Original Article

Evaluation of the Proximal Femur Using the Digital Photographs: Does Change in Proximal Femur Position Due to Anteversion Affect the Measurement of the Size of the Femoral Head Diameter?

Abstract

Background: A plain pelvic radiograph is usually conducted with the lower limbs in internal rotation. This is to correct the anteversion of the femur. However, in the fracture neck of the femur, internal rotation of the fractured limb is avoided, because it would be painful. We examined the effect of correction of anteversion or otherwise on the diameter of the head of the femur using imaging. **Objectives:** This study aimed to determine if there was a significant difference between the femoral head diameter at two different positions, at the normal anatomical position (without correcting the anteversion) and at the corrected anteversion position. It also aimed to document the correlation and the statistical significance between the differences in the size of the diameter at these two different positions with the anteversion angles of the femoral bone. **Materials and Methods:** Two sets of digital photographs of the proximal part of 55 non-sexed, non-paired femoral bones were taken. Images obtained were at two positions: normal anatomical (with anteversion uncorrected) and anteversion corrected positions. The diameters of the head of the femur were documented at these two different positions. The anteversion angles and actual femoral head (AFH) diameters were also measured and documented. **Results:** The femoral head diameters at anatomical positions were persistently larger than those measured after the anteversion was corrected, except in three femoral bones (5%) where no differences were observed. The difference in the two measurements was statistically significant to the anteversion angle of the femoral bone. ($P = 0.0005$). The means of the two sets of measurements were statistically different from each other. Pairwise correlation showed that both were strongly associated with the AFH diameter but the measurements from images with corrected anteversion had a higher value (0.8166) than the measurements from normal anatomical position (0.7526). **Conclusion:** The correction of femoral anteversion produced femoral head size measurements that were closer to AFH diameters compared to those without the correction of the femoral anteversion. Femoral anteversion should always be corrected as per protocol.

Keywords: *Anteversion, diameter, femoral head, femur, hemiarthroplasty, radiograph, size*

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Introduction

A plain anteroposterior radiograph of the pelvis remains the gold standard for pre-operative femoral templating for hip arthroplasty. It is important that both lower limbs are internally rotated to reduce the effect of femoral anteversion when conducting the plain pelvic radiograph.[1,2] The femoral neck anteversion is the torsion or twist present in the proximal femur.[3]

It is the angle subtended by the axis of the femoral neck to the transcondylar axis of the distal femur.[4] It indicates the "degree of twisting" of the neck on the shaft.[3,5] It is important as it affects the biomechanics of the hip.[5] Anteversion should be corrected to achieve proper positioning of the proximal femur during radiographic study. This enables the anatomy of the proximal femur to be well delineate and maximizes the length of the femoral neck.[6]

Poor positioning of the patient when a pelvic radiograph is being performed can cause a distortion in the outcome of the investigation, which can influence the ability to use the radiograph obtained to properly diagnose structural abnormalities.[6] It can also affect the outcome of the templating and produce inaccurate measurements. It is therefore important to position the patient appropriately during the conduct of plain pelvic radiography. Hananouchi *et al.*[1] in

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their study on inappropriate positioning of the lower limb during the conduct of pelvic radiograph (30° and 45° of external rotation of their lower limbs), documented that smaller stems were selected at surgery in more than 80% of cases when compared with patients that were placed with limb in internal rotation.

Estimation of the head of the femur is an important templating parameter in hemiarthroplasty. This is done with a plain pelvic radiograph, just like other pre-operative planning for total hip arthroplasty. However, the fractured neck of the femur would prevent internal rotation of the lower limb during the conduct of the plain pelvic radiograph, as any attempt to internally rotate the limb would be painful and more importantly, the internal turning of the injured lower limb may not be transmitted to the proximal femur as the fracture has caused loss of continuity of the bone. The inability to correct version in a fractured femoral neck might prevent proper delineation of the anatomy.

The use of photography in medicine dated back to 1852.[7] Photography has been widely used in the medical field. A study by Cura *et al.*[8] in Portugal documented various uses of medical photography. It ranged from documentation of patient's clinical progress to seeking second opinion, education, research and publication and to enhance quality presentation at conferences. Digital imaging began in mid 1960s.[9] This has revolutionised photography to become a powerful tool for physicians.[9] Digital photography enhances proper communication between physician with peers, patients, and the public.[10] Digital photography is a useful tool in research and publications and was used in the conduct of this study. Digital images obtained from Smartphones have similar qualities as those obtained from conventional digital cameras.[11,12]

We postulated that the estimated diameter of the femoral head might differ at different positions. The femoral neck with a larger anteversion would make the femoral head closer to the source of radiation for the plain radiograph investigation being conducted than when the anteversion is corrected, whereby the femoral head would be closer to the plate/receiver than the source. We suspect that the diameter of the femoral head might be different at these different positions when positioning the lower limb anatomically (when the anteversion is not corrected) and when the anteversion is corrected by internally rotating the lower limb. This study, therefore, aimed to determine if there was a significant difference between the femoral head diameter at two different positions, at the normal anatomical position (without correcting the anteversion) and at the corrected anteversion position. It also aimed to document the correlation and the statistical significance between the differences in the size of the diameter at these two different positions with the anteversion angles of the femoral bone.

Materials and Methods

This was a descriptive study that involved measurements of femoral head diameter at two positions; first, at the normal anatomical position, "FHana" (without correction of anteversion) and secondly, after the anteversion was corrected by tilting the bone, "FHcor." Ethical approval was obtained from the Hospitals' Ethics and Research Committee before the commencement of the study. Dry Femoral bones used were from the Department of Anatomy of the College of Medicine, University of Lagos. Deformed and distorted femoral bones were excluded. Fifty-five non-sexed, non-paired, adult dry femoral bones were sorted into laterality; 27 right and 28 left femoral bones.

The femoral bone was placed on a flat osteometric board with graph paper on its surface. The graph paper was placed to help note and calculate the effect of magnification on the images obtained. The graph paper was pre-measured with a ruler to confirm the accuracy. A contraption of 30 cm high was made to hold the camera. The upper surface of the contraption on which the camera was placed was parallel to the surface of the osteometric board, to ensure that the images that would be obtained were just as placed on the osteometric board. The focus of the camera was on the proximal femur (femoral head, femoral neck, and the trochanters) [Figure 1]. The first set of pictures taken was for the normal anatomical position of the femoral bone when the condyles and the posterior part of the greater trochanter were touching the osteometric board [Figure 2]. At this position, the head of the femoral was not in contact with the osteometric board due to anteversion angle of the femur. The pictures of all available femoral bones

Figure 1: The set up used to take the digital pictures of the proximal femur

Figure 2: Placement of the femoral bone with the posterior part of the bone and both condyles lying on the flat surface with the femoral head off the board due to anteversion of the femoral neck

Figure 3: Placement of the femoral bone with the femoral head in contact with the board to correct the anteversion of the femoral neck. The lateral condyle was off the board to achieve this correction.

were taken with a label on the side of the bone for proper identification of the bone

The second set of pictures were the images obtained when the anteversion angles were corrected. The proximal part of the femoral bone was tilted until the femoral head was in contact with the osteometric board, meaning that one of the femoral condyles was off the board [Figure 3]. The pictures of all available femoral bones were taken with each bone labelled with its unique nomenclature with a “T” added. All images obtained were stored and were later printed out for analysis.

To measure the diameter of the femoral head from the printed images, the centre of the head was first located by drawing two chords on the printed image of the femoral head. Each chord was then bisected with a straight line. The point where both straight lines that bisected each chord met was noted and taken as the centre of the femoral head. A perfect circle was drawn on the head to incorporate the circumference of the head. The distance from one point at the circumference of the head of the femur to the other through the centre was measured and documented. This is the diameter of the femoral head [Figure 4]. The magnification was also calculated from the printed images, using the graph on which the bone was placed when the picture of the image was taken. The diameter of the head obtained from the printed image was calculated as

$$\text{Head of femur diameter} = \frac{\text{diameter measured from printed image} * \text{graph scale on actual graph}}{\text{Graph scale on printed image}}$$

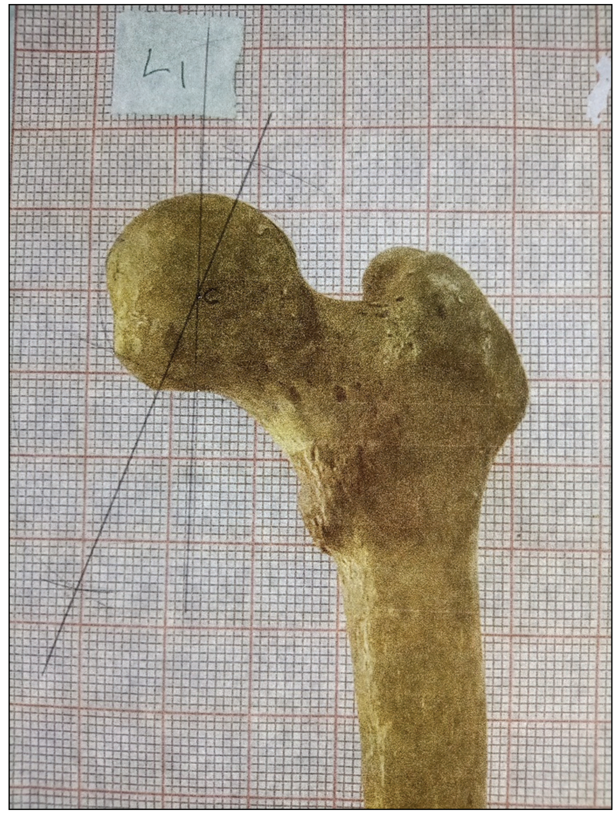

Figure 4: Determining the centre – C of the femoral head.

AFH diameters were obtained using a ring gauge and documented. The femoral head diameter measurements obtained from the printed images (FHana and FHcor) were compared with the AFH diameter.

Lastly, the anteversion angles of the femoral bones were measured using the Kingsley-Olmsted method, which involved determining both the centre head-neckline and the retrocondylar line. The angle formed by the intersection of these lines was read off as the femoral anteversion angle. This was measured using a Goniometer. Each femur was placed with the posterior surface of its condyles and the greater trochanter touching the osteometric board. The centre head-neckline was determined by locating the centres of the head and neck. The centre of the head was the middle of the maximum horizontal diameter of the head of the femur, while the centre of the neck was the midpoint of maximum anteroposterior thickness at the base of the neck, using the Vernier calliper. The line passing through these points was the centre head-neckline. The retrocondylar line passes through the most posterior points of both condyles of the femur, which was represented by the horizontal surface of the osteometric board on which the femoral bone is laid upon, as these most posterior points of the distal femoral condyles laid on this board. Both limbs of the goniometer were held parallel to the axis of the centre head-neckline and the horizontal surface of the osteometric board, which represented the retrocondylar axis respectively. The angle

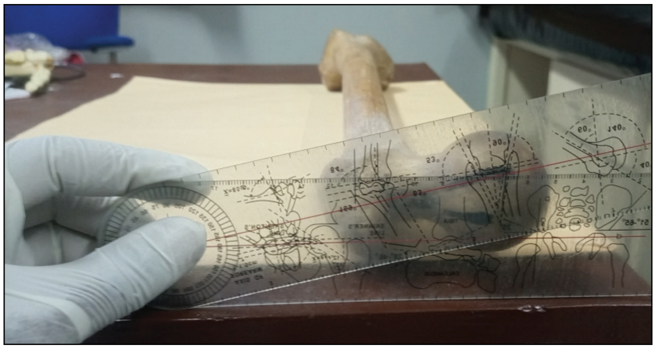

Figure 5: Measurement of anteversion angle

formed was read off from the goniometer, and recorded to the nearest whole integer [Figure 5].

The results obtained from these measurements were analysed using Stata 13. StataCorp College Station, Texas Mean, student *t* test, chi-square test, and pairwise correlation analyses were done. The level of significance was set at $P \leq 0.05$.

Results

There were differences in the measured femoral head size at anatomical position (FHana) and the femoral head size after the anteversion angle was corrected (FHcor). The values of FHana were larger than FHcor in 52 (94.5%), while there was no difference in the remaining three (3, 5.5%). The difference ranged from 0 mm to 4.9 mm with an average of 2.4 ± 1.4 mm. The average FHana was 51.6 ± 3.4 mm while that for FHcor was 49.2 ± 3.1 mm. Student *t* test to compare the mean of the two sets of values, FHana and FHcor revealed a *P* value of 0.0002, which indicated that the difference of the means of both sets of data was statistically significant. The average for AFH was 46.2 ± 2.5 mm [Table 1].

The anteversion angles ranged from 0° to 28°. The femoral bones with small anteversion angles had corresponding small differences between their FHana and FHcor when compared with femoral bones with larger anteversion angles [Figure 5]. There was a significant statistical relationship between the anteversion angles of the femoral bone and differences in its femoral FHana and FHcor. ($P = 0.0005$)

The Pairwise correlation co-efficiency between AFH and FHana was 0.7526, while the correlation co-efficiency between AFH and FHcor was 0.8166. However, there was no statistical relationship between the AFH and either FHana or FHcor ($P = 0.172$ and $P = 0.068$, respectively) [Table 2].

The correlation coefficient between FHana and FHcor was 0.9157, which indicated a very strong association between the two sets of measurements, with a significant statistical relationship ($P = 0.011$) [Table 2].

Table 1: Parameters measured

Parameter	Average	Range
FHana	51.6 ± 3.4 mm	42.9–60.4 mm
FHcor	49.2 ± 3.1 mm	42.7–57.1 mm
AFH	46.2 ± 2.5 mm	40–52 mm
Difference = FHana − FHcor	2.4 ± 1.4 mm	0–4.9 mm
Anteversion angle	19.3° ± 4.3°	8°–28°

FHcor: femoral head diameter in anteversion corrected position, FHana: femoral head diameter in anatomical position, AFH: actual femoral head, DIFFERENCE: the difference in the values between the femoral head diameter in anatomical position and the femoral head diameter in anteversion corrected position

Table 2: Pairwise correlation of the two sets of data measured

Parameters	AFH	FHana	FHcor
AFH	1.000		
FHana	0.7526	1.000	
FHcor	0.8166	0.9157	1.000

FHana: femoral head diameter in anatomical position, FHcor: femoral head diameter in anteversion corrected position, AFH: actual femoral head

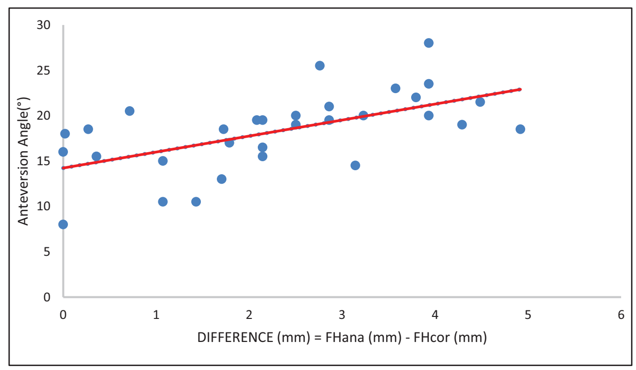

Figure 6: Shows the relationship between the anteversion angles and the values obtained from the difference of the femoral head diameters in two different positions

Discussion

It has always been a standard protocol to rotate internally the lower limb 15° to 20° when performing an anteroposterior view of the pelvic radiograph. This is to demonstrate the profile of the proximal femur anatomically. However, the effect of correction of femoral anteversion on femoral head size is yet to be documented. We therefore conducted this study to highlight the importance of correcting the anteversion angle when conducting a radiographic study of the proximal femur. The results from the study showed persistent differences in the size of the head of the femur at these two different positions. The results revealed that the larger the anteversion angle, the larger the difference in the measured values at the two different positions, with a positive gradient when plotted [Figure 6]. The difference in the measurements of the head at the two different positions was statistically significant to the anteversion angle of the femoral bone. This study therefore showed that the position of the femur at the time of investigation can affect the estimated size of the femoral head measured from the radiograph, and the anteversion angle plays a significant role. This further re-affirms the age-long dictum of correcting the anteversion of the proximal femur before conducting a radiographic study of the pelvis and proximal femur.

The pairwise correlation between FHana and FHcor revealed a very strong association (0.9157, P = 0.011). The largest difference obtained between both sets of values was 5 mm. The mean of both sets of measurements, however, differ significantly. Pairwise correlation analysis of the AFH and both values (FHana and FHcor) revealed that though both FHana and FHcor correlated strongly to the AFH, the FHcor had a higher co-efficiency than the FHana (0.8166 and 0.7526, respectively). It therefore showed that more values from the FHcor were closer to the AFH when compared to values obtained without the correction of the anteversion. This further buttresses the fact that correction of the anteversion angle is important whenever the anteroposterior plain radiograph of the proximal femur is to be conducted.

During the conduct of the plain pelvic radiograph, the values suggested for correction of anteversion have been between 15° and 20°.[3,6,13] The average anteversion angle in this study was 19.3°. A previous study, where two methods were used to determine the average anteversion angles documented 20.5° and 21.3°.[14] Katchy *et al.*[15] documented anteversion angle of 19.04° in south-eastern Nigerians. The suggested values of between 15° and 20° of internal rotation would be sufficient to correct anteversion in an average Nigerian.

Conclusion

The correction of anteversion angle of the femur produced a femoral head diameter that is, closer to the AFH size. Correction of the femoral anteversion is important when the pelvic radiograph is to be conducted, as measurements without correction of the anteversion angles were persistently larger than those with anteversion angles correction.

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Conflicts of interest

There are no conflicts of interest.

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