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## **A study of proximal femoral geometry for standardizing femoral component in total hip replacement**

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**Abstract**---Background and aims - Total Hip Replacement (THR) is the most common, permanent and effective surgical procedure available for the treatment of Osteoarthritis of the hip joint. In case of THR, it is mandatory that the design and dimensions of the femoral component, match (best-fit) the anatomy of the femur more so in cement-less variety. Significant variations are noted in the proximal femoral geometry of different races and ethnic groups Studies show that genetic and environmental factors including lifestyle determine the geometry of the proximal femur. The study is aimed to provide guidelines for future design of the femoral stem for Indian population. Materials & Methods - The present study was conducted on 202 adult human femora available in Anatomy, Orthopaedic & FMT departments of V.S.S Medical College, Burla, Odisha. The head vertical diameter (HVD), head transverse diameter (HTD), and circumference of femoral head (HC) were measured at the upper end of femur. The results were analyzed using statistical package SPSS 17.0 version. Results & Conclusion- - The average HVD was  $41.24 \pm 3.41$  mm. whereas the average HTD was nearly similar with HVD averaging  $41.21 \pm 3.44$ mm.

The average circumference of femoral head (HC) was found  $128.82 \pm 10.19$  mm. The results of the present study could help the forensic anthropologists, orthopaedicians and prosthetists to deliver excellent performance in their respective specialities. The result of the present study can provide a guide for future implants design to provide better fitting implants for the local population

**Keywords**---femur, head vertical diameter, head transverse diameter, head circumference.

## Introduction

Osteoarthritis is the fourth leading cause of disability among old age people across the globe the global incidence of hip osteoarthritis from 1990 to 2019 is increased from 0.74 million to 1.58 million, reflecting a total increase of 115.40%. This was consistent with the increase in the age-standardized incidence rate (ASIR) from 17.02 per 100,000 persons in 1990 to 18.70 per 100,000 persons in 2019, reflecting an upward EAPC trend of 0.32 (0.29–0.34). In addition, the incidence of hip osteoarthritis in men was 1.93-fold higher than that in women, which was inconsistent with the trend of ASIR in the two sexes (male to female ratio = 0.96). India is ranking 3<sup>rd</sup> in highest incidence of hip osteoarthritis after USA and China. Demographic studies show that the percentage of aged people above 65 years of age in India is expected to increase by 274% by the year 2040 [1]. This rise in the percentage of geriatric population in India will increase the morbidity due to osteoarthritis. Total Hip Replacement (THR) is the most common, permanent and effective surgical procedure available for the treatment of Osteoarthritis of the hip joint. Two types of replacements (cemented and cement-less varieties) are being done. Currently cement less type is more commonly performed compared to cemented variety. In case of THR, it is mandatory that the design and dimensions of the femoral component, match (best-fit) the anatomy of the femur more so in cement-less variety. Significant variations are noted in the proximal femoral geometry of different races and ethnic groups [2-5]. Studies show that genetic and environmental factors including lifestyle determine the geometry of the proximal femur [6-8]. The femoral components currently available in the Indian market are designed according to Western standards, not taking into account the ethnic differences or racial differences in the femoral geometry of the Indian population [2-4]. In case of THR, it is mandatory that the design and dimensions of the femoral component, match (best-fit) the anatomy of the femur more so in cement-less variety. Presently in India injured or broken femur replacement surgeries are carried out by using standard sized femur implants selected from a range provided by manufacturers. Femur implants are available in standard sizes of diameter of the femoral head and neck shaft angle. As manufacturer supplied femur implants are used for implantation, there are limitations in design and size of the implant. Surgeons who perform femur replacement surgeries must rely upon the implant manufacturer to provide appropriately sized implants. These implants are manufactured for masses and not for individuals. However, there is discrepancy as regards the measurement of the parameters. The neck shaft angle varies from approximately  $125^\circ$  up to  $132^\circ$  [9]. Undersized or overhanging

femoral implants could lead to altered soft-tissue tensioning and altered patella femoral stresses [10]. Non availability of proper shaped and sized femur implant or improper selection of femur implant could create serious problems for the patients in long run. There is a paucity of literature pertaining to the effects of improperly sized implants on patient outcome [11].

The proximal end of femur has been the subject of much attention for orthopaedic surgeons as operation on proximal femur are one of commonest in orthopaedic surgical practice. The proximal femur in human is subjected to large variety and a magnitude of force during day to day activities [12]. The aim of these operations is to remove pathology and restore anatomy to normal as far as possible. The morphology of proximal femur is also an essential parameter in the design and development of implant for total hip replacement (THR). Inappropriate implant design and size could affect outcome of the surgery with reported complications such as stress shielding, micro motion and loosening. Most of these implants were designed and manufactured from the European and North American region which presumably is based on the morphology of their respective population. The use of such implants in other regions such as India may not be appropriate as the design may not take into consideration the morphology of the local population. The use of implants designed based on other populations posed at least two potential major issues. First and foremost is the difference of the anthropometry of the proximal femur between ethnics due to differences in lifestyle, physique, applied force and their distribution. Another issue is implant morphology mismatch that might cause difficulties during implant placement and could lead to accelerated deterioration of the implant life thus affecting short-term and long-term outcome of the surgery [13].

Thus the basic purpose of this study is to accumulate data on people of developing countries like ours, who's built, physique, habits, genetic makeup and personal life styles are different from western civilization [12]. The database regarding anthropometry of femur is available from western population that is inadequate to make implants in our population. Due to the importance of anthropometry for the success of hip joint replacement, and management of Femoral fractures this study analyses the morphology of the femur for the local population. The data provided in this study will be compared with the design and size of implants available and commonly used in India. This information can then be used in the designing and development of implants suited for local population as well as assisting in decision making during clinical practices.

### **Aims and Objectives**

1. To study proximal femoral geometry in Western-Odisha population using multi-dimensional analysis.
2. To compare these values with those reported in the literature for various ethnic groups.
3. To provide guidelines and recommendations for future design of femoral components in total hip arthroplasty for the Western Odisha population.

## Materials & Methods

The present study was conducted on 202 adult human femora available in Anatomy, Orthopaedic & FMT departments of V.S.S Medical College, Burla, Odisha. All the femora were free of damage or deformity and fully ossified indicating adult bones. Femora with pathological changes (i.e. cortical bone deterioration, extreme osteophytic activity, diffuse osteoarthritis and fracture etc.) were excluded from the study. Age of the bone was above the age of epiphyseal fusion. The instruments used for the measurement of various parameters of femora were as follows:

- 1) Osteometric board.
- 2) Sliding caliper.
- 3) Flexible measuring tape.
- 4) Goniometer.
- 5) Protractor.
- 6) Marker pens

Pic.1&2 - Showing anthropometric tools along with femur.



Head vertical diameter (HVD):- Vertical diameter of head was measured as a distance between highest and deepest points of the head lying in the equatorial plane of the head, by holding the in such a manner that you can see the fovea centralis and avoiding the margins of articular surface of the head, calliper was rotated side to side until the maximum diameter was obtained. Measurement was taken with the help of sliding calliper, in millimetres [14].

Head transverse diameter (HTD):-Transverse diameter of head was measured as a distance between the most laterally projected points on equatorial plane taken at right angle to the vertical diameter of head and avoiding the margins of articular surface of the head, caliper was rotated side to side until the maximum diameter was obtained Measurement was taken with the help of sliding caliper, in millimetres [14].

Head Circumference (HC):- Circumference of head was measured at the same positions as the diameters along the four points marked by marker pen, with the help of flexible measuring tape, in millimetres. [14]

Neck vertical diameter (NVD):- It is the minimum diameter of the neck of the femur at the supero-inferior direction. Neck vertical diameter was measured in the narrowest part of the neck as a distance between superior and inferior surfaces of the neck. Measurement was taken with the help of sliding calliper, in millimetres. [15]

In the present study we have collected dry bones from the institute and hence there were no ethical considerations. The data were analyzed by one sample “t” test using statistical software SPSS version 17.

## Results

Table no. 1- Statistical analysis of parameters of head of femur (unit mm)

S. No.	Parameters	Min	Max	Range	Mean	SD	SE	Mean $\pm$ 2SD
1	HVD	34.20	49.45	15.25	41.24	3.41	0.239	34.42- 48.06
2	HTD	34.00	49.00	15.00	41.21	3.44	0.242	34.33- 48.09
3	HC	108.00	153.00	45.00	128.82	10.19	0.718	108.44-149.20

The head vertical diameter (HVD), head transverse diameter (HTD), and circumference of femoral head (HC) were measured at the upper end of femur. The HVD varied from 34.20 to 49.45 mm; averaging 41.24 mm. HVD was found to have Standard deviation of 3.41 mm. on extending the range to two Standard deviations to cover 95% of the population, the HVD was found to vary from 34.42 to 48.06 mm.

The dimensions of the second parameter for femoral head, HTD were similar to the HVD, with a range of 34.00 to 49.00 mm, an average of 41.21mm and standard deviation (SD) of 3.44mm. Its range for two SDs was from 34.33 to 48.09 mm.

The circumference of femoral head (HC) was found to vary from 108 to 153 mm, averaging 128.82 mm. Its SD was found to be 10.19 mm, and range for two SDs was 108.44 to 149.20 mm.

## Discussion

In the present study three anthropometric parameters were measured and analyzed. These results were compared with previous works on other population and ethnic groups. Unpaired t test was applied to examine whether the difference in the measurements between the two studies are statistically significant. Thereafter the mean value of various parameters was compared with prostheses and implants available in market manufactured by different manufacturer in diverse sizes.

Vertical diameter of head (HVD):- It varies from individual to individual, races and ethnic groups. The muscular forces moving across the hip joint acting between greater trochanter and pelvis has powerful effect on femur head as suggested by Hirsch, Frankel 1960[16]. Articular surface of the bone receive a portion of the force

being applied across the articular surface and head of the femur will respond to such forces. The weight of axial skeletal varies from person to person and this is first borne by the head of the femur, this effect of stress and strain will be reflected by variation in its shape and size. Our results are compared with those of previous workers and summarised in the table given below.

Table no. 2 Showing Vertical diameter of head of femur in comparison with previous studies

	Name of worker	Sample Size	Mean (mm)	SD (mm)	P value
1.	Taner Ziylan et al. 2002, Turkey(17)	72	43.4	3.2	<0.001
2.	P. J. Rubin et al. 1992, France(18).	32	43.4	2.6	<0.001
3.	V S Reddy et al. 1999, Hyderabad(19).	74	45.1	3.58	<0.001
4.	Masood Umer et al. 2010, Pakistan(20).	136	50.1	3.8	<0.001
5.	M Y Barharuddin et al 2011, Malaysia(21).	120	43.62	3.05	<0.001
6.	AK Mishra et al 2009, Nepal(9).	50	42.9	3.53	<0.001
7.	R C Siwach et al 2003, Rohtak(10).	150	43.95	3.06	<0.001
8.	R Chauhan et al. 2002, Delhi(22).	36	45.64	3.13	<0.001
9.	T R Deshmukh et al. 2010, Vidarbha(8).	77	43.30	4.19	<0.001
10.	Edie Benedito Caetano et al 2007(23).	34	41.80	3.10	>.05
11.	Present Study, 2013, Western Odisha Population.	202	41.24	3.41	<0.05

These studies suggest population specific differences in the value of mean of vertical diameter of head as shown by p value. Findings of Edie Benedito Caetano et al 2007 matches with that of present study. Study in nepal population by AK Mishra et al 2009 having mean value 42.9 mm shows some closeness to present study (mean 41.24 mm) probably because of similar built. Study by Taner Ziylan et al. 2002, in Turkey population and P. J. Rubin et al 1992, in France people show similar value of head vertical diameter (mean 43.4 mm) but values are much more as compared to present study. Maximum difference in mean was found in study by Masood Umer et al. 2010, in Pakistani population (mean 50.1). Mean value of vertical diameter of Head of femur in present study is showing significant difference with various studies on western population thereby confirming regional variation.

Transverse diameter of head of femur (HTD) - In the present study mean transverse diameter of head of femur was 41.21 mm, which was significantly higher than study on Bangladeshi population (mean 39.59 mm) by Akhtari Afroze, 2005 (p value < 0.001), and lower than various studies on western populations. The probable explanation for this lower value in Western Odisha population is the same as discussed for the vertical diameter of head; that is, different stress and strain patterns experienced by the head of femur. This is due to the difference in axial skeletal size and weight. The following table is showing summary of comparison of similar studies done by different researchers in the past in different parts of world.

Table no. 3- Showing the Transverse diameter of head of femur comparing with previous studies

Sr No.	Name of worker	Sample Size	Mean	SD	P value
1.	SA Asala, 2000, Whites(24).	260	44.42	2.71	<.001
2.	SA Asala, 2000 , Blacks(24).	260	42,28	2.36	<.001
3.	PS Igbigbi, 2000, Black Malawians(25).	496	48.75	3.38	<.001
4.	Taner Ziylan et al 2002 Turkey (15).	72	44.3	3.3	<.001
5.	Kazuhiro Sakaue, 2004, Recent Japanese(26)	64	43.05	2.08	<.001
6.	Akhtari Afroze, 2005, Bangladeshi(27).	123	39.59	1.26	<.001
7.	R Purkait, H Chandra, 2004,Bhopal(28).	124	42.33	2.28	<.001
8.	Present Study, 2013, Western Odisha Population.	202	41.21	3.44	<.001

These studies suggest there are population specific differences in the value of transverse diameter of head measurement. Study conducted by SA Asala in 2000 shows that the mean value of transverse diameter of head for the African whites and African blacks are different. Thus racial difference also exists in the dimensions of femoral head.

Circumference of head of femur (HC) - In the present study, circumference of head of the femur (mean 128.82) is statistically lower than Brazilians femora (mean 133.96,  $P < 0.001$ ) as shown by DA Silva et al. 2003, and study in New Zealand by AMC Murphy, 2002. This indicates that western populations have larger femoral head as compared to femora in the present study. The mean of the circumference of head of femur in Rohtak by Gargi Soni, 2010 is not showing significant difference with present study ( $p > 0.05$ ). The stress and strain pattern experienced by the femoral head of Indian and western population is different which makes the femoral head larger in westerns. Below mentioned table is showing comparative data of present study with various researchers in other part of world.

Table no.4 - Showing Circumference of head of femur in comparison with previous studies

Sr No.	Name of worker	Sample Size	Mean	SD	P value
1.	DA Silva et al. 2003,brazilians(29).	66	133.96	10.2	<0.001
2.	Gargi Soni, 2010, Rohtak(30).	80	129.72	7.59	>.05
3.	AMC Murphy, 2002, New Zealand(31).	85	140.73	6.68	<0.001
4.	Present Study, 2013, Western Odisha Population	202	128.82	10.19	<0.001

The present study provides valuable parameters which would help the forensic

anthropologists, orthopaedicians and prosthetists to deliver excellent performance in their respective specialities. The result of the present study can provide a guide for future implants design to provide better fitting implants for the local population and thus change the concept of orthopaedic surgeries in our country.

## Conclusion

The authors have used a novel method to measure the parameters in the present study. Significant differences are noted in the proximal femoral geometry of the Western Odisha population. The results of the present study could help the forensic anthropologists, orthopaedicians and prosthetists to deliver excellent performance in their respective specialities. The result of the present study can provide a guide for future implants design to provide better fitting implants for the local population and thus change the concept of orthopaedic surgeries in our country.

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