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Original Article

Femoral Head Size is Correlated With Head Position in Very Elderly Patients

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ABSTRACT

Background: In cases of femoral neck fracture, it is often not possible to accurately determine the original position of the head center to assess appropriate restoration of leg length. The aim of this study was to determine the accuracy of predicting the position of the femoral head center based on new and established correlations between the femoral head diameter (FHD) and the distance between the lesser trochanter and the femoral head center (LT-FHC) in the very elderly (aged ≥80 years) as the mainly affected but yet underinvestigated group.
Methods: The FHD and the LT-FHC distance were determined in 148 subjects (104 males, 44 females); 90 aged ≥80 years and 58 aged <80 years. For each age and gender subgroup one specific (LT-FHC)/FHD ratio was determined. The accuracy of the new determined ratios and the established ratios by others were compared by recalculating the LT-FHC distance of each individual subject.
Results: The FHD and the LT-FHC were significantly correlated, most strongly in elderly females ($R = 0.554$, $P < .001$). Using the new age- and gender-specific ratios, the LT-FHC distance could be predicted within 10 mm of the true value in 95% of the cases and in only 77% using previously reported formulas.
Conclusion: Age- and gender-specific formulas yield higher accuracy than generic formulas. The formulas presented in this study can offer a practical, easy to use instrument for orthopedic surgeons performing hip arthroplasty in very elderly patients in addition to classic techniques to prevent significant leg-length discrepancy.

Leg-length discrepancy (LLD) is seen as one of the most troublesome complications after hip arthroplasty and may influence functional outcome negatively [1-3]. In total hip arthroplasty (THA), leg length can be assessed preoperatively and checked intraoperatively using various methods [2,4-6]. However, in the presence of a fracture of the femoral neck, which is often an indication for hemi hip arthroplasty, the position of the femoral head is distorted which makes it impractical to use this landmark as an extra indicator of the original leg length. The contralateral side might preoperatively be used for this purpose [7]; however, this is not always a reliable alternative because of projection errors on X-rays [8-10] or previous diseases or treatments such as post-traumatic conditions, severe osteoarthritis, congenital hip disease, osteosynthesis, or arthroplasty (Fig. 1).

Various authors identified the distance between the lesser trochanter (LT) and the femoral head center (FHC) (LT-FHC) as a reliable parameter for checking leg length intraoperatively [5,6,11]. Correlations have been described between the size of the femoral head and the LT-FHC. However, studies describing such a correlation have only been performed using small populations or subjects who are not of an age in which femoral neck fractures are common. Other studies have used suboptimal measurement techniques that have not taken into account the 3-dimensional morphology of the proximal femur [7,12-15]. Moreover, as both age and gender affect the morphology of the proximal femur, these known factors should

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Fig. 1. An 86-year-old male with a dislocated fracture of the femoral neck on the left side and severe osteoarthritis on the right side. The right side cannot serve as a reliable source to determine the native position of the femoral head on the left side.

be taken into account in deriving statistical models relating proximal bone dimensions to the height and offset of the femoral head with respect to the remainder of the femur [16-19].

The primary aim of this study was to investigate whether the height of the femoral head with respect to the LT-FHC can be predicted from the diameter of the femoral head in very elderly (aged ≥80 years) and middle-aged adults (aged <80 years), both male and female. The secondary aim was to compare the accuracy of this newly determined prediction model with established prediction models. An accurate prediction model could provide a practical intraoperative method to check the position of the reconstructed femoral head in addition to standard measures to prevent excessive leg lengthening or shortening.

Materials and Methods

Subjects and Imaging Procedures

The very elderly group consisted of 90 healthy Caucasian subjects (40 females and 50 males) aged 80 years and older (mean age 84 years, range 80-105 years). A computed tomography (CT) scan of each subject's right femur was made as an addition to a CT scan that had been ordered for diagnostic purposes, including investigation of inguinal pathology, benign prostate hypertrophy, and diverticulosis of the colon. Subjects with evidence of previous trauma, surgery, or bony pathology (metabolic disease or malignancy) were excluded. The CT scans were performed on a Siemens Sensation Open scanner (Siemens AG, Erlangen, Germany) with a scan field of view of 500 mm. The slice thickness was 1 mm and every image consisted of 512 × 512 pixels, thus each having a size of 0.98 mm × 0.98 mm.

The control group consisted of 58 cadaveric Caucasian subjects (4 females and 54 males) younger than 80 years (mean age 52 years, range 20-79 years). The femoral CT scans of these subjects were made postmortem by the Institute of Orthopaedic Research and Education at The Houston Methodist Hospital, Texas, using a General Electric Medical Systems LightSpeed CT scanner. The scan field of view was 384 mm, the slice thickness was 0.625 mm, and every image consisted of 512 × 512 pixels, thus each having a size of 0.75 mm × 0.75 mm. Causes of death mainly included road traffic accidents and drug overdoses. Subjects with evidence of previous trauma, surgery, or bony pathology (metabolic disease or malignancy) were excluded.

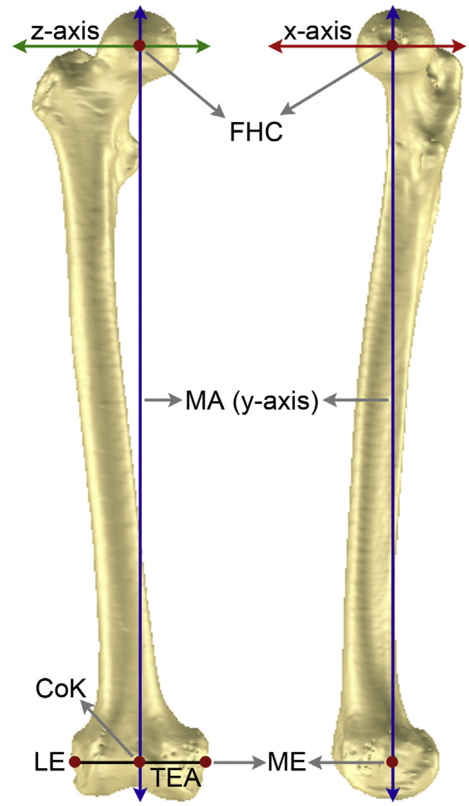

Fig. 2. Overview of landmarks for reconstruction of a standardized axis system. Left: coronal view; right: sagittal view from medial. FHC, femoral head center; ME, medial epicondyle; LE, lateral epicondyle; TEA, transepicondylar axis; CoK, center of knee; MA, mechanical axis.

The accuracy for bone morphological measurements of CT scans with the settings described previously has been proven to be within 1 mm [20,21].

All CT scans were loaded into Materialise Mimics (version 10.01, Materialise, Leuven, Belgium). Cortical bone segmentation of the femur was done by selecting a threshold of at least 226 Hounsfield units. The 3D model of the femur was loaded into reverse engineering software (Rapidform 2006, Inus Technology, Rock Hill, SC) for identification of bony landmarks and measurement of morphologic parameters.

Identification of Bony Landmarks

First, the mechanical axis of the femur was determined by defining the center of the femoral head proximally and the center of the knee distally (Fig. 2). Spherical regions encompassing at least 80% of the subchondral surface of the femoral head were selected and used for calculation of a single sphere of best fit. The geometrical center of this sphere was defined as the FHC. At the distal end of the femur, the most prominent points on the medial and lateral epicondyles were identified and then connected by a vector to define the transepicondylar axis. The midpoint of this vector was defined as the center of the knee.

An XYZ-coordinate system was created with the FHC as the origin as described by the Standardization and Terminology Committee of the International Society of Biomechanics [22] (Fig. 2). The line connecting the FHC with the center of the knee, also known as the mechanical axis, served as Y-axis (anatomically, the proximal-distal direction). The Z-axis was defined as a line perpendicular to the Y-axis (anatomically, the medial-lateral direction) lying in the plane