ABSTRACT / INTRODUCTION: The anterior frontal plane of the pelvis, defined by the bilateral Anterior Superior Iliac Spines (ASISs) and pubic Symphysis (PS), is frequently used as the basis for angular measurements of cup orientation in total hip arthroplasty (THA) utilizing computer assisted navigation.\(^{1,2}\). Proper acetabular cup alignment is dependent on accurate identification of the bony landmarks needed for determination of the pelvic plane. Few studies have addressed the consequences of inaccurate determination of the pelvic frontal plane.\(^{3,4}\) The purpose of this study is, therefore, to predict a potential acetabular cup misalignment due to inaccurate determination of the pelvic plane.

METHODS:

Participants and the Surgery: The human subject part of this study was approved by the Institutional Review Board of Northwestern University. A total of 8 hips (4 female cadavers) and 34 hips (31 individuals) were used. Average age for cadavers was 61.3±18.7 years. There were 12 female and 17 male patients with L-S lordosis with a posteriorly positioned pelvis have plus average age, height, and weight for individuals were 64.6±11.9 years, 172.3±12.6 cm, and 84.1±18.3 kg, respectively; there were 14 female and 17 male. The average age for cadavers was 61.3±18.7 years.

CT Examination: For cadavers and individuals the Computed Tomography (CT) scans in the supine position were obtained after surgery using a protocol of 1.25 mm contiguous axial slices from the superior hip to distal femur. CT was scanned with following parameters: 140kV, 270mA, and 1.0 scan time.

3D Reconstruction Model, Pelvic Plane & Acetabular Cup Alignment: A 3D model of the pelvis together with the prosthesis for all cadavers and individuals was created using Mimics (Materialise Software, Ann Arbor, MI, USA) based on CT scans. Anatomical landmarks were identified on the prothetic acetabular rim (multiple points), bilateral Anterior Superior Iliac Spines (ASISs) and bilateral Pubic Tubercle (PTs). The pelvic plane was then established by ASISs and PTs. An acetabular plane was also computed by fitting the multiple points on the acetabular rim to a plane using the least-square error criterion for determination of cup alignment relative to the pelvic plane.

Coordinate Systems: The coordinate system was established for identification of pelvic orientation. The coordinate system takes the origin as the midpoint between the ASISs, with a pelvic plane defined by the bilateral ASISs and PS. Anatomical landmarks were identified on the prothetic acetabular rim (multiple points), bilateral ASISs and bilateral PTs. The pelvic plane was then established by ASISs and PTs. An acetabular plane was also computed by fitting the multiple points on the acetabular rim to a plane using the least-square error criterion for determination of cup alignment relative to the pelvic plane.

Anterior Frontal Pelvic Plane Orientation: Flexion of the pelvic plane is defined as the pubis posterior to ASIS and extension as the pubis anterior to the ASIS in the midline. Thus, the (+) Flexion and (-) Extension have different meanings depending on the base measurement and the direction. For example, the patients with extended pelvic and prominent pubic areas have negative values indicating extension and the patient’s with L-S lordosis with a posteriorly positioned pelvis have positive values indicating flexion.

Simulation of Pelvic Plane Inaccuracy (Fig. 1): The pelvic plane obtained from 3D model of cadavers and individuals was passively flexed or extended with 2° interval for the simulation of the inaccuracy of the pelvic plane. The acetabular cup was then fixed and cup alignment was calculated relative to the flexed or extended pelvic plane.

Acetabular Component Orientation: The orientation of the acetabular cup (anteversion and inclination) was determined from the acetabular plane, which is established by the landmarks digitized on the acetabular rim, relative to the pelvic plane.

Statistical Analysis: A two-sample student’s t-test (\(p < 0.05\)) with homoscedastic assumption was used to identify a significant difference between the results obtained from cadavers and individuals.

RESULTS SECTION: The relationship between potential acetabular cup misalignment and inaccuracy of pelvic plane calculated from cadavers was similar to that obtained from individuals (\(p > 0.05\)) (Fig. 2). A flexed pelvic plane generated less potential misalignment of anteversion of acetabular cup than an extended pelvic plane (Fig. 2, bottom). However, inclination of the acetabular cup was less sensitive to variation of the pelvic plane than was anteversion of the acetabular cup. This finding suggests that anteversion may be a more important factor in achieving optimum acetabular cup alignment in THA. Fig. 2 commonly showed that a possibility of potential acetabular misalignment had generally grown with increase of inaccuracy of pelvic plane (compare standard deviation at each point with varying pelvic plane). This finding indicates there may be greater acetabular cup misalignment with larger amounts of error in establishment of pelvic plane.

DISCUSSION: This study identifies that acetabular cup alignment in THA has a strong correlation with an orientation of the anterior frontal pelvic plane. Accurate establishments of the pelvic plane with computer navigation THA is important for the accuracy and reproducibility of acetabular cup alignment. In situations were there is significant pelvic tilt, the optimal functional cup position for a patient may vary. The results of this study may then also be used to compensate for degrees of pelvic tilt in conjunction with conventional alignment systems relying on the patient’s upper body or the operating table.


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Fig. 1. Simulation of anterior frontal pelvic plane orientation

Fig. 2. A relationship between acetabular cup misalignment (anteversion: top, inclination: bottom) and inaccuracy of pelvic plane