PROXIMAL FEMUR GEOMETRY IN THE ADULT KENYAN FEMUR AND ITS IMPLICATIONS IN ORTHOPAEDIC SURGERY

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ABSTRACT

Background: Numerous orthopaedic procedures are carried out on the proximal femur. For optimal hip function, these procedures must restore the anatomy of the proximal femur to as near normal as possible. There are currently no local studies that have described in detail the normal anatomy of the proximal femur and its implications in operations on the proximal femur.

Objective: The aim of this study was to determine the neck-shaft angle, femoral neck anteversion angle, femoral neck width and femoral head diameter in adult femora, compare the results with other studied populations and examine the implications of the same in operations on the proximal femur.

Methods: Femoral neck anteversion angle and the neck-shaft angle were determined from digital photographs of 70 cadaveric femora using an open-source image analysis software, ImageJ®(National Institutes of Health, Bethesda, Maryland). Femoral neck width and femoral head diameter were determined by measurement using a digital vernier caliper. The dimensions of available implants were searched from local suppliers of the implants.

Results: Mean femoral neck-shaft angle was found to be 129.21º, while the mean femoral neck anteversion angle was found to be 23.06º. Mean neck-shaft angle was found to be 128.67º on the left while on the right side, it was 129.03º. This difference was not statistically significant. Mean femoral neck anteversion angle was found to be 23.97º on the left side, and 23.03º on the right side, but this difference was not statistically significant. Mean femoral neck width was found to be 29.36mm, with mean width of the left side being 28.67mm and that of the right being 29.36mm. The difference was not statistically significant. Mean femoral head diameter was 42.6mm, with mean diameter of the left side being 41.2mm and that of the right side being 42.6mm. The difference was not statistically significant.

Conclusion: The current study has shown that the femoral neck-shaft and anteversion angles in the Kenyan femora vary from those of other populations. The available implants have angles which may not be suitable for a significant proportion of the local population. It would be prudent to avail a range of implants with different angles to improve the choices available to the surgeon when faced with a patient who requires an operation on the proximal femur.

INTRODUCTION

Operations on the proximal femur are very common in the practice of the orthopaedic surgeon. These range from osteosynthesis for fractures, osteotomies, to hemi- and total joint arthroplasty. These operations aim to restore the anatomy of the proximal femur to as near normal as possible, for optimal hip function. As such, a detailed knowledge of the anatomy of the proximal femur is required, especially of the the neck-shaft and anteversion angles.

In orthopaedic and anatomy textbooks, the neck-shaft angle is reported as being between 120º-140º, while the anteversion angle is reported as being between 10º-30º (1,2). Various studies have shown that these angles vary between populations.

A radiographic study in Kenyans by Otsianyi *et al* (3) found the mean neck-shaft angle to be 127.56º, while Udoaka *et al* (4), in a radiographic study in Nigerians found a range of 130.3º-133.7º, with the lower angle found in the elderly. De Farias *et al* (5) in a radiographic study in Brazil found a mean neck-shaft angle of 130.47º. Studies of anatomic specimens of dried femora have found mean neck-shaft angles of 132.69º in American specimens (6), and between 124.95º- 126.55º in Indian specimens (7,8).

The anteversion angle has also been found to be quite variable depending on the populations studied. Debnath *et al* (9) found a mean anteversion angle of 20.05º in a study of specimens from a Bengali population, while Verma *et al* (7) found a mean angle of 13.4º, also in an Indian population. Unnanuntana *et al* (6), in a study of American femoral specimens found a mean anteversion angle of 10.14º(6). Hartel *et al* (10), in a study utilizing three-dimensional CT analysis of femora from a German population found a mean anteversion angle of 14.2º. While different methods of measurement were used in the studies above, the variations could also point to regional population differences.

The diameter of the femoral neck has important implications considering that the implants used to treat fractures in the proximal femur would usually traverse the neck and lodge in the femoral head. A very narrow neck may not allow adequate implant placement especially for those implants that employ two proximal locking screws. This has been shown, in a study by Ravichandran *et al* (8) on Indian femora, who found that in some of the femora, the neck was not wide enough to adequately accommodate DHS lag screws. This was also observed by Siwach *et al* (11) in an Indian study. A narrow neck may also lead to "stuffing" by the implants, leading to a tamponade effect on the blood vessels with possibility of delayed or non-union.

No local study has been done to study these anthropometric features of the proximal femur and compared them to some of the available implants used in osteosynthesis of fractures of the proximal femur.

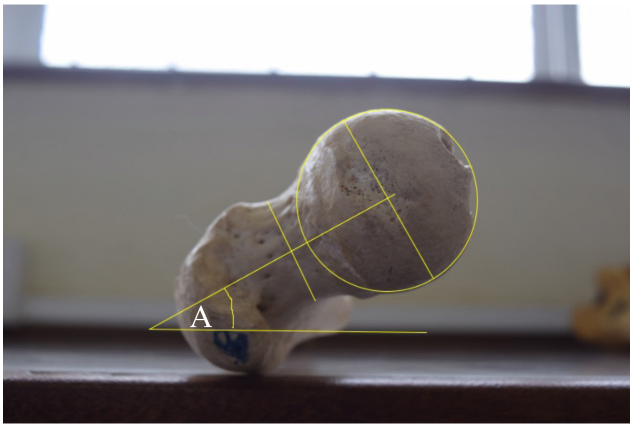
MATERIALS AND METHODS

Dried femora were obtained from the Department of Human Anatomy, Egerton University, Njoro and the Department of Human Anatomy, Kenyatta University, Nairobi. Age and sex of the source cadaver were not available. Only femora from skeletally mature individuals were used. Deformed specimens were excluded from the study.

To determine the femoral neck anteversion angle, each of the specimens was placed on a flat board, with the anterior curve of the femur facing up, and the femur resting on the quadrate tubercle cephalad and the back of the condyles caudad. An end-on digital photograph of the proximal femur was then taken with a Nikon® DSLR camera with the lens placed 10cm away and in line with the flat board. JPEG images were obtained and transferred to a computer.

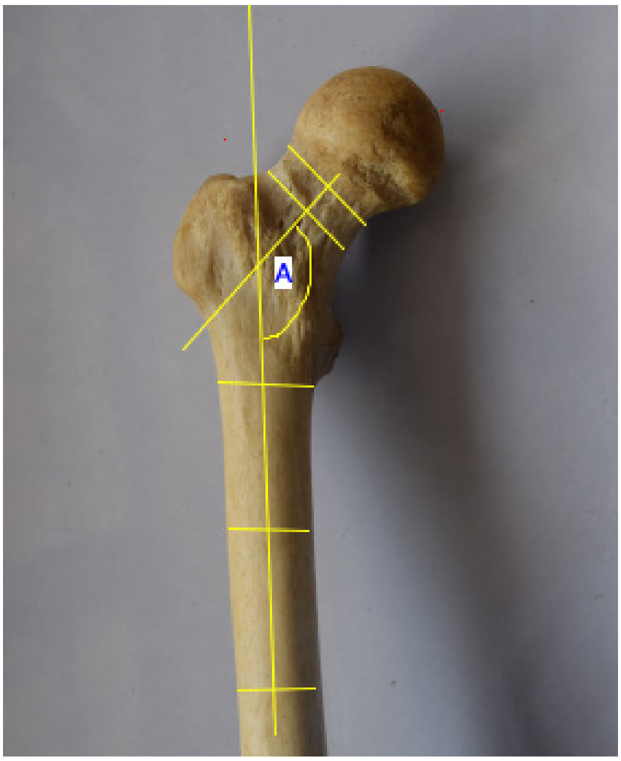
The images were imported to ImageJ® software (National Institutes of Health, Bethesda, Maryland) and the femoral neck anteversion angle obtained as follows: The center of the head of the femur and the center of the neck at its narrowest point were determined. A line joining the two points was used as the neck axis. The angle between this axis and a line running behind the condyles (retrocondylar axis) was determined as the anteversion angle. This is shown in Figure 1. The values obtained were entered into and analyzed on a Numbers®Version 4.1 spreadsheet (Apple Inc).

Figure 1
Determination of the anteversion angle, A



To determine the neck-shaft angle, a digital photograph of the specimen was taken from the anterior aspect, with the specimen internally rotated and the camera lens placed 10cm away from the specimen. JPEG images were obtained and transferred to a computer and imported to ImageJ® software (National Institutes of Health, Bethesda, Maryland). The neck-shaft angle was taken as the angle between the axis of the neck and the axis of the femoral shaft. These axes were obtained by drawing lines through the center of the neck (neck axis) and through the center of the femoral shaft(shaft axis) as shown in Figure 2.

Figure 2
Determination of the neck-shaft angle, A



The results were compared with the neck-shaft angles of available DHS and cephalomedullary nails. The values obtained were entered into and analyzed on a Numbers® Version 4.1 spreadsheet (Apple Inc).

Femoral neck width was obtained by measuring the narrowest part of the neck using a digital vernier caliper. The width of the neck was then compared with the distance needed to safely implant two lag screws in available cephalo-medullary nails. This distance was obtained from the respective product monographs as the sum of the thickness of the two screws and the distance between them. A safe margin of 2.5mm cranially and 2.5mm caudally is added.

Head diameter was obtained by measuring the widest diameter of the femoral head using a digital vernier caliper. The values obtained were entered into and analyzed on a Numbers®Version 4.1 spreadsheet (Apple Inc).

RESULTS

A total of 70 femora were obtained and used in the study. There were 37 from the left side and 33 from the right side. Table 1 shows a summary of the results obtained.

Figure 1
Showing distribution of the neck-shaft angles

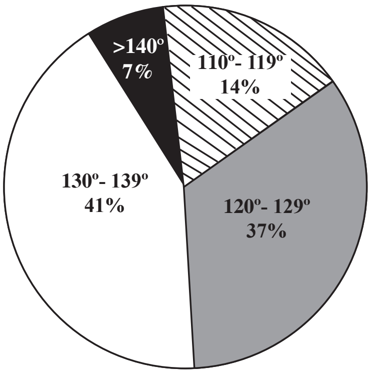


Table 1
Summary of the results obtained

	Mean of total number of specimens	Mean value for left side	Mean value for right side
Neck-shaft angle	129.21º	128.67º	129.03º
Anteversion angle	23.06º	23.97º	23.03º
Neck width	29.36mm	28.67mm	29.36mm
Head diameter	42.6mm	41.2mm	42.6mm

The mean neck-shaft angle was 129.21º, with the mean for the left sided femora being 128.67º and 129.03º for right-sided femora. This difference was not statistically significant. Figure 1 shows the distribution of the neck-shaft angles.

The Dynamic Hip Screw (DHS) implants and cephalo-medullary nails whose dimensions were obtained had neck-shaft angles of between 125º- 135º. Table 2 shows some of the neck-shaft and anteversion angles of the various implants.

Table 2
Neck-shaft and anteversion angles of various implants

	Dynamic Hip Screw(DHS)	TRIGEN® InterTAN® Nail(Smith and Nephew)	TRIGEN TAN®FAN® Nail(Smith and Nephew)	NeoGen® Femoral Nail(Kanghui Medical)	Proximal Femoral Interlocking Nail(IRENE)	T 2 Recon® Nailing System (Stryker)	Natural® Antegrade femur nail(Zimmer)
Neck-shaft angle	130º 135º	125º 130º	130º	130º	135º	125º(Not available locally)	128º(Pirifromis fossa-not locally available) 132º (Trochanteric)
Anteversion angle		12º	12º	5º		10º	

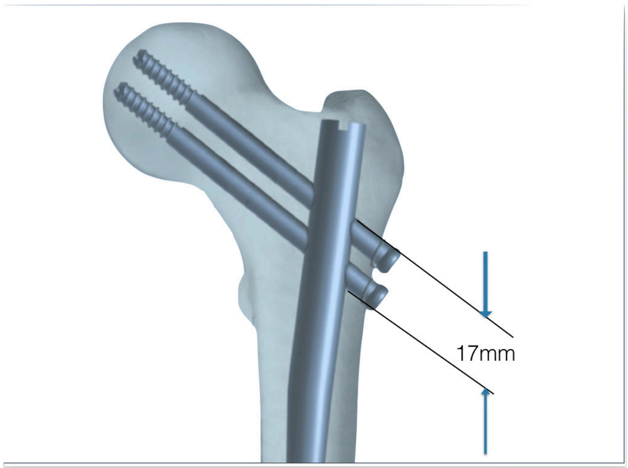
Mean anteversion angle was 23.06º, with a standard deviation of 8.85º. Mean anteversion angle for the left sided femora was 23.97º while that for the right sided femora was 23.03º. This difference was not statistically significant. The implants locally available had anteversion angles of between 5º -12º.

Mean femoral neck width was found to be 29.36mm, with a median width of 28.97mm. Minimum width was 24.65mm.The mean width of the left side was 28.67mm and that of the right was 29.36mm. The difference was not statistically significant.

The distance needed to safely implant two lag screws into the femoral neck in the available reconstruction nails was found to be 22mm, being the sum of the distance between the upper margin of the proximal screw and the lower margin of the distal screw (17mm) and a safe margin of 2.5mm proximal and distal to each screw as shown in Figure 3. This shows that the femoral neck width in the specimens is adequate to receive the two locking screws in the available reconstruction nails.

Figure 3

Minimum distance between two proximal locking screws



Mean femoral head diameter was 42.61mm, with mean diameter of the left side being 41.24mm and that of the right side being 42.62mm. The difference was not statistically significant.

DISCUSSION

The neck-shaft angle has been quoted in textbooks as ranging between 120º-140º (1,2). The mean obtained in the current study was 129.21º, with a range of 111.68º-145.72º. In the current study, 51% of the specimens had a neck-shaft angle of less than 130º, while 29% had an angle of between 130-139º. The average obtained in the current study is slightly higher than 127.56º found by Otsianyi *et al* (3) in a radiographic study done in Kenyans. It is however, closer to the mean of 130.47º found by De Farias *et al* (5) in a Brazilian study. A radiographic study in Nigeria found a slightly higher range of 130.3º-133.7º (4). Studies on anatomic specimens in India have yielded lower neck-shaft angle values of between 124.95º- 126.55º (7,8) while an anatomic study on American femora found a higher mean neck-shaft angle of 132.69º (6).

The locally available implants used for osteosynthesis of proximal femur fractures are the Dynamic Hip Screw (DHS), reconstruction nails and the proximal femur nails. Most of the widely available ones had neck-shaft angles of between 130º-135º. Of the cephalo-medullary nails with lower angles, the 125ºTRIGEN® InterTAN® Nail (Smith and Nephew Inc, Memphis, TN) is locally available, though the cost is prohibitive to most patients. Information from some of the suppliers showed that of the DHS plates available, the 135º DHS plate is the most widely available, compared to the one with an angle of 130º.

The implication of this is that devices with higher angles are locally implanted in femora with neck-shaft angles of less than 130º, which from this study could be more than 50%. This can potentially result in a valgus malreduction, and if the usual starting point is employed, the proximal screws then would end up in the superior quadrant of the femoral head, and a consequent less than ideal Tip-Apex Distance (TAD). It has been shown by Baumgaertner *et al* (12) that an ideal TAD of less than 20mm should be aimed for when fixing proximal femur fractures. A higher TAD would lead to screw cut-out and consequent failure of the fixation. From the current study, 7% of the specimens had an angle of more than 140º. It would therefore be prudent to have a range of devices with different angles so that the surgeon, after preoperative templating can choose the appropriate one for the particular patient.

In textbooks, the femoral neck anteversion angle has been quoted as ranging between 10º-30º(1,2). In the current study, the mean anteversion angle was found to be 23.06º, with a range of 1.17º-39.43º. This was higher than the 13.4º reported in Indian studies by Verma *et al* (7) and 9º reported by Zalawadia *et al* (13). It was also higher than the 10.14º reported by Unnanuntana *et al* (6) in a study on American specimens. It was however close to that obtained in a study done in Bengali specimens by Debnath *et al* (9) who obtained an angle of 20.05º. A CT-based study in a German population found a lower angle of 14.2º (10). Umebese *et al* (14), in a study of Nigerian hips found a mean anteversion of 28º, which is higher than what the current study found. It would appear then that the anteversion angle is generally higher in the African race compared to the Indians and Caucasians. This could be due to the fact that they are more likely to do ground level activities which require that the femur be internally rotated. These are activities like squatting, seating on low traditional stools and floor sitting during rest periods.

Mean femoral neck width was 29.36mm, with minimum width being 24.65mm. For the available reconstruction nails, a minimum distance of 22mm was needed to safely implant two lag screws through the neck into the femoral head, this being the sum of the distance between the two lag screws, which is 17mm with an additional safe margin of 2.5mm on either side of the lag screws.

The current study thus shows that for the available reconstruction nails, the femoral neck width is adequate to safely implant two lag screws. This width was slightly less than that of 30.9mm obtained by Ravichandran *et al* (8) in a study on Indian femora, but close to the mean of 28.9mm for males and 26.0mm for females obtained by Baharuddin *et al* (16) in a radiological study of the proximal femur in the Malay population. Another radiological study by Chiu *et al* (17) in the Malaysian population found a mean neck width of 34.0mm, which is far more than that obtained in the current study.

The mean femoral head diameter in the current study was 42.6mm, with a minimum of 36.5mm and a maximum of 50.9mm, without a significant difference between the right and the left sides. The mode was 43mm with a median of 42mm. The mean was lower than a mean of 52.09mm, obtained by Unnanuntana *et al* (6), in a study on American femora. It was also lower than the mean of 44.9mm obtained in a Malaysian population by Lee *et al* (15).The results of the current study are however closer to those obtained by Baharuddin *et al* (16) in a radiographic study in a Malay population, who reported a mean diameter of 43.6mm for males and 38.9mm for females. The results obtained in the current study are useful in the stocking of hospital inventories for hemiarthroplasty implants, hip resurfacing and for the manufacturers of such implants for the local population.

CONCLUSION

The current study has shown that the femoral neck-shaft and anteversion angles in the Kenyan femora vary from those of other populations. The available implants have angles which may not be suitable for a significant proportion of the local population.

It would be prudent to avail a range of implants with different angles to improve the choices available to the surgeon when faced with a patient who requires an operation on the proximal femur.

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