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Can Anatomic Measurements of Stem Anteversion Angle Be Considered as the Functional Anteversion Angle?

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ABSTRACT

Background: Stem anteversion angle is important in the combined anteversion theory to avoid implant impingement after total hip arthroplasty (THA). However, anatomic measurements of stem anteversion angle may not represent functional anteversion of the femur if the femur undergoes axial rotation. Herein, the femoral rotational angle (FRA) was measured in supine and standing positions before and after THA to evaluate the difference between anatomic and functional measurements.
Methods: A total of 191 hips (174 patients) treated with THA for osteoarthritis were analyzed in this retrospective, case-controlled study. The FRA was measured as the angle between the posterior condylar line and the line through the bilateral anterior superior iliac spines (positive for external rotation) and was measured preoperatively and postoperatively in supine and standing positions with computed tomography segmentation and landmark localization of the pelvis and the femur followed by intensity-based 2D-3D registration. The number of cases in which the absolute FRA remained <15° in both positions was also calculated.
Results: The average ± standard deviation preoperative FRA was 0.3° ± 8.3° in the supine position and −4.5° ± 8.8° during standing; the postoperative FRA was −3.8° ± 9.0° in supine and −14.3° ± 8.3° during standing. There were 134 cases (70%) in which the preoperative absolute FRA remained <15° in both positions while only 85 hips (45%) remained <15°, postoperatively.
Conclusion: Substantial variability was seen in the FRA, especially during the postoperative period. These results suggest that the anatomic stem anteversion angle may not represent the functional anteversion of the femur.

In total hip arthroplasty (THA), stem anteversion and cup alignment affect joint range of motion and play an important role in preventing impingement. Several studies recommended a certain combined anteversion angle (ie, combined anteversion theory [1–3]) to reduce the risk of implant impingement and subsequent dislocation events. Several computer-assisted surgical tools (eg, computed tomography [CT]-based navigation and patient-specific instruments) have been developed with the combined anteversion theory in mind so as to meet the crucial requirement of impingement-free range of motion required during activities of daily living [4–6]. However, it is important to note that the functional alignment of the implant is not constant because the rotation of the pelvis relative to the femur varies according to the position a person must adopt to perform activities of daily living. Ideally, the surgeon would have knowledge regarding the rotational change of both the pelvis and femur during several postures and functional tasks in both preoperative and postoperative configurations.

Functional alignment of the cup has been analyzed in several studies by measuring the sagittal tilt of the pelvis [7–11]. The

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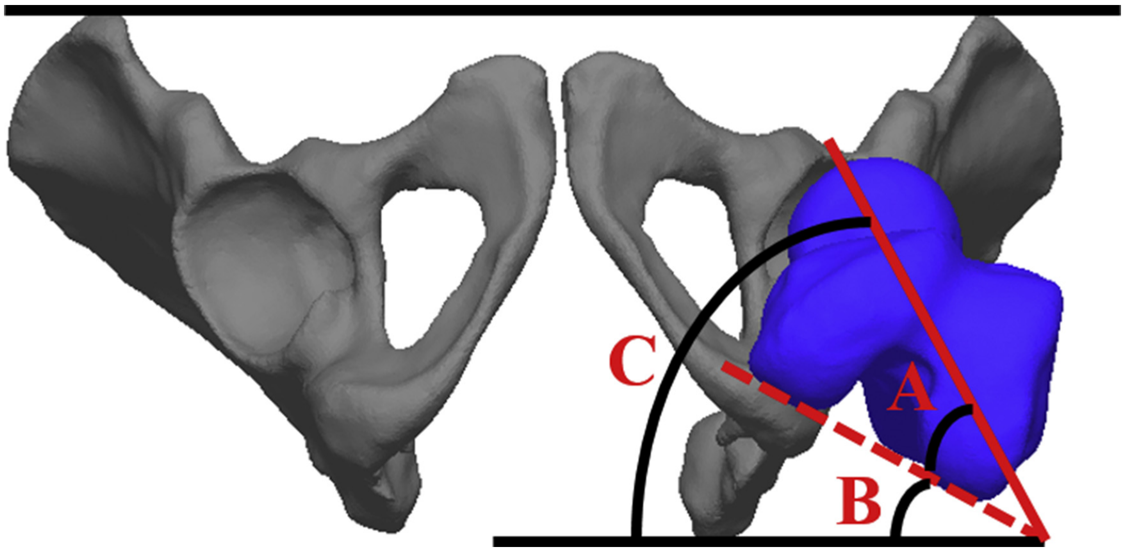

Fig. 1. Definition of femoral anteversion (A), FRA (B), and functional femoral anteversion (C). Femoral anteverison (A) was defined as the angle between the femoral neck (red line) and the posterior condylar line (dotted red line, defined by connecting the most posterior point of each condyle). The FRA (B) was defined as the angle between the posterior condylar line and the line parallel to the line through the bilateral anterior superior iliac spines (black line). Functional femoral anteversion (ie, functional torsion of the femur) (C) was defined as the angle between the femoral neck and the line parallel to the line through the bilateral anterior superior iliac spines. FRA, femoral rotational angle.

literature has provided substantial insight regarding the sagittal tilt of the pelvis during supine, standing, and sitting (in some instances including more than 400 patients), which has improved the approach used in THA [7,11]. In addition, the longitudinal change in pelvic tilt following THA has been described up to 10 years from THA [9]. Compared to the pelvis, there is very little information available in the literature regarding the functional alignment of the femur. Axial rotation notably affects the functional anteversion of the femur (functional femoral anteversion; Fig. 1). Accordingly, there is a need to study how axial rotation of the femur changes during several postures because this could influence the process used to align the implant during surgery. Yet, to date, axial rotation of the femur has only been analyzed in the supine position using CT images [12,13], and thus, the rotational position of the femur in the standing position and its change following THA is poorly understood. The paucity of research devoted to femoral alignment is likely due to the fact that it is very difficult to obtain accurate measurements of axial rotation from standard radiographs [14,15]. For the pelvis, sagittal tilt can be measured from the shape of the pelvic foramen in the anteroposterior radiograph [8–10] and also from the lateral radiograph [7], but such methods have not been standardized for the femur. To this end, we employed an intensity-based 2D-3D registration technique [16,17] to quantify axial rotation of the hip from radiographs obtained in the supine and standing positions. More specifically, the purposes of this study were (1) to measure the axial rotation of the femur in supine and standing positions and quantify difference in these 2 postures and (2) to quantify how axial rotation of the femur changed as a result of THA.

Methods

Institutional review board approval was obtained. As a retrospective study, informed consent was waived. All subjects herein were treated for end-stage hip osteoarthritis (OA) with THA using an anatomic stem [18] designed for Japanese patients (CentPillar; Stryker, Mahwah, NJ) during the period from March 2008 to December 2014. All of the patients included in this study visited our institution for follow-up in 2016. Exclusion criteria were patients who had previous surgeries of the hip, contralateral THA, knee OA (Kellgren-Lawrence classification [19] of grade 3 or 4), and who had received a total knee replacement. Seventeen patients who had 1-stage bilateral THA were included. A total of 191 hips from 174 patients were included. There were a total of 8 men and 166 women. The mean ± standard deviation age was 63 ± 9 years, and the median (range) follow-up was 5 years (1-8 years).

To evaluate axial rotation of the femur, the angle between the posterior condylar line (defined by connecting the most posterior point of each condyle) and the line through the bilateral anterior superior iliac spines was defined as the femoral rotational angle (FRA), as has been defined previously [12,13] (Fig. 1). External rotation was defined by positive values, whereas negative values indicated internal rotation. To measure the preoperative FRA in the supine position, preoperative CT images for CT-based navigation surgery were used. All CT scans were acquired with the patient supine on the gantry with their feet in a comfortable resting position. Images were obtained from the superior iliac crest to the proximal tibia. The CT images were automatically segmented [20]. The bilateral anterior superior iliac spines and the most posterior locations of the 2 condyles were automatically identified with the use of hierarchical and conditional statistical shape models constructed based on a training dataset consisting of 200 CT images of hips acquired for a different study [20]. The identified landmarks were verified manually, and minor corrections were made using software that allowed for multiplanar reconstruction with arbitrary oblique angle (3D template software, Kyocera, Kyoto, Japan).

To measure the FRA in the preoperative standing position, radiographs were acquired in a relaxed standing position. Preoperative CT images and radiographs were aligned using an intensity-based 2D-3D registration system, which is described elsewhere [16,17], and has been used in the clinical setting for studies of the spine [17,21] and pelvis [11] (Fig. 2). Briefly, digitally reconstructed radiographs were obtained by projecting the volumetric CT data to a 2D plane. By computing the gradient correlation similarity score between digitally reconstructed radiograph and the radiograph iteratively, the position of the pelvis and the femur that yielded the highest similarity score was found via a numerical optimization algorithm termed the covariance matrix adaptation evolutionary strategy [22] (Fig. 3). The registration provided the relative position between the pelvis and the femur, which then enabled calculation