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Assessment of proximal femur anthropometry in South Indian population through cadaveric bones and radiologically correlating difference if any between other ethnic groups

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ABSTRACT

Background: The morphology of the proximal femur is a topic of extensive research. The hip joint is one of the most commonly replaced joint. The era of replacement has given rise to various implants that can be used to replace the proximal femur. This present study addresses these issues involving ethnic differences in the geometry of the proximal femur in Indians and its differences between people of various ethnicity.
Methods: The total population that was radiographed was 178 (n=178). There were 78 males and 100 females. The age of the participants were spaced from 25-75 years age groups. The parameters were measured.
Results: The canal flare index in South-Indians was an average of 3.23 with 70% of the study population having normal CFI (3-4.5), 30% of the population having a stove pipe configuration CFI (<3). Majority of the Indian population favour a un-cemented fixation (70%).
Conclusions: In summary all current implants have to be revised on population basis to fit the changing anthropometry of our proximal femur.

Keywords: Femur canal, South Indian population, Canal flare index

INTRODUCTION

The morphology of the proximal femur is a topic of extensive research. The hip joint is one of the most commonly replaced joint. The era of replacement has given rise to various implants that can be used to replace the proximal femur. The integral part of any replacement is to reproduce the biomechanics of the original joint in the prosthetic components in order to achieve good clinical outcome both in terms of patient and implant. Many of the conventional implant systems manufactured by various conglomerate companies are made in correlation with the sizes of the femora of Europeans.[1] The use of these implants in the Indian population, owing to its small size of the femur has been plagued with numerous complications like intra-op splintering of the proximal end of femur. It is also the bane of the Asian-Indian Orthopaedic surgeons to work with such ill-fitting implants.

Most implant systems are usually designed on the basis of European femora, which are believed to be larger than Asian population. The implantation of these prosthesis often results in problems like fractures of the proximal femur or less confirming prosthesis leading to loosening.[2]

This present study addresses these issues involving ethnic differences in the geometry of the proximal femur in Indians and its differences between people of various ethnicity. It also evaluates the adequacy of fit of the conventional femoral stems in Indian population.

The aim and objective of the study was to determine the proximal femur morphology in South Indian population determined with radiographs and from cadaveric dry bones and to determine the differences between anthropometry of South Indian population and other ethnic groups.

METHODS

This is a prospective study consisting of two fundamental parts, involved in assessing the anthropometric dimensions of the proximal femur. In the first part of the study we have evaluated anthropometry of 178 volunteers radiographically. The second part of the assessment was done with cadaveric femora obtained from the Department of Anatomy, PSGIMSR. 50 cadaveric dry femora were obtained and direct measurement of measurable anthropometric data was done. The study was conducted in PSGIMSR Coimbatore, Tamil nadu, India from August 2013 to August 2014.

Inclusion criteria were South Indian population and people of age 25 years and above. Exclusion criteria were no prior pathology in the femur- infection (old/healed/active), congenital anomalies, contractures and deformities around the hip, previous hip surgeries and open epiphysis.

Parameters templated

- Femoral head diameter
- Horizontal offset
- Neck shaft angle
- Endosteal diameter at a level 20 mm above lesser trochanter (D)
- Endosteal diameter at the summit of the lesser trochanter (E)
- Endosteal diameter at a level 20 mm below the lesser trochanter (F)
- Endosteal diameter at the level of the Isthumus (G-10 cm below lesser trochanter)
- Canal flare index.

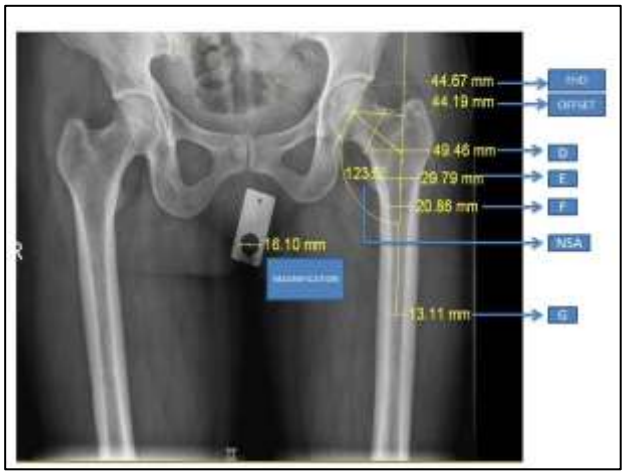

Figure 1: Radiograph templating.

Methodology of templating

Endosteal diameters

The endosteal width is measured at various locations based on reference lines which have been already defined as per Noble P C et al. The apex of the lesser trochanter is taken as the first landmark. The endosteal width at the level of the apex of lesser trochanter (E), endosteal width 20 mm above (D) and below (F) the lesser trochanter and 10 cm below the lesser trochanter (G) is measured. The mid-point of these endosteal width lines are connected to form the axis of the shaft of femur. One more point is taken measuring 10 cm distal to the apex of the lesser trochanter (G) which is considered as the isthumus. Endosteal width at that level is also measured.[3-5]

Femoral head diameter

The femoral head diameter is taken as the largest vertical diameter (superior-inferior) of head perpendicular to the axis of the neck of femur. The neck axis is drawn by drawing neck widths at 2 regions on the neck of femur, preferably in the trans-cervical and sub-capital region. The midpoints of these two lines are joined and extended further to form the axis of the neck. The femoral head diameter is measured perpendicular to this line taking the largest superior-inferior diameter of the femoral head.

Horizontal offset

The horizontal offset is also known as the actual femoral offset. The horizontal offset is measured as the distance between the centre of the femoral head to the axis of the shaft of femur. The x ray is taken in the said protocol mainly to reveal the proper and maximal offset of the femur.[6]

Neck shaft angle

The neck shaft angle is the angle subtended between the shaft axis and the axis of the neck of femur.[3,4,6]

Canal flare index

The ratio between the endosteal diameters 20 mm above the lesser trochanter (D) and at the level of isthumus (G) is called the canal flare index. Based on the values of canal flare index they were grouped in to normal (3-4.7) , champagne flute (high tapering in the proximal segment 4.7-6.5), stove pipe (a straight proximal femur relative to distal).[3]

The diameter of the magnification marker in the radiograph is determined for identification of the radiographic magnification error.

Cadaveric dry femora- study

The second part of the study involved with measuring the endosteal dimensions of cadaveric femur specimens. This was done to find out the true anthropometric parameters

of proximal femur in addition to knowing the fit of available femoral stems, So as to determine mismatch between implant and bone if any.

In our study we have taken 50 cadaveric femora. The cadaveric femora were cut at various positions so as to ascertain the endosteal dimensions at various regions of the cadaveric femur. The femora were cut using a motorized cadaveric cutting saw in the Department of Anatomy- PSGIMSR. The endosteal dimensions were measured using a Vernier calliper, at the regions mentioned below.

Figure 2: Cut sections of dry bones at various reference levels (left to right – D, E, F, G).

Figure 3: Method to measure neck shaft angle of cadaveric dry bone.

RESULTS

The mean femoral head diameter was 47.41 mm with a 95% confidence interval for the mean values, a standard deviation of ±4.5 mm. The mean offset in the study population was found to be 42.75±4.3 mm. The mean CFI was found to be 3.23±0.5.

Table 1: Results of radiographic study.

	Mean	SD	Minimum	Maximum
Age	47	10	25	75
Femoral head diameter	47.41	4.5	35	57
Medullary canal width				
D	43.79	5.2	33	61
E	27.35	4.3	17	43
F	19.92	3.5	12	31
G	13.88	2.8	9	23
Horizontal offset	42.75	4.3	34	53
Canal flare index	3.23	0.5	2	5
Neck shaft angle	126.03	4.6	114	137

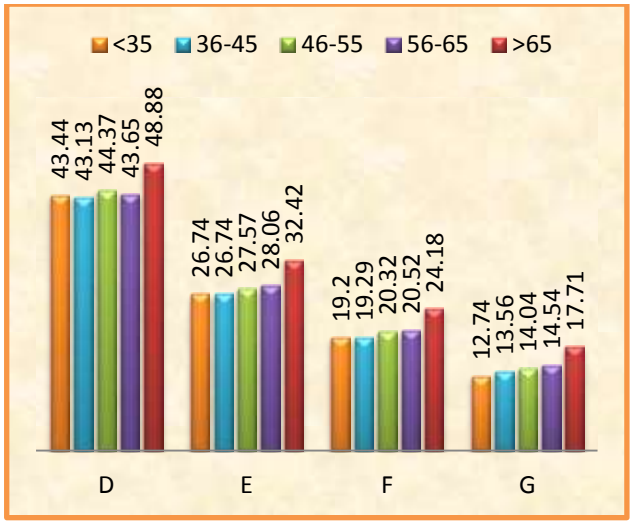

Figure 4: Mean medullary canal width at various levels matched with different age groups.

The above Figure 4 explains the difference in the medullary canal width as the age groups progressed there was a tendency towards increase in the mean width of the endosteal canal diameter.

Table 2: Age wise distribution of canal flare index.

Age group	Stove pipe(<3.0)	Normal (3.0-4.5)	Champagne	Total
<35	4	15	0	19
35-45	21	51	0	72
45-55	14	42	0	56
55-65	12	13	1	26
>65	2	3	0	5
Total	53	124	1	178
%	30%	70%	1%	100%

In the study population 30% had a stove pipe appearance of medullary canal with mean CFI <3. 70 % of the population had normal appearing femora with CFI ranging from 3-4.5 as shown in Table 2.

DISCUSSION

The aim of our study is to evaluate ethnic differences in the anthropometry of proximal femur of South Indians in comparison with other ethnic groups around the world.

The total population that was radiographed was 178 (n=178). There were 78 males and 100 females. The age of the participants were spaced from 25-75 years age groups. The following parameters were measured:

Femoral head diameter

The lowest femoral head diameter measured in our study was 35 and largest femoral head diameter in the study population was 57. The mean femoral head diameter was 47.41 mm with a 95% confidence interval for the mean values, a standard deviation of ±4.5 mm. The most prevalent head size in the given population was estimated in terms of mode for the given range, was found to be 49 mm.

Medullary canal diameters

Medullary canal widths were measured at various locations on the radiographs as described earlier in correlation to the prime seating points of the femoral stem. These levels are the standard reference points to address the changing geometry of the proximal femur. The mean and standard deviations were estimated for each parameter.

Mean canal widths at reference points-

- Endosteal canal width 20 mm above lesser trochanter (D)- 43.79±5.2 mm
- Endosteal canal width at the level of lesser trochanter (E)- 27.35±4.3 mm
- Endosteal canal width 20 mm below the lesser trochanter (F)- 19.92±3.5 mm
- Endosteal canal width at the level of isthumus (G)- 13.88±2.8 mm.

The distribution of endosteal canal widths at various levels were analysed with their age group wise distribution.

As the age groups progressed there was a tendency towards increase in the mean width of the endosteal canal diameter. This was most significant in the >65 years age groups. This was consistent with decreasing trend of canal flare index as age progressed.

Canal flare index

The mean and standard deviation for the same was calculated. The mean CFI was found to be 3.23±0.5. An age wise distribution of the canal flare index.

In the study population 30% had a stove pipe appearance of medullary canal with mean CFI <3.70% of the population had normal appearing femora with CFI ranging from 3-4.5.

There was progressive tendency towards stove pipe appearance of femoral endosteum as age progressed. Most strikingly noted in the >65 years age group with a mean canal flare index of 2.86. The younger age groups predominantly have a more normal type of femur. The distribution was found to be statistically significant in terms of distribution with progressive decline in the endosteal dimension as age progressed, and the femoral endosteum attaining a stove pipe like appearance ($p < 0.05$).

The gender wise distribution of the canal flare index was assessed, mean CFI in males was found to be 3.14±0.4, compared to the mean of 3.29±0.5 in the female pool. There were statistically significant differences in the gender wise distribution of the mean canal flare index ($P < 0.05$).

Horizontal offset

Horizontal offset calculated as the distance between the center of femoral head to the axis of the femoral shaft, which defines the abductor muscle tension was measured in all 178 subjects. The mean offset in the study population was found to be 42.75±4.3 mm.

Differences in anthropometric parameters of Indian femora vs. other ethnic population

The ethnic differences in the anthropometry of the proximal femur was assessed by matching the values of our present study with that of values previously measured in other ethnic populations. For the comparison we have taken the values of proximal femoral anthropometry of the Caucasian population according to the study by Noble P C et al (n-200), the importance of this study was its vitality in bringing up of the dimensions for creation of the various somatotypes for the cemented and un-cemented replacement armamentarium.[4] The study has allowed us to have sufficient arsenal for replacement at the same time allowing the implant to accommodate itself in to bulk of the femora. Anthropometric analysis of a Swiss population based on study by Rubin et al, French population by Massin et al, Malay population by Baharuddin et al, Thai population by Mahasavariya et al.[5,14-16]

Femoral head diameters

The difference in the femoral head diameters across various ethnic groups was assessed.

The present study showed mean femoral head diameters in the South Indian population to be 47.16±4.5 mm. The mean femoral head diameter of Indian population was compared with that of the Malay population 40.81±3.43 mm. The Malay population was found to have smallest femoral head diameters. The mean femoral head diameter of the present study was compared with the Thai population - 43.98±3.47, the Thai population had smaller femoral head dimensions. The mean femoral head diameter of the present study was compared with the Swiss population- 43.40±2.26 mm, the Swiss population had significantly smaller femoral head diameters. The mean femoral head diameters of the South Indian population was compared with the French population, they had lesser mean femoral head diameters- 45.60±4.20 mm compared to Indian population. There was no statistically significant difference in the mean femoral head diameters between Indian and Caucasian femora- 46.1±4.8 mm.

Canal diameters

The population mean endosteal dimensions were measured at four reference levels and assessed between various groups. The mean femoral head diameter at the four reference levels for the South Indian population was endosteal diameter 20 mm above lesser trochanter (D)- 43.79±5.2 mm, endosteal diameter at the level of lesser trochanter (E)- 27.35±4.3 mm, endosteal diameter 20 mm below lesser trochanter (F)- 19.92±3.5 mm Endosteal diameter at the isthumus (G)- 13.8±2.8 mm. There was no statistically significant difference between the endosteal diameters of South Indian and Malay population when matched against present study at the level of D (20 mm above lesser trochanter) and F (20 mm below the lesser trochanter). However at the level of G (isthumal diameter) it was found to be smaller in the Malay population (9.73±1.8 mm). These differences were statistically significant. There is no statistically significant difference in the mean canal diameters at the four reference levels when Indian femora were matched with the Swiss population indicating a close resemblance in terms of endosteal dimensions. There was no statistically significant difference between the endosteal diameters of the South Indian population (present study) and the French population. The endosteal widths of Indian femora was smaller by 2.0 mm in comparison to the Caucasian femora at all 4 reference levels which was statistically significant ($P < 0.05$). Even with a magnification error of 3 mm between present study and Caucasian study the endosteal dimensions are smaller by 2 mm in comparison to Caucasian femora. This suggests that the actual difference is much more.

Offset

The mean offset in the Indian population was 42.75±4.3 mm. The offset values of the South Indian population were compared with the Malay population- 31.50±5 mm. The offset of the Malay population was found to be significantly smaller than the South Indian population. The offset values of the South Indian population were compared with the Japanese population– 30.45±4.26 mm. The offset of the Japanese population was found to be significantly lower than the South Indian population. The offset of the South Indian population was compared with the French population who had a mean offset of 41±6.20 mm. The offset of the French population was close to that of the South Indian population and the difference was not statistically significant. The offset of the South Indian population was compared with the Swiss population who had a mean offset of 47±7.2 mm which was the highest among the ethnic groups in study. The mean offset of the South Indian population was 4.25mm lower than the Swiss population. This probably correlates with the bigger size of the femora among European population. There is no significant difference between the offset of South Indian population and Caucasian population- 43±6.8 mm.

Canal flare index

The mean canal flare index in the Indian population was found to be 3.23.The mean canal flare index of the South Indian population was compared to the Caucasian population which had a canal flare index of 3.8. The difference was statistically significant. The canal flare index of the South Indian population was compared with the French population who had a canal flare index of 3.6. The differences were found to be statistically significant between South Indian and French population, in terms of trending of the canal flare index. This probably suggests a better bone stock in the European population, with the European populations having more Champagne flute configuration of canal flare, therefore will favour more of an un-cemented fixation.

Neck shaft angle

The mean neck shaft angle was found to be 126 degrees in the present study of South Indian population. The verge neck shaft angle of the South Indian population was compared with the Japanese population. The Japanese population had an average valgus femoral angulation with mean neck shaft angle of 137 degrees in comparison to South Indian population.

The neck shaft angle of the South Indian population was compared with the Malay population. The mean neck shaft angle of the Malay population was 130 degrees. There was a slight inclination towards valgus mean femoral angulation in the Malay population when compared with the South Indian population in the present

study. There was no statistically significant difference between the neck shaft angles of present study and Caucasians -125 degrees. Analysis thus indicates more valgus femoral neck shaft angulations Asian population groups.

CONCLUSION

The canal flare index was found to be decreasing with age which is in correlation to the age related decrease in the femoral bone stock. The Asian and Indian femur bone is of much smaller sizes in comparison to European femurs.

Limitations of study

The radiographic study had a mean magnification of 3 mm. There was radiation exposure to normal subjects who have volunteered for the study. The age of the dry bones was not available.

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Conflict of interest: None declared
Ethical approval: The study was approved by the institutional ethics committee

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