

Morphometric study of the acetabulum and proximal femur in north indian adult population: implications for total hip arthroplasty and implant design

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Abstract

Background

Successful total hip arthroplasty (THA) requires accurate restoration of hip biomechanics and appropriate matching of implants to native acetabular and proximal femoral dimensions. Population-specific morphometric data are important for improving implant fit and surgical planning.

Objective

To evaluate acetabular and proximal femoral morphometry in North Indian adults and assess its implications for THA and implant design

Materials and Methods

This retrospective observational study analyzed 100 adult hip observations using digital pelvic radiographs and computed tomography images. Morphometric parameters included acetabular diameter and depth, acetabular inclination, femoral head diameter, femoral neck length, neck-shaft angle, femoral offset, canal flare index, and proximal femoral canal diameter. Statistical analysis was performed using SPSS version 26.0. Sex-related and side-related differences were assessed using t-tests, while Pearson's correlation and multiple linear regression were used to evaluate relationships among morphometric variables. Statistical significance was set at $p < 0.05$.

Results

The mean acetabular diameter was 53.6 ± 3.9 mm, and the mean femoral head diameter was 46.8 ± 3.5 mm. Male hips had significantly greater acetabular diameter, acetabular depth, femoral head diameter, femoral neck length, and femoral offset than female hips ($p \leq 0.001$ for these parameters). No significant right-left differences were observed in the measured parameters. Acetabular diameter correlated positively with femoral head diameter ($r = 0.76$, $p < 0.001$), while femoral offset correlated with femoral neck length ($r = 0.63$, $p < 0.001$).

Conclusion

Significant sex-related differences and positive relationships between hip dimensions were observed, whereas side-to-side differences were not significant.

Recommendation

Population-specific morphometric data should be considered during preoperative templating and implant selection. Larger, multicentre studies using standardized three-dimensional imaging are recommended to validate these findings and support the development of anatomically appropriate implants for the Indian population.

Keywords: Acetabular morphometry; Proximal femur; Total hip arthroplasty; Implant design.

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Introduction

One of the most effective reconstructive procedures in contemporary orthopaedic surgery is total hip arthroplasty (THA), which offers patients with degenerative hip diseases, femoral neck fractures, avascular necrosis, inflammatory arthritis, and congenital deformities significant pain relief and functional restoration. Precise restoration of native hip biomechanics, such as femoral offset, limb length, acetabular orientation, and hip center of rotation, is essential for the long-term durability of hip prosthesis. Instability, impingement, faster polyethylene wear, aseptic loosening, dislocation, and early implant failure can occur when normal anatomy is not replicated. There is significant structural diversity in the acetabulum and proximal femur between various ethnic groups, geographical areas, sexes, and age groups. The majority of the morphometric data used in the design of commercially accessible hip implants comes from Western cultures (1).

As a result, these implants might not precisely match Asian cultures' anatomical dimensions, which could result in prosthetic components that are either undersized or oversized. Therefore, population-specific morphometric studies are crucial for enhancing surgical results and optimizing implant design. Acetabular dimensions, femoral head size, femoral neck length, neck-shaft angle, femoral offset, canal flare index, and proximal femoral canal morphology can all be reliably assessed using morphometric analysis based on radiography and computed tomography. During total hip replacement, these parameters help orthopaedic surgeons with preoperative templating, implant selection, and restoring normal biomechanics. Additionally, precise morphometric databases aid in the creation of prostheses that are appropriate for local populations (2).

Significant sex-related variations in femoral offset, femoral canal geometry, and acetabular diameter have been shown in a number of worldwide investigations. On the other hand, nothing is known about the morphometric traits of the adult North Indian population. Establishing standard morphometric values has become more crucial given the rising number of initial and revision hip arthroplasties being out in India. In order to assess the morphometric features of the acetabulum and proximal femur in people attending Gian Sagar Medical College, Hospital and Research Institute, the current retrospective study was conducted. The results are anticipated to help produce hip implants that are anatomically compatible for the Indian population and to give orthopaedic surgeons useful information during preoperative planning (3).

Aim

To evaluate the morphometric characteristics of the acetabulum and proximal femur in the adult population and assess their implications for total hip arthroplasty and implant design.

Objectives :

Primary Objective

- To determine morphometric measurements of the acetabulum and proximal femur using digital radiographs and CT scans.

Secondary Objectives

- To compare morphometric parameters between males and females.
- To compare right and left hip measurements.
- To determine the relationship between acetabular and proximal femoral dimensions.
- To provide morphometric data useful for implant design and preoperative templating in total hip arthroplasty.

Materials and Methods

Study Design

Retrospective observational study

Study Duration

One year.

Study Setting

Department of Anatomy, Gian Sagar Medical College & Hospital and Research Institute

Sample Size

100 adult hips.

Study Population

Adult patients whose pelvic radiographs and CT scans demonstrated normal hip anatomy.

Inclusion Criteria

- Adults aged ≥ 18 years.

- Digital AP pelvis radiographs with adequate quality.
- CT scans showing complete acetabulum and proximal femur.
- Normal hip anatomy without deformity.

Page | 3 **Exclusion Criteria**

- Previous hip surgery.
- Hip fractures.
- Osteoarthritis grade III or IV.
- Developmental dysplasia of the hip.
- Perthes disease.
- Avascular necrosis.
- Tumors.
- Poor-quality radiographs.

Data Collection

Digital radiographs and CT images retrieved from the hospital PACS were independently reviewed by two orthopaedic surgeons.

Acetabular Measurements

- Acetabular diameter (mm)
- Acetabular depth (mm)
- Acetabular inclination (°)
- Acetabular version (°)

Proximal Femoral Measurements

- Femoral head diameter (mm)
- Femoral neck length (mm)
- Neck-shaft angle (°)
- Femoral offset (mm)
- Canal flare index
- Canal diameter at isthmus (mm)

Outcome Measures

Primary outcome:

- Morphometric measurements of acetabulum and proximal femur.

Secondary outcomes:

- Sex-based comparison.
- Correlation between acetabular and femoral dimensions.
- Implications for implant selection.

Statistical Analysis

Statistical analysis was performed using IBM SPSS Statistics version 26.0.

Continuous variables were expressed as mean $\pm$ SD.

Categorical variables were expressed as frequency and percentage.

Independent Student's t-test compared males and females. Paired t-test compared right and left hips.

Pearson correlation evaluated relationships between morphometric variables.

Multivariate linear regression identified independent predictors of femoral offset.

A p-value <0.05 was considered statistically significant.

Results

A total of 100 adult hips were included in the study. The mean age of the study population was 49.8 ± 13.2 years (range: 20–78 years). Males constituted **58%** of the study population while females accounted for 42%. Right hips represented 52% of observations and left hips 48%.

The mean acetabular diameter was 53.6 ± 3.9 mm, while the mean acetabular depth measured 25.2 ± 2.3 mm. The average femoral head diameter was 46.8 ± 3.5 mm, neck-shaft angle $129.4 \pm 5.6^\circ$, femoral offset 41.8 ± 5.4 mm, and canal flare index 3.78 ± 0.41 .

Male participants demonstrated significantly greater acetabular diameter, femoral head diameter, femoral neck length, femoral offset, and proximal femoral canal diameter than females ($p < 0.001$). However, acetabular inclination and neck-shaft angle did not differ significantly between sexes.

Correlation analysis demonstrated a strong positive relationship between acetabular diameter and femoral head diameter ($r = 0.76$, $p < 0.001$), while femoral offset positively correlated with femoral neck length ($r = 0.63$, $p < 0.001$). Canal flare index also demonstrated a moderate positive correlation with proximal femoral canal diameter ($r = 0.48$, $p < 0.001$).

These findings indicate substantial morphometric variation among adults, emphasizing the need for population-specific implant dimensions for optimal reconstruction during total hip arthroplasty.

Table 1. Demographic Characteristics of Study Population (N=100)

Variable	Number (%)
Age Group (years)	
20–30	15 (15.0)
31–40	22 (22.0)
41–50	27 (27.0)
51–60	20 (20.0)
61–70	11 (11.0)
>70	5 (5.0)
Gender	
Male	58 (58.0)
Female	42 (42.0)
Side	
Right Hip	52 (52.0)
Left Hip	48 (48.0)

Interpretation: Most patients belonged to the 41–50-year age group. Males predominated slightly, and both hips were nearly equally represented

Table 2. Overall Morphometric Measurements

Parameter	Mean ± SD
Acetabular diameter (mm)	53.6 ± 3.9
Acetabular depth (mm)	25.2 ± 2.3
Acetabular inclination (°)	42.6 ± 4.1
Femoral head diameter (mm)	46.8 ± 3.5
Femoral neck length (mm)	34.7 ± 3.6
Neck-shaft angle (°)	129.4 ± 5.6
Femoral offset (mm)	41.8 ± 5.4
Canal flare index	3.78 ± 0.41
Canal diameter (mm)	14.2 ± 1.8

Interpretation

The study established normative morphometric values for acetabular and proximal femoral anatomy in the adult population.

Table 3. Comparison of Morphometric Parameters According to Gender

Parameter	Male (n=58)	Female (n=42)	p-value
Acetabular diameter (mm)	55.8 ±3.1	50.6 ±2.8	<0.001
Acetabular depth (mm)	25.9 ±2.2	24.3 ±2.1	0.001
Femoral head diameter (mm)	48.9 ±2.9	43.9 ±2.5	<0.001
Femoral neck length (mm)	36.2 ±3.3	32.7 ±2.9	<0.001
Neck-shaft angle (°)	129.8 ±5.4	128.9 ±5.8	0.389
Femoral offset (mm)	44.1 ±4.8	38.5 ±4.3	<0.001
Canal flare index	3.84 ±0.38	3.69 ±0.42	0.048

Statistical test: Independent Student's t-test

Interpretation

Male hips demonstrated significantly larger anatomical dimensions than female hips except for neck-shaft angle.

Table 4. Right versus Left Hip Measurements

Parameter	Right Hip	Left Hip	p-value
Acetabular diameter (mm)	53.8 ±3.7	53.4 ±4.0	0.612
Acetabular depth (mm)	25.3 ±2.2	25.1 ±2.4	0.701
Femoral head diameter (mm)	46.9 ±3.3	46.6 ±3.7	0.648
Neck-shaft angle (°)	129.7 ±5.4	129.2 ±5.8	0.731
Femoral offset (mm)	42.1 ±5.2	41.5 ±5.6	0.544

Statistical test: Paired t-test

Interpretation: No statistically significant morphometric differences were observed between right and left hips.

Table 5. Correlation Between Acetabular and Femoral Parameters

Variables	Correlation (r)	p-value
Acetabular diameter vs Femoral head diameter	0.76	<0.001
Acetabular diameter vs Femoral offset	0.54	<0.001
Femoral head diameter vs Neck length	0.58	<0.001
Femoral offset vs Neck length	0.63	<0.001
Canal flare index vs Canal diameter	0.48	<0.001

Statistical test: Pearson correlation

Interpretation: Significant positive correlations indicate proportional anatomical relationships that are valuable for prosthesis sizing.

Table 6. Distribution of Neck-Shaft Angle

Neck-Shaft Angle	Number (%)
<125°	16 (16.0)
125–130°	48 (48.0)
131–135°	28 (28.0)
>135°	8 (8.0)

Interpretation

Nearly half of the hips demonstrated a neck-shaft angle between 125° and 130°, representing the common anatomical configuration.

Table 7. Multiple Linear Regression Analysis for Predictors of Femoral Offset

Predictor	β Coefficient	Standard Error	p-value
Age	0.08	0.05	0.184
Gender (Male)	2.81	0.71	<0.001
Femoral head diameter	0.51	0.09	<0.001
Neck length	0.43	0.08	<0.001
Canal flare index	0.29	0.12	0.017

p < 0.001

Interpretation

Gender, femoral head diameter, neck length, and canal flare index independently predicted femoral offset.

Table 8. Clinical Implications for Total Hip Arthroplasty

Morphometric Parameter	Clinical Significance
Acetabular diameter	Selection of acetabular cup size
Acetabular depth	Cup seating and fixation
Femoral head diameter	Head component sizing
Neck length	Restoration of limb length
Femoral offset	Abductor muscle tension and stability
Neck-shaft angle	Stem alignment
Canal flare index	Stem design selection
Canal diameter	Femoral stem sizing

Interpretation

Each morphometric parameter directly influences prosthesis selection, implant positioning, postoperative stability, and long-term implant survival.

Discussion

Overall Morphometric Characteristics of the Acetabulum and Proximal Femur

The present retrospective observational study evaluated the morphometric characteristics of the acetabulum and proximal femur in 100 adult hip observations, focusing on sex-related differences, bilateral symmetry, and correlations between anatomical parameters. The mean acetabular diameter was 53.6 ± 3.9 mm, and the mean acetabular depth was 25.2 ± 2.3 mm. The mean femoral head diameter was 46.8 ± 3.5 mm, the mean femoral neck length was 34.7 ± 3.6 mm, the mean neck-shaft angle was $129.4 \pm 5.6^\circ$, and the mean femoral offset was 41.8 ± 5.4 mm.

These measurements provide descriptive information about acetabular and proximal femoral anatomy in the study population. Such information may be useful for understanding anatomical variation during preoperative planning for total hip arthroplasty (THA). However, the findings represent the selected study population and should not be interpreted as definitive normative values for all North Indian adults.

The relevance of population-specific morphometric data has been highlighted by previous investigations. Ram Sudhan et al. examined ethnic and sex-related differences in proximal femoral geometry and discussed their implications for prosthetic design (4). Choudhary et al. also investigated acetabular and proximal femoral dimensions using three-dimensional computed tomography (CT), emphasizing their relevance to hip arthroplasty (5). These studies support the importance of

documenting anatomical variation when evaluating implant dimensions, although direct numerical comparisons require similar measurement definitions and imaging methods.

Sex-Related Differences in Acetabular and Proximal Femoral Morphometry

The present study identified statistically significant sex-related differences in several morphometric parameters. The mean acetabular diameter was greater in male hips than in female hips (55.8 ± 3.1 vs. 50.6 ± 2.8 mm; $p < 0.001$). Acetabular depth was also greater in males (25.9 ± 2.2 vs. 24.3 ± 2.1 mm; $p = 0.001$). Similarly, the mean femoral head diameter was 48.9 ± 2.9 mm in males and 43.9 ± 2.5 mm in females ($p < 0.001$). Femoral neck length was greater in males than in females (36.2 ± 3.3 vs. 32.7 ± 2.9 mm; $p < 0.001$), as was femoral offset (44.1 ± 4.8 vs. 38.5 ± 4.3 mm; $p < 0.001$). The canal flare index was also slightly higher in males (3.84 ± 0.38 vs. 3.69 ± 0.42 ; $p = 0.048$). In contrast, the difference in neck-shaft angle was not statistically significant ($129.8 \pm 5.4^\circ$ vs. $128.9 \pm 5.8^\circ$; $p = 0.389$).

These findings indicate that sex-related variation was evident in several linear dimensions of the acetabulum and proximal femur, although not in every measured parameter. The differences may be relevant when assessing anatomical compatibility between native hip dimensions and prosthetic components. Nevertheless, statistical significance does not necessarily indicate clinical significance, and the practical implications of these differences require consideration of actual implant dimensions and clinical outcomes.

The findings are consistent with the broader focus of previous research on ethnic and sex-related differences in proximal femoral geometry. Ram Sudhan et al. examined sex-specific and ethnic variation in proximal femoral morphology in relation to prosthetic design (4). Choudhary et al. evaluated acetabular and proximal femoral dimensions using three-dimensional CT, providing further context for morphometric assessment in hip arthroplasty (5). Together, these studies support the need to consider anatomical variability during implant evaluation rather than assuming that the same dimensions are appropriate for every patient.

Right-Left Differences in Hip Morphometry

No statistically significant right-left differences were observed in the morphometric parameters reported in Table 4. The mean acetabular diameter was 53.8 ± 3.7 mm on the right and 53.4 ± 4.0 mm on the left ($p = 0.612$). Acetabular depth measured 25.3 ± 2.2 mm on the right and 25.1 ± 2.4 mm on the left ($p = 0.701$). The femoral head diameter was 46.9 ± 3.3 mm on the right and 46.6 ± 3.7 mm on the left ($p = 0.648$). The neck-shaft angle was $129.7 \pm 5.4^\circ$ on the right and $129.2 \pm 5.8^\circ$ on the left ($p = 0.731$). Femoral offset was also comparable between the two sides (42.1 ± 5.2 vs. 41.5 ± 5.6 mm; $p = 0.544$).

The absence of statistically significant differences suggests that the measured dimensions were broadly comparable between sides in this sample. Where a patient has normal anatomy on both sides, measurements from the contralateral hip may provide useful supplementary information during preoperative planning for unilateral reconstruction. However, nonsignificant differences do not establish complete anatomical equivalence, and the contralateral hip should not automatically be assumed to represent the affected side.

Previous research has examined acetabular morphology and component positioning using three-dimensional imaging. Kim et al. evaluated acetabular morphology and its relevance to component positioning in primary THA (7). Their work highlights the importance of detailed anatomical assessment during arthroplasty planning. The present study adds a comparison of selected right and left hip measurements, although differences in study design and measured parameters limit direct comparison.

Correlations Between Acetabular and Proximal Femoral Parameters

Correlation analysis demonstrated a strong positive relationship between acetabular diameter and femoral head diameter ($r = 0.76$, $p < 0.001$). Acetabular diameter was also positively correlated with femoral offset ($r = 0.54$, $p < 0.001$). Femoral head diameter correlated positively with femoral neck length ($r = 0.58$, $p < 0.001$), while

femoral offset was positively correlated with femoral neck length ($r = 0.63$, $p < 0.001$). A moderate positive correlation was also observed between the canal flare index and canal diameter ($r = 0.48$, $p < 0.001$).

These results indicate that several anatomical dimensions tend to vary together within the study population. The strong positive correlation between acetabular diameter and femoral head diameter suggests that larger acetabular dimensions were generally associated with larger femoral head dimensions. Similarly, the relationship between femoral offset and neck length suggests that these parameters should be considered together when evaluating proximal femoral geometry. The association between canal flare index and canal diameter may also be relevant when assessing femoral canal morphology.

These correlations do not establish causation or prove that a particular implant configuration will produce better clinical outcomes. However, they support the value of considering related anatomical measurements together during preoperative assessment. Choudhary et al. investigated acetabular and proximal femoral dimensions using three-dimensional CT, while Singh et al. examined three-dimensional CT evaluation of proximal femoral morphology for preoperative planning in THA (5,6). These studies provide relevant context for the use of detailed morphometric assessment when planning hip reconstruction.

Distribution of the Neck-Shaft Angle

The distribution of the neck-shaft angle showed that 48% of the hips had an angle between 125° and 130° , while 28% had an angle between 131° and 135° . Sixteen percent had an angle below 125° , and 8% had an angle above 135° . The overall mean neck-shaft angle was $129.4 \pm 5.6^\circ$.

The largest proportion of observations therefore fell within the 125° – 130° category. The neck-shaft angle is an important component of proximal femoral geometry and is relevant to assessment of the relationship between the femoral neck and shaft during implant planning. Nevertheless, the distribution observed in this sample should not be considered a universal reference range for North Indian adults.

Previous work has evaluated proximal femoral morphology in relation to implant planning and prosthetic design. Choudhary et al. investigated acetabular and proximal femoral dimensions using three-dimensional CT, while Singh et al. examined three-dimensional CT evaluation of proximal femoral morphology for preoperative planning in THA (5,6). These studies reinforce the relevance of evaluating proximal femoral anatomy when selecting and positioning femoral components. Differences in imaging techniques,

anatomical landmarks, and participant characteristics should be considered when comparing neck-shaft angle measurements across studies.

Factors Associated With Femoral Offset

Page | 8 Multiple linear regression analysis identified sex, femoral head diameter, femoral neck length, and canal flare index as statistically significant predictors of femoral offset. Male sex was associated with a regression coefficient of 2.81 (standard error [SE] = 0.71; $p < 0.001$). Femoral head diameter ($\beta = 0.51$, SE = 0.09; $p < 0.001$), femoral neck length ($\beta = 0.43$, SE = 0.08; $p < 0.001$), and canal flare index ($\beta = 0.29$, SE = 0.12; $p = 0.017$) were also statistically significant. Age was not statistically significant in the reported model ($\beta = 0.08$, SE = 0.05; $p = 0.184$).

These results suggest that femoral offset was associated with sex and several other dimensions of proximal femoral morphology in the study population. Femoral offset is relevant to the reconstruction of native hip geometry and should therefore be considered alongside femoral neck length and other anatomical measurements during preoperative planning. The absence of a statistically significant association with age indicates that an independent relationship was not demonstrated in this model; it does not establish that age is unrelated to hip morphology in other populations.

Björdal and Bjørgul discussed the role of femoral offset and restoration of the abductor lever arm in THA, emphasizing the functional relevance of offset during hip reconstruction (9). Singh et al. also examined three-dimensional CT assessment of proximal femoral morphology for preoperative planning (6). These studies support the clinical relevance of evaluating femoral offset and related anatomical parameters. However, the present regression findings should be interpreted as statistical associations rather than evidence that changing any single parameter will necessarily improve postoperative outcomes.

Clinical Implications for Total Hip Arthroplasty and Implant Design

The present study identified sex-related differences in several acetabular and proximal femoral dimensions, positive correlations among selected anatomical parameters, and no statistically significant right-left differences in the measurements reported in the bilateral comparison. These findings may contribute to the descriptive assessment of hip morphology and support careful evaluation of individual anatomy during preoperative planning for THA.

Acetabular diameter and depth may be relevant to assessment of acetabular component dimensions, whereas femoral head diameter, neck length, femoral offset, neck-shaft angle, and canal morphology may contribute to evaluation of femoral component geometry. However, this study did not directly assess implant fit, intraoperative outcomes, postoperative function, complications, or implant survival. Therefore, the findings suggest potential applications for implant evaluation but do not demonstrate that a particular implant design would improve clinical outcomes.

Maratt et al. reviewed the accuracy of digital templating in primary THA, addressing the role of preoperative planning in estimating appropriate implant dimensions (8). Björdal and Bjørgul discussed femoral offset and restoration of the abductor lever arm in THA, highlighting the importance of anatomical reconstruction (9). In addition, Akinmokun et al. examined the morphology and morphometry of the adult acetabulum in relation to hip arthroplasty surgery (10). These studies provide a clinical context for the present findings and support further investigation of the relationship between measured anatomical dimensions, implant compatibility, and surgical outcomes.

Overall Interpretation

The principal contribution of this study is the description of acetabular and proximal femoral measurements in the selected adult population and the identification of sex-related differences and relationships among anatomical parameters. The results indicate that several dimensions differ significantly between male and female hips, while the measured right and left hips showed no statistically significant differences in the parameters reported. The observed correlations further suggest that selected acetabular and proximal femoral dimensions should be considered together when describing hip morphology.

These findings support continued investigation of population-specific morphometric characteristics and their potential relevance to THA planning. However, the study was retrospective and conducted at a single centre, and the sample comprised 100 hip observations. The findings should therefore be interpreted as descriptive evidence from the study population rather than definitive normative values for all North Indian adults. Larger multicentre studies using standardized imaging and measurement procedures are needed to validate these observations and determine whether the identified differences have measurable effects on implant fit and clinical outcomes.

Generalizability

The findings of this study may be applicable to adults with similar demographic and anatomical characteristics who undergo hip imaging in comparable clinical settings. The observed sex-related differences and correlations among acetabular and proximal femoral parameters may provide useful preliminary information for anatomical assessment and preoperative planning for total hip arthroplasty (THA). However, the study was conducted at a single institution and included 100 adult hip observations; therefore, the findings may not be representative of the entire North Indian population or other Indian populations. Differences in geographical background, demographic characteristics, imaging techniques, and measurement protocols may influence morphometric measurements. Further multicentre studies involving larger and more diverse populations are required to validate these findings and establish more representative population-specific reference data.

Limitations

This study has several limitations. First, its retrospective, single-centre design may limit the generalizability of the findings to other geographical and demographic populations. Second, the sample comprised 100 adult hip observations, which may not adequately represent the full range of anatomical variation in the North Indian population. Third, the study relied on previously acquired radiographs and CT images; therefore, image quality, acquisition protocols, and measurement accuracy may have influenced the recorded parameters. Fourth, although the images were independently reviewed by two orthopaedic surgeons, interobserver and intraobserver reliability statistics were not reported. Fifth, the study did not directly assess the compatibility of the measured anatomical dimensions with commercially available implants or evaluate postoperative functional outcomes, complications, or implant survival. Consequently, the implications for implant design and clinical outcomes remain potential applications rather than directly demonstrated effects. Future prospective, multicentre investigations using standardized three-dimensional imaging, validated measurement procedures, and clinical outcome assessments are needed to address these limitations.

Conclusion

Acetabular diameter, femoral head diameter, femoral neck length, femoral offset, and proximal femoral canal dimensions were all clearly sex-related, and the current investigation showed considerable morphometric variability in the acetabulum and proximal femur among the adult population. On the other hand, symmetrical hip anatomy was indicated by the lack of significant bilateral

discrepancies. The significance of customized anatomical evaluation during total hip replacement is further shown by strong positive correlations between acetabular and proximal femoral characteristics. These results show the drawbacks of implementing universal implant designs based mostly on Western anatomical measurements and offer useful normative morphometric data for the Indian population. Prosthetic designs tailored to a particular population or sex may increase implant longevity, decrease surgical problems, improve implant fit, and more precisely replicate native hip biomechanics. Future multicenter studies utilizing advanced three-dimensional imaging and larger sample sizes are recommended to establish comprehensive morphometric databases that support customized implant development and precision-based arthroplasty planning.

Recommendations

Based on the findings of this study, sex-related differences in acetabular and proximal femoral dimensions should be considered during preoperative anatomical assessment and implant templating for THA. Particular attention should be given to acetabular diameter, femoral head diameter, femoral neck length, femoral offset, and proximal femoral canal morphology when evaluating the suitability of prosthetic components for individual patients. The observed correlations among anatomical parameters also support comprehensive assessment of the acetabulum and proximal femur rather than relying on a single measurement.

Further multicentre studies with larger and more geographically diverse Indian populations are recommended to establish reliable population-specific morphometric reference data. Future research should use standardized three-dimensional CT measurement protocols, assess interobserver reliability, and compare measured anatomical dimensions with commercially available implant specifications. Studies evaluating postoperative function, complications, implant fit, and long-term implant survival are also needed to determine whether incorporating population-specific morphometric data into implant design improves clinical outcomes.

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All authors should review and approve the final manuscript and agree to be accountable for their respective contributions.

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List of Abbreviations

AP: Anteroposterior

CT: Computed tomography

PACS: Picture archiving and communication system

SD Standard deviation

SE Standard error

-THA Total hip arthroplasty

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Conflict of Interest

The authors should disclose any financial or non-financial competing interests related to this study. If no competing interests exist, use: "The authors declare that they have no conflicts of interest related to this study."

Data Availability

The data supporting the findings of this study are derived from the radiographic and computed tomography records analyzed during the study. Availability of the underlying data is subject to institutional policies, patient confidentiality requirements, and applicable ethical approvals. Requests for access to de-identified data should be directed to the corresponding author and will be considered subject to the necessary institutional permissions.

Author Contributions

Maninder Kaur: [Conceptualization, study design, data collection, morphometric analysis, manuscript drafting, and/or critical revision, as applicable.]

Ravinder Pal Singh: [Methodology, clinical interpretation, statistical analysis, manuscript review, and/or critical revision, as applicable.]

Neelamjit Kaur: [Supervision, study conceptualization, interpretation of findings, manuscript review, and/or critical revision, as applicable.]

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