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Original Research Article

STUDY ON THE ANATOMICAL EVALUATION OF PROXIMAL FEMORAL MORPHOMETRY AND ITS IMPLICATIONS FOR ORTHOPAEDIC IMPLANT PLANNING IN THE INDIAN POPULATION

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ABSTRACT

Background: Hip disorders require arthroplasty, which necessitates an understanding of the morphology of the proximal femur bone. Variations due to race, lifestyle factors and anthropometry impact the design of the implant and anthropometry outcomes of surgery. Existing prostheses on the basis of the western data highlighted the requirement of morphometric assessment to improve the fitting of the implant, alignment and reduce the postoperative complications. **Materials and Methods:** The descriptive cross-sectional study was conducted among 80 dry adult femoral samples. The intact, non-pathological bones were included. Measurement of the diameter of the head and neck, intertrochanteric length and the angle of the neck-shaft were measured by vernier callipers and a goniometer. Data analysis was done by SPSS version 27. **Results:** The study showed the analysis of 80 femora, with a mean value of diameter 37.92±2.85 mm, and the diameter of the neck was 28.35±3.1 mm, with the neck-shaft angle 133.2°±5.4°. 53.68±5.6 mm was the intertrochanteric length. The left side analysis showed a high head of 38.1 mm, and the neck showed 28.7 mm. The right side showed high tertrochanteric length (55.6 mm) and angle (134.9°). Moderate correlation was shown between the head and fovea (r=0.487) and strong between head and neck (r=0.712), both p<0.001. **Conclusion:** The study concluded that the morphometric analysis showed stable proximal femur anatomy, mild asymmetry, and correlation between head and neck diameter, which helps to design the prosthesis and improve the orthopaedic surgical outcomes.

INTRODUCTION

The prevalence of hip osteoarthritis, fracture neck femur and other hip joint ailments is rising day by day, and Arthroplasty is a significant treatment modality for these patients. The femur bone is the skeleton of the thigh, which carries the weight of the body, and provide structural support to the leg movement. This functions as an attachment of the muscles.[1] The bone morphology is impacted by the race, sex, environmental and lifestyle factors. The study demonstrated that lifestyle parameters impact the geometric indices of the strength of bone in the proximal femur.[2] FHO and VO are important tools for the motion and support of the abductor muscle after the total hip arthroplasty. The available hip prostheses are based on the European data.[3] The small size or the oversized hip prosthesis in the case of Total Hip Arthroplasty can severely impact the functions. The function of the surgical intervention is to reduce the anatomy with fixation of the stable fracture, which aid in bone rebuilding and ensures the stable mobilization. Mostly, the contour fit of the bone and plate is significant for the development of a strong bone.[4] The Morphometric study was done for different populations and communities. While the Morphometric study of the proximal femur was evaluated in different communities and populations. Data from the studies indicated the significant features of the femoral morphometry. Significant differences were noted with the calliper, rather than the values taken by the software.[5]

A statistically significant difference was observed in measurements taken with a calliper than values obtained with the measurement using the software. The predominant and most common procedure to resolve the treating hip joint failure can be due to conditions like osteoarthritis, rheumatoid arthritis, osteonecrosis, trauma, and bone tumours. The planning before the osteotomies and design and formation of the implant for the THA both depends on the analysis of the proximal femur, which is significant to preserve the function of the bipedal erect posture.[6] To reduce the postoperative complications, like the aseptic loosening, insufficient distribution of load and the discomfort due to wrong implant positioning, accurate measurements are essential for the selection of the implant. The accurate alignment ensures the prolonged efficacy of the prosthetic efficacy.[7] The racial and ethnic differences in the morphology of the proximal femur leads to the interaction between different genetic and environmental parameters like age, race, gender, and lifestyle, along with the anthropometric factors of bones. Majorly the THA surgeries utilizes the standard size of femur implantation, which are mostly modified by some anthropometric data taken from the Western culture. This strategic approach leads to the disparity between the sizes of the implant, which can negatively impact the Indian population.[4,8] The aims and objective of the study is to assess the comprehensive morphometric evaluation of the human femur. The objective is to evaluate the parameters, to investigate the anatomical variations and the development of clinical correlations. The study also aims to improve the design of the study, plan of proper surgical care and reduction in the complications.

MATERIALS AND METHODS

This was a descriptive, cross-sectional study where anatomical evaluation of the proximal femoral morphometry has been investigated for effective implant among Indian population. The study was conducted in Chirayu Medical College and Hospital, Bhopal and total of 80 dry adult human femur bone samples were considered for the study. The study was conducted from November 2024 to December 2025. Intact, stable and preserved femora were included in the study. Different morphometric parameters were evaluated like the diameter of the head of the femora, transverse and longitudinal diameters of the fovea capitis, length of the intertrochanteric line, and the neck-shaft angle. Certain criteria were considered for inclusion.

Inclusion Criteria

- Dry adult femur bones were included in the study.
- Well preserved femora were selected.
- Those femur bones were included without any observed pathological alterations.
- Femora with visible identical marks were included for the study.

Exclusion Criteria

- Femora bones with arthritic changes or deformities were not allowed.
- Fractured or eroded bones were excluded.
- Bone affected with infections, or tumours or any congenital deformities were not considered for the study.

Procedure

The study included 80 adult human femur bones which were selected under certain criteria. Intact and well-preserved bones were included in the study, while damaged or visible deformities were excluded. The bones were divided into left and right sides. Vernier callipers were utilised for the morphometric measurements, and a goniometer was used. Various parameters were measured, like the diameter of the femoral head as well as the transverse and longitudinal diameters of the fovea capitis. The diameter of the femoral neck, the length of the intertrochanteric line and the angle of the neck shaft were measured. All parameters were carefully measured under specific standard anatomical features to ensure accuracy and consistency. The values were recorded and analysed in Microsoft Excel.

Statistical Analysis

Data analysis was performed in tabular form and was done by using SPSS software of version 27. Descriptive statistical methods were used. Mean as well as standard deviation was calculated for the parameters to evaluate the morphological variations of the proximal femoral bone.

RESULTS

Table 1 showed the statistical analysis of the proximal femur's morphometry, where 80 femora were included, with reduced variation observed in the diameter of the head, 37.92 ± 2.85 mm, and the neck diameter is 28.35 ± 3.1 mm, which indicated structural stability, significant for the transmission of load. The neck-shaft angle (133.2° ± 5.4°) is within the normal range, reflecting the anatomical alignment. Contrastingly, high variation was observed for foveal diameter, which suggested morphological diversity, while the length of the intertrochanteric range was 53.68 ± 5.6 mm. This highlighted the variability in the size of the implant.

Table 1: Statistical analysis of the proximal femur's morphometry

Parameter	N	Mean	Std Dev	Minimum	Maximum
Head Diameter	80	37.92	2.85	31	42
Transverse Diameter of Fovea	80	10.74	2.05	5	20
Longitudinal Diameter of Fovea	80	9.28	2.1	5	15
Diameter of Neck	80	28.35	3.1	22	35
Intertrochanteric Length	80	53.68	5.6	40	68
Neck-Shaft Angle	80	133.2	5.4	123	151

Table 2 showed the side-wise morphometric analysis, which demonstrated consistent asymmetry between the left and the right femora. The left side showed high mean values for the diameter of head (38.1 mm

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vs 37.85 mm), transverse (11.4 mm vs 10.2 mm) and longitudinal (9.7 mm vs 8.95 mm) and the neck diameter (28.7 mm vs 28.05 mm). These values showed great robustness. The right side showed intertrochanteric length (55.6 mm vs 51.8 mm), and the neck-shaft angle was 134.9° vs 132°. Comparable values for standard deviations were noted, with high variations on the right, specifically for the intertrochanteric length and neck-shaft angle. This indicated high dispersion.

Table 2: Morphometric variations for left and right side femur bone

Parameter	Group	N	Mean	Standard Deviation	S.E. Mean
Head Diameter	L	40	38.1	2.6	0.41
	R	40	37.85	3.05	0.48
Transverse Diameter of Fovea	L	40	11.4	1.8	0.28
	R	40	10.2	2.1	0.33
Longitudinal Diameter of Fovea	L	40	9.7	1.9	0.3
	R	40	8.95	2.2	0.35
Diameter of Neck	L	40	28.7	3	0.47
	R	40	28.05	3.3	0.52
Intertrochanteric Length	L	40	51.8	4.8	0.76
	R	40	55.6	5.6	0.89
Neck-Shaft Angle	L	40	132	5.1	0.81
	R	40	134.9	5.8	0.92

Table 3 demonstrated the moderate positive association between the diameter of head and the longitudinal diameter of the fovea. This reflected the rise of the femoral head size which is related with the high longitudinal dimension of the fovea. The p value suggested the association. The correlation is not strong, which implied the effect of the head size on the foveal dimensions. The findings showed moderate, consistent association between the factors, which is required for the understanding of the morphology of head and the structural variation.

Table 3: The correlation between the head diameter of a femur and longitudinal diameter of fovea

	Head Diameter	Longitudinal Diameter of Fovea
Head Diameter		
Pearson Correlation	1	0.487
Sig. (2-tailed)	—	0
N	80	80
Longitudinal Diameter of Fovea		
Pearson Correlation	0.487	1
Sig. (2-tailed)	0	—
N	80	80

Table 4 demonstrated the correlation analysis, indicated the strong positive relationship between the diameter of the head and neck. This indicated the large size of the femoral head, which was related to the high neck diameter, which reflected the growth and the structure of the proximal femur. The high correlation coefficient suggested the p-value. The findings highlighted the strong, biological association between these parameters, which is significant to understand the proximal femoral biomechanics.

Table 4: The correlation analysis for the head diameter and neck diameter of proximal femur

	Head Diameter	Neck Diameter
Head Diameter		
Pearson Correlation	1	0.712
Sig. (2-tailed)	—	0
N	80	80
Neck Diameter		
Pearson Correlation	0.712	1
Sig. (2-tailed)	0	—
N	80	80

DISCUSSION

The morphometric variations are observed among the parameters of the proximal femur. The difference in the statistical data was noted in femur neck diameter (FND) and cervicodiaphyseal angle (CDA), which noted the asymmetry between right and left femora. There exists strong positive correlation between the femoral head offset (FHO) and vertical offset (VO), which suggested the interdependence in hip. Other parameters are observed with consistent distribution, to support the reliability of the measurements. The result findings highlighted the significance of the population-specific data and help to improve the design, fit and the outcome of the reconstructive orthopedic procedures.[9] The morphometric data for the proximal femur was analysed, which indicated the variations in the anatomy. The length of the femur was 426.6 ± 15.82 mm, the length of the femur neck was 3.455 ± 0.378 mm and the neck shaft angle was 125.27 ± 2.54°. These indicated the population-specific parameters that differs from other groups. The result findings emphasized the variations, which are impacted by several genetic and environmental factors like lifestyle and physical activity. These differences are recognized which is significant for the accurate operative planning and selection of the right implant.[10] The morphometric variations of the proximal femur are significant, where the mean femur length was shorter than the international averages. Significant difference was noted in the length of the femur, length of the femoral neck and the neck-shaft angle. The positive correlation was observed between the length of the femur and the diameter of the femoral head, while a negative correlation exists between the length of the femur and the neck-shaft angle. The findings indicated the anatomical characteristics and emphasized the significance of the region-specific design of the implant to increase the surgical outcome and reduce the complications in total hip arthroplasty.[11] The proximal femur is an important area of interest as it is involved in the articulation of the hip joint, and it contributes to the mechanics of locomotion and the weight-bearing capacity of the femur. Hence, a greater understanding of these variations will be helpful in constructing a better-fitted prosthesis. In this study, six morphometric parameters of the proximal femur were studied and measured in 100 dry adult femur bones - head diameter, transverse diameter of fovea, longitudinal diameter of fovea, diameter of neck, intertrochanteric line length, neck shaft angle and correlations were noted. The data obtained is specific for the southern Indian population and hopes to aid in the production of better fitted hip prostheses for patients.[12] The mean diameter of the femoral head, the dimension of the neck and the neck-shaft angle (124.11±6.37°) indicated the anatomical pattern related to the specific population. The side differences were observed in the antero-posterior diameter of the femoral neck and neck-shaft angle, with high values on the left side. This reflected asymmetry and variation in the proximal femoral. The result findings emphasized the variations impacted the regional and biological parameters. The study provides the importance of incorporating the measurements in designing the implant, for more improved accuracy and orthopaedic interventions.[13] The review demonstrated the significance of the ethnic and sex-based variations in proximal femoral morphology. The Korean males provide the largest diameter of the head, while the Brazilian population showed small values of sexual dimorphism. Wide variation was noted in the case of neck-shaft angle and femoral anteversion, while Chinese females showed high anteversion rather than males. The Indian population showed a low diameter of the femoral head on CT rather than the radiographic measurements, which indicated the modality. The results revealed the heterogeneity in proximal femoral geometry. The study emphasized the requirement for the ethnicity- and sex based designs of the implant for more improvement and favourable outcomes in the total hip arthroplasty.

CONCLUSION

The study concluded that morphometric assessment of the proximal femur of 80 adult bones, demonstrated the pattern of anatomy with moderate variation. Certain parameters like diameter of head and neck showed now dispersion, which indicated the structural stability. This is significant for effective transmission of load and the joint congruency. The value of the neck-shaft angle is within the normal range, confirmed the preserved alignment. Side-wise analysis highlighted mild asymmetry, with the left femur showed high robustness. This exhibited high intertrochanteric length and neck-shaft angle, which suggested functional and biomechanical differences. Correlation analysis showed moderately positive association between the head diameter and foveal dimensions and the strong positive relation between the diameter of head and neck, which reflected coordinated growth. These findings highlighted the significant variation in anatomy and associations which are significant to design the prosthesis, plans orthopaedic surgery and improved the population-specific clinical outcomes.

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