INTRODUCTION: In total hip arthroplasty (THA), computer navigation has become popular and provided high precision of alignments of acetabular components. Although some coordinate systems of the pelvis are used for preoperative planning and biomechanical study of the hip joint, it is controversial which coordinate system is appropriate for the reference of the alignment of acetabular components. Most of navigation systems use the coordinate system defined by the anterior pelvic plane through bilateral anterior superior iliac spines and the midpoint of bilateral pubic tubercles, which is named as the anatomical coordinate system. It has been, however, reported that pelvis tilts anteriorly or posteriorly with various angles among patients in the supine position and the pelvic tilt angle with the patient supine is a good approximation of the functional pelvic tilt angle with the patient standing. Radiographic evaluation was also made in supine position, where pelvic rotation was estimated based on the interrelationship between the pubic symphysis and the center of sacrum. Thus, it is theoretically recommended that the pelvic coordinate system adjusted for pelvic tilt and rotation in the supine position for navigation surgery, which is named as the functional coordinate system.

Preoperative simulation of hip range of motion is also very important to prevent postoperative complications due to impingement of prostheses and bones. In the biomechanical study, it is generally recommended the definition of the pelvic coordinate system that has been proposed by International Society of Biomechanics (ISB). In this definition, the coordinate system is defined by a plane through bilateral anterior superior iliac spines and the midpoint of bilateral posterior superior iliac spines, which is named as the ISB coordinate system.

It is unknown how these coordinate systems differ from each other and their effect of different coordinate systems on the cup alignment. The purpose of the present study was to evaluate the interrelationship among the 3 reference pelvic coordinate systems using 3D-CT and evaluate its effect on the cup alignment.

METHODS: Fifty patients who were candidates for unilateral THA with computer navigation underwent computed tomographic scanning preoperatively. 40 patients had a diagnosis of developmental dysplasia, and 10 patients had a diagnosis of primary coxarthrosis. The average age was 60 years (range, 30 to 79). They were all females. There were 27 hips in Crowe I and 13 hips in Crowe II or III. Preoperative computed tomography images were obtained using a helical CT scanner (High-speed Advantage, General Electric, Milwaukee, WI). The following pelvic landmarks were digitized on coronal, sagittal and axial images: pelvic bone, symphysis and sacrum. The functional coordinate system was defined by the computer navigation underwent computed tomographic scanning software (Virtual Place-M; Medical Imaging Laboratory, Tokyo, Japan); anterior superior iliac spines, posterior superior iliac spines, pubic tubercles, the center of sacrum body and ischial tubercities.

The unit vectors of the anatomical pelvic coordinate system were defined as follows. The X axis was perpendicular to the anterior pelvic plane that included the bilateral anterior superior pelvic spines and the midpoint of bilateral pubic tubercles. The Y axis was parallel to the line passing through bilateral anterior superior pelvic spines. The Z axis was perpendicular to the X and Z axes.

The unit vectors of the functional pelvic coordinate system were defined as follows. The pelvic midsagittal plane through the pubic symphysis and the center of sacrum and perpendicular to the line through bilateral ischial tubercities was determined. The Y axis was perpendicular to the midsagittal plane and the Z axis was parallel to the CT table on the midsagittal plane. The X axis was perpendicular to the Y and Z axes.

The unit vectors of the ISB pelvic coordinate system was defined as follows. The Z axis was perpendicular to the pelvic plane through the bilateral anterior superior pelvic spines and the midpoint of bilateral posterior superior pelvic spines. The Y axis was parallel to the line passing through bilateral anterior superior pelvic spines. The X axis was perpendicular to the Y and Z axes.

The relationship of the functional coordinate system and the ISB coordinate system to the anatomical coordinate system was calculated. The cup alignment angles relative to the functional coordinate system and the ISB coordinate system was calculated for acetabular components implanted at 40 degrees of radiological abduction and 15 degrees of radiological anteversion relative to the anatomical coordinate system.

RESULTS: The functional coordinate system was tilted anteriorly with a mean of 3.4 degrees (SD, 7.1; range, -17 to 15 degrees) against the anatomical coordinate system. The functional coordinate system tilted laterally with a mean of 1.5 degrees (SD, 1.0 degrees; range, 0.1 to 5.0 degrees) and rotated with a mean of 0.3 degrees (SD, 2.3; range, -5.0 to 5.2 degrees). The absolute rotation was 1.9 degrees (SD, 1.3; range, 0.05 to 5.2 degrees). Applying the functional coordinate system to the above mentioned cup alignment, the radiological abduction angle of cups was 39.9 degree (SD, 1.6 degrees; range, 35.9 to 43.3 degrees) and the radiological anteversion angle of cups was 12.7 degree (SD, 4.4 degrees; range, 2.6 to 24.8 degrees). (Fig.1)

The ISB coordinate system was tilted posteriorly with a mean of 11.2 degrees (SD, 5.6 degrees; range, -3.8 to 26.9 degrees) against the anatomical coordinate system. Applying the ISB coordinate system to the above mentioned cup alignment, the radiological abduction angle of cups was 40.2 degree (SD, 0.7 degrees; range, 39.7 to 43.2 degrees) and the radiological anteversion angle of cups was 22.1 degree (SD, 3.4 degrees; range, 12.4 to 31.0 degrees). (Fig.2).

DISCUSSION: The functional coordinate system tilted anteroposteriorly up to 17 degree and rotated up to 5.2 degrees and tilted laterally up to 5.0 degree against the anatomical coordinate system. Large variations among patients were seen in pelvic anteroposterior tilt, which had more influence on the anteversion angle than the abduction angle of acetabular cups. This indicated that acetabular cups implanted referencing the anatomical coordinate system could deviate from target cup orientation in the functional position, that is, supine and standing positions.

The ISB coordinate system tended to tilt posteriorly compared with the anatomical coordinate system. If the ISB coordinate system is applied to the reference of THA, the anteversion of acetabular cups and the flexion angle of the hip joints can be underestimated. Thus it is not suitable for the biomechanical analysis of THA. In conclusion, there were significant differences among the anatomical coordinate system, the functional coordinate system and the ISB coordinate system. The definition of the pelvic coordinate system has a significant influence on the alignment of acetabular cups.

REFERENCES: