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Article

The Utility of Lesser Trochanter Version to Estimate Femoral Anteversion in Total Hip Arthroplasty: A Three-Dimensional Computed Tomography Study

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Abstract: Objective: Femoral anteversion is an important parameter that can prevent complication following total hip arthroplasty (THA) caused by improper positioning of the implant. However, assessing the femoral anteversion can be challenging in situations with significant defect of the femoral neck. In this study, the lesser trochanter version was nominated as alternative parameter to femoral anteversion. So, the main objective of this study is to determine whether the femoral anteversion correlates with the lesser trochanter version. **Design:** Retrospective study. **Methods:** Three-dimensional images of 100 femora were generated and their femoral anteversion and lesser trochanter version was measured. Correlation between the parameters were calculated. **Results:** The mean lesser trochanter version was 38.54° ± 7.86° (mean ± SD), while the mean femoral anteversion was 11.84° ± 10.06°. The lesser trochanter version was inversely correlated with the femoral anteversion with a correlation coefficient of −0.72. **Conclusions:** The lesser trochanter should be considered as an additional bony landmark to assess proper implant positioning in THA.

Keywords: lesser trochanter; 3D-CT scan; total hip arthroplasty; femoral anteversion

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1. Introduction

Dislocation is still a common early complication following total hip arthroplasty (THA) [1]. There are many predisposing factors and the cause is multifactorial. One factor that is determined by the surgeon is implant position and alignment. Malposition is a common cause for dislocation [2]. An understanding of the normal proximal femoral anatomy is important for proper implant positioning to prevent complications after the surgery [3]. With the incidence of revision, THA is expected to increase by 43% in 2030 from 50,220 in 2014 [4]; therefore, proper implant positioning is a major concern in THA.

The combined anteversion of the femoral neck and acetabular cup was measured in order to avoid implant impingement following THA. With a mean of 29.6° and 33.5°, males had lower combined anteversion than women [5]. The reference level for combined anteversion in clinical practice has been defined as being between 25° and 35°, with a maximum threshold of 45° in women [6].

In terms of femoral anteversion, the mean was 11.1° for men and 12.2° for women, with a general mean of 11.6° [5]. The reference level for femoral anteversion in clinical practice should be within a fixed range of 10° to 20°, which corresponds to the natural adult hip anatomy [7].

Numerous landmarks of the distal femur have been well established for total knee arthroplasty. The operating surgeon is not over reliant on one axis for femoral component rotation, but can use these to cross check. Among these landmarks are the posterior condylar plane, bi-epicondylar axis, trochlear-groove axis, and in revisions, the linea aspera [8–10]. The lesser trochanter is a conical eminence protruding from the bone just distal and posterior from the femoral neck. It is an attachment site of the iliopsoas muscle, resulting in its relatively constant position in relation to the femoral neck [9]. Consequently, the lesser trochanter version may have a constant relationship to the femoral neck anteversion independent of changes in the magnitude and direction of forces acting on the femur [10].

The objective of the current study is to evaluate the correlation between lesser trochanter version and femoral anteversion generated from 3D images produced from computed tomography (CT) scans to determine its utility as a reliable anatomical landmark for THA.

2. Methods

This retrospective study was carried out in a trauma center of a tertiary care hospital, University of Malaya Medical Centre, Malaysia. The study was approved by the local ethics committee (MREC ID: 20159-1635). Records from a total of 100 patients who were referred to the trauma center with peripheral vascular disease or possible vascular damage and had their lower limb CT scan were reviewed. Informed consent was obtained from all patients.

The left femur was selected for this study provided it was not seriously deformed due to prior damage or extreme degenerative process (osteoarthritis grade ≤ 2 according to Kellgren and Lawrence classification). If one side of the femur was damaged due to a fracture or prior surgery, the right femur was used.

The 3D image of each femora was generated by importing the CT scans into the medical 3D imaging programme Mimics® (Materialise NV, Leuven, Belgium). Images were displayed in axial, sagittal and coronal views. The image of the femur was isolated from the surrounding soft tissue and other bone parts using thresholding, region growing, and segmentation tools available in the software (Figure 1). Any misorientation caused by the patient's positioning during scanning was realigned into a standard and reproducible manner.

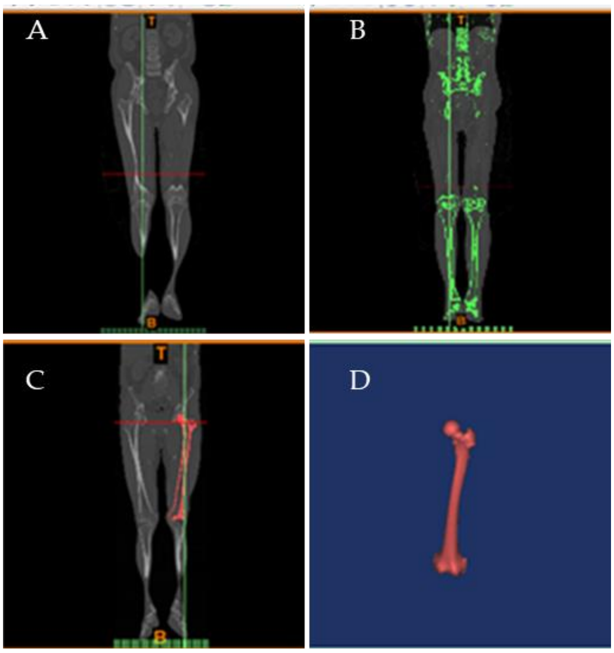

Figure 1. Isolation of the femoral image. (**A**) 3D image generated by Mimics® (**B**) Thresholding value of 226 to 3070 Hounsfield units was used to visualize the cortical bone. (**C**) The femur was isolated using a combination of region growing and segmentation tool. (**D**) The isolated femoral 3D image.

The anatomical axis of the femur is considered as a line that passes through the long axis of the femur through the medullary canal. The medullary canal image was isolated, enabling the generation of a best-fit line that determines the anatomical axis of the femur. Figure 2 depicted the determination of the femur anatomical axis.

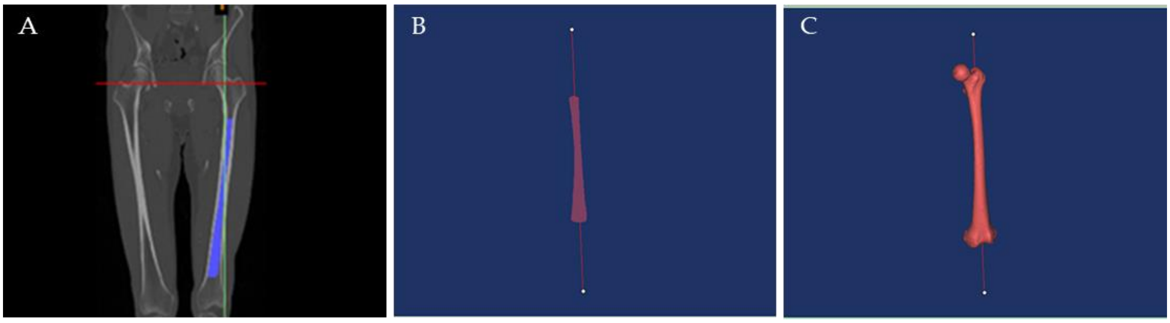

Figure 2. Determination of the femur anatomical axis. (**A**) Isolation of the medullary canal image. (**B**) Generation of the best-fit line through medullary canal. (**C**) Integration of the femur anatomical axis to the femoral image.

The femoral neck axis is considered as a line that starts from the center of the femoral neck to the center of the femoral head. Initially, a best-fit sphere for each of the femoral head and the femoral neck were defined before a line connecting the two centers was generated. The femoral neck axis determination is illustrated in Figure 3.

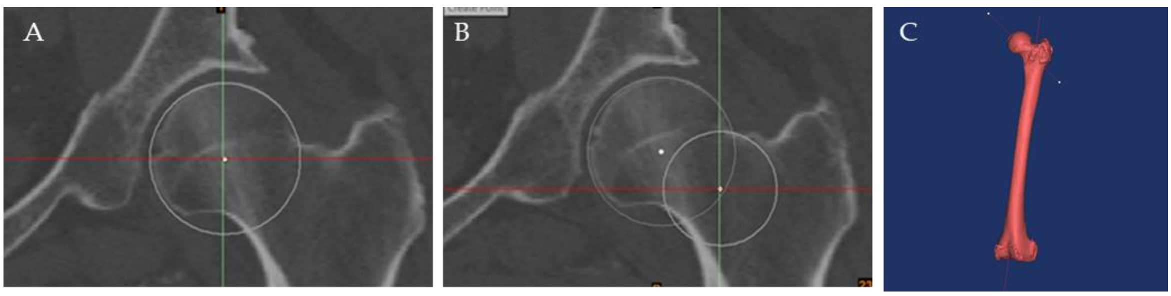

Figure 3. Determination of the femoral neck axis. (**A**) Generating best fit sphere on the femoral head. (**B**) Generating the best fit sphere on the femoral neck. (**C**) Femoral neck axis illustration.

The femoral anteversion is defined as the angle between the femoral neck axis and the transcondylar axis. The transcondylar axis was generated by fitting two best fit spheres to each of the femoral condyles before a line connecting the centers of these spheres was drawn. The angle of the line connecting the center of these spheres relative to the femoral neck angle is the femoral anteversion (Figure 4).

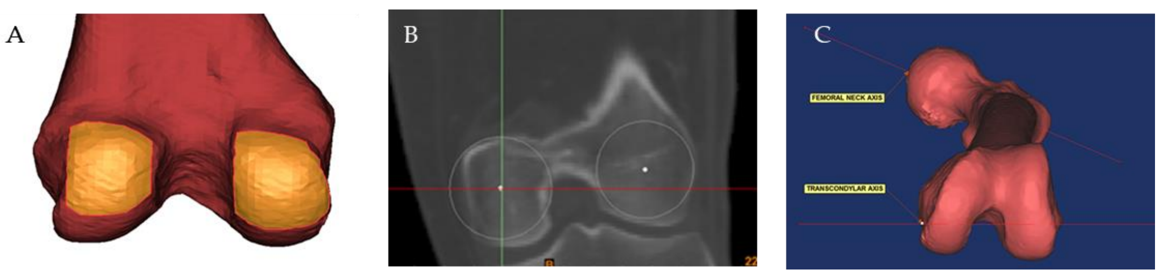

Figure 4. Measurement of femoral anteversion. (**A**) Defining femoral condyles using brush function. (**B**) Generating best fit spheres on the femoral condyles to establish the transcondylar axis. (**C**) Defining femoral anteversion as the angle between femoral neck axis and the transcondylar axis.

The lesser trochanter axis is considered as a line that starts from the tip of the lesser trochanter to the femoral axis. First, the tip of the lesser trochanter was defined using the brush function before the best-fit line was drawn accordingly. The lesser trochanter version is then defined as the difference in angle between the lesser trochanter axis and the femoral anteversion as shown in Figure 5.

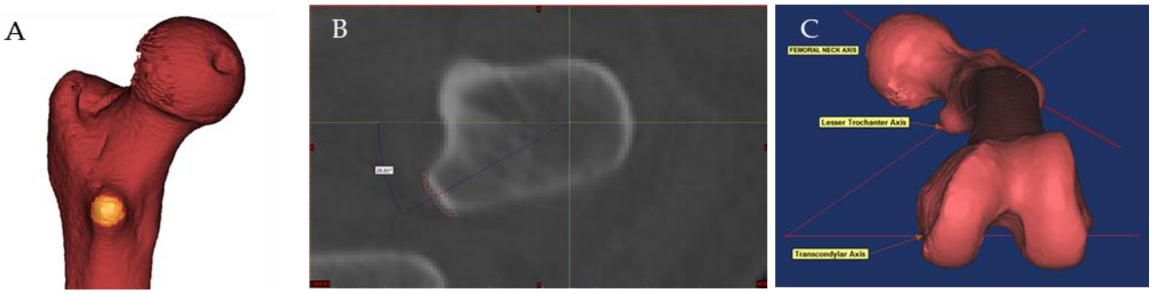

Figure 5. Measurement of the lesser trochanter version. (**A**) Defining the lesser trochanter tip using the brush function. (**B**) Drawing lines connecting the lesser trochanter tip and the femoral axis. (**C**) Defining the lesser trochanter version as the difference in angle between the lesser trochanter axis and the femoral anteversion.

The intraclass correlation coefficient (ICC) was used to determine the reliability of the parameters tested. ICC was obtained for values obtained by two observers (inter-observer) and values obtained by a single observer two months later (intra-observer). Observer A is the study's lead investigator, while Observer B is a research assistant with previous Mimics® training and experience.

The Pearson's correlation coefficient between the two parameters was used to evaluate the correlation between the lesser trochanter version and the femoral anteversion.

3. Results

3.1. Participants

A total of 100 femora were examined, with an even distribution (50%) of femurs from male and female patients. The patients were 34% Malay, 25% Chinese, and 41% Indian in ethnicity. The patients in this sample were 56.1 year old on average. The majority of the patients are above the age of 50, but not above the age of 90. The participants ranged in age from 17 to 87 years old.

3.2. Data Analysis

Table 1 shows the lesser trochanter version and femoral anteversion measurements of the femora. The intra-observer ICC and inter-observer ICC, respectively, were both 0.98 for lesser trochanter and both 0.99 for the femoral anteversion. The lesser trochanter version and femoral anteversion have a strong inverse correlation, with a correlation coefficient of −0.72.

Table 1. Summary of measured parameters.

Parameter	Mean (SD)	Range	Intra-Observer ICC	Inter-Observer ICC
Lesser trochanter version	38.54° ± 7.86°	16.99° to 54.38°	0.98	0.98
Femoral anteversion	11.84° ± 10.06°	−17.63° to 43.98°	0.99	0.99

4. Discussion

The current study used a 3D reconstruction technique to evaluate an additional parameter to describe the rotational profile of the femur. The results supported the hypothesis that the lesser trochanter version demonstrated significant correlation to the femoral anteversion.

This reiterates the utility of the lesser trochanter version to estimate the femoral anteversion in the case of significant defect of the femoral neck during total hip arthroplasty (THA).

The mean femoral anteversion angle of the current study was comparable to other established studies involving the normal hip [5,10–13]. Individuals with osteoarthritis or hip dysplasia typically had higher femoral anteversions, normally greater than 20° [14]. Furthermore, in comparison to older patients and men, younger patients and females tended to have higher femoral anteversion [5]. The current study evaluates normal femora from older and equally distributed male and female populations. Hence, the resulting mean femoral anteversion was closer to the lower end of the range, namely 9.0° to 19.8° [10,13].

Femoral anteversion is defined as the angle between the proximal femoral neck axis and the distal femoral condylar axis [15]. Caution is required in defining these two axes, as different definition can influence the accuracy of the femoral anteversion measurement.

The femoral neck axis is traditionally considered to be a straight line connecting the center of the femoral head and the center of the femoral neck with the axis of the femoral shaft [16]. As a result, the proximal femoral axis used to be defined as a straight line between the center of the femoral head and center of the femoral shaft, termed the head-shaft axis. However, when a straight line was constructed between the center of the femoral head to the center of the femoral neck, termed the head-neck axis, the line usually passes in front of the axis of the femoral shaft, revealing the discrepancy between these two definitions [17]. Hoiseth et al. (1989) compared the two methods of measuring femoral anteversion and found that the head-shaft method consistently underestimated femoral anteversion by 10 degrees compared to the head-neck method [17]. They concluded that the head-neck definition of femoral neck axis is a more accurate method to measure femoral anteversion, which has been adopted in the current study.

In terms of the femoral condylar axis, different definitions of the axis exist. There are four definition of condylar axis, whereby all four methods use three points along the long axis of the femur to construct the axis [18]. The methods differ in the two points that are used to define the condylar axis. In one method, the condylar axis is defined as the line between the two most posterior aspect of the femoral condyles. In another method, a line is drawn between the most medial and lateral points on the condyles. In a third method, two spheres of the condyles in cross section are visually defined, and the line connecting the center of the two spheres defines the condylar axis. The fourth method involves drawing two tangents, one to the most anterior aspect of the femoral condyles and the other to the most posterior aspect of the condyles; the angle between the two lines is bisected to give the condylar axis. Each of these four methods yields a different pair of points for defining the condylar axis and the condylar plane. Therefore, the angle of anteversion will depend on the pair of points that is chosen [18]. After aligning the femur using various axes, Iranpour et al. (2010) found that the condylar axis defined by a line connecting the center of two spheres within the medial and lateral femoral condyles was the closest in aligning with the chondylar groove [19]. Hence, the third method was adopted for the current study.

The lesser trochanter version has been proposed as a guide to estimate femoral anteversion before [10,20]. This is due to the fact that due to the attached iliopsoas muscle, the orientation of the lesser trochanter relative to the femoral neck axis remains, independent of variations in the magnitudes and directions of forces on the femur [9]. However, Yun et al. (2013) and Shon et al. (2012) defined their lesser trochanter axis as the line passing through the base of the posterior lesser trochanter and the posterior cortex of the femur, which was adjacent to the hemispheric lateral cortex of the femur [10,20], while the current study considers the line from the femoral neck axis of the femur to the tip of the lesser trochanter as the lesser trochanter axis. As a result, there is a huge difference in terms of the reported lesser trochanter version in the current study compared to the -8.0° value reported by Yun et al. (2013) [10].

The support for using the lesser trochanter version as a guide to estimate the femoral anteversion had been controversial. Worlicek et al. (2017) found significant differences in the angle between the posterior lesser trochanter line and the posterior femoral condyle axis between male and female THA patients and between left and right femora [21]. They also found out that there was a significant difference in the angle between the lesser trochanter axis and the femoral neck axis after THA due to the varying post-THA femoral version from healthy femoral version [22]. Therefore, they opposed the idea of using lesser trochanter version as guiding landmark to estimate femoral anteversion. However, another study that estimated the accuracy of the lesser trochanter index (LTI) in predicting the underestimation of offset in the anteroposterior pelvic radiographs reported a femoral offset of less than 5% for LTI between 0° to 30° rotational projections. This suggested a good correlation between the femoral version and the lesser trochanter version, thus supporting the use of LTI as a useful guide in preoperative templating of THA [23]. Meanwhile, in another study that assessed the relationship between the femoral neck anteversion and the lesser trochanter version in symptomatic patients with ischiofemoral impingement (IFI) in comparison with patients with asymptomatic hips, it was reported that the mean lesser trochanter version was not increased significantly in patients with symptomatic IFI as compared to those with asymptomatic hips. Therefore, the lesser trochanter version is also suitable to be used as a guide to estimate femoral anteversion in THA for patients with symptomatic IFI [24]. Similarly, another recent study also supported the use of the lesser trochanter version as a landmark guide for femoral anteversion estimation. The study reported that by measuring the overlay of the center of the femoral head and the center of the femoral shaft at the most prominent aspect of the lesser trochanter for the proximal reference of femoral anteversion with the posterior condylar axis as the distal reference produced the highest interobserver reliability [25]. The measurement method and results reported by the study were of close proximity with this current study. Hence, the findings in this study may contribute additional support for the validity of the measurement method stated as well as the role of lesser trochanter version as an additional bony landmark to guide femoral anteversion estimation, particularly in multiethnic Asian population. In particular, the lesser trochanter would be useful in preoperative planning to determine femoral anteversion in a case with dysplastic femur.

During surgery, the lesser trochanter can be easily visualized owing to the attachment of the iliopsoas muscle, which is mainly on the anterior surface of the lesser trochanter [20]. Thus, this particular bony landmark is not only useful during the surgical planning, but also as a visual guide during the surgery for estimating the femoral anteversion. From the results, the lesser trochanter axis was measured to be about 36–38 degrees from the femoral neck axis. Accordingly, the orientation of the implant that is outside of this angle range in reference to the lesser trochanter can be an indicator of a potential malpositioning.

The current study is not without limitations. Although prudence has been taken to include equal distribution of male and female femora, the population still consists of only healthy and elderly individuals. Inclusion of more heterogenic data from femora affected by different musculoskeletal disorders, such as osteoarthritis or hip dysplasia, are probably needed. Furthermore, the size and shapes of the human femur can also differ depending on gender, age, stature, and ethnic background, reiterating the need to include a more heterogenic population to obtained a more balanced average [5,13].

5. Conclusions

In conclusion, the current study demonstrated a consistent relationship between the lesser trochanter version and the femoral anteversion, suggesting that the lesser trochanter version could be used to estimate the femoral stem anteversion during total hip arthroplasty.

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Institutional Review Board Statement: The study was approved by the local ethics committee (MREC ID: 20159-1635).

Informed Consent Statement: Informed consent was obtained from all patients participated in the study.

Data Availability Statement: Data sharing not applicable to this article as no datasets were generated or analyzed during the current study.

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Conflicts of Interest: The authors declared no conflict of interest that can influence the interpretation of the study.

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