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Radiological Assessment of Proximal Femur Geometry using Picture Archiving and Communication System

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ABSTRACT

Introduction: Proximal Femoral Geometry is subjected to a wide range of ethnic variations. Various research article indicates that the geometry of the proximal femur in the Indian population considerably differ from the European and American standard. Proximal femur morphometry parameters are vital to design and develop arthroplasty components. Currently, arthroplasty components widely used are based on western standards. Improper size of hip joint arthroplasty may result in joint congruence, micromotion, osteoarthritis and tendinopathy. The present study comprehensively analyzes the proximal femur anthropometry in the South Indian population and comparison with other ethnic groups.

Aims: To determine the proximal femur geometry using radiographs and to analyze the proximal femoral geometrical variation between the south Indian population and various ethnics.

Materials and Methods: A study was conducted in 388 non - pathological hip joint X-rays collected from the Southern Indian population. The primary objective of the study is to measure proximal femoral geometry and compare the difference with various ethnic groups. Measurements like femoral head diameter, Neck width, Neck shaft angle, Femoral offset and Medullary canal diameter are calculated using Picture Archiving Communication System (PACS).

Result: In the present study, the proximal femur anthropometry of the South Indian population differs from the Western population. In some parameters, the present study also differs from the North Indian population Neck shaft angle in the present study is smaller than the western as well as in the South African population.

Conclusion: The present study of the proximal femur in the south Indian population considerably differs from the dimensions of the Western ethnic population. The study may aid in the development of proximal femoral arthroplasty components suitable for the Indian population.

Key Words: Proximal Femur, Femoral head diameter, Anthropometry of Femur, Neck shaft angle, Radiology, Hip joint, Morphometric analysis

INTRODUCTION

The geometry of the proximal femur is extensive prosthetic research in orthopaedics. The morphological parameters of the proximal femur have a wide range of deviations in various ethnic groups. Design and development of hemiarthroplasty and complete arthroplasty components need accurate geometry of proximal femur and acetabulum.[1]At present wide variety of conventional hemiarthroplasty and complete arthroplasty components are used in the Asia population. But the designs of these implants are based on Eurasian ethnics. The most used implants in the proximal femur are cancellous screws, proximal femoral nails and dynamic hip screws (DHS).[2]With no other data available in Indian ethnic currently the mismatched implants are particularly designed and developed for western ethnic with no other option employed in Indian ethnic.[3] Mismatched implant design and inappropriate design will lead to severe postoperative clinical complications such as joint pain, joint congruence, slipped capital femoral head and gluteal tendinopathy.[4] In uncemented hip

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arthroplasty integration of hip arthroplasty mainly depends upon the quality of its primary stability. Leung et al.[5] reported the need to modify the gamma nail to suit the Asian population as the femoral head diameter, neck width varies from the western standard. To minimize the post-operative and intraoperative complications, the arthroplasty components should be designed based on the anthropometry parameters of the Indian population. The study aims to get detailed parameters of the proximal femur.

MATERIALS AND METHODS

The study was conducted at BKL Walawakar rural medical college and hospital, Dervan, Maharashtra, Vinayaka Mission's Kirupananada Variyar Medical College, Salem, Tamilnadu. The study was conducted on 388 non-fractured anteroposterior X-ray pelvic radiographs of right and left samples for 3 months. The pelvic radiographs were taken by keeping the patients supine with both limbs in neutral rotation. The measurements like Neck-shaft angle (NSA), Head diameter (HD), Neck Width (NW), Vertical offset (VO), Horizontal offset (HO), Medullary canal diameter at various levels. Measurements were taken using a picture archiving communication system (PACS) and for the accuracy of the measuring process, the radiograph was optimized in full-screen view and the images were magnified to the highest resolution and measurements were taken using Radiant DICOM software.

Inclusion criteria

All asymptomatic hip patients irrespective of sex who had undergone Lower Abdomen X-ray. Age group 20-75 included**.**

Exclusion criteria

A person with pre-existing hip deformities, osteoarthritis, rheumatoid arthritis, tuberculosis hip, tumours of the hip patients underwent hip replacement surgery one or both. Patients with a malignant tumour. Skeletally immature patients, deformities of the lower limb and spine were excluded from the study.

Head diameter

The femoral head diameter is measured by taking the largest superior-inferior diameter of the femoral head parallel to the transcervical and sub-capital line.[1,6,7] (figure 1).

Neck width

The narrowest part of the femoral neck is parallel to the sub-capital line and perpendicular to the neck shaft axis.[8,9](figure 1).

Neck shaft angle

The femoral shaft axis is a line drawn by intersecting the midpoint of the transcervical line through equidistance points from the mediolateral surface of the femoral shaft centre in the centre of the medullary canal.[1,10,11](figure 2)

Horizontal offset

Horizontal offset is also called as femoral offset from the center of the femoral head to the line intersecting the long axis of the femur.[1,2] (figure 3).

Vertical offset

Vertical offset is also called a femoral head position offset. Center of the femoral head to the apex of the lesser trochanter.[12] (figure 3).

Medullary canal diameter

Medullary canal diameter is measured in four different levels.[9] (figure 1).

1. Transverse diameter of the medullar canal at the level of apex of lesser trochanter (A)
2. 20 mm above the apex of lesser trochanter (B)
3. 20 mm below the apex of lesser trochanter (C)
4. 10 cm below the apex of lesser trochanter (D)

Canal flare index

The canal flare index is calculated by the diameter of the medullary canal 20 mm above the apex of lesser trochanter (B) divided by 20 mm below the apex of lesser trochanter (C). based on the values of canal flare index the medullary canal isthmus is classified as normal (3-4.7), champagne flute (High tapering in the proximal segment 4.7-6.5), stovepipe (a straight proximal femur).[9] (figure 1).

All the measurements are taken in the Research Lab, Department of Anatomy. To avoid error, the data was measured twice by the research supervisor.

Statistical Analysis

The statistical work was done using GraphPad Prism version 8.1.1. The statistical analysis includes Mean, standard deviation, range, Pearson coefficient.

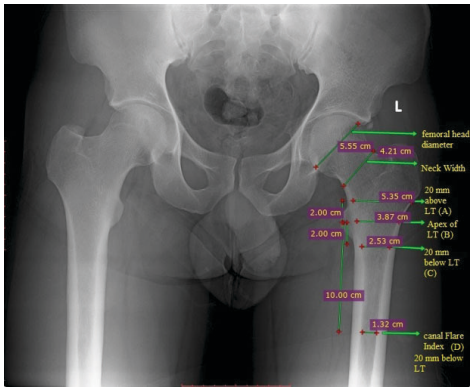

Figure 1: Sagittal X-ray of Hip showing femoral head diameter, Neck Width,Medullary canal diameter, Canal Flare Index.

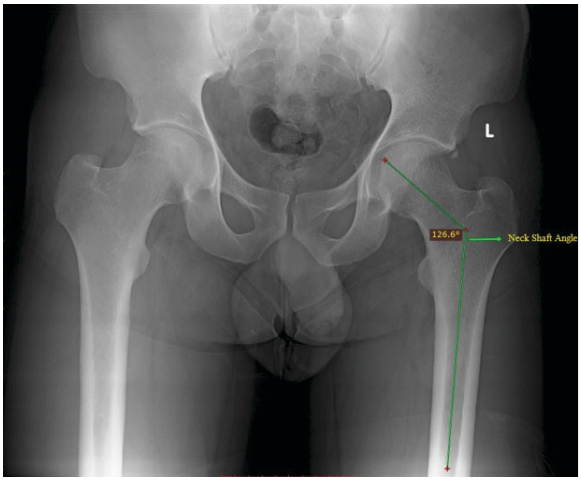

Figure 2: Sagittal X-ray of Hip showing Neck Shaft Angle.

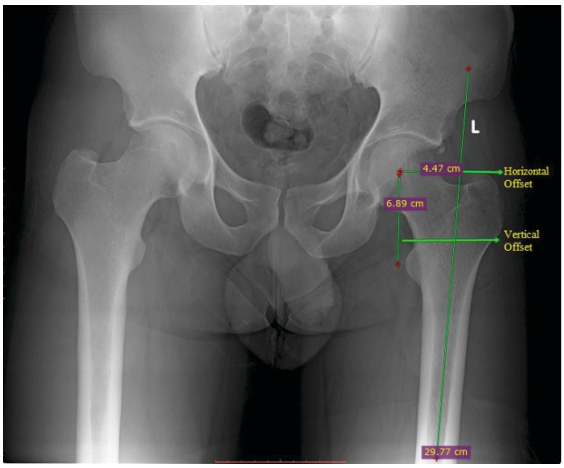

Figure 3: Sagittal X-ray of Hip showing Horizontal and Vertical axis.

RESULTS

Femoral head diameter

The mean value of the femoral head diameter was 48.42 mm (Table 3). The mean value of the femoral head diameter in males was 52.07 mm and in females was 47.15 mm (Table 1). In males, the range of femoral head diameter was 23.3 - 58.8 mm and in the female range of femoral head, the diameter was 40.5 - 56.6 mm(Table 1). The gender difference Femoral head diameter was statistically significant ($p<0.0002$) (****). However, there is no statistical difference between right and left femoral head diameter (Table 2).

Neck width

The mean value of the femoral neck width was 35.53 mm (Table 3). The mean value of the neck width in males was 38.29 mm. and in females 32.80 mm (Table 1). The minimum neck width in males was 30.29 and the maximum neck was 49.2 mm (Table 1). In the female range of the femoral neck, the width was 28.1-43.4 mm. The p-value of the neck width came statistically significant ($p<0.0001$) ****.

Neck shaft angle

The Neck shaft angle means the value was 128.96°. The mean value of the neck-shaft angle in males was 134.52° and in females, the neck-shaft angle was 128.40°. The value of the neck-shaft angle in a male range between 119.8-155.2°and in females, the neck-shaft angle range between 111.8° -151.1°. The p-value is highly significant ($p<0.0001$) ****.

Horizontal Offset

The mean value of the horizontal offset was 39.37mm (Table 3). For males, the mean horizontal offset was 42.63 mm and in females mean value was 39.11 mm. The value of horizontal offset in the male range between 23.7 - 65 mm and in the female range between 23.3 -52 mm (Table 1). The p-value of males and females is statistically significant ($p <0.0002$) ***

Vertical offset

The mean value of the vertical offset was 58.16 mm (Table 3). The mean value of vertical offset males was 61.47 mm and the mean Vertical offset in females was 54.78 mm. The range of vertical offset in males was 44 -74.8 mm and in females range of vertical offset was 33.4 - 66.7 mm (Table 1). The vertical offset is significantly higher in males than females ($p<0.0001$) ****.

Medullary canal diameter

The mean value of the medullary canal at the level of apex of the lesser trochanter was 30.12 mm (Table -3). The mean value of the Medullary canal in males was 30.11 mm and in females was 28.89 mm. The mean value of the medullary canal 20 mm above the lesser trochanter (A) was 47.18 mm**.** In male medullary canal diameter, 20 mm above lesser trochanter (A) was 48.41mm and female 47.15 mm. The canal diameter 20 mm below the lesser trochanter (B) in males was 23.62 mm and in females 21.86 mm (Table 1). The canal diameter 10 cm below the Lesser trochanter (B) was 15.25 mm (Table -3). The mean canal diameter 10 cm below Lesser trochanter (D) in males was 15.69 mm and 14.94 mm in females (Table 1)

Canal flare index

The mean canal flare index in males was 3.08 and in females was 3.15. Based on the values of the canal flare index of the South Indian population classified as normal.

Table 1: Anthropometric parameters of male and female hip joints.

Parameters	Male			Female			p-value
	Mean	Standard Deviation	Range	Mean	Standard Deviation	Range	
Femoral head diameter	52.07	5.22	23.3 - 58.8	47.15	2.67	40.5-56.6	p<0.0002 ****
Neck width	38.29	3.53	30.80 – 49.2	32.80	5.63	28.1-43.4	p<0.0001 ****
Neck shaft angle	134.52°	6.90	119.8° -155.2°	128.40°	7.14	111.8°-151.1°	p>0.8
Horizontal Offset	42.63	9.6	23.7 -65	39.11	6.50	23.3-52	p<0.0001 ****
Vertical offset	61.47	6.99	44 - 74.8	54.78	4.56	33.4-66.7	p<0.0001 ****
Medullary canal diameter (At the Apex of Lesser trochanter)	30.11	5.60	18.7 -59.9	28.89	5.89	15.7-37.7	p<0.08 ***
Medullary canal diameter (20mm above Lesser trochanter)	48.41	5.66	15.8-34.2	47.15	3.51	18.1-58.7	p<0.0001 ****
Medullary canal diameter (20mm below Lesser trochanter)	23.62	3.11	28.5-59.7	21.86	3.30	13.4-30.6	p<0.0001 ****
Medullary canal diameter (10 below Lesser trochanter)	15.69	5.60	10.1-50.8	14.94	2.77	10-33.5	p<0.04 **

Table 2: Anthropometric analysis of right and left Hip joint.

Parameters	Side	Mean	Range	Standard deviation	p-value
Femoral head diameter	Right	48.73	24.3-58.6	5.11	p>0.8
	Left	48.71	23.3-58.8	5.79	
Neck width	Right	35.34	28.1-43.7	3.975971401	p>0.4
	Left	35.83	28.4-49.2	4.40	
Neck shaft angle	Right	128.20°	111.8°-151.1°	7.99	p>0.7
	Left	128.60°	117.8 °-155.2°	7.10	
Horizontal Offset	Right	39.04	23.3-65	7.42	p>0.7
	Left	40.69	23.7-55.2	6.00	
Vertical offset	Right	57.64	33.4-74.8	8.00	p>0.3
	Left	58.71	42.6-74.6	7.00	
Medullary canal diameter (At the Apex of Lesser trochanter)	Right	29.96	18.7-59.9	5.69	p>0.2
	Left	29.12	15.7-37.8	4.49	
Medullary canal diameter (20mm above the Lesser trochanter	Right	48.41	28.5-59.7	5.66	p>0.5
	Left	47.34	18.1-59.7	6.23	
Medullary canal diameter (20mm below the Lesser trochanter	Right	22.61	13.4-34.2	3.78	p>0.5
	Left	22.88	15.1-29	3.05	
Medullary canal diameter (10 cm below the lesser trochanter	Right	15.06	10-33.5	3.57	p>0.6
	Left	15.47	10.1-50.8	5.46	
	Left	35.58	22.9-49.3	4.40	

Table 3: Analysis of hip joint morphometry in various ethnic

Parameters	Rubin et al. [13] (Swiss) n=32	Husmann et al [14] (France), n=310	Mahaisavariya et al . [15] (Thai), n=108	Noble et al.[16] (Caucasian), n=80	Asala et al. [17] (South Africa) N=504	Saikia et al.[8] (Indian), n=104	Rawal et al.[3] (Indian), n=98	Sengodan et al. [1] Indian), n=400	Supreeth et al.[12] (Indian) n = 200	Present study n =388
Femoral head diameter	43.4±2.6	-	43.98±3.47	45.9	54.23		45.41±3.66	42.627.5	40.9	48.42
Neck width	_-	_-	_-	_-	-	_	_	27.5	28.29	35.53
Neck shaft angle	122.9°	129.2°	128.04°	125.4°	-	139.5°	124.42°	135.4°	130.68°	128.96°
Horizontal Offset	47	40.5	_-	_-	-	_-	40.23	37.6	36.50	39.37
Vertical offset	56.1	57.3	48.94	_-	-	_	52.33	46.9	49.20	58.16
Medullary canal diameter (At the Apex of Lesser trochanter)	27.9	_-	_-	_-	-	_-	_-	20.2	26.14	30.12
Medullary canal diameter (20mm above Lesser trochanter)	_-	_-	_-	_-	-	_-	_-	_-	-	47.18
Medullary canal diameter (20mm below Lesser trochanter)	_-	_-	_-	_-	-	_-	_-	_-	-	22.04
Medullary canal diameter (10m below Lesser trochanter)	-	-	-	-	-	-	-	-	-	15.25

DISCUSSION

Anthropometry knowledge of proximal femur and acetabulum plays a vital role in better understanding the hip joint biomechanism. As socioeconomic reason and the various type of occupation has an important contribution in a morphological variation of the hip joint in males and females. In the present study comprehensive analysis of morphometry of proximal femur in the South Indian population using X-ray imaging and compared the difference with the other ethnic population. As morphometric data of proximal femur help us to evaluate the parameters of the western prosthesis as well as aid in the design and development of hemiarthroplasty components.

Femoral head diameter

The mean femoral head diameter in the South Indian population was 48.42 mm compared to the swiss population was 43.4±2 mm.[13] Similarly the mean femoral head diameter in the Thai population was 43.98± 3.47 mm.[15] (Table 3). The mean femoral head diameter of the Swiss and Thai population is significantly smaller than the South Indian population.

However, Asala *et al*.[17]reported femoral head diameter of the South African population was 54.23 mm, which is significantly larger than the present study conducted in South Indian ethnic. Moreover, there is no significant difference in femoral head diameter between the right and left proximal femur (Table 2). The study conducted by Rawal *et al.*[3]in the North Indian population shows that the mean femoral head diameter in North Indian Population is comparatively smaller than the present study conducted in the South Indian population. Anthropometry knowledge of the femoral head has an important clinical significance in the orthopaedic literature. As improper size femoral head diameter may cause various clinical complications such as femoral head dysplasia and premature osteoarthritis.

Neck width

The mean neck width in the present study was 35.53 mm. Sengodan et al.[1] and Supreeth *et al*.[12] of the South Indian population reported mean neck width was 27.5 mm and 28.29 mm (Table 3). However, the present study of the South Indian population means neck width is significantly larger than the similar studies done in the South Indian population**.** There is no significant difference in neck width between the right and left proximal femur (Table 2). Variation of neck width between the male and female reported by sengodan *et al*.[1] Similar variation of neck width in males and females has observed in the present study was statistically significant $p<0.0001$****.In females, as age progresses bone rigidity gradually starts decreasing than the male. femoral neck width has an important indicator to analyze bone rigidity and also aid in predicting hip fractures.

Neck shaft angle

The mean neck-shaft angle was 128.96° observed in the present study conducted in the South Indian population. In the study reported by Husmann *et al.* in France ethnic population, the mean neck-shaft angle was 129.2°.[14]Bo et al.conducted a similar study in the Japanese ethnic population, the neck-shaft angle was 137°. The neck-shaft angle of the present study conducted in the South Indian population is significantly smaller than the Japanese population.[18]Jalali Kondori *et al.* in the Iranian population reported the mean Neck shaft angle is 139.5°.[19]These studies indicate that the mean neck-shaft angle in the present study of the South Indian population is significantly smaller than the western ethnic.

Horizontal and vertical offset

The horizontal offset helps in adduction, enhances the range of motion, reduces the crunches and limping. In the present study mean horizontal offset was 39.37 mm. The mean Horizontal offset in males was 42.63 mm and in females 39.11 mm. The Horizontal offset is significantly larger than the female. However, there is no significant difference between the right and left proximal femur morphometry (Table 2). A similar study done by Rawal *et al.*[3] reported the mean horizontal offset was 40.23 mm of the North Indian population (Table 3). The horizontal offset of the study conducted in the present study of the South Indian population is smaller than the North Indian population. However, other studies on the western ethnic population have not reported the horizontal offset.

The mean vertical offset in the present study was 58.16 mm. The vertical offset of the present study is larger than the similar study conducted by Mahaisavariya *et al.* in the Thai population.[15] (Table 3). The mean vertical offset in males was 61.47 mm and in females 54.78 mm(Table 1). The mean vertical offset of the male is significantly larger than the female and the $p<0.0001$ **** value is statistically significant. However, there is no significant difference between the right and left vertical offset (Table 2).

Medullary canal diameter

Medullary canal diameter is used to decide the stem size during the selection of prosthesis and aid orthopaedics to decide cemented or uncemented prosthesis. The medullary canal diameter was observed in four different levels 1) Mean canal diameter at the apex of lesser trochanter (B) was 30.12mm 2) Mean canal diameter 20 mm above the lesser trochanter (A) was 47.18 mm. 3) The mean canal diameter 20 mm below the lesser trochanter (C) was 22.04 mm and 4) 10 cm below the apex of lesser trochanter (D) was 15.25 mm (Table 3).

In the present study canal diameter at the apex of the lesser trochanter is significantly larger than the Swiss population reported by Rubin *et al.*[13]and Supreeth et al.[12] However, the canal diameter is 20 mm above and 20 mm below the lesser trochanter was not reported by other authors. Furthermore, there was statistical significance between the gender and there was no statistical difference between right and left medullary canal diameter at various levels.

Canal flare index

The diameter of the canal flare index decreases when age progresses, the present study reported an average canal flare index was 3.09. Based on the values of the present study of canal flare index, the medullary canal isthmus for the present study is classified as normal (3-4.7).

CONCLUSION

The present study comprehensively analyzed the anthropometry measurement of the proximal femur in males and females. The statistical data show male anthropometry measurements are larger than the female. But the average results showed femoral head in the present study was larger than the western ethnic population. Furthermore, the neck-shaft

angle of the present study is smaller than the other ethnic population.

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Conflict of interest

None

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None

Author's contribution

Govindhasamy Paramesh– Collected Data, conceived and designed the analysis, Wrote the paper

Vanga Rajitha- Contributed data, analysis tools, wrote the paper.

Burute Pushpa-Performed Analysis

Kaleelkal Radhamani Sindhu - other contributions.

Govindhasamy Rekha- Performed analysis, other contributions.

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