Section: Anatomy

Original Research Article

STUDY ON MORPHOMETRY OF PROXIMAL FEMUR

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Abstract

Background: Femur is the longest and heaviest bone in the human skeletal system, supporting the body's weight during standing, walking and running. **Aim:** This study aims to perform an osteometric analysis of the upper end of the femur, focusing on the qualitative and quantitative measurements of the femoral head, neck, greater and lesser trochanters, intertrochanteric line, and intertrochanteric crest. **Materials and Methods:** This cross-sectional observational study was conducted on 100 (50 right and 50 left) adult dry femora at the Institute of Anatomy, Madurai Medical College. Adult human dry femur bones of both sexes in the Institute of Anatomy, Madurai Medical College, were included. Bones with visible osseous pathologies like tumours, deformities, fractures, and Trauma were excluded. **Result:** There is no significant difference in head vertical diameter, head transverse diameter, neck vertical diameter, and head length superiorly, head length inferiorly, neck length superiorly, neck length inferiorly, intertrochanteric length and neck-shaft angle on comparing both sides. There is a significant difference in neck Transverse diameter on comparing both sides with a p-value of <0.01. Quantitatively, there is no significant difference in all the Proximal Femoral Osteometric Parameters on the right and left sides. But there is a significant difference in Neck Transverse Diameter on comparing both sides with a p-value of <0.01. **Conclusion:** The values of all the parameters are greater in the Western population than in the present study. This study will help the Orthopedicians and prosthetists to build suitable prosthesis for Indians.

INTRODUCTION

Bone is a dynamic tissue that adjusts to the physiologic and mechanical demands of the body, providing rigid attachment sites for muscles and acting as a system of levers to amplify small movements.[1] Femur is the longest and heaviest bone in the human skeletal system, supporting the body's weight during standing, walking and running. The femur is divided into three main parts: the proximal portion (Head & Neck), the shaft and the distal portion (lower condyles).[2] It articulates with the hip bone forming the hip joint, and the tibia and patella, forming the knee joint. In the erect posture, the distal ends of the femur become close together towards the knees.

The knee joint's gradual downward and inward inclination is used to increase balanced bipedal mobility. There are metric differences in skeletal components among different populations, and these variations are related to genetic and environmental factors. Anthropometric skeletal measurements show regional diversity between or even within the same people.[3] Skeletal measurements and the shape of bones can guide clinicians in determining the risk factors for fractures, such as hip fractures.[4] The risk of hip fracture can be predicted by factors like BMI, bone mineral density, the direction and severity of the fall, muscle strength, body habitus, femoral morphometry, family history or lifestyle factors.

Femoral geometry has been linked to hip fracture in postmenopausal women, especially to the Femoral Neck Width.[5] The femoral heads support the body's weight entirely, suggesting that the morphometry of the proximal femur may contribute to femoral neck strength. Femoral morphometric parameters, including Femoral neck width, Femoral head width, intertrochanteric width, and Femoral neck-shaft angle, have been related to the mechanical strength of the upper end of the femur. These parameters are also associated with the resistance of bone to impact, the highest values found in races with an increased incidence of hip fracture. Hip joint replacement (hip arthroplasty) is the surgical replacement of all or part of the hip joint with an artificial material. The procedure can be either Total Hip Arthroplasty or a hemiarthroplasty.[6]

Using commonly available implants of western manufacture can lead to thigh pain and inadequate implant fixation, leading to complications such as stress shielding, micromotion and loosening. Leung et al.[7] demonstrated the modified gamma nails to suit the Asian population, as smaller femoral heads can lead to nonunion of neck fractures or AVN. The incidence of intraoperative complications like splintering and fractures ranges from 4 to 21%. These are due to large implants that have been manufactured with western parameters.

The present study is being undertaken to analyse the dimensions of the proximal femur involving the head, neck and trochanters. The standard commercially available marked prosthesis may not be the best fit for Indian patients due to wide anatomic variation, leading to complications such as aseptic loosening, improper load distribution, and discomfort. More accommodating designs are needed to ensure stable fixation to enable proximal and distal filling at the femoral canal. Knowledge is scarce regarding the dimensions of the femur's head, neck and trochanters among the Indian population. This study will help design appropriate implants to suit the Femora of the Indian people and reduce the complication rates.

Aim

This study aims to perform an osteometric analysis of the upper end of the femur, focusing on the qualitative and quantitative measurements of the femoral head, neck, greater and lesser trochanters, intertrochanteric line, and intertrochanteric crest. The study aims to obtain statistical analysis of each parameter by comparing left and right femora measurements and comparing the values obtained with those reported in the literature and commonly used implants in Orthopaedics.

MATERIALS AND METHODS

This cross-sectional observational study was conducted on 100 (50 right and 50 left) adult dry femora at the Institute of Anatomy, Madurai Medical College.

Adult human dry femur bones of both sexes in the Institute of Anatomy, Madurai Medical College, were included. Bones with visible osseous pathologies like tumours, deformities, fractures, and Trauma were excluded.

The following parameters are measured to the proximal end of the femur using Vernier Callipers and Goniometer. Head Vertical Diameter, Head Transverse Diameter, Neck Vertical Diameter, Neck Transverse Diameter, Head Length Superiorly, Head Length Inferiorly, Neck Length Superiorly, Neck Length Inferiorly, Intertrochanteric Length, and Neck Shaft Angle were measured.

For all the 100 femora, a quantitative and qualitative assessment was done. The quantitative data is subjected to statistical analysis (Descriptive), and the results are presented.

The femora were studied qualitatively under the following features. Femoral head: Femoral head appears normal (more than half a sphere). Fovea centralis: Fovea centralis is found to be normal in position in all the specimens (just above the centre of the head), and the shape is rounded in all specimens except in 7 specimens, where it is found to be oval.

Femoral neck: The femoral neck with numerous vascular foramina on its anterior surface is observed. Greater trochanter: It is observed as the quadrilateral bony prominence over the lateral aspect of the head at the junction of the neck and the shaft in all 100 bones.

Lesser trochanter: It is observed as the conical projection over the posteromedial aspect of the femoral head at its junction with the neck in all 100 bones. Except in 2, in which the shape of the lesser trochanter appears to be rounded.

Intertrochanteric line: It is seen as the prominent ridge over the anterior aspect at the femoral neck with the shaft in all 100 bones. Intertrochanteric crest: It is observed as a smooth ridge over the posterior surface at the junction of the femoral neck with the shaft. Gluteal tuberosity: It is observed over the posterior aspect of the femur in all 100 bones except in 3 specimens, in which it is depressed and flat.

All the parameters of the femora on both the right and left sides were tabulated; mean and standard deviation were calculated. The student t-test was applied, and a two-tailed student t-test made the side-wise comparison. A significance level of ($P<0.05$) was used for all analyses.

RESULTS

The present study was undertaken on 100 dry adult femurs. The study was done both qualitatively and quantitatively. Osteometric analysis was done on the proximal end of the femur.

There is no significant difference in head vertical diameter, head transverse diameter, neck vertical diameter, head length superiorly, head length inferiorly, neck length superiorly, neck length inferiorly, intertrochanteric length and neck-shaft angle on comparing both sides [Table 1].

Table 1: Comparison of femora parameters

		Mean	SD	P-value
HVD in mm	Right	41.83	3.75	>0.05
	Left	41.97	4.11	
HTD in mm	Right	43.15	3.55	>0.05

	Left	43.41	3.77	
NVD in mm	Right	31.68	3.43	>0.05
	Left	32.66	4	
NTD in mm	Right	24.24	2.46	<0.05
	Left	25.83	2.95	
HLS in mm	Right	31.38	3.47	>0.05
	Left	32.18	3.49	
HLI in mm	Right	23.13	2.98	>0.05
	Left	22.47	2.79	
NLS in mm	Right	22.91	2.59	>0.05
	Left	23.66	3.62	
NLI in mm	Right	29.11	2.68	>0.05
	Left	30.21	3.40	
IL in mm	Right	56.97	5.99	>0.05
	Left	58.1	6.04	
NSA in mm	Right	129.04	4.47	>0.05
	Left	127.98	4.01	

There is a significant difference in neck Transverse diameter on comparing both sides with a p-value of <0.01 [Table 1, Figure 1].

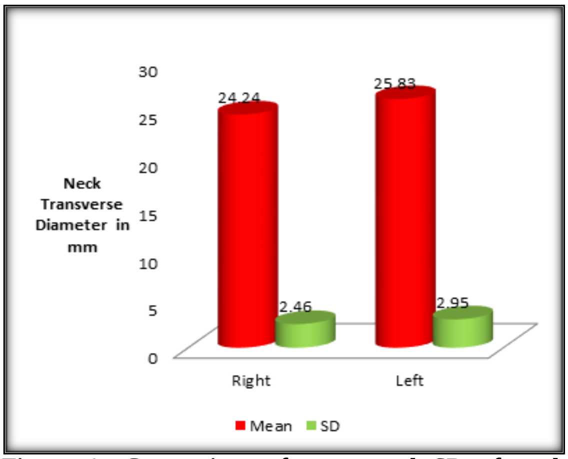

Figure 1: Comparison of mean and SD of neck transverse diameter

Quantitatively, there is no significant difference in all the Proximal Femoral Osteometric Parameters on the right and left sides. But there is a significant difference in Neck Transverse Diameter on comparing both sides with a p-value of <0.01 [Table 2].

Table 2: Showing parameters of femora

Variable	**HVD**		**HTD**		**NVD**		**NTD**		**HL**	
	Right	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**	**Left**
Mean	41.83	41.97	43.15	43.41	31.38	32.16	31.68	25.83	31.38	32.16
SD	3.75	4.11	3.55	3.77	3.47	3.49	3.43	2.95	3.47	3.49
Range	27.4-48.3	28.1-48.1	32.3-50.7	31.4-50.2	21.2-38.5	23.7- 39.3	24.7- 38.7	20- 31.9	20- 31.9	23.7- 39.3
p-value	0.85		0.72		0.18		<0.01		0.25	
	HL (INF)		NL (SUP)		NL (INF)		ITL		NSA	
	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left
Mean	23.13	22.47	22.9	23.66	29.11	30.21	56.97	58.1	129.04	127.98
SD	2.98	2.79	2.59	3.62	2.68	3.4	5.99	6.04	4.47	4.01
Range	17.3-30.7	13.3-28.2	19.4-30.3	19.4-30.4	22.1-28.3	20.1-38.8	44.6-68	39.5-67.6	120-138	122-137
p-value	0.25		0.23		0.07		0.34		0.21	

Figure 2: Showing measurement of femoral head length superiorly using vernier calipers

Figure 3: Showing measurement of femoral head vertical diameter using vernier calipers

Figure 4: Showing measurement of femoral neck transverse diameter using vernier calipers

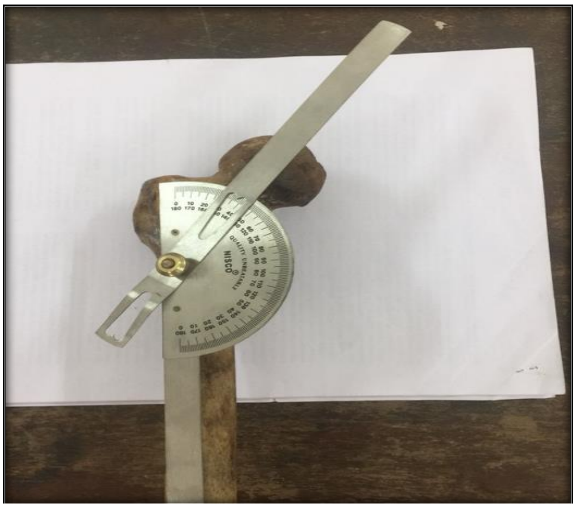

Figure 5: Showing measurement of neck shaft angle of femur

DISCUSSION

Several studies said that racial differences had been shown to exist in the femoral head dimensions. The gross shape of the long bones is due to intrinsic factors, while the adaptation of the bone to the functional environment determines the specific features. Therefore, heredity is a major factor in forming the shape of long bones due to its different functions in different races. Incongruous implant size or design may cause micro-movements, laxation and intra-operative complications like intra-operative fractures and may negatively affect the operation outcome. Most of the parameters of Indian femora are markedly different from other ethnic groups. For example, the average femoral head is less than the average Western value by 5mm. Likewise, other anthropometric measurements can be seen to vary markedly from the Western values. So, implants designed for Western skeletons occupy much more space than the Indian femoral head and neck.

Mishra et al.[8] reported the mean head vertical diameter was 52.02mm, Nwoha et al.[9] 50.35mm, Igbigbi et al.[10] 48.3mm, Afroze et al.[11] 45.65mm, Rubin et al.[12] 43.4mm, Yusof et al.[13] 43.4mm, and Ziylan et al.[14] 43.67mm. Our study's mean head vertical diameter was 41.9 mm, which is closely comparable with a study by Rubin et al., and Ziylan et al.

Mishra et al.8 reported the mean head transverse diameter was 54.16mm, Nwoha et al.9 50.75mm, Igbigbi et al.[10] 50.51mm, and Afroze et al.[11] 42.2mm. The mean head transverse diameter of our study was 43.28 mm, which is closely comparable with a study by Afroze et al.[11]]

Tamer et al. reported the mean neck width was 28.51mm, Chiu et al.[15] 34mm, Caetano et al.[16] 28.60mm, Siwach et al.[17] 31.8mm, Mishra et al.[8] 30.52mm, and Ravichandran et al.18 30.99mm. The mean neck width of our study was 32.19 mm, which is closely comparable with a study by Siwach et

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al.[17] Our study's mean neck transverse diameter was 25.03 mm, and Murilimanju et al.[19] studied the NTD was 23.9 mm, which is closely correlated. A study by Osorio et al.[20] reported the mean neck length was 35.9mm, and Mishra et al.8 46.22mm. In our study, the mean neck length was 28.49 mm, and Isaac et al.[21] reported the neck length was 28.35 mm, which is closely correlated.

Murilimanju et al.[19] reported the mean femoral head length superiorly was 30.8 mm, and the mean head length inferiorly was 21.2 mm. In our study, the mean FHLS was 31.77 mm. FHLI was 22.8 mm, which is correlated with a study by Murilimanju et al.[19] According to Osorio et al.20, the neck shaft angle was found to be 124.17°, Rubin et al.[12] 122.9°, Husmann et al.[22] 129.2°, Isaac et al.[21] 126.9°, Toogood et al.23 126.7°, and Noble et al.[24] 125.4°. In our study, the neck shaft angle was found to be 128.4°, which is closely comparable with Husmann et al.[22] and Isaac et al.[21]

On comparing of neck shaft angle with commonly used implants, such as Dynamic hip screw (DHS) was 125-155°, commonly used DHS was 135°, Condylar Blade plate was 95-130°, commonly used was 95 or 110°. In the present study, the neck-shaft angle used for implants was 128.4°. In a comparison of Neck width between the dimensions of the Indian femora and the dimensions of implants (Ao Screws), our study found the neck width was 25.03 mm. A study by Ravichandran et al.[18] reported 30.99 mm, and the implant's dimension was 6.5 mm (three screws are commonly used- 6.5 x 3 =19.5mm).

Based on our study findings and quantitative measurements, the femora specimens appear to be mostly normal, with some variations in shape and size. The femoral head shape was normal in more than half a sphere, and the fovea centralis was normal in position and shape in most specimens, except in seven specimens where it is oval. The femoral neck has numerous vascular foramina on its anterior surface, and the greater trochanter was quadrilateral in shape in all specimens. The lesser trochanter was conical in shape, except in some specimens where it was rounded. The intertrochanteric line was observed as a prominent ridge over the anterior aspect at the junction of the femoral neck with the shaft. The intertrochanteric crest was observed as a smooth ridge over the posterior surface at the junction of the femoral neck with the shaft. The gluteal tuberosity was observed over the posterior aspect of the femur in most specimens, except in some specimens where it was depressed and flat.

CONCLUSION

Qualitative parameters were measured in all the Femora and statistical analysis of each parameter by side wise comparison was made. The values of the parameters obtained were compared with those reported in the literature. And the values were compared with dimensions of commonly used implants in the field of Orthopaedics. The values observed for all the parameters were greater in the Western world than in the present study and it was concluded that Western people were taller and heavier than the average Indians, thus showing regional variation. This study will encourage the biomechanical engineers to bring a revolution in the designing and manufacturing of implants with a correct morphometric data to suit our Indian Population and for an improvised surgical outcome with prevention of complications.

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