International Journal of Orthopaedics Research
www.orthopaedicsjournal.in
E-ISSN: 2663-0923, P-ISSN: 2663-0915
Received: 12-08-2025, Accepted: 11-09-2025, Published: 26-09-2025
Volume 7, Issue 2, 2025, Page No. 49-52

An observational study of morphometric assessment of proximal femur and acetabulum dimensions using 3DCT in case of hemiarthroplasty and total hip arthroplasty

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Abstract
Introduction: Orthopaedic implants are medical devices aiming to restore skeletal functions. The success of THR depends on the ideal placement of both acetabular and femoral components, so having a complete awareness regarding acetabular and femoral parameters including its morphology is an important requirement for successful surgery.
Aim: The aim of the study is to evaluate the morphometric characteristics of the proximal femur and acetabulum dimensions in Indian population to establish a database for making and performing total hip prosthesis.
Objectives: To measure Acetabulum dimensions, Femoral head diameter, femoral neck isthmus diameter, femoral neck length, neck shaft angle, Anteversion angle, vertical offset, Horizontal offset, Intramedullary canal diameter at narrowest portion of shaft and make a data based
Result: Significant gender differences were observed in neck length, with females having a longer neck length compared to males. The study emphasises the importance of detailed morphometric assessments in improving surgical outcomes in hip arthroplasty. The integration of 3DCT in orthopedic surgery represents a significant advancement in personalised medicine, allowing for more accurate and individualised treatment approaches.
Conclusion: Recommendations are future studies should aim to include larger and more diverse populations to enhance the generalisability of the findings. Longitudinal studies are recommended while considering these data‟s, to evaluate the long-term outcomes of hemiarthroplasty and THA. Collaboration across multiple centers would also help in validating the results and establishing comprehensive guidelines for preoperative planning.

Keywords: Morphometric assessment, proximal femur, acetabulum dimensions, orthopaedic implants

Introduction

Orthopedic implants are medical devices aiming to restore skeletal functions, for example, facilitating fracture healing1 and replacing degenerative of joint2. Success of the function restoration depends on performance of implant that restores biomechanics of the skeletal as normal as possible. Performance of implant depends upon various factors including material3 implant texture4, fitting categories (cemented/cementless), mechanical design and geometry Among aforementioned factors, geometry of implant is one of the crucial factors which affect the clinical success. Design of implant should compensate well to the morphology of specific population. Mismatching between implant and morphology of bone usually presents post-clinical complications. The success of THR depends on the ideal placement of both acetabular and femoral components, so having a complete awareness regarding acetabular and femoral parameters including its morphology is an important requirement for successful surgery. Most implants currently available in the market have been derived from Caucasian morphology. Clinical complication observed in Caucasian is then less than our population with such implants. This is confirmed by evidence of several reports relating to mismatching in recent years occurring in Asian population. Although custom-made implant is available to make design best-fit for specific patient however cost of production is relatively high and patient needs to wait in a certain time for implant production. Due to these reasons, standard implant is more preferred. In order to reduce the clinical complication from mismatching, morphological study is required to carry out. Preoperative planning in orthopedic surgery and trauma reached a new height with the revolution that 3D imaging brought on. New software programs allow for the management of 3D images in an economical and simple way. It has made for the routine use of this technology in many orthopedic surgery and trauma departments worldwide. Custom-made prosthetic implants, pre-modeling of osteosynthesis plates, and preoperative planning are some of the uses of 3D technology in orthopedic surgery and trauma. In practically all of them, the use of a mirror image of the healthy side is taken to establish the working normal for each patient.

Dimensional assessment should be carefully performed to obtain precise data for implant design. Obtaining precise dimensions depends on factors including data acquisition technique, method of measurement and measured subject. 3D technique presents more accurate dimensions then 2D and can be used to measure dimensions more accurately.

In addition, dimension of dry bone is different from living adult bone by 2 mm, then there is chance of error of data correction from anatomical specimens and these head to be revised with correction factor for accurate dimensions that is needed for implant design. Moreover, currently focus on implant designs is more on gender specific to give more accuracy.

As per our knowledge a few studies are there for morphometric parameter evolution from Indian population and most of the implants i.e. PFNA2 Acetabulum cup, femoral stem, femoral head are designed on studies which

are Caucasian population. Siwach *et al*. (2018)81 & Chen *et al*. (2013)94 reported comparison done to mismatching of PFNA2 in Japanese and Chinese population respectively.

Aim and Objectives

Aim

The aim of the study is to evaluate the morphometric characteristics of the proximal femur and acetabulum dimensions in Indian population to establish a database for making and performing total hip prosthesis.

Objectives

To measure Acetabulum dimensions, Femoral head diameter, femoral neck isthmus diameter, femoral neck length, neck shaft angle, Anteversion angle, vertical offset, Horizontal offset, Intramedullary canal diameter at narrowest portion of shaft and make a data based.

Inclusion Criteria

- Patient admitted for unilateral hip arthroplasty.
- Patient present with fracture neck of femur with age mor then 60yr, they are planned for unilateral hemiarthroplasty of hip

Exclusion Criteria

- Patient with fracture of bilateral neck of femur.
- Patient with osteoarthritis of bilateral hip.
- Patient with bilateral acetabulum fracture.
- Old operated case of proximal femur and acetabulum pathology.

Observation and Results

Table 1: Measurements of Various Anatomical Parameters

Parameter	Minimum	Maximum	Mean	Std. Deviation
Acetabular diameter	46.6	53.3	50.287	1.9269
Head diameter	42.1	50.1	46.30	2.0046
Neck length	34.2	43.4	37.843	2.2322
Neck isthmus diameter	20.1	32.5	25.467	3.1328
Canal diameter	8.2	14.9	11.033	1.405
Vertical Offset	30.8	53.2	38.353	5.7037
Horizontal Offset	32.5	48.5	39.577	3.9179
Anteversion angle	11.9	16	14.263	1.2859
Neck shaft angle	126	145.9	133.643	4.7454

Acetabular Diameter: The mean acetabular diameter was 50.287 ± 1.9269 mm, with a range from 46.6 mm to 53.3 mm.

Head Diameter: The mean head diameter was 46.30 ± 2.0046 mm, ranging from 42.1 mm to 50.1 mm.

Neck Length: The mean neck length was 37.843 ± 2.2322 mm, with a minimum of 34.2 mm and a maximum of 43.4 mm.

Neck Isthmus Diameter: The mean neck isthmus diameter was 25.467 ± 3.1328 mm, ranging from 20.1 mm to 32.5 mm

Canal Diameter: The mean canal diameter was 11.033 ± 1.405 mm, with values ranging between 8.2 mm and 14.9 mm.

Vertical Offset: The mean vertical offset was 38.353 ± 5.7037 mm, ranging from 30.8 mm to 53.2 mm.

Horizontal Offset: The mean horizontal offset was 39.577 ± 3.9179 mm, with values ranging between 32.5 mm and 48.5 mm

Anteversion Angle: The mean anteversion angle was 14.263 ± 1.2859 degrees, ranging from 11.9 degrees to 16 degrees

Neck Shaft Angle: The mean neck shaft angle was 133.643 ± 4.7454 degrees, with values ranging between 126 degrees and 145.9 degrees.

Table 2: The Anatomical Measurements of Various Parameters Were Compared Between Males and Females

		Gender		P Value
		M	F	
Acetabular diameter	MEAN	50.617	49.851	0.089
	SD	1.675	2.3336	
Head diameter	MEAN	46.817	45.624	0.142
	SD	1.653	2.5069	
Neck length	MEAN	37.644	38.142	0.014
	SD	1.6685	2.9448	
Neck isthmus diameter	MEAN	25.85	24.892	0.072
	SD	3.5837	2.3294	
Canal diameter	MEAN	10.811	11.367	0.806
	SD	1.3087	1.5347	
Vertical Offset	MEAN	38.717	37.808	0.829
	SD	5.5875	6.0809	
Horizontal Offset	MEAN	38.944	40.525	0.957
	SD	3.819	4.0365	
Anteversion angle	MEAN	14.311	14.192	0.608
	SD	1.3253	1.2788	
Neck shaft angle	MEAN	134.861	131.817	0.696
	SD	4.5701	4.5851	

The anatomical measurements of various parameters were compared between males and females in the study. The mean acetabular diameter was slightly higher in males (50.617 ± 1.675 mm) compared to females (49.851 ± 2.3336 mm), but this difference was not statistically significant (P=0.089). Similarly, the head diameter was marginally larger in males (46.817 ± 1.653 mm) than in females (45.624 ± 2.5069 mm), without significant statistical difference (P=0.142)

A notable finding was in the neck length, where females exhibited a longer neck length (38.142 ± 2.9448 mm) compared to males (37.644 ± 1.6685 mm), with the difference reaching statistical significance (P=0.014).

The neck isthmus diameter was also compared, showing a larger mean value in males (25.85 ± 3.5837 mm) than in females (24.892 ± 2.3294 mm), though this difference was not significant (P=0.072).

The canal diameter was slightly larger in females (11.367 ± 1.5347 mm) compared to males (10.811 ± 1.3087 mm), but this difference did not reach statistical significance (P=0.806).

Vertical offset measurements were also similar between genders, with males having a mean of 38.717 ± 5.5875 mm and females 37.808 ± 6.0809 mm (P=0.829).

In terms of horizontal offset, males had a mean value of 38.944 ± 3.819 mm, while females had a mean value of 40.525 ± 4.0365 mm, with no significant difference (P=0.957)

The anteversion angle was almost identical between the genders, with males showing 14.311 ± 1.3253 degrees and females 14.192 ± 1.2788 degrees (P=0.608).

Finally, the neck shaft angle was slightly greater in males (134.861 ± 4.5701 degrees) compared to females (131.817 ± 4.5851 degrees), though this difference was not statistically significant (P=0.696). Overall, apart from the significant difference in neck length, other anatomical parameters did not show significant variations between genders.

Discussion

Acetabular Diameter: In the present study, the mean acetabular diameter was found to be 50.287 ± 1.9269 mm and mean acetabulum diameter in male and female are 73 50.617 ± 1.675 and 49.851 ± 2.336 respectively.

Femoral Head Diameter: The femoral head diameter in the current study averaged 46.30 ± 2.0046 mm. Which is equivalent to Rawal *et al* (2012)

Neck Length: The mean neck length in this study was 37.843 ± 2.2322 mm. Smith *et al*. (2014) 88 found comparable neck length measurements, underscoring its importance in achieving optimal joint function and reducing the risk of complications postsurgery.

Neck Isthmus Diameter: The neck isthmus diameter was found to be 25.467 ± 3.1328 mm. Chantarapanich *et al* (2017) 79 reported similar values 27.87mm of NIDS, Verma *et al* (2017) 80 also reported similar values 24.01±3.0 mm highlighting the relevance of this measurement in selecting the appropriate implant size and ensuring surgical precision

Horizontal offset & Vertical offset: In the present study, the mean Horizontal offset was found to be 39.577 ± 3.9179 mm and the mean of vertical offset was found to be 75 38.353 ± 5.7037 mm

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Neck-Shaft angle: In present study, the mean neck shaft angle was found to be 133.643 ± 4.7454 degree. Carmona *et al* (2018) 83. examined upper femur anatomy in a diverse cohort and found that parameters such as femoral neck shaft angle (in Asian population – 124.8 ± 6.2 degree and in Caucasian population - 124.6 ± 6.2 degree) and femoral offset varied with age, gender, and ethnicity.

Canal diameter: In present study, the mean of canal diameter at isthmus position was found to be 11.033 ± 1.405 mm. Rawal *et al* (2012) 75 also mention femoral canal diameter at isthmus position of various population, mean of 9.02 ± 1.92mm in Indian population, mean of 12mm in Caucasian population, mean of 13.1 ± 2.1 in Swiss population, and mean of 11.6 ± 2.7 mm in France population.

Gender Differences: A significant difference was observed in neck length between males (37.644 ± 1.6685 mm) and females (38.142 ± 2.9448 mm) (P = 0.014). and in other parameters This is consistent with the findings of N. chantarapanich *et al* (2017) 79, who noted significant gender differences in femoral anatomy and recommended personalized surgical planning to optimize outcomes.

Ethnic Considerations: Carmona *et al* (2018) 83. examined upper femur anatomy in a diverse cohort and found that parameters such as femoral neck shaft angle and femoral offset varied with age, gender, and ethnicity. This highlights the importance of considering demographic factors in morphometric assessments, which can influence surgical outcomes

Conclusion

In conclusion, the morphometric assessment of proximal femur and acetabular dimensions using 3DCT provides critical insights that can significantly improve the outcomes of hemiarthroplasty and total hip arthroplasty. The precise measurements obtained from 3DCT enable surgeons to tailor prosthetic components to the patient's unique anatomical features, thereby enhancing joint stability and function while minimising the risk of complications. This study underscores the importance of incorporating detailed morphometric data into preoperative planning to achieve optimal surgical results.

The integration of 3DCT in orthopedic surgery represents a significant advancement in personalized medicine, allowing for more accurate and individualized treatment approaches. Despite the limitations, the findings highlight the potential benefits of using advanced imaging technologies to enhance the precision and effectiveness of hip arthroplasty procedures. Future research should continue to explore the full capabilities of 3DCT and other innovative techniques to further refine and improve surgical outcomes.

The primary limitation of this study is the relatively small sample size, which may not fully represent the broader population. Recommendations are future studies should aim to include larger and more diverse populations to enhance the generalisability of the findings. Longitudinal studies are recommended while considering these data‟s, to evaluate

the long-term outcomes of hemiarthroplasty and THA. Collaboration across multiple centers would also help in validating the results and establishing comprehensive guidelines for preoperative planning.

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