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Original Research Article

A STUDY ON THE PROXIMAL FEMORAL GEOMETRY FOR STANDARDIZING THE FEMORAL COMPONENT DESIGN TO SUIT INDIAN NEEDS IN TOTAL HIP REPLACEMENT

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ABSTRACT

Background and aims: The percentage of elderly people above 65 years of age & incidence of Osteoarthritis in India is expected to be very high by 2040 AD. The final weapon in the management armamentarium of osteoarthritis is Total Hip Replacement. The femoral component design plays a major role in the success of the surgery. The anatomy of the upper end of femur varies with different populations. The study is aimed to provide guidelines for future design of the femoral stem for Indian population.

Materials and Methods: 200 dry human bones were studied. The parameters including: Femoral head off set, femoral head diameter, femoral neck diameter, canal width, endosteal and extra cortical width, ante version angle and neck shaft angle were studied using UTHSCSA Image tool software. The results were analyzed using statistical package SPSS 17.0 version.

Results: The average femoral head offset, neck shaft angle and ante version angle was 40.75 mm, 131.48 degrees and 10.69 degrees respectively. The head diameter and neck diameter was 41.77 mm and 28.66 mm respectively. The canal width was 34.87 mm, 49.27 mm and 30.09 mm respectively at the level, 20 mm above the level and 20 mm below the level of lesser trochanter, endosteal width at the level of isthmus was 15.9 mm and extra cortical width at the level of isthmus was 14.03 mm

Conclusion: The guideline values obtained for the parameters, particularly the femoral head offset, ante version angle and neck shaft angle are strongly recommended for designing femoral stems.

KEY WORDS: Femoral Offset, Femoral Diameter, Femoral Stem, Osteoarthritis.

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INTRODUCTION

Osteoarthritis is the fourth leading cause of disability among old age people across the globe [1]. 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 AD [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].

An ill fitting femoral component results in micromotion at the bone-implant interface hindering the in growth of trabecular bone leading to aseptic loosening, stem fracture, anterior thigh pain and many other complications [5]. Most of the orthopedic surgeons in India, currently feel the need of a femoral component that will be more suitable for the Indian femora.

Aims and Objectives:

The study is expected to:

1. Obtain morphological data for the important parameters including femoral head offset, femoral head diameter, femoral neck diameter, canal width (at the level of lesser trochanter; 20mm above and below the level of lesser trochanter), endosteal and extracortical width (at the level of isthmus), ante-version angle and neck shaft angle of the South Indian femora

2. Provide guidelines and recommendations for future design of femoral components in total hip arthroplasty for the South Indian population

MATERIALS AND METHODS

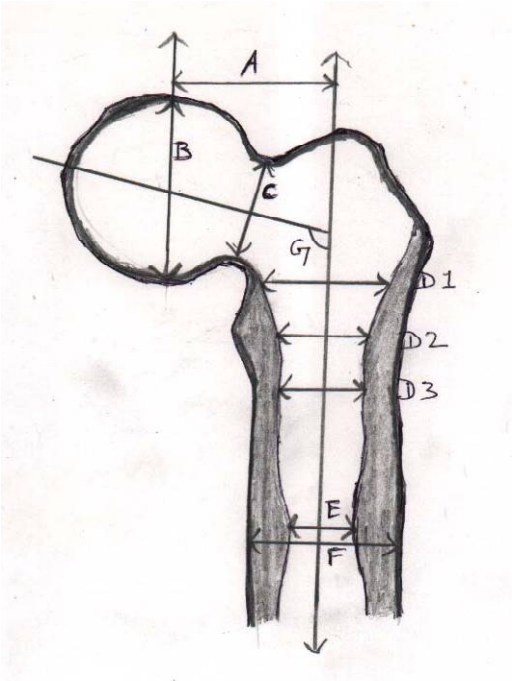
The present study is a descriptive study of human dry bones. The samples were selected from the bones available in the bone banks of medical colleges (bones procured from cadavers of South Indian origin) in and around the parent institution of study (Coimbatore, Tamil Nadu, South India).

Two hundred (200) dry human bones (105 belonging to right side and 95 bones belonging to left side) were utilized for the study. The gender of the bones was not identified.

As criteria of inclusion, normal bones without any obvious pathology were included for the study and diseased / fractured bones with obvious deformity which can affect the outcome of the study were excluded from the study.

The parameters were measured based on standard guidelines [3-10]. The femoral head offset (a) was measured as the distance between the centre (of rotation) of the femoral head and the line bisecting the axis of the femur. The femoral head diameter (b) the distance between the highest point and lowest point on the femoral head was taken as the superior-inferior diameter of the head; the distance between the most anterior point and most posterior point was taken as the antero-posterior diameter of the head; average of both these values was taken as the diameter of head of femur, femoral neck diameter (c) – the distance between the superior border and inferior border of the neck taken at the midpoint; canal width (d) - width of the intramedullary canal taken between the two inner cortices at three levels- at the level of lesser trochanter, 20 mm above the level of lesser trochanter and 20 mm below the level of lesser trochanter; endosteal width (e)distance between the two inner cortex and extra cortical width (f) - distance between the outer cortex at the level of isthmus (narrowest portion of the femoral canal);the neck shaft angle (g) - angle formed between the long axis of the neck of femur and long axis of shaft of femur), the anteversion angle (h) – angle formed between the long axis of the femoral neck and a line parallel to the dorsal aspect of the femoral condyles were measured. Figure 1 shows the line diagram depicting the parameters (a-g).

Fig. 1: Showing the various parameters.



A- Femoral head offset
B- Superior inferior diameter of head
C- Neck diameter
D1-Canal width 20 mm above lesser trochanter
D2-Canal width at the level of lesser trochanter
D3- Canal width 20mm below lesser trochanter
E-Endosteal width at the level of isthmus
F-Extracortical width at the level of isthmus
G-Neck shaft angle

Two methods were used to study the parameters- radiographic method and photographic method. The parameters studied in each of these methods were different. Parameters including femoral head offset, canal width, endosteal and extra cortical widths alone were studied in radiographs. Parameters including femoral head diameter, neck diameter, neck shaft angle and ante-version angle alone were studied in photographs. The measurements were done on the radiographs and photographs using the validated image tool software [11] (UTHSCSA Image Tool for Windows version 3.0, San Antonio, TX, US).

In the first step digital roentgenograms (AP view) of all the bones selected for the study were taken using standardized techniques [2]. The bones were placed directly over the X-ray cassette to minimize the magnification. The distance between the X-ray source and the film was kept standard as 90 centimeters throughout the study. The digital images of the X rays were transferred to a PC unit.

In the second step each of the femurs were digitally photographed in standardized position on acrylic osteometric board (OB) in three views; a straight view, a view from the superior aspect and a view from the lateral aspect. The distance between the camera lens (Sony DCR W270, Tokyo, Japan) and the object was constantly maintained as 10cms. The images were stored in a memory card and transferred to a PC unit. Each image was resized independently. Finally the measurements were done using the image tool software (Fig. 2 A, 2B, 2 C, 3A & 3 B).

Fig. 2a: Orientation of right femur on graduated osteometric board. The femoral head is 10 cm away from the camera lens (C). NA-neck axis; SA-shaft axis; OA-optical axis; 1&1'-parallel line drawn along the upper and lower border of head; 2-head superior-inferior diameter; Asterix (*)-neck-shaft angle.

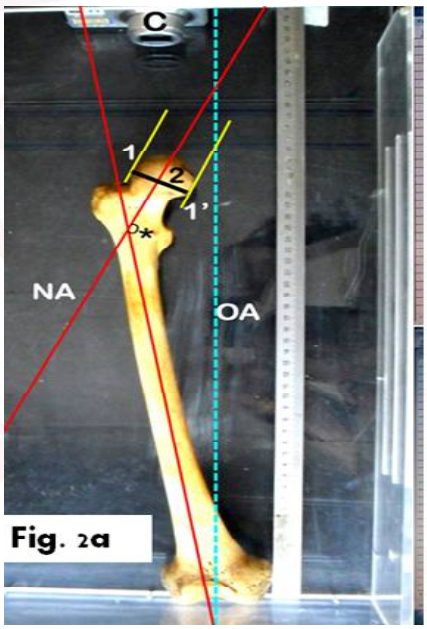


Fig. 2b: Screenshot picture showing the measurement of femur using Image tool software. HSID-head superior inferior diameter. Measurement is displayed on the left side

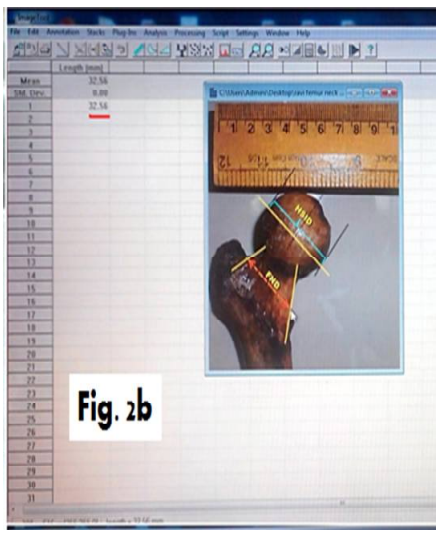


Fig. 2c: Screenshot picture showing the measurement of femur using Image tool software. HAPD-head antero posterior diameter. Measurement is displayed on the left side

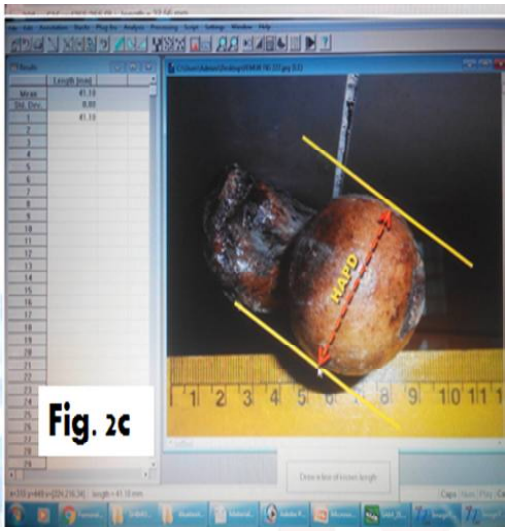
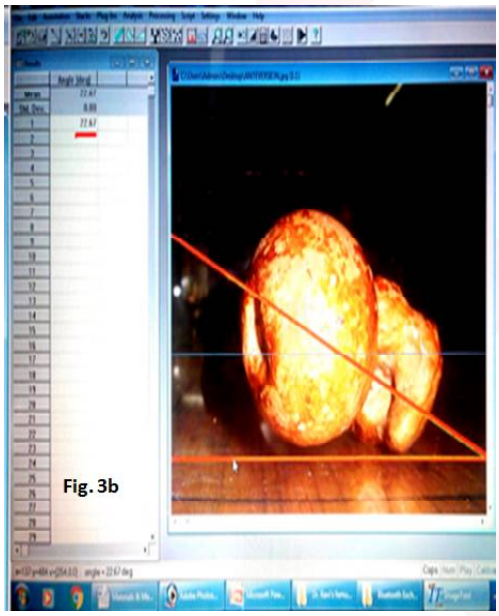


Fig. 3b: Screenshot picture showing the measurement of femoral neck anteversion of right femur using Image tool software. The measurement is displayed on left side (red color underline).



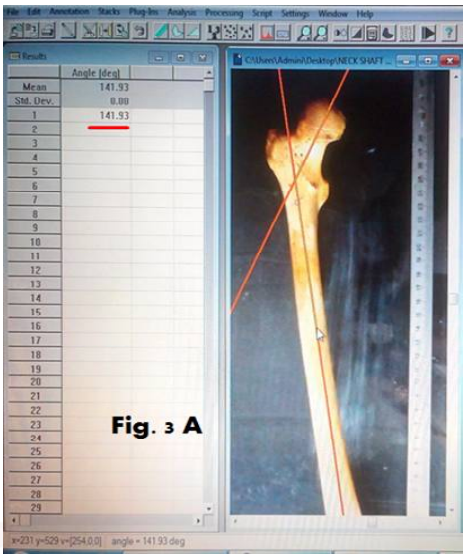
The study involves dry bones and hence there are no ethical considerations.

The data were analyzed (independent "t" test, mean, standard deviation) using SPSS version 17 statistical package.

RESULTS

The average femoral head offset in the present study was 40.75 ± 0.32 mm. The average neck shaft angle was 131.48 ± 9.47 degrees and the average anteversion angle was 10.69 ± 2.63 degrees. The values for the remaining parameters including head diameter, neck diameter,

Fig. 3a: Screenshot picture showing the measurement of neck shaft angle of right femur using Image tool software. The measurement is displayed on left side (red color underline).



canal width, extracortical and endosteal widths are presented in Table 1.

Table 1: Shows the mean and SD value of all the parameters (n=200 bones).

Parameter	Mean	Median	Mode	SD
Femoral head offset	40.75 mm	4.12	4	0.32
Femoral head diameter	41.77 mm	4.2	4.6	0.36
Neck diameter	28.66 mm	2.8	2.7	0.4
Canal width:				
At the level of LT	34.87 mm	3.4	3.4	0.32
20mm above the level of LT	49.27 mm	4.9	4.6	0.39
20mm below the level of LT	30.09 mm	3	2.9	0.35
Endosteal width at the level of isthmus	15.9 mm	1.6	1.5	0.3
Extracortical width at the level of isthmus	14.03 mm	1.4	1.1	0.28
Anteversion angle	10.69 deg.	11	11	2.63
Neck shaft angle	131.48 deg.	132	138	9.47

DISCUSSION

Total hip replacement surgery is the permanent cure for patients suffering from osteoarthritis of the hip. In this procedure the hip joint is replaced by an artificial femoral prosthesis and acetabular component. The success of the surgery depends on the perfect design of the femoral component that suits the geometry of the local population. The stability of the femoral component depends on a balance of proximal and distal load transfer from the implant to the femur [12]. Ill-fitting femoral components lead to long term complications and failure of the procedure. The published data of Swiss, French, Thai, Caucasians and North Indian population

and the mean values of the present study [2,3,5,13-15] is presented in Table 2.

Table 2: Available data on the proximal femoral geometry in different populations.

Parameter	Rubin et al [13] Swiss	Husmann et al [14] French	Mahaisavariya et al [15] Thai	Noble et al [3] Caucasian	Rawal BR et a1 [5] Indian	Siwach et al [2] Indian	Present study South Indian
Femoral head offset (mm)	47± 7.2	40.5 ±7.5	Parameter not studied	43 ± 6.8	40.23 ± 4.85	38 ± 5.52	40.75 ± 0.32
Femoral head diameter	43.4 ± 2.6	Parameter not studied	43.98 + 3.47	46.1 ± 4.8	45.41 ± 3.66	43 .53 ± 3.4	41.77 ± 0.36
Neck diameter	Parameter not studied	Parameter not studied	Parameter not studied	Parameter not studied	Parameter not studied	29.5± 3.19	28.66 ± 0.40
Canal width:							
At the level of LT	27.9 ± 3.6	Parameter not studied	Parameter not studied	29.4 ± 4.6	Parameter not studied	23.8 ± 3.20	34.87 ± 0.3
20mm above the level of LT	43.1 ± 5.2	42.6 ± 5.5	Parameter not studied	45.4 ± 5.3	36.78 + 5.32	43.5 ± 4.37	49.27 ± 0.39
20mm below the level of LT	21 ± 2.7	Parameter not studied	Parameter not studied	20.9 ± 3.5	Parameter not studied	16.57 ± 1.99	30.09 ± 0.35
Endosteal width at the level of isthmus (mm)	13.7 ± 2.1	Parameter not studied	Parameter not studied	27 ± 3.1	Parameter not studied	10.11 ± 1.90	15.9 ± 0.30
Extracortical width at the level of isthmus (mm)	26.7 ± 1.8	Parameter not studied	Parameter not studied	12.3 ± 2.3	Parameter not studied	24.42 ± 2.54	14.03 ± 0.28
Anteversion angle (degrees)	Parameter not studied	Parameter not studied	Parameter not studied	Parameter not studied	10.9 ± 4.22	13.68 ± 7.92	10.69 ± 2.63
Neck shaft angle (degrees)	122.9 ± 7.6	129.2 ± 7.8	128.04 ± 6.14	124.7 ± 7.4	124.42 ± 5.49	123.5 ± 4.34	131.4 ± 9.47

Most of the currently available orthopedic implants are designed according to the Caucasian standards [3,13,16]. The mean results of the present study were compared with the mean values of the Caucasian study. Analysis showed that there is a significant difference in the proximal femoral parameters of the South Indians and the Caucasians (Table 3).

Table 3: Statistical Comparison of available mean values published in the Caucasian study (Noble et al) with the mean values of the present study.

Parameter	Caucasian study- Noble et al [3] (n=200)	Present study (n=200)	"t" value	"p"value	Significance
Femoral head offset (mm)	43 ± 6.8	40.75 ± 0.32	-4.64	<0.001	Significant
Femoral head diameter	46.1 ± 3.66	41.77 ± 0.36	16.651	<0.001	Significant
Canal width:					
At the level of LT	29.4 ± 4.6	34.87 ± 0.39	16.781	<0.001	Significant
20mm above the level of LT	45.4 ± 5.3	49.27 ± 0.39	10.29	<0.001	Significant
20mm below the level of LT	20.9 ± 3.5	30.09 ± 0.35	36.94	<0.001	Significant
Extracortical width at the level of isthmus (in mm)	27 ± 3.1	14.03 ± 0.28	58.929	<0.001	Significant
Endosteal width at the level of isthmus (in mm)	12.3 ± 2.3	15.9 ± 0.30	-21.95	<0.001	Significant
Neck shaft angle (in degrees)	124.7 ± 7.4	131.4 ± 9.7	7.884	<0.001	Significant

The mean results of the present study were compared with the results of other Indian investigators (Table 4 & 5). The observations of the present study for the parameters femoral head offset and anteversion angle were similar to the observations by Rawal BR et al (the difference between the means was not statistically significant) whereas the other two parameters (femoral head diameter and neck shaft angle) was not similar (the difference between the means was statistically significant).

The observations for all the parameters (except canal width at 20 mm above and 20 mm below the lesser trochanter) differed significantly from the observations made by Siwach et al. (the difference between the means was statistically significant) Based on the comparison with Siwach et al, it is evident that majority of the proximal femoral parameters differ between the South and North Indian populations.

Studies show that the size of the anatomical femoral head offset is determined by the neck-shaft angle [17] and the physiological femoral offset is determined by the anteversion angle [11].

Therefore the parameters, femoral offset, neck shaft angle and ante version angle play a vital role in the design of a femoral prosthesis. A strong correlation has been found between femoral head offset and abductor muscle lever arm and strength [18].

A post operative restoration of the femoral offset is vital for proper functioning of the abductor lever arm and to improve function and longevity of the total hip replacement surgeries. If the femoral offset and neck shaft angle of the implant does not coincide with that of the local population, the chances of failure are high.

A mismatch between the canal width and stem diameter can result in aseptic loosening and dislocations. The long term complications of cemented total hip replacement, particularly the loosening rate of the femoral component [19] has led to the development of implants with biological fixation. In such implants, stable primary fixation of the components is mandatory to obtain bony in growth and secondary long term stability. Optimum filling of the proximal metaphysis by the implant is one

Table 4: Comparison of the available mean values in the published Indian study (Siwach et al) with the mean values of the present study.

Parameter	Siwach et al [2] (n=150)	Present study (n=200)	"t " value	"p" value	Significance
Femoral head offset (mm)	38 ± 5.52	40.75 ± 0.32	6.094	<0.001	Significant
Femoral head diameter	43 .53 ± 3.4	41.77 ± 0.36	-6.313	<0.001	Significant
Neck diameter	29.5 ± 3.19	28.66 ± 0.40	3.681	<0.001	Significant
Canal width:					
At the level of LT	23.8 ± 3.20	34.87 ± 0.3	-14.585	<0.001	Significant
20mm above the level of LT	43.5 ± 4.37	49.27 ± 0.39	-2.464	0.0149	Not Significant
20mm below the level of LT	16.57 ± 1.99	30.09 ± 0.35	-2.376	0.0188	Not Significant
Endosteal width at the level of isthmus (mm)	10.11 ± 1.90	15.9 ± 0.30	-42.417	<0.001	Significant
Extracortical width at the level of isthmus (mm)	24.42 ± 2.54	14.03 ± 0.28	57.413	<0.001	Significant
Anteversion angle	13.68 ± 7.92	10.69 ± 2.63	-4.444	<0.001	Significant
Neck shaft angle	123.5 ± 4.34	131.4 ± 9.47	9.494	<0.001	Significant

Table 5: Comparison of the available means of Rawal Br (Indian study) with the mean of the present study.

Parameter	Rawal BR et al [5] (n=98)	Present study (n=200)	"t" value	"p" value	Significance
Femoral head offset (mm)	40.23 ± 4.85	40.75 ± 0.32	-1.512	0.1315	Not significant
Femoral head diameter	45.41 ± 3.66	41.77 ± 0.36	13.952	<0.001	Significant
Anteversion angle	10.9 ± 4.22	10.69 ± 2.63	0.526	0.5993	Not significant
Neck shaft angle	124.42 ± 5.49	131.4 ± 9.47	-8.028	<0.001	Significant

way of achieving primary stable fixation and allowing physiological load transfer [20]. Data on endosteal morphology is therefore very essential in the design of the femoral prosthesis.

The present study has been conducted with dry bones without considering the age and gender of the bones. The authors recommend future studies including these parameters in live individuals using specialized techniques (Three dimensional CT scans).

CONCLUSION

The authors have used a novel method (Image tool software) to measure the parameters in the present study. Significant differences are noted in the proximal femoral geometry of the Caucasians and South Indians. The results of the present study could be used as a guide for future designs of the femoral prosthesis in South Indian population.

Conflicts of Interests: None

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