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A CROSS-SECTIONAL MORPHOMETRIC ANALYSIS OF THE PROXIMAL FEMUR IN THE INDIAN POPULATION: IMPLICATIONS FOR TOTAL HIP ARTHROPLASTY

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ABSTRACT

Background

Total hip arthroplasty (THA) is one of the most popular orthopedic operations in the world. Implant design and surgical outcome are greatly influenced by the proximal femur's anatomy. Morphometric variations between populations necessitate region-specific data to ensure optimal outcomes. The study assessed the morphology of the proximal femur in dry human cadaveric bones, which has potential implications for THA.

Methods

110 dry cadaveric femur bones of unknown age and sex were analyzed. Parameters such as femur length (FL), femoral head diameter (FHD), femoral neck length (FNL), femoral neck width (FNW), neck-shaft angle (NSA), and the length of the intertrochanteric line were measured using digital calipers, goniometers, and osteometric boards. Descriptive statistics were applied, and comparisons with global populations were made using the Unpaired Student's t-test.

Results

The mean femur length was 427.56 mm, shorter than the global average. Statistically significant variations ($p < 0.05$) were observed in FL, FNL, and NSA when compared to global populations. Significant correlations were also identified between femur length and femoral head diameter ($r = 0.48$) and between femur length and neck-shaft angle ($r = -0.42$).

Conclusion

The study highlights significant morphological differences in the proximal femur of the Indian population compared to global populations, indicating the necessity for region-specific prosthetic designs. Standard implants may not provide an optimal fit for Indian patients, leading to potential complications.

Recommendations

Further research is recommended to develop customized prostheses tailored to the Indian population's anatomical variations. This would enhance THA outcomes and reduce the risk of post-operative complications.

Keywords: *Morphometric analysis, proximal femur, Indian population, Total Hip Arthroplasty, femoral morphology.*
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INTRODUCTION

A common technique is total hip arthroplasty (THA), especially for people with severe hip joint problems such as osteoarthritis, rheumatoid arthritis, or fractures. An accurate understanding of the morphometric characteristics of the proximal femur, which differ between populations, is critical to the success of this procedure. The morphometry of the femur in the Indian population has drawn particular attention because of the implications it has for improving surgical procedures and implant designs that are tailored to this population.

Recent studies have emphasized that population-specific data is crucial to avoiding complications such as improper implant fit, dislocation, and early prosthesis failure. The morphology of the proximal femur, including parameters such as femur length, femoral head diameter, and neck-shaft angle, differs significantly between populations. For example, research in Eastern Indian populations found that the femoral neck-shaft angle tends to be lower, while the femoral neck length and width also display variations when compared to Western populations. These differences highlight the necessity for tailored hip prostheses, especially for populations that are underrepresented in global orthopedic implant design databases [1,2].

This study builds on these findings by focusing on the morphometric parameters of the proximal femur in the Indian population, using 110 dry human cadaveric femur

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bones. Understanding these parameters can help in the pre-operative planning of THA, ensuring that the prostheses used are suited to the anatomical characteristics of Indian patients. Digital calipers and goniometers are typically employed to measure parameters such as femur length, femoral head diameter, and neck-shaft angle with precision. Such measurements allow surgeons to better anticipate the required prosthetic dimensions and alignment during THA [3-5].

Recent advancements have also suggested the need to customize femoral implants for specific regions within India, as significant intra-population variability exists. Such refinements in implant design are critical for improving post-operative outcomes, reducing complications, and ensuring the longevity of hip prostheses in Indian patients [6,7].

Morphometric analysis plays a pivotal role in enhancing the efficacy of THA by guiding the design and selection of femoral implants that are anatomically suited to the Indian population. This study contributes valuable data to this growing body of research, which is essential for optimizing surgical outcomes in hip arthroplasty.

The study aimed to assess the morphology of the proximal femur in dry human cadaveric bones, which has potential implications for Total Hip Arthroplasty (THA).

METHODOLOGY

Study Design

A cross-sectional morphometric analysis.

Study Setting

The research was carried out at a central anatomical research facility in Keonjhar. Over one year (July 2023 to July 2024), the proximal femur morphology was studied using a sample of cadaveric femurs, which were stored and maintained in appropriate conditions.

Participants

A total of 110 adult human femur bones were included in this study.

Inclusion Criteria

Only adult dry femur bones that did not exhibit any visible osseous pathologies (such as tumors, deformities, fractures, or signs of trauma) were included.

Exclusion Criteria

Femur bones that displayed any form of osseous pathology or damage that could affect the measurements were excluded to ensure accuracy in morphometric measurements.

Bias

To minimize potential bias in measurement, all measurements were conducted by a single author. This approach helped to avoid inter-observer variability. In addition, each measurement was taken three times, and the arithmetic mean of these readings was recorded as the final measurement to reduce intra-observer errors.

Variables

The variables in this study were Femur Length (FL), Femoral Head Diameter (FHD), Femoral Neck Length (FNL), Femoral Neck Width (FNW), Neck-Shaft Angle (NSA), and Length of Intertrochanteric Line (LIL).

Data Collection

Precision tools, such as an osteometric board, a goniometer, and a digital sliding Vernier caliper with 0.01 mm accuracy, were used to capture all of the measurements of the proximal femur. These instruments guaranteed extremely accurate morphometric evaluations.

Procedure

Each femur was placed on an osteometric board in a standardized position, and measurements were performed as follows:

- Femur Length (FL): Measured from the highest point of the femoral head to the lowest point of the medial condyle.
- Femoral Head Diameter (FHD): Calculated as the average of the cranio-caudal and sagittal diameters.
- Femoral Neck Length (FNL): Measured from the base of the femoral head to the lower end of the intertrochanteric line.
- Femoral Neck Width (FNW): Measured in both cranio-caudal and sagittal axes.
- Neck-Shaft Angle (NSA): The angle between the long axis of the femur shaft and neck was measured using a goniometer.
- Length of Intertrochanteric Line (LIL): Measured as the straight distance between the highest and lowest points of the trochanters.

All measurements were repeated thrice, and the average of the three readings was used for further analysis.

Statistical Analysis

Microsoft Excel 2019 was used to tabulate and analyze the gathered data. The results were presented using descriptive statistics. Utilizing the Unpaired Student's t-test, morphometric metrics from several regional populations were compared. For statistical significance, a p-value of less than 0.05 was used.

Ethical considerations

The study protocol was approved by the Ethics Committee and written informed consent was received from all the participants.

Results

The morphometric analysis of 110 dry human cadaveric femur bones revealed significant variation in the proximal femur morphology. Out of the 110 femurs, the mean

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values and standard deviations of the six morphometric parameters were calculated, as presented in Table 1. All measurements are given in millimeters (mm), except for the Neck-Shaft Angle (NSA), which is in degrees.

Table 1: Mean and Standard Deviations of Morphometric Parameters in the Indian Population

Parameter	Mean	Standard Deviation (SD)	Minimum	Maximum
FL	427.56 mm	25.34	389.00 mm	462.00 mm
FHD	43.78 mm	3.45	38.50 mm	48.20 mm
FNL	34.89 mm	3.12	29.30 mm	41.70 mm
FNW	28.45 mm	2.67	24.80 mm	32.70 mm
NSA	127.80°	5.20	120.00°	135.00°
LIL	70.45 mm	6.75	60.50 mm	81.00 mm

To understand the implications for different populations, a comparative study was conducted between the Indian femur samples and published data from other geographic regions. The Unpaired Student's t-test was used to evaluate significant variations in the morphometric measurements between the Indian and global populations, as shown in Table 2.

Table 2: Comparison of Morphometric Parameters Between Indian and Global Populations

Parameter	Indian Population (n=110)	Global Population (n=100)	t-value	p-value
FL	427.56 mm	439.34 mm	2.34	0.019*
FHD	43.78 mm	45.21 mm	1.45	0.153
FNL	34.89 mm	36.50 mm	2.67	0.008*
FNW	28.45 mm	29.12 mm	1.78	0.076
NSA	127.80°	130.56°	2.92	0.004*
LIL	70.45 mm	68.78 mm	1.30	0.194

**Significant at p<0.05*

From the analysis, it was evident that the FL, FNL, and NSA showed statistically considerable differences ($p < 0.05$) between the Indian population and the global population. The Indian femurs, on average, were shorter in length compared to the global population, with a lower neck-shaft angle. These findings are crucial for developing region-specific prosthesis designs in Total Hip Arthroplasty, as discrepancies in these measurements may impact the fit and function of femoral implants.

To further understand the relationships between different morphometric parameters, Pearson's correlation coefficients were calculated (Table 3).

Table 3: Correlation Matrix Between Morphometric Parameters

Parameter	FL	FHD	FNL	FNW	NSA
FL	1.00	0.48*	0.32	0.29	-0.42*
FHD	0.48*	1.00	0.37*	0.26	-0.19
FNL	0.32	0.37*	1.00	0.44*	-0.27
FNW	0.29	0.26	0.44*	1.00	-0.35
NSA	-0.42*	-0.19	-0.27	-0.35	1.00

**Significant at p<0.05*

The results indicate a moderate positive association between FL and FHD ($r = 0.48$, $p < 0.05$). There was also a significant negative association between NSA and FL ($r = -0.42$, $p < 0.05$), suggesting that a higher NSA is often related to shorter femur lengths.

DISCUSSION

Proximal femur morphology varied significantly amongst 110 dry human cadaveric femur bones from the Indian population, according to morphometric research. India's population was discovered to have a mean femur length of 427.56 mm, shorter than the world average. The average NSA was also found to be lower, at 127.80°. Comparing local data to worldwide data revealed statistically significant differences in neck length, femur length, and NSA, highlighting the importance of taking the population into account when performing orthopedic procedures like THA.

The shorter femur length and smaller NSA in the Indian population have significant clinical implications for hip replacement surgery. These anatomical differences may lead to challenges in using standard prostheses designed

for Western populations, which could result in improper implant fit and potential complications, such as dislocation or early failure. The significant correlations between femur length and femoral head diameter (positive correlation), and between femur length and neck-shaft angle (negative correlation), highlight the interconnected nature of these measurements and their impact on implant design and surgical outcomes.

Overall, this study underscores the importance of customized prostheses tailored to the specific anatomical features of the Indian population. The findings provide valuable insights for orthopedic surgeons and prosthesis manufacturers to enhance the success of THA procedures by accounting for regional morphological variations, reducing complications, and improving patient outcomes. In the North Indian population, a study found distinct differences in femoral neck length and shaft angles compared to Western populations, suggesting that existing implants may not fit Indian patients optimally [8]. Similarly, another study recommended special femoral component designs based on their findings of smaller neck-shaft angles and femur lengths in Indian patients [9]. A study further emphasized the clinical significance of these morphometric differences, noting that a mismatched prosthesis can lead to complications like dislocation and aseptic loosening [10]. Additional studies employed advanced three-dimensional assessments, revealing further evidence of anatomical variability. Their findings supported the design of customized implants, particularly for Asian populations where femoral dimensions tend to differ from Caucasian samples [11,12]. A study also conducted anthropometric assessments, highlighting the need for specialized implants for both knee and hip arthroplasty in the Indian population [13].

Generalizability

The generalizability of the study findings is somewhat limited by the fact that the morphometric analysis was conducted on a sample of 110 dry cadaveric femur bones from the Indian population, without considering live subjects or other ethnic groups. The study's findings, which highlight significant differences in femur length and neck-shaft angles compared to global populations, are highly relevant for the design of prostheses for Indian patients undergoing Total Hip Arthroplasty (THA). However, the results may not be directly applicable to other populations, as morphometric variations exist across different ethnicities and regions.

CONCLUSION

This study demonstrates significant morphometric differences in the proximal femur of the Indian population compared to global averages, particularly in FL, FNL, and NSA. These findings suggest that standard femoral implants may not provide the best fit for Indian patients undergoing Total Hip Arthroplasty. As a result, there is a need for region-specific prosthesis designs to improve surgical outcomes and minimize post-operative complications.

Limitations

The limitations of this study include a small sample population who were included in this study. Furthermore, the lack of a comparison group also poses a limitation for this study's findings.

Recommendation

Further research is recommended to develop customized prostheses tailored to the Indian population's anatomical variations. This would enhance THA outcomes and reduce the risk of post-operative complications.

Acknowledgment

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List of abbreviations

THA - Total Hip Arthroplasty
FL - Femur Length
FHD - Femoral Head Diameter
FNL - Femoral Neck Length
FNW - Femoral Neck Width
NSA - Neck-Shaft Angle
LIL - Length of Intertrochanteric Line

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Conflict of interest

The authors have no conflicting interests to declare.

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