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Original article:

Morphometric study of some lower femoral anatomy in Eastern Indian population

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ABSTRACT:

Introduction: Knee joint, being in pivotal role in bipedal locomotion, encounter frequent traumatic as well as degenerative threats. Study of the anatomy of the distal femur is important for the design of total joint replacement and internal fixation material.

Methods: One hundred twenty seven adult dry femora were considered for the study. Bicondylar Width and Shaft Robustness measured for all the femora by a single author using suitable calipers and following standardized methods.

Observations & Results: Mean bicondylar width of 127 study samples observed to be 7.421 ± 0.603 cm, of which 62 left sided femurs showed 7.398 ± 0.599 cm and 65 right sided femora having 7.443 ± 0.610cm measurements. Comparison of shaft width of left and right sides revealed mean shaft widths of 3.150 ± 0.331 cm and 3.189 ± 0.345 cm respectively. Mean shaft width came as 3.170 cm with standard deviation of 0.337when calculated for all the femora. Mean Robustness Index obtained in the study as 42.86 ± 4.61with no significant left vs. right variation.

Conclusion: Knowledge of mean bicondylar width and shaft robustness with their significant correlation and robustness index of Eastern Indian population will act as ready-reckoner for biomedical engineers engaged in prosthesis designing for Indian recipient.

Key words: Femur, Femoral Shaft, Femoral Condyle, Bicondylar width, Robustness Index

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INTRODUCTION:

The femur is the longest and strongest bone in the human body. It transmits weight from the ileum to the upper end of the tibia through an unstable bony arrangement at the knee joint. Its length is associated with the striding gait, its strength with weight and muscular forces. Its shaft, almost cylindrical in most of its length, is bowed forward. It has a proximal rounded, articular head projecting medially from its short neck, which, in turn a medial extension of the proximal shaft. The distal extremity is wider and more substantial, and presents a widely expanded double condyle bearing partly articular surface for transmission of weight to the tibia. Anteriorly the condyles are confluent and continue into the shaft; posteriorly they are separated by a deep intercondylar fossa and project beyond the plane of the popliteal surface. The articular surface is a broad area, like an inverted U, for the patella and the tibia[1].

Central to the functional complex of bipedal locomotion are the relationships between the two femora and the pelvis. Various aspects of this complex are critical to the biomechanics of gait and stride. In the process of evolution femur has experienced many notable changes as a consequence of bipedal stride namely size of femoral head, neck-shaft angle, length of shaft, antero-posterior bowing of the shaft, size and relative position of trochanters, robustness of shaft, obliquity of femoral shaft, bicondylar width, relative size of the condyles, inter-condyloid notch etc**.** Body weight load started to be borne by the femur contributing these changes [2, 3]. The distribution of varied mechanical properties could be the functional adaptation of the human femur against external bending forces mainly caused by muscle activity[4].In the erect posture, femur distally approaches its fellow, for the purpose of bringing the knee joints near the line of gravity of the body[1]. It is assumed that the plane of the femoral condyles i.e. the bicondylar plane in normal locomotion will be horizontal to the ground[5]. But one striking character of the lower end of femur is the relative lengths of the medial and lateral condyles[6].Quantitative anatomy of the distal femur is important for the design of total joint replacement and internal fixation material[7]. Joint replacement involving the distal femur requires the use of highly complex surgical techniques, as this would involve the accurate placement of well-fitted implants and adequate balancing of the surrounding soft tissues. The use of an appropriate femoral component size is essential to maintain the normal functional range of motion of the knee. In addition, a mismatch between the prosthesis size and bone may result in a number of severe complications. It has been demonstrated that using an undersized component will result in implant loosening, whilst an oversize component may cause impingement of the surrounding soft tissues. The use of appropriate component size is therefore crucial to produce long-term success following knee arthroplasty[8]. Hence, study of distal femoral anatomy for Indian population is appropriate with increasing trend of Total Knee Arthroplasty as treatment of choice in degenerative knee diseases.

AIMS & OBJECTIVES:

1. To study bicondylar width and shaft width from the available teaching dry femora in the Medical Colleges of Kolkata.
2. To generate anthropometric data related to lower end of femur for designing knee prosthesis.
3. To compare the generated data with the previous workers in the field.

MATERIAL & METHODS:

Total 127 dry femora irrespective of age and undetermined sex available in the department of Anatomy of the five Government Medical Colleges of Kolkata were taken for the study. Femori that on gross inspection had evidence of fracture, deformity, post-mortem damage or arthritis were excluded from the study. The bones with complete morphological features were studied.

For measuring bi-condylar width and shaft width the following methods were adopted[7, 9]**.** Each femur was placed with posterior surface of femoral condyles and greater trochanter touching on the smooth horizontal surface of Physical Anthropometry table. Femur was held firmly with the help of a bone holding clamp. Using a pelvimeter maximum bicondylar width (M) was taken (Fig.1). The bicondylar width thus obtained, recorded for computation.

Shaft Robustness should be measures at a standard and identical site for all the study samples. An ideal site for assessing shaft robustness (D) is obtained by multiplying bicondylar width value (M) with a constant Index of Shaft Robustness 1.15 suggested by Kern and Straus [D = M X 1.15]. Value thus obtained used to reach a horizontal plane proximal to the bicondylar plane. Transverse diameter of the shaft (R) was measured at the obtained height using Martin's Sliding Caliper (Fig. 2) and recorded for computation. Same procedure was repeated for each of the study samples.

A single author performed all measurements for consistency. Each measurement was repeated three times and the mean value was recorded. Measurement error was assessed for every anatomical parameter according to the method described by White and Folkens for osteometric studies[10]. All measurements were rounded to two decimal places.

OBSERVATION & RESULTS:

Out of 127 femur used for the study 62 were of left side and 65 belonged to the right side. From the frequency distribution table it was observed that bicondylar width of 27 (46.54%) femora on the left side fell between 6.50 cm and 7.49 cm. Bicondylar width of 29 (46.78%) left sided femora measured in the range of 7.50 cm to 8.49 cm. Out of the 62 left sided femora, 56 (90.32%) turned out to be in the range of 6.50 cm–8.49 cm (Table 1).

Bicondylar width of 31 (47.69%) right sided femur observed between 6.50 cm and 7.49 cm. Bicondylar width of 28 (43.08%) right sided femur measured in the range of 7.50 cm to 8.49 cm. Thus out of 65 right sided femur 59 (90.76%) were between 6.50 cm and 8.49 cm (Table 2).

On statistical analysis mean bicondylar width for left sided femur was 7.398 cm with standard deviation of 0.599. Similarly, mean bicondylar width for right sided femora was found to be 7.443 cm with standard deviation of 0.610. When total 127 femora considered, mean bicondylar width of 7.421 ± 0.603 cm was obtained (Table 3). Mean bicondylar width determined on left side thus lower than that on the right side. Measurements were put to statistical analysis to determine whether these differences were statically significant. Using SPSS software student's t-test applied to the values to obtain t = 0.338 in d f = 125 has a $P > 0.05$. Whatever left-right difference is observed in bicondylar width in the present study was not statistically significant.

Multiplying individual value of bicondylar width by 1.15 (the standard factor), height from bicondylar plane, at which transverse diameter of shaft was to be measured, is obtained. Shaft width measured in that plane of 56 (86.15%) femur out of 65 right sided study sample fell between 2.75 cm and 3.74 cm (Table 4). Shaft width of 53 (85.48%) out of 62 left sided femur found to be in the same range (Table 5). Statistical comparison of shaft width of left and right sides revealed mean shaft widths of 3.150 cm and 3.189 cm with standard deviations of 0.331 and 0.345 respectively. Mean shaft width for total 127 femora came as 3.170 cm with standard deviation of 0.337 (Table 6). When test applied t = 0.258 in d f = 125 revealed. With $P > 0.05$ statistically appreciable variation in shaft robustness between the sides cannot be opined.

Gradually increasing mean shaft widths on either side have been noticed with increasing bicondylar width with exception at 7.50 –7.99 cm on left side and at 7.00 – 7.49 cm on right side, where shaft width values show some dip. A significant correlation (r) between bicondylar width and shaft width obtained with r_1 (left side) = 0.335 in d f = 60 and r_2 (right side) = 0.468 in d f = 63 where $P < 0.05$ in either series (Table 7).

Index of robustness of shaft calculated following standardized method by dividing value of shaft width by value of bicondylar width and multiplied it by hundred[7]. Mean index of robustness of shaft for the left sided femora has come 42.74 with standard deviation 4.48. For the right sided femora mean robustness index came as 42.97 ± 4.41. When all the 127 femora were considered for getting mean robustness of shaft, it came as 42.86 with standard deviation of 4.61. With $t = 0.394$ in d f = 125, $P > 0.05$ revealed on statistical analysis (Table 8). Difference whatever obtained between index of robustness of femoral shaft of left and right side, thus, has got no significance.

DISCUSSION:

An important factor required to achieve long-term success in total knee arthroplasty surgeries is the use of geometrical matched prosthesis, which simulates the natural conditions of knee joints[8]. Many workers are engaged in research work to generate anthropometric data for designing knee prosthesis [11, 12, 13, 14, 15, 16, 17, 18].Bicondylar width was measured by many researchers as sole or a part of some other study of lower femoral anatomy. Bicondylar width came fairly constant in the current study and left vs. right variation whatever obtained found to be statistically insignificant (Table 3). Mean bicondylar width was found 8.39 cm±0.63 cm by Terzidis et al.[7] in Caucasian (Greek) population. In contrast, 7.421 ± 0.603 cm obtained in the present study samples of short statured Indian population, supposed to be due to proportionate lesser value of all dimensions from their Caucasian counterpart. Researcher like Gualdi[19] and Macho[20] showed left-right asymmetry in shaft robustness. In the present study, some degree of variation has been noticed. For left side, mean shaft width came 3.150 ± 0.331 cm whereas for right side it was 3.189 ± 0.345 cm. However when student's t-test applied on these values, left-right asymmetry which was found, proved to be insignificant with $P > 0.05$.With an aim to deduce if there is any significant relationship present between bicondylar width and shaft width, statistical test applied to the values of both the parameters obtained in the current study (Table 7).

Relationship, when drawn, between bicondylar width and shaft width, correlation coefficient came 0.335 and 0.468 respectively for left and right sides respectively with $P < 0.05$, from which we can infer that some degree of obvious relationship exist between these two dimensions (Table 7). From the two scatter plots we can demonstrate the centralized trend which denotes the positive relationship between the bicondylar width and the shaft width (Fig 3 & 4). Forensic experts and anthropologists frequently encounter with fragment bones. Regression analysis of shaft width with bicondylar width show high reconstructability of bicondylar width from shaft width and vice versa (Fig 5 & 6). For determining index of robustness of femoral shaft, Kern and Straus[9] used a study group comprising of 22 U.S. whites, 15 Eskimos, 2 U.S. Negroes, 7 Kaffirs and 15 Australians. They reported the mean index as 44.90 ± 0.62 for their 58 samples. Statistical comparison of their value with 42.86 ± 4.61, the value of current study in d f = 183 returned $t = 3.53$. A significant variation has been observed in the two study groups as $P < 0.05$ found between them.

This variation may be explained from the life-style pattern in this part of India; people in Eastern India enjoy relatively sedentary lifestyle when compared to the study group of Kern and Straus[9]. This finding therefore strengthens suggestion of Wescott[21] regarding significant variation in robusticity in different population group based on mobility.

CONCLUSION:

Replacement arthroplasty of knee is becoming fast popular mode of treatment in various permanent knee diseases. Knowledge of mean bicondylar width and shaft robustness with their significant correlation in eastern Indian population, whose robustness index also showed significant variation, will act as ready-reckoner for biomedical engineers engaged in prosthesis designing for Indian recipient.

Table 1: Frequency distribution of bicondylar width in left sided femora. n = 62

Bicondylar width (cm)	Frequency in numbers	Percentage of total
6.00 - 6.49	4	6.45%
6.50 - 6.99	15	24.19%
7.00 - 7.49	12	19.35%
7.50 - 7.99	19	30.65%
8.00 - 8.49	10	16.13%
≥ 8.50	2	3.23%
TOTAL	**62**	**100.00%**

Table 2: Frequency distribution of bicondylar width in right sided femora. n = 65

Bicondylar width (cm)	Frequency in numbers	Percentage of total
6.00 - 6.49	3	4.62%
6.50 - 6.99	17	26.15%
7.00 - 7.49	14	21.54%
7.50 - 7.99	16	24.62%
8.00 - 8.49	12	18.46%
≥ 8.50	3	4.62%
TOTAL	**65**	**100.00%**

Table 3: Comparison between bicondylar widths of left and right side. n = 127

Sidedness	Number of femora studied	Mean bicondylar width	Standard Deviation
Left	62	7.398	0.599
Right	65	7.443	0.610
TOTAL	**127**	**7.421**	**0.603**

t = 0.338 **d f = 125** **P > 0.05**

Table 4: Frequency distribution of shaft widths in left sided femora. n = 62

Shaft width (cm)	Frequency in numbers	Percentage of total
2.00 - 2.24	0	0.00%
2.25 - 2.49	1	1.61%
2.50 - 2.74	6	9.68%
2.75 - 2.99	14	22.58%
3.00 - 3.24	18	29.03%
3.25 - 3.49	14	22.58%
3.50 - 3.74	7	11.29%
≥ 3.75	2	3.23%
TOTAL	**62**	**100.00%**

Table 5: Frequency distribution of shaft widths in right sided femora. n= 65

Shaft width (cm)	Frequency in numbers	Percentage of total
2.00 - 2.24	1	1.54%
2.25 - 2.49	0	0.00%
2.50 - 2.74	5	7.69%
2.75 - 2.99	14	21.54%
3.00 - 3.24	15	23.08%
3.25 - 3.49	17	26.15%
3.50 - 3.74	10	15.38%
≥ 3.75	3	4.62%
TOTAL	**65**	**100.00%**

Table 6: Comparison between shaft widths of left and right side. n=127

Sidedness	Number of femora studied	Mean shaft width (cm)	Standard Deviation
Left	62	3.150	0.331
Right	65	3.189	0.345
Total	**127**	**3.170**	**0.337**

t = 0.258 d f = 125 P > 0.05

Table 7: Correlation between bicondylar width and shaft width in left and right sided femora. n =127

Bicondylar width (cm)	Shaft width (cm)			
	Left side		Right side	
	Mean	S. D.	Mean	S. D.
6.00 - 6.49	3.035	0.629	2.993	0.231
6.50 - 6.99	3.034	0.227	3.097	0.306
7.00 - 7.49	3.269	0.392	3.005	0.365
7.50 - 7.99	3.057	0.258	3.219	0.252
8.00 - 8.49	3.273	0.169	3.407	0.299

r_1= 0.335 d f = 60 P< 0.05 r_2= 0.468 d f = 63 P< 0.05

Table 8: Comparison between robustness index of femoral shaft on left and right side. n=127

Sidedness	Number of femora studied	Mean robustness index	Standard Deviation
Left	62	42.74	4.84
Right	65	42.97	4.41
Total	**127**	**42.86**	**4.61**

t = 0.394 d f = 125 P > 0.05

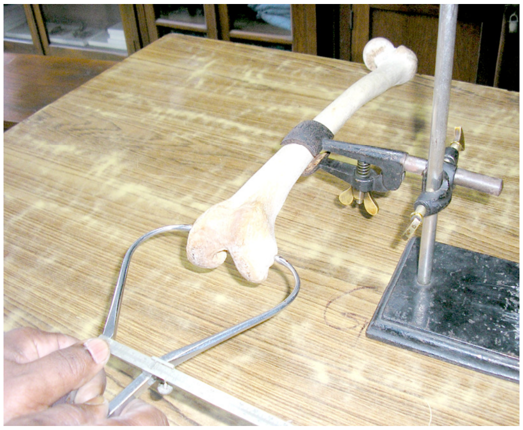


Fig 1: Measuring bicondylar width ‘**M**’

Fig 2: Measuring shaft robustness ‘**R**’

Fig 3: Correlation between shaft width and Bicondylar width on left side

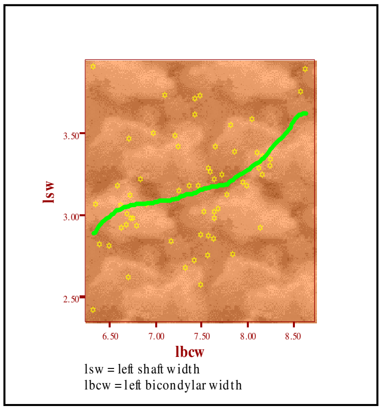


Fig 4: Correlation between shaft width and Bicondylar width on right side

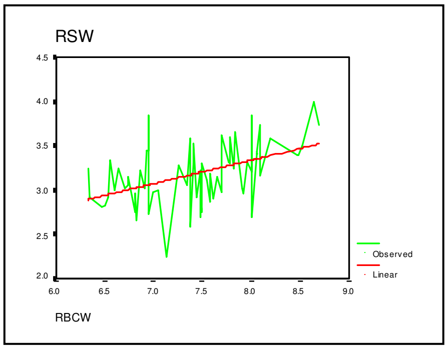
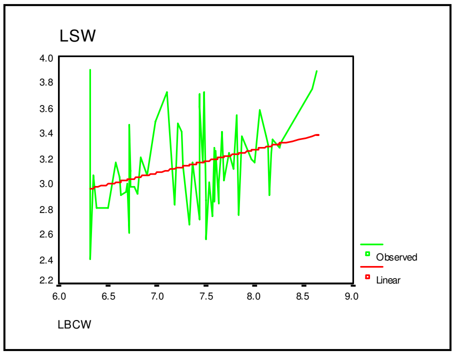


Fig 5: Regression curvefits showing relationship of dependant variable left sided shaft width (LSW) with left sided bicondylar width (LBCW)



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