ISSN: 2676-7473

RBMS.2019;24(1):e2

ORIGINAL RESEARCH

Determination of anterior femoral bowing to length ratio in Iranian population

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Date Received: June, 2018 *Date Accepted: October, 2018* *Online Publication: January 28, 2019*

Abstract

Due to the existence of different races and ethnicities and their different life styles, anatomical structure of people vary from one region of the world to another. The goal of this study is to determine the anterior femoral bowing to length ratio, which can be useful for planning major medical and therapeutic projects as well as designing medical equipment (including nails, orthoses and prosthetics). Lateral X-rays of femur bones of 250 patients who referred to Taleghani hospital in recent years (2011-2016) were retrieved from hospital archives and studied. 150 patients were females and 100 were males, ages ranging from 16 to 57 years old. All patients were Iranians with different ethnical backgrounds that referred to radiology centers of Tehran and Taleghani hospital and their records were saved in these centers archive. Based on femoral length, X-rays were categorized into eight groups; 300^{mm}, 320^{mm}, 340^{mm}, 360^{mm}, 380^{mm}, 400^{mm}, 420^{mm} and 440^{mm}, which are standards for manufacturing femoral nails in Iran as well as imported nails to Iran. Results showed significant difference compared to available femoral nails on the Iranian market, which indicates that these nails are not standard for Iranian population. Data analysis was based on anterior femoral bowing to length ratio alone. Gender and age were not considered for data analysis in this study and results were conclusive for all ages and genders.

Keywords: Femoral nail, Anterior bowing of femur, Iranian population, Femur

Introduction

The femur is the longest and strongest bone in human body, which articulates with the acetabulum at the proximal end, forming the hip joint [1] and articulates with the tibia and patella at the distal end forming the knee joint [2]. The femur consists of a shaft and two ends. The proximal end includes a round head, a neck, and two greater and lesser trochanters.

The femoral head is smooth and about 2/3 of the globe and is located in the acetabulum fossa of the pelvic bone. There is a small fovea on the head, which is the attachment site of round ligament of the head [3]. The femoral shaft is almost cylindrical with a little convexity to the front. There is a prominent and double-edged line on the middle third of posterior surface of the shaft, which is called the linea aspera [3].

Anterior femoral bowing is a known feature of human beings. Studies have shown no direct association between anterior femoral bowing and morphological specifications, which several factors affect the bowing [6-4]. Fetal femoral bowing changes with different stages of growth [7]. Muscular tensions and mechanical forces of joints and intrinsic and extrinsic factors affect the femoral bowing [8]. The femur is a heavy and long bone that is affected by weight and mechanical factors at all stages of growth, which cause changes to its shape and structure [9]. Therefore, physical and morphological factors (e.g. length, weight, bone density, femoral neck, etc.) are important in determining anterior femoral bowing [5,10].

Due to the existence of different races and ethnicities and their different life styles such as nutrition, location, climate, etc. skeletal structures and physical features of humans vary from one geographical region to another [11,12] and show exclusive specifications for that region [13,14].

This issue is of great importance in skeletology and medicine, specially regarding treatment aspects of orthopedic surgery [12,15]. Features such as bone density; size and physical specifications can be pointed as important factors regarding treatment options [14,16]. These features cause variations in treatment methods in different parts of the world [17]. Therefore, identification of these structural features is important patients treatment [18,19].

Anterior femoral bowing depends on factors such as age, gender, bone length and race. Therefore, collected data vary in different parts of the world. Also, the bowing varies in different generations, which is directly related to peoples' life styles [20].

Currently, most femoral nails have a radius of 150^{mm} to 300^{mm} [21,22]. However, studies have shown significant difference between anterior femoral bowing and nail radius in most cases [23,24]. This incompatibility of nails with femoral shape and size cause complications such as perforation of distal cortex of the femur and pain in the knee and femur (which is reported in %75 to %90 of patients after surgery) [24,25].

Materials and Methods

Study population were selected from radiology centers of Tehran since Iranians of different ethnical backgrounds reside in this city and also patients from other cities refer to Tehran to have access to outstanding specialists and advanced medical facilities.

With respect to medical ethics principles and cooperation of imaging centers, X-rays of femurs of patients were collected. These were lateral X-rays of the femur. X-Rays of 250 patients aging from 20 to 60 years old taken during (2011-2016) were studied. All X-Rays showed the whole femur and belonged to patients with healthy femur bones. Based on femoral length, the X-Rays were categorized into eight groups of 300^{mm}, 320^{mm}, 340^{mm}, 360^{mm}, 380^{mm}, 400^{mm}, 420^{mm}, 440^{mm}, which are standards for manufacturing femoral nails in Iran as well as imported nails.

Femur Measurement

Collected X-rays show the lateral view of femur, which is used for measurement of bone bowing. First, we measured the femoral length (FL). At this stage, bone length was measured from the greater trochanter to the lateral epicondyle on X-rays and taking into account the image scale, the actual length was calculated (Fig. 1-1).

Next, a point on the femoral shaft (A) near the greater trochanter is marked and a line perpendicular to the bone crossing that point (A) is drawn. Bone thickness is measured at that point and its central point (A') is marked, which is indicative of diaphyseal bone center at that section (Fig. 1-2). Another point (B) is marked near the lateral epicondyle and the diaphysealcentral bone point (B’) at that section is determined as well.

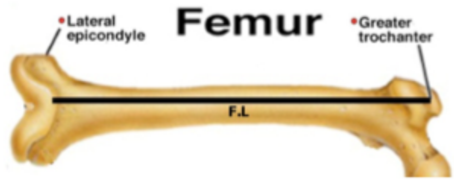

Figure 1-1: Measuring the length of the femur (F.L)

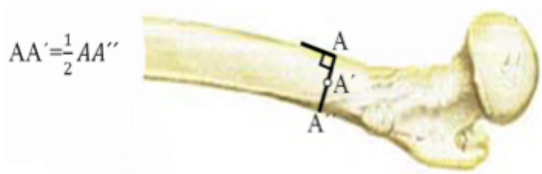

Figure 1-2: Marking point A'

A straight line is drawn between these two points (A’ and B’) and the length of A’B’ line is measured. The central point (C) of A’B’ line is calculated and highlighted. Another line perpendicular to the A’B’ which crosses the C point is drawn, and femoral bone thickness is measured at this section and the central point (C’) is marked (Fig. 1-3).

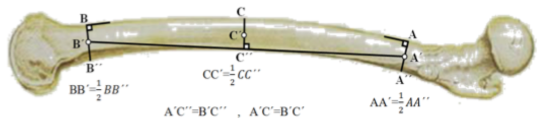

Figure 1-3: Marking three points on bones

The distance between C and C’ is measured. Results are A’B’= X and CC’ = Y which are calculated in actual lengths considering the image scale and are used for measurement of bowing by drawing an arc using three points.

Employing mathematical and engineering formulas is a common way of calculating the radius (Fig. 1-4). However, in order to facilitate the dissertation process, we preferred using available engineering software such as AutoCAD.

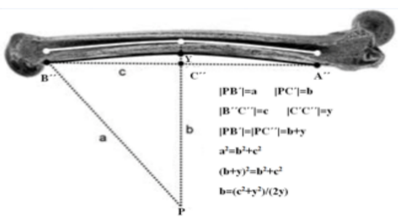

Figure 1-4: Math calculations to obtain the curvature of the thigh

Calculation of anterior femoral bowing

In this study, we preferred using the AutoCAD software for calculating the anterior femoral bowing due to higher speed and more precise calculations of the software and large quantity of data. By utilizing drawing commands and facilities such as drawing lines using point data like Cartesian and marking the beginning, end and middle points using the “Snap” section commands and drawing circles using determined points, we can calculate the radius with higher precision compared to conventional mathematical calculations. Steps are as follows: After opening the AutoCAD program, the “Line” command is selected and a point is marked on the screen as the beginning point. Then, by entering Cartesian coordinates or typing the length of the X line (A’B’), the line that represents the distance between A’ and B’ points is drawn. Using the “Midpoint” command from the “Snap” section, the midpoint of the X line is marked and a line perpendicular to this line measuring the length of Y line (CC’), which has been calculated previously, is drawn. Selected points of these lines represent the three A’, B’ and C’ points which have been determined earlier on the images.

Next, by using the “Arc” command, an arc is drawn using three points. First the A’ point is selected, then the C’ and after that the B’ points are marked. The drawn arc is indicative of the anterior femoral bowing. Then by using the “Radius” command from the “Dimension” section, the radius of the drawn arc is calculated (Fig. 3-5).

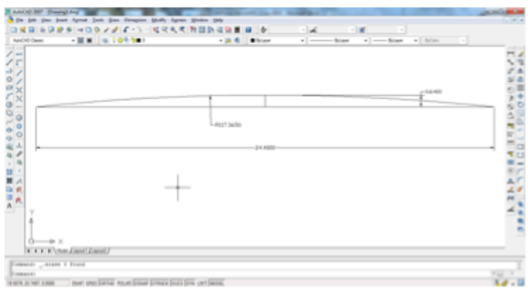

Figure 1-5: Measuring the arc with AutoCAD

Calculated data for each image is recorded in a table to be analyzed. All data regarding medical images are calculated and recorded in a table such as the following and analyzed by the XLSTAT software.

	L: Femur length	X: Line length	Y: Line length	R: Length of Radius
1	32.2^{cm}	27.5^{cm}	0.98^{cm}	77.05^{cm}
2	34.2^{cm}	24.00^{cm}	0.64^{cm}	112.82^{cm}
3	28.7^{cm}	20.16^{cm}	0.35^{cm}	145.32^{cm}
4				

Table 1-1: Sample Table of Measuring Notes

Results

Due to imports and designing nails by reverse engineering methods inside the country, results from samples, which were analyzed by XLSTAT software, show significant difference regarding the size of orthopedic nails on the Iranian market (Table 2-1).

Femur length	300	320	340	360	380	400	420	440
R^{mm}	3300	3000	2650	2350	2000	1750	1650	1600
Regression	1330.13	1237.21	1003.40	986.32	953.25	892.68	738.27	708.13
R_{th}^{mm}	1650	1475	1150	1125	1125	1035	900	875

Table 2-1: Comparison of the results with existing curvature

In this table, the first row shows femoral length (R), the second row shows the bowing radius of available nails in the Iranian market, the third row shows results of linear regression calculations and the fourth row shows results according to linear regression diagram (R_{th}), which represents the most ideal bowing. All measurements are calculated in mm. All available standards for designing orthopedic nails are based on European and American specifications. Furthermore, due to differences in race, climate, life style and nutritional habits [11,12] in Iran, significant differences are observed.

Discussion

By studying samples from previous generations, researchers have realized that anterior femoral bowing has been different among different generations [26]. They came to this conclusion by using digital imaging technology and comparing the images [26,27]. In a study, researchers studied 600 bone models. They used CT scan to collect data regarding these bones. These scientists created a special software to analyze the data to come up with precise conclusions [20]. This software uses anatomical planes that pass through intramedullary (IM) axis to analyze the images. The 0.3 and 0.7 points of distance from the proximal to the distal end of the femur along the anatomical plane were studied. The third point was marked above the intercondylar notch of the femur. Using three points, a circle was drawn. Collected data was compared to images of the Asian race (Fig. 3-1) [20].

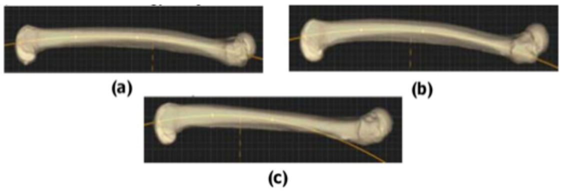

Fig. 3-1
(a): Average Case
(b): Greatest Bow Case
(c): Femur with Proximal Third

In another study, an experimental method and mathematical algorithms were used to determine anterior femoral bowing. They used cadaver samples to measure the bowing, considering the greater trochanter and the piriformis fossa. In this method, researchers studied both femurs of 5 females and 4 males of Caucasian race, aging 64±11 years old. Using a guide wire, a flexible nail was entered into the piriformis fossa and data was collected using fluoroscopic imaging techniques.

Results of this study were analyzed by custom designed software. This software drew a circle using three points on the femur (Pi-1, Pi, Pi+1) and anterior femoral bowing radius was calculated (Ci = 1/|Ri|) (Ri = Pc – Pi) (Fig. 3-2) [28].

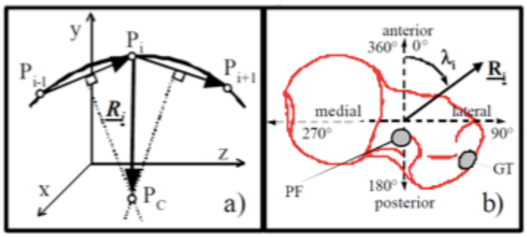

Fig. 3-2
a) 3-D curvature calculation and
b) Definition of li with PF and GT insertion sites

Another study of radiologic images of adult Caucasians showed changes in bone density with increase of age from childhood to adolescence, entering middle ages and senility [29,30]. These variations are also noticed between male and female genders [30,31]. In this case, differences depend on sexual hormones during puberty and morphometric variations [32].

According to morphometric data, senile changes happen mostly at the proximal part of the bone. Bone shaft becomes more susceptible to fracture with age. These studies were performed to evaluate femoral nails compatibility [33,34] with different racial, ethnical and gender specifications [35,36]. This study was performed on a group of 104 people including 50 males and 54 females aging from 18 to 68 years whom were

clinically studied [33].
These researchers used CT scan and computer analysis to compare their data. They used the "DICOM" software to obtain raw data from images and calculated anterior femoral bowing via Martin and Saller method (Fig. 3-3) [37].

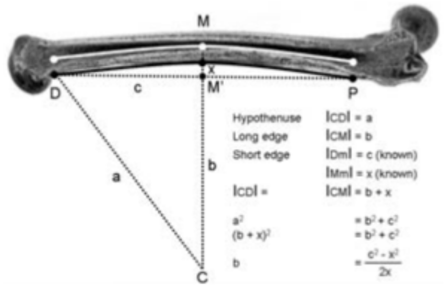

Fig. 3-3: The computation of anterior bowing on the representative digital image in the lateral projection

By marking three points on the femur and following Karakas and Harma method, a circle was drawn [33,36] and the radius of the circle was calculated, which is indicative of femoral bowing. Data was analyzed using T-student statistical analysis for independent sample and Pearson correlation coefficient [38]. Researchers also performed a study named "comparison of osteometric femoral bone dimensions among the South Africans of different ethnic groups and South African whites" on residents of the South Africa to determine whether different ethnical groups of South Africa should be considered as homogenous population or not [39,40]. They used three variables of the femur as standards, as follows [41]:

- Maximum femoral length (BL): length of the line connecting the femoral head to the most distal part of the medial condyle (Fig. 3-4a).
- Femoral head breadth (HB): maximum diameter of the femoral head (Fig. 3-4b).
- Bicondylar breadth (BCB): length of the line between cortexes of medial and lateral condyles (Fig. 3-4c).

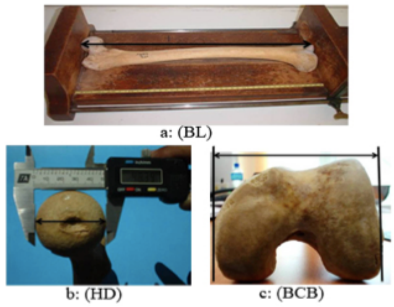

Figure 3-4: Three variables of the thigh, as measured standard
a) Femoral bone length (BL) being measured on an Osteometric board.
b) TA Electronic digital caliper measuring maximum head diameter (HD) of the femur.
c) Bone condylar breadth (BCB).

In this study, eight tribes (Zulu, Tswana, Swazi, Sotho, Xhosa, Shan, Venda and Ndebele) in South Africa were studied [42,43]. A total of 230 femurs from eight different African tribes and SAED were included using random sampling at the Department of Anatomy at University of the Witwatersrand, Johannesburg, South Africa. 25 of the samples belonged to Zulu, 25 to Xhosa, 25 to Swazi, 33 to Ndebele, 24 to Tswana, 25 to Sotho, 25 to Shan and 24 to Venda tribe, which were selected from male femurs to be compared with SAED group [45,46]. Average age range for this group was 29 to 65 years and ages were recorded approximately [39].
Results didn't show any significant difference among these eight groups, but comparing to SAED bone length, the difference was significant. Femurs of Zulu and Ndebele groups had larger HB and BCB compared to the other six groups. Results for maximal femoral length from diameter were obtained for each group separately using regression (Table 3-1) [47].

	SAED South African Ethnic groups	BL (mm)		HD (mm)		BCB (mm)	
		Mean	SD	Mean	SD	Mean	SD
1	SAED (n=24)	475.6	25.85	47.53	2.59	77.27	4.05
2	Zulu (n=25)	462.6	22.67	45.28	2.33	74.33	5.08
3	Ndeble (n=33)	461.6	26.51	45.67	3.07	73.30	4.71
4	Shan (n=25)	458.0	26.18	44.58	2.92	70.80	3.38
5	Venda (n=24)	456.8	29.88	44.75	2.58	72.50	4.10
6	Sotho (n=25)	455.4	22.63	43.27	2.36	70.58	4.58
7	Xhosa (n=25)	453.7	22.56	44.34	2.70	65.94	3.76
8	Swazi (n=25)	450.1	20.03	42.23	2.66	71.51	3.99
9	Tsuwana (n=24)	447.3	19.24	44.58	2.21	73.06	4.07
	F-ratio	2.318		6.465		4.972	
	P-Value	0.013		0.000		0.000	

Table 3-1: Mean, standard deviations and univariate F-ratio for femur in male

Conclusion

In previously mentioned studies, researchers used skeletons of past generations [20] and CT

Scan imaging and help of volunteers or images from archives of imaging centers to calculate and determine standards for residents of certain region. Foreign researchers had access to larger sample size and more advanced technologies, which we had limitations set by the Ministry of Health and also limitations in terms of imaging equipment. Due to the importance of standard bowing calculation in Iran, 251 images were provided and analyzed in cooperation with several imaging centers. Considering the importance of this issue, in order to perform a more thorough and precise survey, we suggest this research to be registered as a national project in a larger scale so that governmental facilities and larger statistical population can be employed to determine skeletal measurements compatible with Iranians. Furthermore, this research can include other skeletal dimensions such as the tibia, hand, spine and etc. Results will have a major influence on designing orthopedic nails and medical equipment.

Conflict of interest

Authors declare no conflict of interest.

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