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Pelvic Tilt in Patients Undergoing Total Hip Arthroplasty: When Does it Matter?

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ABSTRACT

Pelvic tilt (PT) affects the functional anteversion and inclination of acetabular components in total hip arthroplasty (THA). One-hundred and thirty-eight consecutive patients who underwent unilateral primary THA were reviewed. Most cases had some degree of pre-operative PT, with 17% having greater than 10° of PT on standing pre-operative radiographs. There was no significant change in PT following THA. A computer model of a hemispheric acetabular component implanted in a range of anatomic positions in a pelvis with varying PT was created to determine the effects of PT on functional anteversion and inclination. Based on the study results, tilt-adjustment of the acetabular component position based on standing pre-operative imaging will likely improve functional component position in most patients undergoing THA.

Accurate placement of components during total hip arthroplasty (THA) is essential to avoid complications such as dislocation [1], impingement [2], and accelerated bearing wear [3]. Surgical navigation has been demonstrated to improve the accuracy and precision of component positioning compared to traditional freehand techniques [4]. Use of surgical navigation also offers the surgeon the ability to make fine modifications to component position based on patient factors such as pelvic tilt (PT) [5]. For example, a navigation system can calculate the tilt-adjusted anteversion of an acetabular component. Implementations of tilt-adjustment vary by manufacturer. Techniques utilized range from adjustment based on measurement of PT in a supine position by digitizing the floor plane and anterior pelvic plane (APP) to adjustment without measurement of the APP in the lateral position.

Reports in the literature are conflicting with regard to the extent and frequency of change in PT following THA [6,7]. Surgeons often make adjustments to component position in the setting of conditions like ankylosing spondylitis to protect against anterior dislocation due to the pelvic hyperextension (increased posterior PT) caused by a fixed sagittal spinopelvic relationship [8]. However, subtle PT may exist in patients without grossly evident spinal pathology. Zhu et al. found that approximately 94% of patients undergoing THA had some degree of PT when positioned supine on the operating table. They also reported that approximately 15% of patients had greater than 10° of anterior or posterior PT and suggested that accounting for PT may improve component position in these patients [9].

Changes in PT in standing and supine positions can confound these techniques of tilt-adjustment [10]. Whether PT changes postoperatively is another cause for concern when using preoperative PT for tilt-adjusted acetabular component positioning. The impact of PT on acetabular component anteversion been studied and quantified as approximately 0.7° increase in anteversion for each degree of posterior PT [11,12], but the effect of PT on acetabular component inclination may be underappreciated.

The purpose of this study was to consider the incidence of standing PT in a patient cohort undergoing primary unilateral THA and to evaluate the utility of tilt-adjusted navigation. Therefore, the following questions were posed:

1. What is the incidence of PT in patients undergoing THA?
2. Does PT change following THA? If so, can pre-operative radiographic parameters, such as PT or pelvic incidence, be used to estimate post-operative PT?
3. How does PT impact anteversion and inclination of the acetabular component?

Methods

Definitions

The anterior pelvic plane (APP) is an anatomic plane defined by the two anterior superior iliac spines (ASIS) and the pubic tubercle. The coronal plane is a functional plane and is defined as any vertical plane that divides the body into ventral and dorsal sections [12]. Pelvic tilt (PT) is the angle between the APP and the coronal plane [7]. A negative PT angle indicates posterior tilt, and a positive PT angle indicates anterior

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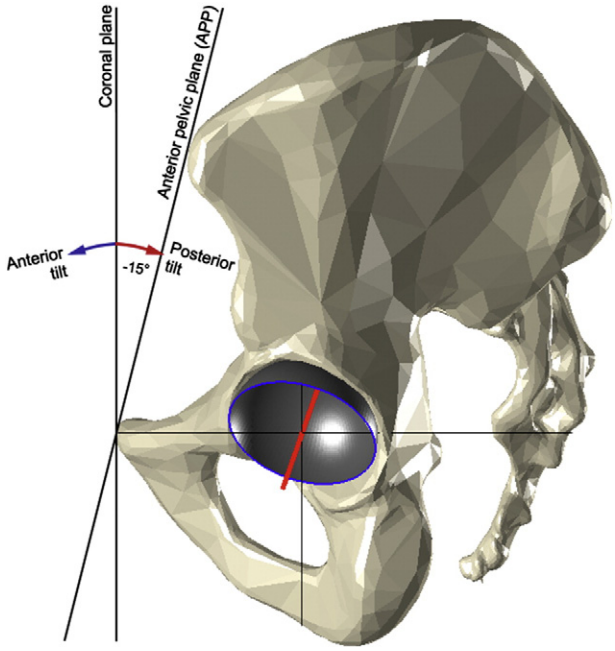

Fig. 1. A line representing the anterior pelvic plane is drawn in relation to the line representing the coronal plane in a pelvis with 15° of posterior pelvic tilt.

tilt (Fig. 1). Pelvic incidence was measured as the angle between a line perpendicular to the sacral plate at its midpoint and a line connecting this point to the midpoint between the femoral heads [13]. Radiographic anteversion is the angle between the acetabular axis and the coronal plane. Radiographic inclination is the angle between the face of the acetabular component and the transverse axis [14]. APP anteversion and inclination are the radiographic anteversion and inclination with the APP parallel to the coronal plane (Table 1). We defined functional anteversion and inclination as the radiographic measurements of anteversion and inclination of an acetabular component with the pelvic in a standing position. We elected to measure PT on standing lateral radiographs to be consistent with our evaluation of anteversion and inclination on standing AP radiographs.

Radiographic Measurements

One-hundred and thirty-eight consecutive patients who underwent a unilateral primary THA by a single surgeon were included in this study. Patients with prior contralateral THA, conversion THA, and instrumented lumbosacral fusion were excluded. Average age was 57 ± 11 years, average body mass index (BMI) was 28 ± 6 kg/m^2, and 67 patients (49%) were female. Patients had standing lateral radiographs taken pre-operatively and six weeks post-operatively. Both PT and pelvic incidence were measured pre-operatively for each patient, and PT was measured on the post-operative imaging. Sagittal PT was defined as the difference between the anterior pelvic plane and the coronal plane. Correlation coefficients were calculated between pre-operative PT and post-operative PT and pelvic incidence and post-operative PT. Student's t-test was used to test the significance of the difference in pre-operative and post-operative PT. Alpha level was set at 0.05 for all tests. Statistical analysis was performed in SPSS Statistics v22 (IBM Corp., Armonk, New York).

Computer Model

To understand the impact PT has on acetabular component orientation, an anatomically accurate three-dimensional model of a male pelvis was obtained from BodyParts3D (Database Center for Life Science, The University of Tokyo, Tokyo, Japan). This model was loaded into Matlab 2013a (The MathWorks Inc., Natick, MA) and a surface mesh of the pelvis was rendered with the center of rotation (COR) of the left hip at the origin of the coordinate system. Neutral or 0° of PT was set such that the APP was aligned to the coronal plane. A 50 millimeter 180° hemispheric acetabular shell was rigidly fixed at the center of rotation (COR) of the acetabulum with 40° APP inclination and 25° APP anteversion (Fig. 2). The pelvis and acetabular shell were rotated through the axis defined by the CORs of both hips in 1° increments from 0–30° of anterior (+) PT and 0–30° posterior (−) PT. The functional inclination and anteversion of the acetabular component was calculated for every 1°. This pelvic tilt ranging sequence was repeated for a range of acetabular component orientations with the cup positioned in the pelvis from 0° to 40° of APP anteversion and 35°–50° of APP inclination in 1° increments.

Results

Pelvic Tilt Before and After THA

Mean pre-operative PT was 0.6° ± 7.3° (range: −19.0° to 17.9°). A total of twenty-three patients (17%) had ≥10° of sagittal PT during standing, with 9 patients having ≥10° of posterior PT and 14 patients having ≥10° of anterior PT preoperatively. Mean post-operative pelvic tilt was 0.3° ± 7.4° (range: −18.4° to 15.0°). Mean change in pelvic tilt was −0.3° ± 3.6° (range: −9.6° to 13.5°), with no significant difference between pre-operative and post-operative PT ($p=0.395$). 19 patients (14%) had greater than 5° change in pelvic tilt post-operatively. Only 1 patient had greater than 10° change in pelvic tilt post-operatively. Pre-operative PT was strongly correlated with post-

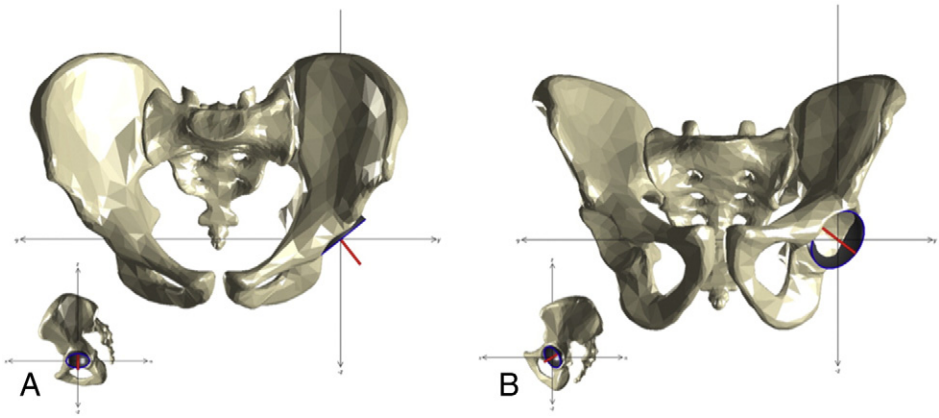

Fig. 2. Figure demonstrating position of acetabular shell with 30° APP anteversion and 40° APP inclination with A) 20° of anterior pelvic tilt and B) 20° of posterior pelvic tilt changing the functional anteversion to 44.2° and the functional inclination to 50.9°.