Morphometric analysis of lower end of adult dry femur in south Indian population – A cross-sectional observational study and its clinical significance

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ABSTRACT

Introduction and Aim: The human knee is the largest and most complex joint in the body. The distal end of femur in conjunction with the proximal end of tibia and patella, functions as a knee joint. The purpose of our study is to do a morphometric analysis of adult dry femur, which will greatly aid in implant selection and lessen the complications after knee surgery. The main objectives of our study were to study the various anatomical parameters of the lower end of femur that would facilitate orthopedicians design appropriate knee prosthesis based on the anthropometric data obtained.

Materials and Methods: Our study was an observational and a descriptive study, done on 100 dry adult femur bones. The cross- sectional data was obtained from the Department of Anatomy in a Medical college in Chennai, India. Six parameters related to the lower end of Femur were studied. All measurements from the right and left femur were recorded separately. The data obtained were then entered in Microsoft Excel sheet. The p-value < 0.05 was considered statistically significant.

Results: The mean bicondylar width for the right and left sides were 72.82 mm and 71.62 mm. The average Medial Condylar Antero-posterior distance for the right and left sides were 56.62 mm and 57.14 mm. Inter Condylar Notch Width for the right and left sides were 21.66 and 21.5 mm respectively. Except for Lateral Condylar Antero-posterior distance, not all other data showed any statistical significance between the two sides.

Conclusion: Our study provides morphometric data of femoral condyles by direct method, which would be useful to select accurate prosthesis, minimize the mismatch and reduces the post- operative complications after implants. The data available from such studies and the knowledge gained will largely help orthopedicians to plan placement of intramedullary nails, plates, screws and pins, while also taking care to avoid injury to the adjacent neuro-vascular bundle.

Keywords: Femur; condyles; inter-condylar notch; knee-joint; osteoarthritis.

INTRODUCTION

The femur or thigh bone is the largest, longest and one of the strongest bones in the body with the most powerful muscles attached to it. It essentially is comprised of three parts, the shaft, proximal end and the distal end. The shaft is slightly convex anteriorly the longer length of the bone enables a strong striding gait (to walk or run by taking long steps), its weight and its sturdy nature helps the muscular forces that it must withstand to maintain erect posture (1).

While the proximal end constitutes part of the hip joint, the distal end takes part in the knee joint. The distal end is a widely expanded structure with two massive condyles, namely medial and lateral. The inter-condylar notch is located posteriorly between the two condyles. The condyles of femur are partly articular and make a hinge joint inferiorly with corresponding condyles of tibia and anteriorly with patella, giving integrity and stability to the knee joint while walking and prolonged standing (2). The knee joint is the complex variety of synovial joint formed by the condyles of femur, tibia and posterior articulating surface of patella. It is the combination of three primitive joint cavities – femora-patellar, medial and lateral condylar. Anterior surface of both condyles forms patellar articulating surface for posterior articulating surface of patella and posterior surface of condyles of femur articulates with condyles of tibia and separated each other by Intercondylar fossa. The knee joint is a complex variety of synovial joint, where the distal end of femur articulates with the proximal tibia and patella forming femorotibial and femoropatellar articulations respectively. The two condyles are in continuity on the anterior surface, while on the posterior aspect, they are separated by the inter-condylar fossa (3).

Osteoarthritis is one of the common medical conditions in the geriatric population. This degenerative condition of the knee joint is a condition that hampers the mobility of the elderly individuals, making them more prone to many of the immobility-associated diseases. Many a times, total knee replacement arthroplasty has been the treatment offered for such individuals.

A thorough understanding of the anatomical aspects of the distal end of the femur is very imperative for the radiologists and orthopedicians, as knee replacement requires implant placement with highest degree of accuracy (4).

Various morphometric studies have been conducted in the past using radiography, computerized tomography or magnetic resonance imaging (5, 6). Though these methods of evaluation are non-invasive, with a higher degree of magnification, technique and projection, the major limitation is that they are relatively indirect ways of measurements with a higher probability of inaccuracy (7). Mismatch in the size of the femoral condyles and the prosthesis used may lead on to loosening of implant or impingement of surrounding soft tissue (8). Therefore, in order to maintain the normal functional range of knee joint, it is very crucial to use the exact size of femoral condyles for total knee arthroplasty (9). A direct morphometric analysis of the femoral condyles would greatly help the radiologists and the clinicians in selection of the appropriate size of implant and will improve the prognosis after replacement surgeries involving knee joint.

The objective of our study is to determine the side of the femur and morphometric analysis of adult dry femur in the south Indian population. The data obtained in such morphometric study will greatly aid in selection of appropriate size of implant and prevent the complications after knee replacement surgery.

MATERIALS AND METHODS

Our study was an observational and a descriptive study, done on 100 dry adult femur bones. The cross-sectional data was obtained from the dry adult femur bones available in the Department of Anatomy in a Medical college in Chennai, India.

The main objectives of our study were to study the various anatomical parameters of the lower end of femur, to facilitate the orthopedicians design appropriate knee prostheses based on the anthropometric data obtained and to compare our work with the rest of the studies available in literature. The 100 bones studied included 50 each from the right and left sides.

Those bones that on gross inspection had any evidence of fracture, post-mortem deformity or arthritic changes were excluded from the study. Bones that were un-ossified or having pathological abnormalities like tumours or deformities were also excluded from our study.

The following are the parameters studied. Measurements were done using Vernier caliper. All measurements were done by a single anatomist to avoid measurement related artefacts and for consistency in our study. The measurements taken were rounded up to two decimals.

The six parameters studied were:

1. Bicondylar width (BCW) - The maximum distance between medial and lateral condyles in transverse plane.
2. Medial condylar antero-posterior distance (MCAPD) -The maximum anterior to posterior distance of medial femoral condyle.
3. Lateral condylar antero-posterior distance (LCAPD) -The maximum anterior to posterior distance of lateral femoral condyle.
4. Medial condylar Transverse distance (MCTD) - The maximum medial to lateral surface distance of medial femoral condyle.
5. Lateral condylar Transverse distance (LCTD) - The maximum medial to lateral surface distance of lateral femoral condyle.
6. Intercondylar notch width (ICW) - the maximum distance of posterior aspect of medial and lateral surface of Intercondylar notch.

Statistical Analysis:

All measurements from the right and left femur were recorded separately. The data obtained were then entered in Microsoft Excel sheet and analysed using SPSS software for mean and standard deviation (SD). Independent t-test was used to calculate the differences in the parameters of right and left femur. The p-value < 0.05 was considered statistically significant.

OBSERVATION AND RESULTS

Of the 100 dry femur bones studied, 50 each were from the right and left sides. The mean bicondylar width for the right and left sides were 72.82 mm and 71.62 mm, with a SD of 3.89 and 5.67 respectively and a p value of 0.2201. The average Medial Condylar Antero-posterior distance for the right and left sides were 56.62 mm and 57.14 mm, with a SD of 4.19 and 4.82 with a P-value of 0.5661. The Lateral Condylar Antero-posterior distance for the right and left sides were 58.52 mm and 56.92 mm, with a SD of 3.44 and 4.41 and the P-value was 0.0458. This value was found to be statistically significant between the right and left sides. The Medial Condylar Transverse distance for the right and left sides were 22.64 mm and 23.12 mm, with a SD of 3.96 and 2.17 with a p-value of 0.4541. The Lateral Condylar Transverse distance for the right and left sides were 22.86 mm and 23.12 mm, with a SD of 3.12 and 2.34 with a P-value of 0.6384. Inter Condylar Notch Width for the right and left sides were 21.66 and 21.5 mm respectively, with a SD of 2.69 and 4. 64 and a ‘P’ value of 0.8334. Fig 1 (1a to 1f) illustrates the various parameters studied.

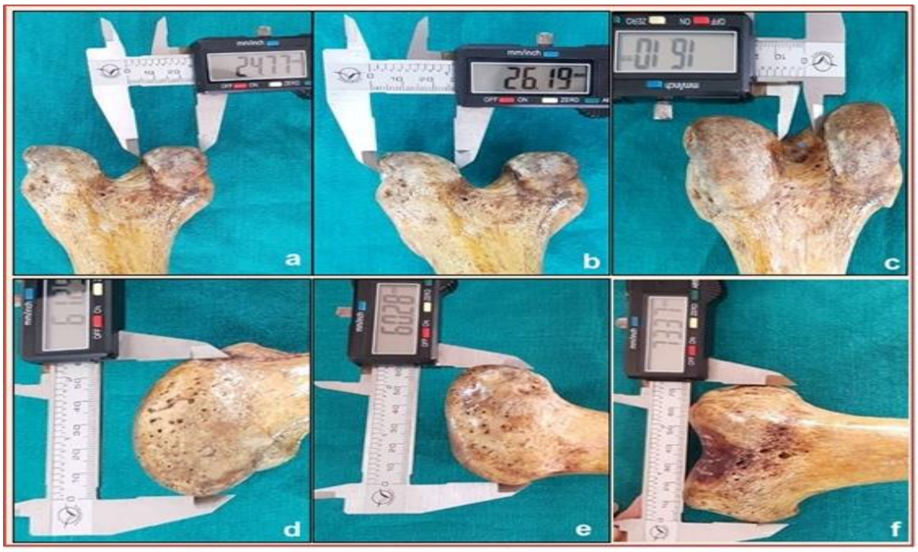

Fig. 1: Six parameters studied in the distal end of femur: **1a**: Medial condylar transverse diameter (MCTD); **1b**: Lateral condylar transverse diameter (LCTD); **1c**: Inter-condylar notch width (ICNW) **1d**: Lateral Condylar A-P distance (LCAPD); **1e**: Medial Condylar A-P distance (MCAPD); **1f**: Bicondylar width (BCW).

Table 1: Mean and standard deviation for various parameters on right and left femurs

Parameter	Right			Left			P-value
	Range (mm)	Mean	SD	Range	Mean	SD	
BCW	64.91 - 85	72.82±3.89	3.89	63.32 – 86.15	71.62±5.67	5.67	0.2201
MCAPD	48.34 – 63.11	56.62±4.19	4.19	47.40 – 63.7	57.14±4.82	4.82	0.5661
LCAPD	50.27 – 64.70	58.52±3.44	3.44	50.23 – 64.86	56.92±3.41	4.41	0.0458
MCTD	18.67 – 28.25	22.64±3.96	3.96	19.24 – 27.90	23.12±2.17	2.17	0.4541
LCTD	17.53 – 29.2	22.86±3.12	3.12	18.76 – 28.3	23.1±2.34	2.34	0.6384
ICNW	16.10 – 25.60	21.66±2.69	2.69	15.96 – 27.12	21.5±4.64	4.64	0.8334

Table 2: Comparison of various parameters of femoral condyles of our study with that of other studies on dry femur (values are expressed in mm)

Author, Year Region and method of study	BCW		MCAPD		LCAPD		MCTD		LCTD		ICW	
	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left
Ravichandran *et al.*, (6). 2010, Tamil Nadu. Dry femur	74.58 ± 0.57	73.97± 0.61									18.89± 0.29	18.65 ± 0.27
Terzidis *et al.*, (13). 2012, Greek, Dry Femur	MALE											
	88.6±0.42		61.1±034		61.1±033						22.0±0.18	
	FEMALE											
	78.5±0.30		55.9±0.29		55.4±0.21						18.7±0.10	
Ameet *et al.*, (8). 2014, Nepal. Dry femur	72.5± 5.3	73.3± 5.3									18.0± 3.0	17.9± 2.5
Mistri *et al.*, (12). 2015, West Bengal, Dry femur	74.43 ± 6.10	73.98± 5.99									19.12± 2.5	18.65 ± 2.8
Magetsari *et al.*, (17), 2015. Indonesia, CT Scan	MALE											
	70.56 ± 5.17		44.2± 4.91		43.30 ± 6.75							
	FEMALE											
	61.40±4.01		40.85±5.73		40.95±5.17							
Moghtadaei *et al.*, (10), 2016, Iran, CT Scan	MALE											
					63.35±3.1		24.62±1.9		24.42±2.0		21.76±3.0	
	FEMALE											
					56.53±2.98		21.33±0.2		21.37±1.6		17.37±2.5	
Neelima *et al.*, (11). 2016, Andhra Pradesh, Dry femur			57.83±0.69		58.0±0.51		21.33±0.43		21.08±0.44		22.83±0.41	
Shweta *et al.*, (5). 2017, Delhi Dry Femur	73.1± 6.14	72.16± 6.58									20.82± 2.57	21.0± 3.13
Biswas *et al.*, (7) l. 2017, West Bengal, Dry femur	71.71 ± 4.50	70.71± 5.25	52.97 ± 3.77	54.74 ± 3.85	56.20 ± 3.36	56.05 ± 4.29	25.48 ± 2.05	27.28 ± 2.29	27.80 ± 2.91	28.03± 2.56	20.86± 2.52	19.45 ± 2.57
Zalawadia *et al.*, (3), 2017, Gujarat, Dry femur	MALE											
	74.48 ± 1.90	74.59± 2.75	57.21 ± 2.53	57.77 ± 2.15	58.36 ± 3.03	59.68 ± 2.16	30.31 ± 1.66	31.32 ± 1.35	31.32 ± 1.72	31.99± 1.15	20.31± 2.94	20.91 ± 1.32

	FEMALE											
	67.42 ± 1.93	66.7± 2.59	53.44 ± 1.82	54.37 ± 2.20	54.98 ± 1.89	54.66 ± 2.87	27.47 ± 1.33	27.91 ± 1.52	28.76 ± 1.47	28.96± 1.33	19.42± 2.32	19.27 ± 2.74
Chavda *et al.*, 2019 (14), Gujarat, Dry femur	69.6± 5.04	69.8± 4.96	52.9± 4.99	53.5± 4.15	54.7± 4.01	55.0± 4.31	26.7± 2.03	26.9± 2.23	30.3± 3.05	29.6 ± 2.03	20.4± 3.17	18.7± 2.52
Present study	72.82 ± 3.89	71.62± 5.67	56.6± 4.19	57.14 ± 4.82	58.52 ± 3.44	56.92 ± 4.41	22.64 ± 3.96	23.12 ± 2.17	22.86 ± 3.12	23.12± 2.34	21.66± 2.69	21.5± 4.64

All the morphometric data, including the range, mean, standard deviation and the P-value for each of the six parameters studied, are consolidated and presented in Table 1. Except the Lateral Condylar Antero-posterior distance, the morphometric parameters of right and left femurs were not statically significant.

DISCUSSION

The human knee is the largest and most complicated joint in the body and one of the most frequently injured (10). The high incidence of injury to the knee may be related to many factors, but its basic diarthrodial structure together with its location between the body's two longest lever arms namely the femur and the tibia make it particularly more vulnerable to sports related injuries (11). The complexity of the knee joint is further enhanced, as it has to perform two opposed requirements, namely mobility and stability. The distal end of femur in conjunction with the proximal end of tibia and patella functions as a knee joint that works in axial compression under the action of gravity (12). Such complexity of this joint makes it very vulnerable in many occupations and sports.

Ombregt illustrates that the mechanism of function of the distal femur can be well compared with a double wheel. Here, the medial and lateral condyles are the components of the two wheels with the patellar surfaces acting as a rail and the intercondylar notch is the junction between them. By flattening the anterior and posterior end of the 'rail', rotational movements become possible; the intercondylar spines act as the central pivot. The convexity of the condyles in both the planes, the medial condyle extending distally than the lateral and the greater prominence of the lateral condyle give additional support and stability to the knee joint and prevent the patella from sliding laterally. The tibial aspect of the joint is two curved 'gutters', separated by an anteroposterior eminence. These gutters are not congruent with the corresponding condyles but the menisci correct this lack of compatibility (13).

The knee joint is essentially a hinge joint, with movements taking place in one direction, namely flexion and extension. The twin wheel arrangement of the condyles of femur slide, glide and roll over the concave shaped gutters, namely the patella and upper end of tibia. The situation is more complex than what we could infer, as the knee joint also takes part in internal and external rotation of tibia in relation to femur. In addition, if the anterior and posterior ends are flattened, a rotation movement may be possible.

With increase in the life span of men and women in our country, osteoporosis and degeneration of the weight bearing joints have become increasingly common these days. With improvisations in the imaging techniques and with sophistications in the prostheses used, total knee replacement is becoming more and more popular these days. The success of arthroplasty depends on a proper understanding of the morphometry and appropriate geometrically matched prosthesis (14). It is therefore mandatory to have knowledge of proper morphometric data before selection of the implant size.

In our study, six parameters of lower end of dry femur were measured and the data was collected by direct method using vernier caliper. Such a direct method of measurement gives an accurate morphometric data for making precise prosthesis for joint replacement surgery with fewer complications. Table 2 summarizes the comparison of various parameters of femoral condyles with other studies on dry femur (values are expressed in mm).

In our study, the average Bicondylar width was 72.22±4.88mm. Our data correlated well with the studies done by Ameet *et al.,* Shweta *et al.,* and Biswas *et al.,* (15-17). On the other hand, similar studies done by Ravichandran *et al.,* and Ankur *et al.,* showed higher values, while Hiren *et al.,* documented lower values (18-20). The radiological findings of Magetsari *et al.,* who completed the measurements using computed tomography (CT scan) correlated well with our study (21). Our study similar to other studies showed no statistically significant difference between right and left sides for bicondylar width.

The average medial condylar antero-posterior distance is 56.62±4.5mm. Neelima *et al.,* also observed similar results in their study (22), while higher values were observed with Terzidis *et al.,* in Greek population (23). Biswas *et al.,* and Hiren *et al.,* observed lower values (17, 20). CT scan values by Magetsari *et al.,* were observed to be lower than the present study (21).

The average lateral condylar Anteroposterior distance observed in our study was 57.72±4.01 mm. Neelima *et al.,* (22) observed similar values, Biswas *et al.,* (17) noted higher values and Hiren *et al.,* (20) had lower values than the present study. CT scan values of Magetsari *et al.,* (21) had lower values than the present. There was no statistically significant difference was observed in both MCAPD and LCAPD in this study. In our study, the average medial condylar transverse distance was 22.88±3.18 mm. Similar values seen in Neelima *et al.,* (22) and the values were slightly higher in the study Biswas *et al.,* (17) on Bengali patients. CT scan values by Magetsari *et al.,* (21) were slightly higher than this study. The average Lateral condylar transverse distance 22.99±2.75 mm. Neelima *et al.,* (22) observed similar values while higher values were observed in Shweta *et al.,* (16). Moghtadaei *et al.,* observed higher values than the present study (24). The mean values of transverse diameter of medial and lateral condyle did not show any statistical significant difference.

The average Intercondylar width in our study was 21.5±3.77 mm. Similar values were observed in Neelima *et al.,* (22), Shweta *et al.,* (16) and Biswas *et al.,* (17). Moghtadaei *et al.,* (24), who studied the CT scan in Iranian population, shows similar values of 21.76±3.0 mm. Lower values were reported by Rumeysa *et al.,* (25). The variations observed in the measurements amongst different studies from different regions could be attributed to influence of heredity, race, environment, lifestyle and effects of civilization, which may in turn alter the physique, build, stature and bony dimensions of individuals.

Limitations of the study

Our study was done on 100 dry Femur bones from our department. There was an inherent bias in choosing the bones, as we had equal numbers in each arm of our study. The sample size, though sizeable, was not adequate to reflect the bony habitus of the entire South Indian population, for which, the power of study would be very high. The resource constraints in our department, difficulties in involving multiple centres and practical difficulty in getting bones from other sources also were the reasons for a smaller sample size. Moreover, there was a difficulty in segregation of bones based on gender, as the sex determination of bones was undetermined. A proper analysis based on the gender of the bones might probably aid the clinicians in selecting appropriate prosthesis for knee replacement surgeries. Moreover, the right and left femur bones studied did not belong to the same individual. Our future studies shall consider all these factors in order to achieve a better and representative data.

CONCLUSION

Knee replacement surgery is one of the most common procedures performed for various conditions related to knee joint. Total knee replacement is usually considered as the end point treatment of severe degenerative diseases of the knee. It is considered as the gold standard treatment for management of patients with osteoarthritis of the knee joint. It is important to design accurate knee joint implants, which would be beneficial to improve the quality of life and cause less complication after arthroplasty. Our study provides morphometric data of femoral condyles by direct method, which would be useful to select accurate prosthesis, minimize the mismatch and reduces the post- operative complications after implants. The data available from such studies and the knowledge gained will largely help orthopedicians to plan placement of intramedullary nails, plates, screws and pins, while also taking care to avoid injury to the adjacent neuro-vascular bundle. Therefore such studies will be of great help in orthopaedic surgery to diagnose pathologies in the knee and plan derotation osteotomy of femur. Combining the study with studies done on the proximal end of femur could largely help in understanding the racial variations. High heritable inheritance in shape and measurements of distal femur could make these traits very useful in assessment of ancestral properties in contexts of Forensic science.

CONFLICT OF INTEREST: Declared none.

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