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Basic Science

Agreement Between Proximal Femoral Geometry and Component Design in Total Hip Arthroplasty: Implications for Implant Choice

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ABSTRACT

Background: The present study aimed to analyze the agreement between proximal femoral geometry of adult hips and femoral component design in total hip arthroplasty.

Methods: Anatomical femoral offset (FO_{Anat}) and the anatomical neck-shaft angle (NSA_{Anat}) of 800 adult hips were measured by computed tomography scans, and anatomical femoral neck height (FH_{Anat}) was calculated. Corresponding best-fit implants of the most common hip system (standard, high offset and varus variant) were identified for each hip. Finally, the precision of the best possible anatomic reconstruction was assessed.

Results: The mean FO_{Anat} was 38.0 mm (range: 19.8-57.9 mm, standard deviation [SD]: 6.4 mm), the mean NSA_{Anat} was 130.8° (range: 107.1°-151.9°; SD: 6.5°), and the mean FH_{Anat} was 32.6 mm (range: 14.4-52.0 mm; SD: 5.5 mm). In 450 (56.3%) hips, the standard variant was identified to be the best-fit implant, followed by the varus (n = 282, 35.3%) and the high offset (n = 68, 8.5%) variants. The mean minimal distance from the best-fit implant was 4.5 mm (range: 0.1-20.2 mm, SD: 3.4 mm). Excellent agreement (distance: <2 mm) between hip anatomy and best-fit implant was found in 203 (25.4%) hips, combined excellent and acceptable agreement (distance: <6 mm) in 569 (71.1%) hips, whereas 213 (28.9%) hips were graded as poor (distance: ≥6 mm).

Conclusion: The present study revealed a mismatch between proximal femoral anatomy of a relevant proportion of adult hips and implant geometry of the most common femoral component in total hip arthroplasty.

The correct reconstruction of anatomic parameters of the hip joint is thought to be critical for optimal postoperative function after total hip arthroplasty (THA) [1-4]. The femoral offset and leg length were identified as relevant predictors of clinical function, and insufficient restoration might lead to failure of the THA [2-5]. Today, a wide range of standard femoral components with varying neck-shaft angles is available, and lateralized variants allow for the reconstruction of the femoral offset without influencing leg length [6-8]. To further improve the adaptability of the implant, combinations with modular femoral heads with varying lengths enable the reconstructions of a wide spectrum of anatomic configurations. However, little is known on the agreement between proximal femoral geometry of adult hips and component design in THA.

For the present study, an analysis of the proximal femoral anatomy of computed tomography (CT) scans of 800 adult hips was performed, and corresponding best-fit implants were identified [9]. The precision of the anatomic reconstruction was assessed.

The aim of this study was to improve our knowledge on proximal femoral anatomy and to determine the agreement between anatomy and the most common femoral implant.

Material and Methods

After screening and eligibility determination, a retrospectively identified cohort of 400 adult patients (800 hips) undergoing whole-body CT scans for trauma was included. The study protocol aimed to generate 4 individual groups of patients of 100 patients. Therefore, the inclusion process was performed for each group until 100 patients were included. The search identified all trauma CT

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scans (n = 1362). These were divided by sex (906 male vs 456 female), and subcohorts were sorted by age of the patient (at the time of the scan). Finally, these cohorts were tested for eligibility using the inclusion and exclusion criteria. Patients with fractures, deformities, or implants in the pelvis or femur were excluded; only patients with mature skeletons were included. When 100 scans were included per group, the process stopped, and the rest of the scans excluded per protocol. The detailed inclusion and exclusion process is illustrated in Figure 1. Four groups (male <65 years, male ≥65 years, female <65 years, female ≥65 years) with 100 patients each were generated. Overall, patients had a mean age of 54.3 years (range: 18-100 years, standard deviation [SD]: 22.1 years); males of 53.2 years (range: 18-89 years; SD: 22.6 years) and females of 55.4 years (range: 18-100 years; SD: 22.4 years) [9].

CT scans were acquired with a Brilliance iCT 256 scanner (Philips Healthcare, Cleveland, OH). The radiographic data were stored in DICOM (Digital Imaging and Communications in Medicine) format in a picture archiving and communication system and analyzed by using a picture archiving and communication system client (IMPAX EE; AGFA HealthCare GmbH, Bonn, Germany).

Radiographic measurements were performed following a predefined protocol. In short, axial CT images were reformatted with a multiplanar reconstruction plugin, and each femur was reconstructed in the coronal plane of the femoral neck, eliminating hip flexion and rotation [10]. The coronal plane was defined as the plane between the femoral neck axis in the axial reconstruction and the long axis of the femur in the sagittal reconstruction [5]. Detailed methods, patient characteristics, and data on the neck-shaft angle (NSA) can be found in [9].

Calculation of Anatomic Characteristics

The proximal part of the femur represents a right triangle (Fig. 2). The femoral neck (FN) corresponds to the hypotenuse, the femoral offset (FO) is the opposite, and the proximal part of the femoral shaft axis is the adjacent; the latter is defined as the femoral neck height (FH). The angle between FH and FN is termed α; equaling 180° minus the NSA of the femur.

Anatomic variables are labeled with the subscripted suffix $_{Anat}$. The FO_{Anat} was measured directly in the reconstructed CT image of the proximal femur. The femoral neck axis and the long femur axis were drawn, and the cutting point was defined as the lower margin of the FH_{Anat}; the NSA_{Anat} was measured (Fig. 2). FH_{Anat} was calculated according to Formula 1:

$$FH_{Anat} = FO_{Anat}/\tan(180^\circ - NSA_{Anat}) \quad (1)$$

Geometry of Femoral THA Components

Similar to the femur, the proximal part of a femoral component is a right triangle (Fig. 3). For prosthetic variables, no suffix was added.

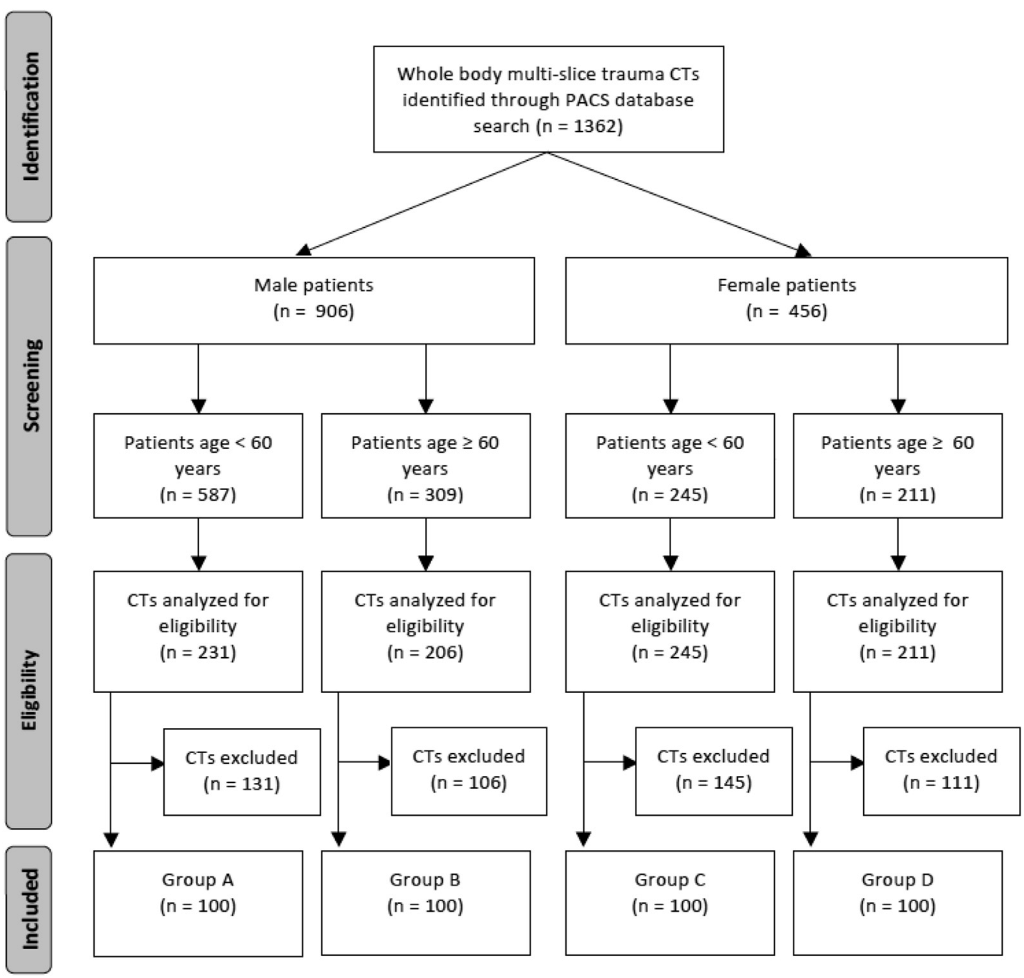

Fig. 1. Flowchart of inclusion of 400 patients. CT, computed tomography; PACS, picture archiving and communication system.