THE ANTERIOR CURVE OF THE ADULT FEMUR IN A KENYAN POPULATION AND ITS MISMATCH WITH AVAILABLE INTRAMEDULLARY NAILS

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ABSTRACT

Background: There are currently no studies which have documented the anterior femoral curvature in Kenya or elsewhere in Africa, and compared it to the curvature of the available intramedullary nails.
Objective: To determine the anterior femoral curvature in cadaveric femora and to compare this with the curvatures of locally available femoral intramedullary nails.
Methods: We determined the radii of 66 cadaveric femora by the method described by Karakas and Harma. The radii of locally available femoral intramedullary nails were also obtained from the respective product monographs.
Results: We found that the radius of the curvature ranged from 52.02cm to 165.82cm with a mean of 96.4cm and standard deviation of 25.61cm. The radii of locally available intra-medullary nails ranged from 127cm to 200cm.
Conclusion: The radius of curvature of the adult femora in Kenyans is less than that of other populations. There was a large mismatch between the available intramedullary nails and the femoral curvature. Further study of the complications resulting from this mismatch and a review of the design of the nails for local use is recommended.

INTRODUCTION

Locked intramedullary nailing is currently the standard method of care for femoral shaft fractures and selected proximal femur fractures (1, 2). The nails are introduced either antegrade or retrograde for distal femur fractures and in morbidly obese patients.

The anterior curve of the femur has important implications in intramedullary nailing of the femur and prosthetic replacement of the proximal femur. Various studies have documented the anterior femoral curvature in some populations. In a CT based study of 3,922 femora, Marrat *et al* (3) found a mean anterior radius of curvature of 145cm (SD 55cm), while Egol *et al* (4), in a study of 892 cadaveric femora found a radius of 120cm (SD 36cm). Both studies were done in an American population.

A mismatch between the curve of the femur and the curve of the nail may result in various complications intraoperatively or postoperatively. These include malreduction with loss of cortical contact especially posteriorly due to the straightening of the femur, abutment of the tip of the nail on the anterior cortex, anterior cortical perforation, iatrogenic fracture and jamming of the nail (5-10). No studies have documented the incidence of these complications locally. Failure of distal locking may also occur. Soren (11), in a review of 78 patients who underwent SIGN® nailing of the tibia and femur reported a rate of 5% failure of distal locking. While no separate figures were given for the femur and tibia, the femur is likely to have contributed a greater proportion of the failed locks as it is generally harder to lock the femoral nails than the tibial nails. There may also be delayed union due to loss of cortical contact.

Although intramedullary nailing is now widely used in our country, no local study has been done to determine the femoral curvature in our population and to compare this with the locally available intramedullary nails, which are often imported from China, India, the United Kingdom or the United States of America.

MATERIALS AND METHODS

Cadaveric femora from the Department of Human Anatomy, Egerton University, Njoro and the Department of Human Anatomy, Kenyatta University were obtained. Age and sex of the source of cadaver were not available. The cadavers were sourced from various parts of the country. The femora were obtained from skeletally mature individuals. Deformed specimens were excluded from the study.

The method described by Harma *et al* (12) was used to calculate the radius of anterior curvature of the specimens. This proceeds as follows: the arc of curvature of the femur was taken to be part of the circumference of a circle whose radius is the radius of curvature of the femur.

The femur was placed on a flat board, with the femur resting on the quadrate tubercle cephalad and

at the beginning of the flare of the condyles caudad. A piece of paper, with a red line measuring 5cm was used as a reference and placed just below the specimen of the femur. The set-up was digitally photographed, using a Nikon® D5300 DSLR camera and JPEG images obtained.

The images were then analysed using ImageJ® software (National Institute of Health, Bethesda, Maryland) as follows: The distance between the lower border of the lesser trochanter and the beginning of the flare of the condyles was measured, and the mid-point obtained. The distance between this mid-point and the beginning of the femoral flare was measured (**Distance c**). From the mid-point above, a perpendicular line was drawn to the posterior cortex of the femur and the distance measured (**Distance x**).The distance c forms one side of a right angled triangle whose hypotenuse is the radius of the curve (**a**) as shown in Figure 1. The other side of the triangle (**Distance b**) is not known. However, it is known that the sum of **b** and **x** (**b+x**) would also constitute the radius of the curvature. Thus **b + x = a**

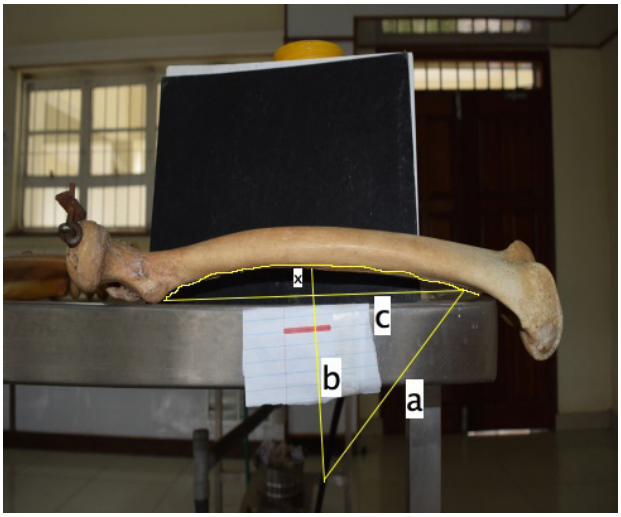
From Pythagoras theorem, $\mathbf{a^2=b^2+c^2}$ But, **a = b+x**

Thus: $\mathbf{(b+x)^2 = b^2+c^2}$, $\mathbf{b = \frac{c^2-x^2}{2x}}$

X is known and so is **c**. It is therefore possible to calculate the value of **b**. Once the value of **b** is determined, the radius of curvature can be gotten as it is the sum of **b** and **x** i.e. radius of curvature, **a = b+x**

Figure 1

A photo of the set-up of the femur with the parameters used to calculate the radius of the anterior curve of the femur



The values obtained were entered into and analysed on a Number® Version 3.2 spreadsheet (Apple Inc).

The radii of curvature so obtained were then compared with the radii of curvature of locally available femoral intramedullary nails. These are, the SIGN® Nail (SIGN Fracture Care International, Richland,WA), IRENE® Antegrade Femoral Interlocking Nail (TianJin ZhengTian Medical Instrument Co. Ltd, Beijing, China), Antegrade Femoral Nail (DePuy-Synthes,West Chester, PA), Zimmer ®Natural ®Femur nails (Zimmer, Inc.Warsaw, IN), OrthomedE® Femur nail (6th of October City, 3rd Industrial area, 201/ 3 Giza, Cairo, EGYPT.),TRIGEN® INTERTAN® Nail and TRIGEN ®TAN® Nail (Smith & Nephew, Inc.Memphis,TN).

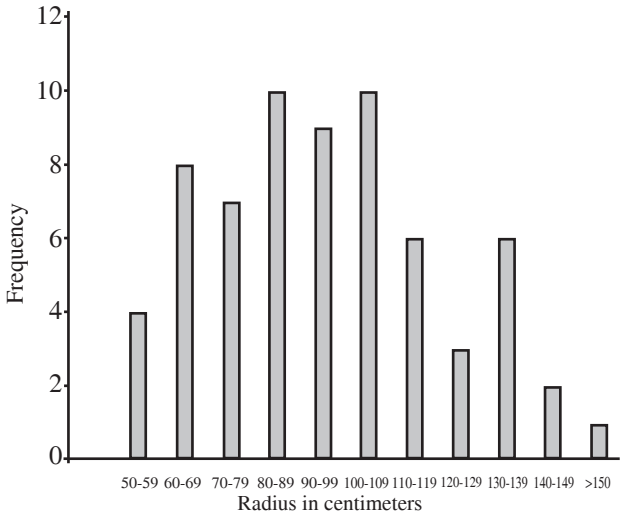
The radii of curvature of the nails were obtained from the respective product monographs/catalogues. For the femoral nails for which we could not obtain the product monographs/catalogues, the radius of curvature was established in the same way that we established the radius of the anterior curvature of the femur.

RESULTS

Radii of anterior curvature of the studied femora: A total of 66 femora were obtained and used for the study. The mean radius of curvature was 96.4cm, with a standard deviation of 25.61cm.The minimum radius of curvature was 52.02cm while the maximum was 165.8cm.

Figure 2

Frequency of different ranges of radii of the femora studied



Radii of curvature of locally available femoral nails: The radii of curvature of the femoral nails ranged between 127cm and 200cm. The SIGN Nail, which is widely used now, however is a straight nail, but with a 9^0 proximal bend and a 1.5^0 distal bend to aid in insertion. The rest of the femoral nails had their radii as shown in Table 1.

Table 1
Femoral nails with their radii of curvature

Nail	Radius of curvature
Antegrade Femoral Nail (DePuy-Synthes,West Chester,PA)	150 cm
TRIGEN® INTERTAN® Nail and TRIGEN® TAN® Nail (Smith & Nephew, Inc. Memphis,TN)	150 cm, 200 cm
Zimmer®Natural® Femur Nails System (Zimmer, Inc. Warsaw, IN)	127 cm to 152 cm
IRENE® Antegrade Femoral Interlocking Nail (TianJin Zheng Tian Medical Instrument Co., Ltd, Beijing, China)	Not available from product monograph Calculated radius 175 cm
OrthomedE® Femur nail (6th of October City, 3rd Industrial area, 201/ 3 Giza, Cairo, Egypt.)	Not available from product monograph Calculated radius 145 cm

The longer radii of curvature of the femoral nails show that the nails sampled were straighter than the femora studied.

DISCUSSION

Intramedullary nailing is now the accepted mode of treatment for adult femoral shaft fractures and selected proximal and distal femoral fractures (1,2). A mismatch between the curvature of the nail and the femur may result in complications like angular malreduction with loss of cortical contact, anterior cortical perforation, iatrogenic fracture, difficulties in distal targeting and jamming of the nail during insertion or extraction (5-8). A study by Soren (11) showed a failure of distal locking of 5% in 78 patients who underwent femoral and tibial intramedullary nail with the SIGN® nail.

This study found the mean radius of anterior curvature of femora to be 96.4cm. This is lower than what other studies have shown. Marrat *et al* (3) found a mean anterior radius of curvature of 145cm (SD 55cm) while Egol *et a*l (4) in a study of 892 cadaveric femora found an average radius of the anterior curvature of 120cm (SD 36cm). Harper *et al* (13) also found a higher average curvature of 114.4cm though their study was of a small number of femora. These studies were all done in American populations. Xiu-Yun *et al*, (14) in a study of 426 Chinese femora, found a mean radius of curvature of 97.14cm (SD 21.168cm).

This indicates that the adult femur in Kenyans and probably other Africans is much more curved than other populations. An increased femoral bowing is thought to be associated with a higher weight for an individual's height (15). Shackelford and Trinkaus (16) postulated that the extent of femoral bowing is dependent on mobility level. This may explain why the sampled femora were more bowed than those in the other studies as a Kenyan population is likely to walk more than those in the other studies as Kenya is less motorized than the populations in the other studies.

The radius of locally available nails ranged from 127cm to 200cm. There was also a very commonly used nail that is straight i.e. the SIGN® nail. This implies that the available nails are much more straight than the average femora in Kenya.

Insertion of a straight nail or one that is less curved than the femur results in straightening of the femur with resultant opening up of the fracture site posteriorly. This also increases the risk of anterior cortical perforation, iatrogenic fracture and jamming of the nail (5-9). In a retrospective review of 158 Chinese patients who had undergone nailing with the short straight Proximal Femoral Nail Antirotation II (PFNA II), Chang *et al* (10) found that in 74.7%, the tip of the nail was located anterior to the center of the canal axis, and in 34.8%, the tip of the nail abutted on the cortex. There may also be failure of distal targeting. A study in Kenya by Soren (11) indicated that 5% of the distal locks were missed when the straight SIGN nail was used for femoral and tibial nailing.

This problem of a mismatch between the femoral curvature and that of intramedullary nails is not unique to Kenya alone. Other studies have similarly showed a mismatch between the curvature of the femur and femoral nails. Harma *et al* (12) in their study done in Anatolia, Turkey found the mean cortical bowing of femora was 77cm (radius) , while the nails they studied had a radius of curvature of between 150cm and 300cm. In a study using American femora, Egol *et al* (4) also documented a mismatch between femoral bow and the curvature of femoral nails.

CONCLUSIONS AND RECOMMENDATIONS

The anterior femoral curvature in a Kenya population is higher than other populations. The available femoral nails are less curved than the femora in Kenya. This points to an inadequacy in the design of the nails for use in our local population. These nails are often imported

from other countries like The United Kingdom, The United States, India or China.

Though there are other factors that determine the outcome of a femoral nailing procedure, the large mismatch between the available nails and the femora should warrant further study into the possible complications resulting from this mismatch as this has not been studied locally. The larger anterior curvature of femora in Kenya should be borne in mind when designing femoral nails for local use.

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