callipers (Singh and Bhasin)



Photo.4 Determination of Neck shaft angle



Photo.5 Determination of anterior neck length



Photo.6 Determination of height of neck

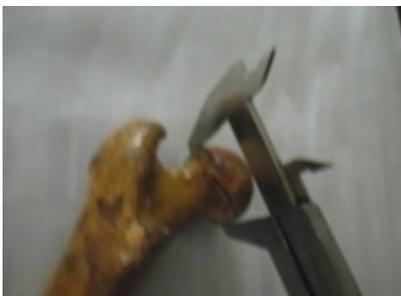


Photo.7 Determination of vertical diameter of head

Results

The dimensions of implants used for treatment are tabulated in table I. The descriptive statistics (frequency, mean, range, standard deviation, standard error) for the variables NSA, Length of neck, Height of neck, Width of neck and Vertical diameter of the femoral head are presented in table II & III. These are statistically analyzed by using Microsoft Excel. 50 right and 50 left femora used in this study which are unpaired. Bilateral variations with P values is presented in table IV. Comparison of variables studied and dimensions of implants are presented in table V, VI and VII

Table – I : Dimensions of Orthopaedic Implants commonly used for treatment of Proximal Femoral Fractures

IMPLANTS	DIMENSIONS
1. DHS plate Barrel diameter Plate thickness Barrel width Barrel length Barrel angle	12.6 mm 5.8mm 19.0 mm 38 mm long , 25 mm short 120° – 150° (135° commonly used)
2. DHS Lag screw Thread diameter Thread length Shaft diameter Screw length	12.5mm 22.0 mm 8.0mm 80-100 mm (85 mm commonly used)
3. Cannulated Cancellous screw Thread diameter Shaft diameter Length	6.5 mm 4.5 mm 25 – 120 mm
4. Proximal Femoral Nail Standard angle PFN Lockingscrew(inferior) thread diameter Length PFN Locking screw (superior) – thread diameter Length	125° / 130°/135° 9.2 mm 70 -120 mm(85 mm commonly used) 6.3 mm 55 – 120 mm (70 mm commonly used)

Table-II:Descriptive statistics of right femora

Variable	Frequency	Mean	Range	Std. Dev	Std. Error	Mean+/-2SE
NSA (degrees)	50	125.7°	116° - 135°	4.43	0.627	124.44°-126.95°
Length of Neck (cm)	50	3.164	2.6-4.6	0.40	0.0579	3.048---
Anterior	50	3.578	2.7-5.2	9	0.0678	3.279
Posterior		3.371		0.47	0.0628	3.442---
Mean (cm)				9		3.713
				0.44		3.2454---
				4		3.4966
Neck Diameter (cm)	50	3.036	2.5-3.6	0.28	0.0398	2.9564---
Superoinferior (height)	50	2.632	2.2-3.2	1	0.0361	3.1156
Anteroposterior (width)				0.25		2.559---
				5		2.7042
Vertical Diameter of Head (cm)	50	4.212	3.6-5.0	0.35	0.049	4.114—4.31

Table – III :Descriptive Statistics of Left Femora

Variable	Frequency	Mean	Range	Std. Dev	Std. error	Mean=/-2SE
NSA (degrees)	50	127.74°	119°- 139°	4.19	0.593	126.55°-128.92°
Length of neck (cm)	50	3.118	2.6-4.0	0.328	0.0464	3.0252-
Anterior	50	3.566	2.8-4.6	0.409	0.0578	3.210
Posterior		3.342		0.368	0.0521	3.450-3.681
Mean						3.240-3.443

Neck Diameter (cm)	50	3.05	2.6-4.0	0.322	0.0455	2.959-3.141
Superoinferior (height)	50	2.648	2.2-3.1	0.253	0.0358	2.577-2.719
Anteroposterior (width)						
Vertical diameter of head (cm)	50	4.118	3.5--5	0.328	0.0463	4.025-4.210

Table-IV: Showing dimensions of right and left femora with P-values

Variable	Frequency	Right Femora	Left Femora	P- value		
		Mean	Std. Dev	Mean	Std. Dev	
NSA (degrees)	50	125.7 ^o	4.43	127.74 ^o	4.19	0.0200
Neck length (cm)	50	3.371	0.444	3.342	0.368	0.7229
S I diameter (cm)	50	3.036	0.281	3.05	0.322	0.8173
A P diameter (cm)	50	2.632	0.255	2.648	0.253	0.7535
Vertical Diameter (cm)	50	4.212	0.350	4.118	0.328	0.1690

Table-V: Comparison between the dimensions of South Indian Right and Left Femora and dimensions of Dynamic Hip Screws

Variable	Present	Study	Dimensions of Implants
	Right	Left	
Neck Shaft Angle	125.7 ^o	127.74 ^o	120 ^o /125 ^o /130 ^o /135 ^o /140 ^o /145 ^o /150 ^o (barrel angle 135 ^o commonly used)
Length of Neck	3.371 cm	3.342cm	2.2 cm (thread length of lag screw)
Anteroposterior diameter of neck (width)	2.632cm	2.648cm	12.6mm+ 5.8mm=18.4mm i.e.1.84cm (barrel diameter + thickness)
Vertical diameter of head	4.212 cm	4.118cm	12.5 mm + 6.5mm = 19 mm i.e. 1.9 cm (thread diameter of lag screw + CC screws)

Table –VI : Comparison between the dimensions of South Indian Right and Left Femora and dimensions of Cannulated Cancellous Screws

Variable	Present Study	Left	Dimensions of Implants
	Right		
Anteroposterior diameter of neck (width)	2.632cm	2.648cm	6.5 mm (three screws used commonly- 6.5 x 3 = 19.5 mm i.e. 1.95 cm)
Vertical Diameter of Head	4.212 cm	4.118 cm	6.5 mm (three screws used commonly - 6.5 x 3 = 19.5 mm i.e. 1.95 cm)

Variable	Present Study		Dimensions of Implants
	Right	Left	
Neck Shaft Angle	125.7 ^o	127.74 ^o	125 ^o / 130 ^o / 135 ^o (standard angle of PFN)
Anteroposterior diameter of neck (width)	2.632cm	2.648 cm	9.2 mm +6.3 mm = 15.5 mm i.e 1.55 cm (thread diameter of PFN screws)
Vertical Diameter of Head	4.212 cm	4.118 cm	9.2 mm + 6.3 mm = 15.5 mm i.e. 1.55cm (thread diameter of PFN screws)

Table -VII: Comparison between the dimensions of South Indian Right and Left Femora and dimensions of Proximal Femoral Nail and its Locking Screws

Discussion

Knowledge of the proximal end of femur serves as a basis for the treatment of pathological condition of femur and hip¹². Fractures of the proximal femur involving the neck and trochanters are quite common. It is a prerequisite for the complete understanding of mechanics of hip joint. The orthopaedic implants are considered universally applicable to all skeletons, irrespective of the differences among various ethnic groups. Although different sizes of same design generally are available from manufacturers, there is little evidence that ethnic morphologic differences are taken into account in orthopaedic implant design². Size of implants mismatch South Indian femora. Any alteration of the normal physiology and Anatomy is likely to affect the end functional result³.

Kate 1967 worked on 1000 femora of Indians and obtained the average NSA as 128.4^o. Moreover he found a difference in the angle between various races of India, the largest angle being 133^o from Madurai and smallest angle 122^o from Mumbai. He also mentioned the Formosans to have the lowest average NSA 125.6^o and the Andamanians the highest angle 134^o¹³. Isaac B et al 1993 found average NSA 126.7^o in South Indians⁵. Siwach 2003 found NSA as 123.5^o in Indians². Saikia KC (2008) has reported NSA in North Eastern population as 139.5 degrees which is higher as compared to others, because the North Eastern part of India is inhabited by numerous endogenous tribes and castes that have their own distinct social, linguistic and biological identity¹⁴. Ravichandran (2011) found average NSA as 126.5 degrees in Indians⁶. Noble PC et al 1988 found NSA as 124.7 degrees in Caucasians USA¹⁵. Too good et al (2009) found NSA as 129.3^o in Caucasians and African-Americans. Hoaglund FT, Low LD (1980) found the average NSA of Caucasians as 136 degrees and 135 degrees in Hong Kong Chinese. He concluded that there are significant differences in dimensions of proximal femoral geometry between Caucasian and Hong Kong Chinese population¹⁶. In the present study, the average NSA of right femur is 125.7^o and average NSA of left femur is 127.74^o.

Ravichandran (2011) found mean neck length as 3.188cm⁶, Siwach (2003) found maximum neck length as 3.72cm, minimum neck length as 2.26cm³. Rawal BR(2012) found it to be 4.8cm¹⁷, whereas, Noble PC et al (1988) found average neck length as 3.55cm (Western study)¹⁵ and Desousa et al (2010) study on Brazilians found it to be 3.04cm¹⁸. In the present study the mean length of the neck of right and left femora are 3.371 cm and 3.342cm respectively.

Siwach 2003 observed the mean diameter of the neck as 3.18cm superoinferiorly and 2.49cm anteroposteriorly³. Hoagland and Low 1980 found it to be 3.3cm in Caucasians and 3.1cm in Hong Kong Chinese¹⁶. Ravichandran 2011 found it to be 3.097cm⁶ and Desousa 2010 found mean width of neck as 3.09cm¹⁸. In the present study mean diameter of neck of right femora is 3.036 cm superoinferiorly (height of neck) and 2.632cm anteroposteriorly (width). The mean diameter of neck of left femora is 3.053cm superoinferiorly and 2.648cm anteroposteriorly Reddy et al (1999) obtained head diameter as 4.51cm¹⁹, Chauvan R et al (2002) found vertical diameter of femoral head as 4.54cm in right femora, 4.58cm in left femora of males and 4.38cm in right femora, 4.46cm in left femora of females²⁰. Hoagland and Low (1980) found it to be 4.6 cm in Caucasians and 4.5 cm in Hong Kong Chinese¹⁶. AK Mishra (2009) found it to be 4.42cm², whereas Noble PC found average femoral head diameter as 4.61cm¹⁵. In the present study the mean vertical diameter of head in right and left femora are 4.212cm and 4.118cm respectively.

Race, climate, heredity and geographical areas have strong influence over the anthropometric parameters of bone²⁰. Ian Gilligan (2010) studied on extensive sampling of more than 8000 femora from over 80 countries. Results indicate that while climatic factors are implicated in intergroup and regional variation, additional factors such as cultural buffering from the environment—especially regular use of thermally effective clothing which alter the microenvironment of the body need to be considered²¹. Therefore it is clear that the proximal femoral geometry varies among different ethnic groups.

Dimensions obtained in this study are compared with the dimensions of the available orthopaedic implants (table nos 17,18&19) , and it is observed that these implants mismatch the South Indian femora due to their large size. The orthopaedic implants used in the treatment of fractures are based on the Caucasian model with cervical diaphysal angle of 135^o (Hoaglund & Low, 1980; DHS/DCS-system

standard, 1997)¹⁸. Use of such implants in South Indians not only affect the functional end result of surgery but also negate the very purpose of internal fixation and an early rehabilitation. Crucial elements for the choice of fracture fixation and implant is the quality of bone. Any fixation method used in osteoporotic fractures should be safe and easy to apply with regard to complications and outcome¹⁰. Earlier they used Fixed angle nail plates. The experience with Fixed angle nail plates devices indicated the need for a device that would allow controlled fracture impaction. This gave rise to Sliding nail plates devices, which later on gave rise to Sliding hip screws, which are being used commonly with 135° plates⁹. The DHS has proved to be superior to fixation by screws alone or by angled blade plates¹⁰. The DHS, PFN, TFN, Cannulated Cancellous Screws etc., are used commonly in the treatment of proximal femoral fractures. Insertion of these screws needs reaming which removes available cancellous bone. Screws with large thread diameter occupy greater area in the neck and head of femur. Such a large area drilled in the neck of South Indian femora takes away viable cancellous bone. Therefore it is clear that these screws occupy more space in the neck and would cause tamponade effect resulting in non union and avascular necrosis^{6,3}. Based on the observations in this study, it is clear that there are significant differences between the dimensions of South Indian femora, and Western population.

This study also undertook to find out the differences between the unpaired right and left femora. Olav Reikeras et al 1982 studied with regard to bilateral differences concluded that average bilateral differences in femoral neck angle were not significant, but individual variations were considerable¹². Issac B et al (1993) found the neck shaft angle ranging from 120° to 136° with a mean of 126.7° with no significant side differences⁸. In the present study little difference is found in the dimensions of right and left femora except NSA which are 125.7° in right femora and 127.74° in left femora. The P value of NSA obtained is considered to be significant which is 0.0200. P values of Necklength (0.7229), SI & AP diameters of neck (0.8173 & 0.7535) and vertical diameter of head (0.1690) are found to be non significant.

Conclusion

In the present study significant differences were found between the dimensions of South Indian proximal femora and the available data from different regions indicating ethnic variations. As race, climate, heredity and geographical areas have strong influence over the anthropometric parameters of bone, proximal femoral geometry varies among different ethnic groups. Thus the implants designed for Western skeleton mismatch South Indian femora, as there are significant differences between the dimensions of the two. Implants that are designed by taking into account, anthropometric and biomechanical data may help in designing patient specific implants thereby preventing complications.

Unpaired femora when compared bilaterally, a little difference is found in parameters of proximal femora with less significance, except the neck shaft angle which is 127.74° in left femora and 125.7° in right femora.

However, in future further analysis and refinement in methodology may be expected to clarify these findings and address some of the unresolved questions regarding these parameters.

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