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Effects of posterior pelvic tilt on anterior instability in total hip arthroplasty: A parametric experimental modeling evaluation

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ABSTRACT

Background: Anterior dislocation is one of the concerns of patients with posterior pelvic tilt undergoing total hip arthroplasty. This study aimed to evaluate the magnitude of posterior pelvic tilt constituting a risk for anterior dislocation by measuring the range of motion until impingement and dislocation under various pelvic tilt.

Methods: Using a jig mounted prosthetic hip model, the ranges of external rotation at extension and internal rotation at flexion until reaching dislocation were tested. The site of impingement prior to dislocation was also recorded. Posterior pelvic tilt and the cup version were changed with 10° increments from 0° to 40° and from 10° retroversion to 30° anteversion, respectively. Effects of increasing femoral offset were also tested. We defined a required range of motion as having 30° external rotation at extension and 40° internal rotation at 90° flexion.

Findings: External rotation decreased in a posterior pelvic tilt-dependent manner. In the case with more than 20° posterior pelvic tilt, available external rotation extended beyond required range with the cup anteversion of 20°. Decreasing cup anteversion improved external rotation, however, internal rotation decreased simultaneously. In the case with posterior pelvic tilt more than 20°, only cup anteversion with 0° or 10° satisfied the required range of motion. A +4 mm horizontal offset improved external rotation by 10° with delaying bony impingement.

Interpretation: More than 20° of posterior pelvic tilt may cause anterior instability and diminish the optimal range of cup version. Increasing the femoral offset improved external rotation without reducing internal rotation.

1. Introduction

Dislocation is one of the most frequent complications following total hip arthroplasty (THA), with an incidence of 0.6% to 11% in the early postoperative period (Hedlundh et al., 1996; White et al., 2001; Woo and Morrey, 1982). Posterior dislocation is predominant, however, anterior dislocation is seen in approximately 30% of all dislocations (Di Schino et al., 2009; Dorr et al., 1983; Sariali et al., 2012). Factors affecting dislocation include patient characteristics, implant design, and variations in surgical techniques (Amstutz et al., 1975; Matsushita et al., 2009, 2010). Of these factors, 13% to 30% of dislocations are reportedly caused by implant malpositioning (Daly and Morrey, 1992; Hedlundh et al., 1997).

Surgeons place the cup by referencing pelvic bony landmarks or planes such as the anterior pelvic plane (APP), formed by the anterior superior iliac spines and pubic symphysis (Digioia et al., 2002; Eddine et al., 2001; Parratte and Argenson, 2007; Parratte et al., 2009). However, as sagittal pelvic tilt changes the version of the cup relative to femoral component, any excessive pelvic tilt may lead to functional implant malpositioning and subsequent dislocation. Previous studies have described large inter-individual variations in pelvic tilt ranging from 20° posteriorly to 20° anteriorly (DiGioia et al., 2006; Eddine et al., 2001). There are also intra-individual variations; decreased lumbar lordosis with aging leads to increasing posterior pelvic tilt in elderly people (Schwab et al., 2009). Likewise, patients with advanced-stage ankylosing spondylitis have a high incidence of posterior pelvic tilt (Bhan et al., 2008; Tang and Chiu, 2000). In these cases with posterior pelvic tilt, anterior dislocation is a concern after THA because posterior pelvic tilt is thought to be accompanied by increased anteversion of the cup. The relationship between pelvic tilt and range of motion after THA needs to be clarified in these particular cases.

The purposes of this study were to evaluate the magnitude of posterior pelvic tilt constituting a risk for anterior dislocation by measuring the range of motion (RoM) until impingement and dislocation under various pelvic tilt with use of hip model and to examine the effects of cup anteversion and horizontal offset of stem in improving the limited RoM.

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2. Methods

2.1. THA model

We developed a jig mounted Sawbones THA model with cementless 52 mm cup, 28 mm ball and cementless stem (Sawbones, Vashon, WA, USA) as previously described (Amstutz et al., 1975; Matsushita et al., 2010) (Fig. 1). This model allows the hip to move in six dimensions and mimics the hip impingement and the subsequent dislocation. Briefly, the pelvis was set so that the APP was perpendicular to the ground and parallel to the frame of the THA model (namely, pelvic tilt was 0° relative to the vertical plane). Following the previous anatomical studies (Hsu et al., 1990; Oswald et al., 1993), the femur was placed in the valgus position, 7° relative to the functional axis, whereas the center of femoral head was set at the center of rotation. A cementless stem (JMM, Osaka, Japan) was inserted into the femoral model using a standard technique. In all cases, a femoral head with a diameter of 28 mm and a neck length of +3 mm was used. A 52-mm cup (JMM, Osaka, Japan) was fixed and a flat liner with a non-elevated rim was used. A spring was placed in the bottom of the jig at distal femur to permit attachment of the cup and femoral head with a force of 20 N. Although the contact force in this study was smaller than the physiological force reported in the biomechanical study (Nadzadi et al., 2003), this study did not evaluate the mechanical force but the geometric hip motion such as the impingement and the subsequent dislocation. Therefore, the contact force does not seem to affect these evaluations. The model allowed the hip joint to be moved in six dimensions (flexion, extension, abduction, adduction, internal rotation, and external rotation), measured with reference to the anterior pelvic plane. This model was further modified in this study; the femoral axis had 7° of freedom of motion when impingement occurred, therefore a dislocation following impingement could be mimicked.

2.2. Measurements

To reconstruct posterior pelvic tilt, we configured the anterior pelvic plane from 0° to 40° posteriorly in 10° increments around the axis connecting the femoral head centers. To evaluate RoM, the ranges at which impingement and dislocation occurred were determined using a built-in goniometer (Fig. 1B). Dislocation was defined visually as the point when the marked center of the femoral head crossed the edge of the liner. We determined two ranges of motion: (i) external rotation with 0° of both extension and abduction (ER), and (ii) internal rotation at ranges of flexion from 50° to 90° with 0° of abduction (IR). The flexion angle was defined as the angle between the ground plane and femoral axis regardless of pelvic tilt. In addition, the point of impingement, that is, implant-to-implant or bone-to-bone contact, was recorded in each test. We defined a required RoM for daily life as having 30° of ER with 0° of extension, and 40° of IR with 90° of flexion, according to both in vitro and in vivo studies (Miki et al., 2007; Nadzadi et al., 2003; Seki et al., 1998; Sugano et al., 2012; White et al., 2001).

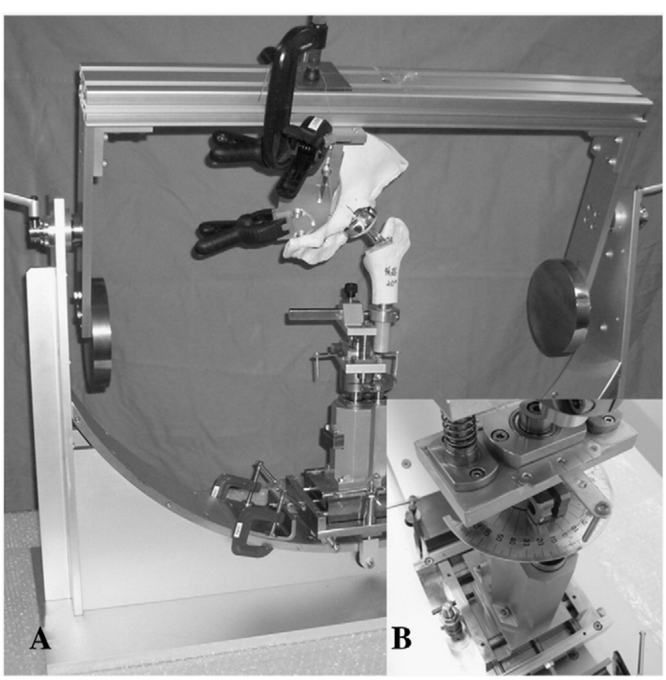

Fig. 1. A THA model used in this study. (A) The THA model, which can be moved in six dimensions (flexion, extension, abduction, adduction, internal rotation, and external rotation) with reference to the vertical axis, can mimic impingement and dislocation. (B) A goniometer was set to this apparatus with the precision of ±1° in each measurement.

2.3. Cup anteversion and femoral offset

Anteversion of the cup was determined using the radiographic definition. Briefly, the angle of anteversion was defined as the version angle along the axis of acetabular cup at the coronal plane (Murray, 1993). Cup was set from 10° of retroversion to 30° of anteversion. The inclination of the cup was fixed at 45°. In each component position, the center of rotation remained at the femoral head center. The Lewinnek's safe zone was defined as the cup anteversion from 5° to 25° (Lewinnek et al., 1978). The cup anteversion required for the case with posterior pelvic tilt was compared to the Lewinnek's safe zone.

Two different horizontal offsets were tested: standard (0 mm) and 4 mm lateral (+4 mm offset.) The neck shaft angles were 135° and 130°, respectively.

3. Statistical methods

All measurements were performed in triplicate; the average was used as the RoM. The IR and ER in each pelvic tilt and cup anteversion were evaluated with linear regression method. The slopes of the liner regression were recorded.

4. Results

Posterior pelvic tilt resulted in a decreased ER in a pelvic tilt-dependent manner with any anteversion of the cup (Fig. 2). In the case with 20° of the cup anteversion, decrease in ER occurred at rate of −0.83° per degree of posterior pelvic tilt ($R^2 = 0.99$). The site of impingement was between the posterior greater trochanter and ischium from 0° to 20° posterior pelvic tilt and changed to the implant impingement between neck and liner at more than 20° posterior pelvic

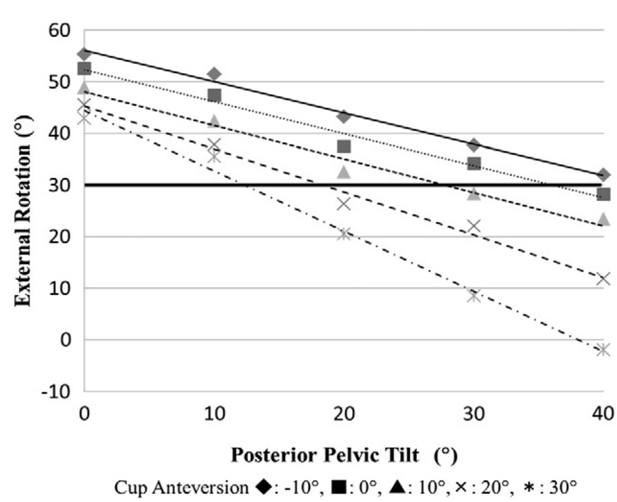

Fig. 2. The effect of posterior pelvic tilt on ER. ER decreased in a posterior PT-dependent manner. Solid, dotted and chain lines are regression lines for each cup anteversion.