Variation in coronal and sagittal stem alignment and its impact on prosthetic range of motion in total hip arthroplasty

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Introduction: Prosthetic impingement causes not only dislocation but also mechanical problems including excessive wear of bearing materials and/or neck fracture in total hip arthroplasty (THA). Various computer simulation studies have been conducted to find out the optimal combination of cup and stem alignment to minimize the risk of prosthetic impingement. Cup alignment can be changed easily by manual adjustment, while stem alignment is more constrained by the individual femoral anatomy including femoral neck anteversion and antero-lateral bowing of the femoral shaft. Because of the wide variation in femoral anteversion, adjustment of cup anteversion according to the stem anteversion is needed, however, there is a paucity of published data regarding the variation in coronal and sagittal stem alignment which may influence the risk of prosthetic impingement. The purposes of the present study were to investigate the individual variations in coronal and sagittal stem alignment by virtual surgeries using an anatomical-type stem and to evaluate its impact on the prosthetic range of motion (ROM).

Material and Methods: 531 sets of computed tomography (CT) data of the pelvis and femur were stored from 453 consecutive patients who underwent THA using CT-based computer navigation from January 2005 to October 2012. The CT images from this database were used to investigate the variation in alignment of an anatomical-type stem (Centpillar, Stryker Orthopaedics, Mahwah, NJ, USA). The average age was 60.1 years (SD 12.1). 56 patients (66 hips) were male and 397 patients (465 hips) were female. Preoperative diagnosis was osteoarthritis (OA) secondary to developmental dysplasia of the hip in 392 hips, primary OA in 51 hips, osteonecrosis of the femoral head (ON) in 73 hips, and other in 15 hips. Virtual surgeries using the anatomical-type stem were performed to match the shape of the femoral canal using a CT-based Hip Navigation Planning System (Stryker Orthopaedics).

After digitizing landmarks, the unit vectors of the anatomical femoral coordinate system were defined as follows. The Y-axis was perpendicular to the posterior femoral plane including the most posterior point of the greater trochanter and the bilateral posterior condyles; the x-axis was perpendicular to the line passing through the trochanteric fossa and the mid-point of the bilateral epicondyles on the posterior femoral plane; and the z-axis was perpendicular to the X- and Y- axes. Sagittal femoral tilt (FT), varus angle and anteversion were measured as the deviation between the stem axis and the Z-axis in a sagittal projection, between that and the Z-axis in a coronal projection, and between that and the Y-axis in an axial projection.
respectively. Additionally, the effect of variation in FT and varus angles of stem on prosthetic ROM was evaluated as follows. The size, radiographic anteversion and abduction of the acetabular component (Trident, Stryker Orthopaedics) were set at 52 mm, 15° and 40°, respectively. The size of the stem was No. 6. The head diameter and offset length selected were 32 mm and standard length, respectively. Stem anteversion was changed from 0 to 60 degrees with increments of 5°. The FT and varus angles were then changed by 5°, and 4 ROMs - namely flexion, extension, internal rotation at 90° of flexion, and external rotation until prosthetic impingement were measured. Statistical analyses were conducted using Spearman’s rank-correlation method, Mann-Whitney’s U test, and multiple regression analysis. P-value < .05 was taken to indicate statistical significance.

**Results:** The mean FT was 11.1° (SD 1.5°; range, 6.0° to 17.0°) and the mean varus angle was 0.15° (SD 1.5°; range -5.0° to 5.0°) with a mean anteversion of 31.0° (SD 11.6°; range 2.0° to 76.0°). There was no significant correlation between FT and patient age (p=0.202). There was no significant difference in FT between males and females (p=0.684) or among the secondary OA group, the primary OA group and the ON group. A significant correlation was found in varus angle with patient age (p<0.001). There were significant differences in varus angle between males and females (p=0.008), and between the secondary OA group and the ON group (p<0.001). A significant correlation was found in the femoral anteversion with patient age (p=0.011). There were significant differences in femoral anteversion between males and females (p=0.001), and between the secondary OA group and the other groups (p<0.001). Multiple regression analysis revealed that only age correlated with varus angle (p=0.003). Age (p<0.001) and diagnosis (p=0.006: secondary OA vs primary OA, p<0.001: secondary OA vs ON) significantly correlated with femoral anteversion.

The ROM simulation revealed that changes in FT and varus angles influenced particularly flexion. With 30° of stem anteversion, a 5° increase in FT and a 5° increase in varus stem alignment caused a 4° decrease and a 5° increase in flexion ROM, respectively. Furthermore, as stem anteversion increased, the influence of FT change on prosthetic ROM increased; while as stem anteversion decreased, the influence of varus angle on prosthetic ROM increased.

**Discussion:** This study revealed that variations in FT and in varus angles are very small, because the FT of 529 hips (99.6%) and the varus angle of 529 hips (99.6%) were within 5° of the average in the present study. The ROM simulation showed that changes in both coronal and sagittal stem alignment had the most influence on flexion ROM among the 4 ROMs. With 30° of stem anteversion, 5° differences in FT and in varus angle produced to a difference of 4° and 5° of flexion ROM, respectively. Assuming that a difference of 5° in prosthetic ROM is small, the variations in FT and in varus angles in our patient population were not worth being considered in determining the combination of cup and stem alignment.

**Conclusion:** The variation in FT and varus angles of stems matched to individual femoral anatomies was found to be very small and their impact on prosthetic range of motion was small.