Original Research Article

MULTIDETECTOR COMPUTED TOMOGRAPHIC ASSESSMENT OF ANTERIOR FEMORAL BOWING IN ADULTS WITH UNILATERAL FEMUR FRACTURE

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ABSTRACT

Background: There are well-known variations in the degree of femoral bowing between racial groups. Although femoral bowing is more pronounced in Asian races, most available orthopaedic implants are not made to accommodate this pronounced bowing. This study is to determine the dimensions of the femoral shaft on the contralateral limb in men and women presenting with unilateral femur fracture and to identify the most important influences of femoral antecurvature- age, femur length, shaft thickness, gender and ethnicity.

Materials and Methods: A sample of 60 adults were examined for maximum femoral length (MFL), mid-shaft transverse diameter (MTD), and anterior bowing (AB). On digital images, the femoral shaft's linear dimensions and AB were measured.

Results: Mean AB, MFL, and MTD in males were 806.88 mm, 433.7 mm, and 25.84 mm, respectively. These values were 406.0 mm, 25.14 mm, and 736.79 mm for females respectively. In males, there was a significant correlation between age and AB ($r = –0.58$, $P < 0.001$), with AB rising steadily with age. In females, there was just a weak correlation seen between AB and age. There was no difference in the other metrics between males and females, except for MFL, where males exhibited longer MFL ($P < 0.001$). Males showed a strong correlation ($r = –0.45$, $P < 0.001$) between MFL and age, while females showed a very poor correlation.

Conclusion: The amount of femoral bowing observed in our population exceeds other ethnic groups cited in literary research. This could lead to variable degrees of mismatch between the femurs of our study population and the femoral intramedullary implants made in the West. It is advised that orthopedic surgeons precisely assess the femoral bowing prior to surgery. It is of utmost importance to prioritize the development of femoral intramedullary nails specific for Indian population.

Keywords: Femoral bowing, Femoral antecurvature, Femoral shaft dimensions, Intramedullary nail, Ethnic variation, Indian population, Femur morphology, Orthopaedic implants.

INTRODUCTION

Racial differences exist in the degree of femoral bowing. Anthropologists and forensic scientists have examined variations in femoral ante curvature between racial and ethnic groups.[1] The radius of curvature in black population was greater than whites, meaning that femoral bowing/ante curvature was less pronounced in blacks compared to whites. It is to note that as the radius of curvature of femur increases, its bowing/ante curvature decreases, suggesting an inverse relationship between radius of curvature and anterior femoral bowing. This concept holds utmost importance in manufacturing of orthopaedic implant (intramedullary nails) which are the mainstay of treatment of femur shaft fracture.

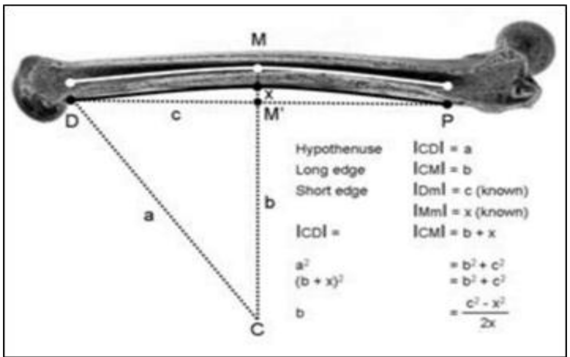
Asian skeletons are very different from those of western population in terms of osteometry.[2-9] There is increased magnitude of femoral bowing in Asian races whereas most of the western manufactured orthopaedic implants for femur do not match this exaggerated bowing, due to the racial difference. So there occurs a varying degree of mismatch between the western-manufactured femoral intramedullary implants and the femur of Asian population, resulting in anterior thigh pain, implant failure and periprosthetic fracture. This is because the intramedullary nails are designed based on universal anthropologic measurements. Via radiological evaluation of variation in anterior bowing of femur amongst population, could help address this issue of mismatch and pave way to better surgical outcome and reduce any untoward complications in cases where intramedullary implants of femur are desired. The radius of curvature (ROC) of most currently available nail designs ranges between 1500 and 2000 mm. Because Asian patients have shorter femurs with greater anterior curvature, recent clinical research have highlighted the issue of distal anterior encroachment or even nail tip perforation.[10-14] The femur's radius of curvature ranges from 885 to 1446 mm, which is a fairly wide range amongst races.[1520] Because of the difference caused by sex hormones throughout puberty, female bones are naturally smaller than men's.[21-23] Medical conditions like age related osteoarthritis, nutrition related factors like obesity and vitamin D deficiency, especially at a younger age are some of the factors leading to increased femoral bowing.[24-26] The femoral anterior bow is measured with great repeatability, accuracy, and convenience using the CT reconstruction method. Hence MDCT with two dimensional (2D) reformat is preferred for its better image resolution and ease of operation. Its advantage lies in quick picture processing with new software and workstations. The main disadvantage of MDCT is the radiation exposure to the patients which can be reduced by reducing the milliampere-seconds value, increasing the pitch, adjusting the milliampere-seconds value based on patient size, and lowering the beam energy.[28] Hence MDCT aids in better preoperative analysis and surgical planning as compared to conventional radiography. The aim of this study to evaluate femoral radius of curvature in sagittal plane using multidetector computed tomography on contralateral limb in adults presenting with unilateral femur shaft fracture, and objective to evaluate the variation of femoral radius of curvature, with age, sex, height, weight, ethnicity, femur length and midshaft femur thickness.

MATERIALS AND METHODS

This study is a hospital based observational study conducted in Department of Radiodiagnosis and Department of Orthopaedics, Assam Medical College, Dibrugarh, Assam, in one year duration from March 2023 to February 2024. Considering a moderate correlation found between radius of curvature and femur length (r = 0.44) among adult population49, the sample size for the present study is calculated and rounded off to be 60 with 95% confidence interval and 90% power. 60 consecutive Patients who were clinically diagnosed with femur shaft fracture by Department of Orthopaedics and planning for intramedullary fixation underwent a CT of contralateral femur to determine its radius of curvature during our study period after taking informed written consent. Ethical clearance of the present institute was taken. Patients with bilateral femur fracture, unilateral femur fracture whose contralateral femur showed old fractures, gross deformity, implants and radiological artefacts, pregnant females and physically inactive patients were excluded from this study. A computed radiography unit ALLENGERS-525 X-Ray machine was used for Standard AP and lateral views of affected femur were taken with 59 KVP and 18 mAS.

CT acquisition protocol: Multidetector computed tomography of femur was carried out with the Philips Brilliant iCT 256 CT Scanner. In order to minimize motion artifacts, scans were obtained using the helical mode. 120 Kv, 240 mAs, 2 mm section thickness, and 0.5 mm collimation were the scanning parameters that were taken. Computed tomography scans of normal contralateral thigh of unilateral shaft femur fracture were obtained. With the patient in supine position, axial, coronal and sagittal images were obtained from upper pole of the hip joint up to the caudal end of the knee joint using bone algorithm. After post-processing the acquired data and bone reconstruction multiplanar reformations were created. A separate evaluation of reformatted axial, coronal, and sagittal images was carried out. The femur was assessed for anterior bowing and the findings compared with age, sex, height, weight, ethnicity, maximum femoral length (MFL) and mid-shaft transverse diameter (MTD). and maximum femoral length (MFL) was measured using the Martin and Saller method.64 The greatest distance between the lowest margin of the medial condyle and the topmost margin of the femur head was measured for MFL. The transverse diameter at the shaft's center is the MTD.

Using the sagittal film, anterior bowing (AB) was measured in accordance with Harma and Karakaş65,66. The femoral curvature was recognized as an arch using this method, and the radius of the hypothetical circle to which this arch would belong is computed. Here are the definitions of the three points that made up the arch: 1. Proximal, or the lesser trochanter's lower border (P); 2. Distal, or the condyle's starting point for widening (D); 3. Midpoint, or the halfway point between the proximal and distal points (M). The line that connected P and D (PD) was traced when these reference points had been identified. The formula $a^2 = b^2 + c^2$ was used to determine the radius of the imaginary circle to which this PMD arch belonged.



Findings were recorded and tabulated in Microsoft Excel Worksheet and computer-based analysis was performed using the Statistical product and service solutions (SPSS) 20.0 software (SPSS, Chicago, Illinois, USA) and Microsoft Excel 2010.

Categorical data were presented as frequency (%) and quantitative data as mean ± SD and median. Correlation between the various CT findings were evaluated using Pearson correlation coefficient and tested using t test. A p value of <0.05 was considered statistically significant.

RESULTS

60 patients with unilateral femur shaft fracture, planned for intramedullary nailing were included in the study. Most of the patients in our study group belong to 18-30 years of age comprising of 23.33% (14 patients). Least number of cases were seen in >80 years of age comprising of only 8.33% (5 patients).

More cases of femur shaft fracture were seen in males (68%, 41 patients) compared to females. (32%, 19 patients) Maximum number of male patients who suffered from femur shaft fracture belonged to the age group of 18-30 years (29.26%, 12 patients). Least number of cases were observed in the age group >80 years (7.31%, 3 patients). Maximum number of female patients who suffered from femur shaft fracture belonged to the age group of 41-50 years (26.31%, 5 patients). Only 2 cases (10.52%) each were observed in age group of 18-30, 31-40, 71-80 and Road traffic accident was the most common cause of femur shaft fracture consisting of 80% of total cases (48 patient).

Comparing Radius of Curvature of Femur to Age Group in Study Population:

Table 1: Comparing radius of curvature of femur to age group

Age Group	Radius of curvature (mm)		
	Mean	**Standard deviation**	**Median**
18-30	905.64	150.18	933
31-40	851.1	115.81	857
41-50	781.62	150.07	724
51-60	738.12	111.87	705.5
61-70	690.77	161.8	623
71-80	697.5	144.72	685.5
>80	665.6	109.83	664

Age group of 18-30 has the highest value of mean and median radius of curvature. Mean value measures 905.64 mm with a standard deviation of 150.18 mm and median measures 933 mm. Age group >80 years has the lowest value of mean. Mean measures 665.6 mm with a standard deviation of 109.83 mm. Lowest median value of 623 mm is observed in the age group of 61-70. With increasing age of the patient, radius of curvature is noted to decrease suggesting a moderate negative correlation ($r = -0.52$, $p < 0.001$) between age and radius of curvature.

Table 2: Comparing radius of curvature to age group in males

Age	ROC (mm)		
	Mean	**SD**	**Median**
18-30	922	155.7	1027
31-40	870.12	80.17	857
41-50	795.33	158.2	706
51-60	745.8	95.18	703
61-70	682.16	152.89	626
71-80	703.5	173.21	703.5
>80	675	117.88	664

Age group of 18-30 has the highest value of mean and median radius of curvature in males. Mean value measures 922 mm with a standard deviation of 155.7 mm and median measures 1027 mm. Age group >80 years has the lowest value of mean. Mean measures 675 mm with a standard deviation of 117.88 mm. Lowest median value of 626 mm is observed in the age group of 61-70. With increasing age of male patients, radius of curvature is noted to decrease suggesting a moderate negative correlation (r= -0.58, p <0.001) between age and radius of curvature.

Table 3: Comparing radius of curvature to age group in females.

Age	ROC (mm)		
	Mean	SD	Median
18-30	804	49.49	804
31-40	775	247.48	775
41-50	773.4	163.32	742
51-60	725.33	159.02	722
61-70	708	213.58	623
71-80	685.5	119.5	685.5
>80	651.5	140.71	651

Age group of 18-30 has the highest value of mean and median radius of curvature in females. Mean value measures 804 mm with a standard deviation of 49.49 mm and median measures 804 mm. Age group >80 years has the lowest value of mean. Mean measures 651.5 mm with a standard deviation of 140.71 mm. Lowest median value of 623 mm is observed in the age group of 61-70. Weak negative correlation (r= -0.3) is noted between age and radius of curvature in females without any significant difference. (p= 0.2) The radius of curvature of the male individuals did not significantly differ from females. (p = 0.16). Mean and median value of ROC was 806.8 mm and 794 mm respectively for male and 736.78 and 742 respectively for females with a standard deviation of 160.6 mm in males and 146.74 mm in females. The radius of curvature of the male individuals did not significantly differ from females. (p = 0.16). Height range of 181-185 cm has the highest value of mean and median radius of curvature in our study population. Mean value measures 977 mm with a standard deviation of 112.76 mm and median measures 1056 mm. Height range of 156-160 cm has the lowest value of mean and median. Mean measures 672.12 mm with a standard deviation of 75.35 mm and median measures 623 mm. Very weak positive correlation (r=0.19) exists between radius of curvature and height of individual. The radius of curvature did not significantly differ with height of study population. (p = 0.13) Weight range of 91-100 kg has the highest value of mean and median radius of curvature in our study population. Mean value measures 850.42 mm with a standard deviation of 176.4 mm and median measures 942 mm. Weight range of 61-70 kg has the lowest value of mean and median. Mean measures 696.18 mm with a standard deviation of 142.76 mm and median measures 664 mm. Very weak positive correlation (r= 0.13) exists between radius of curvature of femur and weight of individual. The radius of curvature did not significantly differ with weight of study population. (p = 0.33) Bihari community has the highest value of mean radius of curvature in our study population. Mean value measures 888 mm with a standard deviation of 127.04 mm. Highest median value is seen in Singpho community and it measures 943 mm. Mising community has the lowest value of mean. Mean measures 699.66 mm with a standard deviation of 131.72 mm. Lowest median value is noted in Rabha community with a value of 629mm. The radius of curvature did not significantly differ with ethnicity of study population. (p = 0.6).

Comparing Radius of Curvature of Femur-to-Femur Length of Study Population

Table 4: Comparing radius of curvature to femur length of study population.

FEMUR LENGTH (mm)	ROC (mm)		
	Mean	SD	Median
380-390	669.75	101.78	650.5
391-400	697.12	157.64	651
401-410	746	33.94	746
411-420	760.25	175.62	766
421-430	805	112.93	772.5
431-440	806.42	175.61	798
441-450	808.75	86.51	771
451-460	855.25	2.5	855.5
461-470	907.5	109.60	907.5
471-480	1029	1.41	1029
481-490	1054.5	2.12	1054.5
491-500	1061	1.41	1061

Individuals with femur length of 491-500 mm has the highest value of mean and median radius of curvature in our study population. Mean and median values measures 1061 mm with a standard deviation of 1.41

mm. Individuals with femur length of 380-390 mm has the lowest value of mean and median radius of curvature. Mean measures 669.75 mm with a standard deviation of 101.78 mm and median measures 650.5 mm. Strong positive correlation (r= 0.66, p<0.001) exists between radius of curvature of femur and femur length of individual. Individuals with mid femur transverse diameter of 27.1-28 mm has the highest value of mean radius of curvature in our study population. Mean measures 880.42 mm with a standard deviation of 156.70 mm. The highest median value is noted with mid femur transverse diameter of 28.1-29 measuring 1028 mm. Individuals with mid femur transverse diameter of 23.1-24 mm has the lowest value of mean radius of curvature measuring 647.66 mm with a standard deviation of 102.97 mm. Lowest median value measures 623 mm in the study population with mid shaft transverse diameter of 26.1-27. None to very weak correlation (r= 0.03) exists between ROC and midshaft transverse diameter. The radius of curvature did not significantly differ with mid shaft transverse diameter of femur in our study population. (p = 0.82) Age group of 18-30 has the highest value of mean and median maximum femur length. Mean value measures 452.78 mm with a standard deviation of 35.39 mm and median measures 448 mm. Age group of 41-50 has the lowest value of mean and median. Mean measures 406.22 mm with a standard deviation of 18.91mm and median measures 399 mm. Median value of 399 mm is also seen in the age group of 61-70. There occurs a moderate negative correlation (r= -0.42, p< 0.001) between age and maximum femur length. Age group of 18-30 has the highest value of mean and median maximum femur length among males in our study population. Mean value measures 459.83 mm with a standard deviation of 30.53 mm and median measures 464 mm. Age group of 41-50 has the lowest value of mean. Mean measures 397.33 mm with a standard deviation of 2.88 mm. Lowest median value is noted in 61-70 age group in males with a value of 398.5 mm. There occurs a moderate negative correlation (r= -0.45, p< 0.001) between age and maximum femur length in males. Age group of 18-30 has the highest value of mean and median maximum femur length among females in our study population. Mean value measures 410.5 mm with a standard deviation of 43.13 mm and median measures 410.5 mm. Age group >80 has the lowest value of mean and median. Mean measures 385 mm with a standard deviation of 4.24 mm and median measures 385 mm. There occurs a very weak negative correlation (r= -0.14) between age and maximum femur length in females. The maximum femur length did not significantly differ with age among females in our study population. (p = 0.58). The mean maximum femur length value for females was lower than that of males, with a p-value <0. 001.Age group of 41-50 has the highest value of mean and median midshaft transverse diameter. Mean value measures 26.56 mm with a standard deviation of 2.23 mm and median measures 26.25 mm. Age group 18-30 also has a median value of 26.25 mm. Age group >80 has the lowest value of mean and median. Mean measures 24.18 mm with a standard deviation of 1.37 mm and median measures 23.9 mm. Median value of 23.9 mm is also seen in the age group of 71-80. None to very weak correlation (r= 0.03) exists between midshaft transverse diameter and age. The midshaft transverse diameter of femur did not significantly differ with age in our study population. (p = 0.78). Age group of 71-80 has the highest value of mean midshaft transverse diameter among males in our study population. Mean value measures 27.97 mm with a standard deviation of 1.54 mm. Highest median value of 28.3 mm is noted in age group 41-50. Age group >80 has the lowest value of mean and median. Mean measures 24.06 mm with a standard deviation of 0.56 mm and median measures 23.9mm. There occurs a very weak positive correlation (r= 0.14) between midshaft transverse diameter and age in males. The midshaft transverse diameter of femur did not significantly differ with age in our study population among males. (p = 0.39). Age group of 41-50 has the highest value of mean and median midshaft transverse diameter among females in our study population. Mean and median values both measure 27.45 mm with a standard deviation of 2.75 mm. Age group 71-80 has the lowest value of mean and median. Mean and median measures 22.9 mm with a standard deviation of 0.84. Very weak negative correlation (r= - 0.13) exists between midshaft transverse diameter and age in females. The midshaft transverse diameter of femur did not significantly differ with age in our study population among females. (p= 0.59). No age-related difference in midshaft transverse diameter could be established between the genders. (p= 0.35).

Representative Case- Male patient aged 65 years with history of RTA, leading to fracture shaft femur on right side.

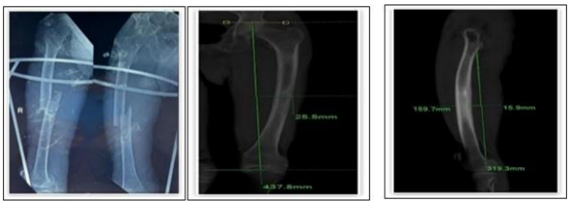


Figure 1: (A) AP and lateral radiograph of right femur showed fracture shaft femur. (B) CT evaluation of the normal contralateral femur was performed. Maximum femur length measured 437.8 mm and midshaft transverse diameter measured 25.5 mm. (C) Radius of curvature measured 794 mm using Harma and Karakas formula.

DISCUSSION

In our study, mean age of the study participants was 48 with a standard deviation of 19 years. The mean radius of curvature in our study population is 784.68 mm with a standard deviation of 158.66 mm. and a median value of 770 mm. The highest value of ROC in our study population was 1062 mm belonging to a male aged 28 years. The lowest ROC in our study population was 550 mm belonging to a female aged 64 years. The average ROC of male subjects in our study population was 806.88 mm ± 158.8 mm with a median value of 794 mm. The average ROC of female subjects in our study population was 736.79 mm ± 142.84 mm with a median value of 742 mm. The value of mean radius of curvature of our study matches closely to Harma et al,[45] where the mean medullary bending in the Turkish population was 722 mm. Mixed samples of Asian and Caucasian femurs were investigated and a ROC of 885 mm was calculated by Schmutz et al.[48] The mean ROC was 943 mm in the study by Thiesen DM et al.[49] The femurs of Asian women had the lowest ROC, measuring 826 mm in their study. Curvature radius of the femoral anterior bowing in a Thai population was measured with an average ROC of 895:46 ± 238:06mm by Chantarapanich et al.[46] This wide difference in radius of curvature is a proof of the ethnic and regional variation of femoral antecurvature and that the radius of curvature of our study population matches closely to studies conducted in the Asian continent. The average femur length of our study population was 424.95 mm ± 30 mm with a median value of 419 mm. 380 mm was the lowest femur length that was measured in a 25-year-old female patient while 496 mm was the highest measured value of femur length in a 28-year-old male patient. The average femur length of male subjects in our study population was 433.7 mm ± 30.85 mm with a median value of 429 mm. The average femur length of female subjects in our study population was 406.05 mm ± 20.4 mm with a median value of 402 mm. Our findings are slightly less than those of Karakas HM et al,[45] who found that the average maximum femur length in the study population in Turkey was 433.6 mm, 448.2 mm and 419 mm among total population, males and females respectively. The average midshaft transverse diameter of our study population was 25.62 mm ± 2.66 mm with a median value of 25.9 mm. 20 mm was the lowest midshaft transverse diameter that was measured in a 25-year-old female patient while 30 mm was the highest measured value of midshaft transverse diameter in a 35-year-old male patient. The average midshaft transverse diameter of male subjects in our study population was 25.84 mm ± 2.58 mm with a median value of 26.4 mm. The average midshaft transverse diameter of female subjects in our study population was 25.14 mm ± 2.77 mm with a median value of 25.2 mm.

Comparing Radius of Curvature of Femur to Patients age and Gender: The age groups with the highest mean value of radius of curvature were 18-30 years (905.64 mm ± 150.18 mm) and with the least radius in the age group >80 (665mm ± 109.83mm). Similarly, the age groups with the highest median value of radius of curvature were 18-30 years (933 mm) and with the least radius in the age group >80 (664 mm). Moderate negative correlation (r= -0.52, p <0.001) exist between age and radius of curvature in our study population. The age groups with the highest mean value of radius of curvature among males were 18-30 years (922 mm ± 155.7 mm) and with the least radius in the age group >80 (675mm ± 117.88mm). Similarly, the age groups with the highest median value of radius of curvature among males were 18-30 years (1027 mm) and with the least radius in the age group >80 (664 mm). Moderate negative correlation (r= -0.58, p <0.001) exists between age and radius of curvature in males. The age groups with the highest mean value of radius of curvature among females were 18-30 years (804 mm ± 49.49 mm) and with the least radius in the age group >80 (651.5 mm ± 140.71 mm). Similarly, the age groups with the highest median value of radius of curvature among females were 18-30 years (804 mm) and with the least radius in the age group >80 (651 mm). Weak negative correlation (r= -0.3) is noted between age and radius of curvature in females without any significant difference. (p= 0.2) The mean value of radius of curvature among males were 806.8 mm ± 160.6 mm with a median value of 794 mm. The mean value of radius of curvature among females were 736.78 mm ± 146.74 mm with a median value of 792 mm. The radius of curvature of male individuals did not significantly differ from females in our study population. (p = 0.11). However, in our study there was a moderate negative correlation between age and ROC (r= -0.52 using Pearson's correlation coefficient), but we could not prove a significant difference in ROC of male and female femurs (p= 0.11). This could be attributed to the small sample size of our study population (60 patients) compared to the study by Thiesen DM et al. which had a sample size of 1232 participants. Reid et al,[59] found that the degree of femoral bending rises with age when comparing the femoral curvature of a group of elderly women to their childhood radiographs. This finding provided evidence for the age link with the degree of bowing. We found a weak negative correlation between age and ROC of female subjects; however, this finding was not statically significant, possibly due to the smaller number of female patients in our study group (19 patients). In our study, a weak negative correlation was established between ROC and age of female subjects without any significant difference. (r= -0.3, p= 0.2). These findings could be due to the small sample of female patients in our study population (19 patients) compared to males (41 patients). However, we found a moderate negative correlation (r= -0.52, p <0.001) between age and radius of curvature in our total study population and similar correlation between age and ROC of males (r= - 0.56, p <0.001). No significant difference of AB amongst gender could be established in our study as well.

Comparing radius of curvature of femur to height of study population: Height of our study population extended from 150-185 cm. The groups with the highest mean value of radius of curvature were 181-185 cm (977 mm ± 112.76 mm) and with the least radius in the group 156-160 cm (672.12 mm ±

75.35mm). Similarly, the groups with the highest median value of radius of curvature were 181-185 cm (1056 mm) and with the least radius in the group 156-160 cm (699 mm). Our study showed a very weak positive correlation (r=0.19 using Pearson's correlation coefficient) between radius of curvature and height of individual. The radius of curvature did not significantly differ with height of study population. (p = 0.13).

Comparing radius of curvature of femur to weight of study population: eight of our study population extended from 40-100 kgs. The groups with the highest mean value of radius of curvature were 91-100 kgs (850.42 mm ± 176.4 mm) and with the least radius in the group 61-70 kgs (664 mm). Very weak positive correlation (r= 0.13) exists between radius of curvature of femur and weight of individual. The radius of curvature did not significantly differ with weight of study population. (p = 0.33).

Comparing radius of curvature of femur to ethnicity of study population: The radius of curvature did not significantly differ with ethnicity amongst the study population. (p = 0.6). in our study where radius of curvature varied widely from 699.66 ± 131.72 mm in Mising community to 888mm ± 127.04 mm in Bihari community.

Comparing radius of curvature to maximum femur length and maximum femur length to age and gender: Maximum femur length extended from 380 mm - 500 mm in the study population. Strong positive correlation (r= 0.66, p<0.001) exists between radius of curvature of femur and femur length of individual. The age groups with the highest mean value of maximum femur length were 18-30 years (452.78 mm ± 35.39 mm). and least maximum femur length in the age group 41-50 (406.22mm). Similarly, the age groups with the highest median value of maximum femur length were 18-30 years (448 mm) with the least value in the age group 41-50 and 61-70 both being 399 mm. There occurs a moderate negative correlation (r= -0.42, p< 0.001) between age and maximum femur length. The age group amongst males with the highest mean value of maximum femur length were 18-30 years (459.83 mm ± 30.53 mm) and with the least maximum femur length in the age group 41-50 (397.33 mm ± 2.88 mm). There occurs a moderate negative correlation (r= -0.45, p< 0.001) between age and maximum femur length in males. The age group amongst females with the highest mean value of maximum femur length were 61-70 (412 mm ± 38.18 mm) with the least maximum femur length in the age group >80 (385 mm ± 4.24 mm). Similarly, the age group amongst females with the highest median value of maximum femur length were 61-70 (412 mm), with the least maximum femur length in the age group >80 (385 mm). There occurs a very weak negative correlation (r= -0.14) between age and maximum femur length in females. The maximum femur length did not significantly differ with age among females in our study population. (p = 0.58). The mean maximum femur length value for females was lower than that of males, with a p-value <0.001. In our study males had longer MFL compared to females (P< 0.001). We could not however establish a significant correlation between MFL and age in females (r= -0.14, p =0.58) possibly due to mismatch in the sample size of females (19) and male (41) participants in the study. a moderate negative correlation (r= -0.45, p< 0.001) between age and maximum femur length in males is found. In a study involving Americans of various ethnic backgrounds (Asian, African, and others), Marrat et al,[55] demonstrated A moderately strong positive correlation exists between femoral length and radius of curvature. Moreover, he stated, an increase in each additional centimetre of femoral length correlated with an increase of 3.1 cm (right) to 3.4 cm (left) in the radius of curvature. Findings of Marrat et al are in accordance with our findings where we found a strong positive correlation between maximum femur length and radius of curvature. According to Tang et al,[47] A shorter radius of curvature correlated with shorter femora, similar to our study. According to a regression analysis, performed by Thiesen DM et al.[49] The most significant predictor of the curvature's variations was femur length. Femur length and ROC showed a moderate correlation (r = 0.44), with longer femurs showing an increased radius of curvature. In our study we did find a strong positive correlation (r= 0.66) between maximum femur length and radius of curvature.

Comparing radius of curvature to midshaft transverse diameter of femur and midshaft transverse diameter to age and gender: Midshaft transverse diameter extended from 21 mm - 30 mm in the study population. Midshaft transverse diameter was grouped and the group with the highest mean value of radius of curvature were 27.1-28 mm (880.42 mm ± 156.70 mm) and with the least radius in 23.1-24 mm (647.66 mm ± 102.97 mm). Similarly, the groups with the highest median value of radius of curvature were 28.1-29 mm (1028 mm) and with the least radius in 26.1-27 mm (623 mm). None to very weak correlation (r= 0.03) exists between ROC and midshaft transverse diameter. The radius of curvature did not significantly differ with mid shaft transverse diameter of femur in our study population. (p = 0.82). The age groups with the highest mean value of midshaft transverse diameter were 41-50 years (26.56 mm ± 2.23 mm) and with the least midshaft transverse diameter in the age group >80 (24.18 mm ± 1.37 mm). Similarly, the age groups with the highest median value of midshaft transverse diameter were 18-30 years (26.25 mm) and with the least value in the age group 71-80 and >80 both being 23.9 mm. None to very weak correlation (r= 0.03) exists between midshaft transverse diameter and age. The midshaft transverse diameter of femur did not significantly differ with age in our study population. (p = 0.78). The age group amongst males with the highest mean value of midshaft transverse diameter were 71-80 years (27.97 mm ± 1.54 mm) and with the least midshaft transverse diameter in the age group >80 (24.06 mm ± 0.56 mm). Similarly, the age group amongst males with the highest median value of midshaft transverse diameter were 41-50 years (28.3 mm) and with the least value in the age group >80 (23.9 mm). There occurs a very weak positive correlation (r= 0.14) between midshaft transverse diameter and age in males. The midshaft transverse diameter of femur did not significantly differ with age in our study population among males. (p = 0.39). The age group amongst females with the highest mean value of midshaft transverse diameter were 41-50 years (27.45 mm ± 2.75 mm), with the least midshaft transverse diameter in the age group 71-80 (22.9 mm ± 0.84 mm). Similarly, the age group amongst females with the highest median value of midshaft transverse diameter were 41-50 years (27.45 mm), with the least value in the age group 71-80 (22.9 mm). Very weak negative correlation (r= - 0.13) exists between midshaft transverse diameter and age in females. The midshaft transverse diameter of femur did not significantly differ with age in our study population among females. (p = 0.59). No age-related difference in midshaft transverse diameter could be established between the genders. (p= 0.35). In our study there was only a weak positive correlation of MTD with age in males and female which was not statistically significant. (r= 0.14, p= 0.39). This difference could be attributed to the small sample size and unequal distribution of patients in different age group. Similarly, none to very weak correlation existed between ROC and midshaft transverse diameter without any statistical difference in our study population.

Limitations of our Study: There are various limitations on this study. Since every participant in this study comes from a single state, we are unable to ascertain if femoral anterior bow indexes vary by regions within the nation. a small sample size (60 patients) with uneven distribution of participants in terms of age and gender. We considered that the left and right femurs are symmetric. At the proximal femur, this has been demonstrated to be true scientifically.[75] Even if it appears reasonable to extrapolate this over the entire femur, there's still a chance that our assumption was incorrect. In our study we measured only the antero-posterior femoral bowing without taking into account its lateral bowing.

CONCLUSION

Our study shows a ROC value which is less than many studies in the western literature however matches closely to few studies done on the Asian population, suggesting that Asian femurs among all are more anteriorly bowed. According to the current study, variations in femur length and age are the strongest factors contributing to variation in ROC. The moderate negative correlation between age and ROC in the total study population could be explained by the fact that with increasing age osteoporotic changes starts to set in leading to increased bowing angle. It is also possible that the greater degree of femoral AB in older population may have had origins in greater levels of physical work and carrying heavy load during their youth. Female bones are naturally smaller than male bones, a difference that is influenced by sex hormones during puberty. The differences in MFL indicate that the men in our sample were larger than the women. In several parts of India, including Assam, elderly participants have smaller bodies possibly due to their early hardships, which causes MFL to significantly decline with age. The femur's form and structure are constantly changing according to external stresses. We hypothesise that axial loading and bending forces are at least somewhat responsible for the age-dependent shortening of the femur. Very weak positive correlation (r=0.19) exists between radius of curvature and height of individual. The radius of curvature did not significantly differ with height of study population. (p = 0.13). Very weak positive correlation (r= 0.13) exists between radius of curvature of femur and weight of individual. The radius of curvature did not significantly differ with weight of study population. (p = 0.33). The radius of curvature did not significantly differ with ethnicity amongst the study population. (p = 0.6). None to very weak correlation (r= 0.03) exists between ROC and midshaft transverse diameter. The exaggerated anterior bowing in our study population would lead to increased failure rate and complications of IM nailing. In cases of femur shaft fracture where IM nailing is intended and in hip replacement routine assessment of ROC of opposite femur may be advised to look for any exaggerated femoral bowing so as to prevent surgical complication and achieve better outcomes. Currently, imports account for the majority of femoral long-stemmed prosthesis and intramedullary nails used in India. There is a dearth of regional research, and the prostheses and nails made by well-known domestic medical device companies are likewise made to resemble Western prostheses. Thus, it is necessary to prioritize the development of femoral long-stemmed prosthesis and intramedullary nail for Indian population. The design and use of domestic femoral long-stemmed prostheses will be greatly impacted if more such studies as ours are conducted and applied to large-scale femoral data statistics in various parts of India.

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