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The Validity of Using the Posterior Condylar Line as a Rotational Reference for the Femur

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ABSTRACT

Rotation of the femur is usually measured by the posterior condylar line (PCL). However, the functional position of the PCL has not been studied well. The angles between the PCL and the horizontal body line (HBL) were measured on preoperative computed tomographic (CT) images of 324 hips with osteoarthritis and compared with the CT images taken after hip arthroplasty. The PCL rotated 0.4° (±10.9° SD) internally from the HBL on preoperative CT images and was significantly correlated with femoral anteversion, Kellgren-Lawrence grade, and sex. On postoperative CT images, the PCL rotated 10.1° (interquartile range, 1.7°-15.5°) internally from the HBL. There was individual variance in the position of the PCL, and caution may be needed when using it as a rotational reference.

Total hip arthroplasty (THA) is a procedure for patients with osteoarthritis (OA) that improves their activities of daily living and quality of life. Although the longevity of implants has improved [1-3], there are still some postoperative complications, such as dislocation and bearing complications due to implant malorientation. Good design of implants and secure surgical techniques are the keys to solving these remaining issues [4,5]. Combined acetabular and femoral anteversion has often been suggested to obtain an appropriate hip range of motion without impingement [5-7]. However, the reference coordinates of the femur to measure femoral anteversion need more study because there are no reports on whether the posterior condylar line (PCL), which is the most often used as a reference to measure femoral anteversion and is assumed to be a reference line of rotation for the lower extremities [8-12], is functionally a useful reference of rotation. If the axial rotational position of the PCL is functionally quite variable in each patient, it may not be appropriate to use the PCL to measure functional femoral anteversion (Fig. 1). In addition, if the axial rotational position of the PCL changes substantially after THA, it may also not be appropriate to use the PCL as a rotational reference for the femur.

To investigate the difference between the PCL and the horizontal line of the body, the axial rotational position of the femur in patients with hip OA was measured using computed tomographic (CT) images taken before and after THA, and then the related factors were evaluated. We hypothesized that the difference between the PCL and the horizontal line of the body is quite small on both preoperative and postoperative CT images, and we also hypothesized that OA is a factor related to axial rotation of the femur because external contracture is often seen in OA patients.

Methods

A total of 375 hips with hip OA treated with THA between January 2009 and April 2014 were evaluated, and patients who had a history of previous surgery of the acetabulum or femur, history of fracture, history of total knee arthroplasty, history of cranial nerve disease, history of capital femoral epiphysis, and whose CT scans were not recorded correctly were excluded (Table 1). In total, 324 hips from 291 patients (30 men, 261 women; median age, 63 years; age range, 30-86 years) were initially included as the subjects of this study. Of these 324 hips, postoperative CT images were taken from 250 hips to be included as the final subjects of this study. Postoperative CT images were taken at a median of 4 weeks (range, 2 weeks to 1 year) after THA. According to the Kellgren-Lawrence (KL) classification [13], there were 36 grade 3 hips and 288 grade 4 hips. The preoperative and postoperative CT images taken in a supine resting position for navigation were used for

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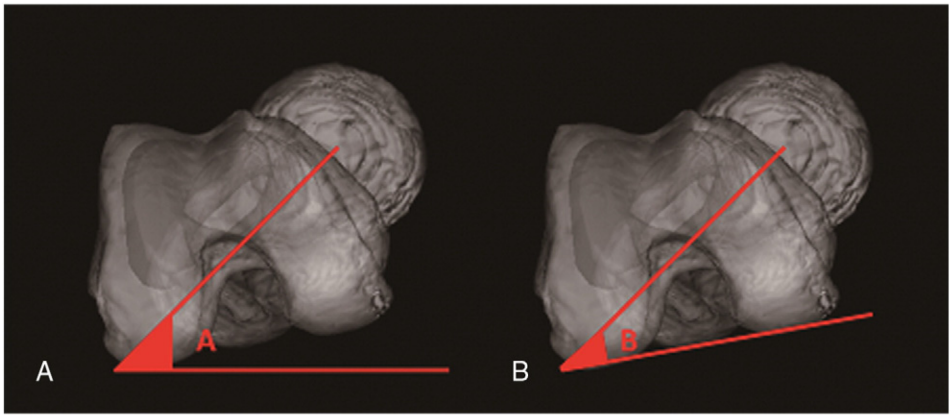

Fig. 1. Functional femoral anteversion and anatomical femoral anteversion. (A) Angle A indicates the functional femoral anteversion, which is the angle between the horizontal line of the body and a line including the head center and the neck center. (B) Angle B indicates the anatomical femoral anteversion, which is the angle between the PCL and a line including the head center and the neck center.

anatomical measurements. Identifying patient information was erased from the CT images, and the research was approved by the institutional review board at Osaka University Hospital. Measurements were done with the use of 3D template software (Kyocera Medical, Osaka, Japan).

To measure the axial rotational position of the femur and related factors, the coordinate systems of the acetabulum and the femur were constructed first. For the acetabulum, the anterior pelvic plane (APP), which is a plane including the most anterior points of the bilateral anterior superior iliac spines (ASISs) and the pubic tubercles, was first constructed (Fig. 2). After constructing the APP, the functional pelvic plane (FPP) was created by rotating the APP around the horizontal axis of the pelvis by the pelvic inclination in the supine position (Fig. 2) [10-12,14-19]. The X-axis of the FPP was set parallel to the ASIS, the Y-axis was set perpendicular to the FPP, and the Z-axis was set perpendicular to the X- and Y-axes (Fig. 2). On the other hand, the table top plane, which is an anatomical plane including the most posterior point of the proximal femur and the medial and lateral posterior condyles, was set as the coordinate system of the femur, with the vertical axis parallel to a line through the femoral head center and the knee center [8-12]. After setting the coordinate system, the axial rotational position of the femur was measured as the femoral rotational angle, which was defined as the angle between the PCL and a line through the bilateral ASISs (Fig. 3). The value was positive if the femur was externally rotated and negative if the femur was internally rotated.

To analyze the factors related to the femoral rotational angle, femoral anteversion, femoral abduction angle, femoral flexion angle, axial rotational angle of the pelvis, and pelvic sagittal tilt were also measured. Femoral anteversion was measured as the angle between the PCL and a line including the head center and the neck center [20]. The femoral abduction angle was measured as the angle between the Z-axis of the FPP and the vertical axis of the femur on the XZ-plane of the FPP, and the femoral flexion angle was measured as the angle between the Z-axis of the FPP and the vertical axis of the femur on the YZ-plane of the FPP (Fig. 3). The axial rotational angle of the pelvis was measured as the angle between a line through the bilateral ASISs and the horizontal line of the body in supine position; it was defined as positive for clockwise rotation (Fig. 4). On the other hand, pelvic sagittal tilt was measured as the angle between the APP and the FPP on the YZ-plane of the FPP; it was defined as positive for posterior inclination (Fig. 4). To analyze the effect of OA on the axial rotational angle according to our hypothesis, a control group who had unilateral hip OA was selected from the 291 patients. Since it has been reported [21] that most hip OA cases in Japan are secondary OA due to developmental dysplasia of the hip, 38 patients who had bilateral developmental dysplasia of the hip with unilateral OA were selected from among the 291 patients, and the OA side was compared with the non-OA side.

All statistical analyses were performed with SPSS statistical software version 23 (IBM Japan, Tokyo, Japan). Normality tests were performed with Kolmogorov-Smirnov test. When the factors were normally distributed, bivariate analysis was carried out with the unpaired *t* test, and correlation was assessed by Pearson correlation coefficient. When the factors were nonnormally distributed, bivariate analysis was carried out with the Wilcoxon signed rank test, and correlation was assessed by Spearman rank correlation coefficient. Multivariate analysis was conducted by generalized linear regression models with an appropriate distribution, and the effects of femoral anteversion, femoral abduction angle, femoral flexion angle, axial rotational angle of the pelvis, pelvic sagittal tilt, age of the patient, KL grade, and sex on femoral rotational angle were calculated. Intraobserver and interobserver reliabilities were calculated using intraclass correlation coefficients and their 95% confidence intervals (CIs) to assess the reliability of measuring the femoral rotational angle. Thirty patients were measured twice by the author for intraobserver reliability, and the same 30 subjects were also measured by an orthopedic surgeon to assess interobserver reliability. $P < .05$ was considered to represent a significant difference and a significant correlation.

Table 1
Study Exclusion Criteria.

Exclusion Criteria	No. of Cases
Previous surgery of the acetabulum or femur	35
History of fracture	7
Cranial nerve disease	3
Previous total knee arthroplasty	3
Poor CT data	2
Capital femoral epiphysis	1

Results

The mean femoral rotational angle on preoperative CT images was $-0.4°$ ($\pm 10.9°$ SD; range, $-32.4°$ to $29.6°$). Median femoral anteversion was 26.4° (interquartile range [IQR], 19.3°-34.5°), with 23.6° for men and 26.7° for women. There was a significant negative correlation between axial femoral rotation and femoral anteversion ($r = -0.52$; $P < .01$), and there was also a significant correlation between axial femoral rotation and pelvic sagittal tilt ($r = 0.20$; $P < .01$) (Table 2). The femoral rotational angle was significantly larger for patients with KL grade 4 than for those with KL grade 3 (grade 4: $0.5° \pm 10.8°$ SD, grade 3: $-7.2° \pm 9.8°$ SD; $P < .01$). There was also a significant difference in sex (men: $5.4 \pm 12.5°$ SD, women: $-1.0 \pm 10.6°$ SD; $P = .01$). The other factors were not significant (Table 2).