Does Intraoperative Fluoroscopy Optimize Limb Length and the Precision of Acetabular Positioning in Primary THA?

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abstract

Reduced limb length discrepancy and more accurate cup positioning are purported benefits of using fluoroscopy for total hip arthroplasty (THA). The authors compared limb length discrepancy and cup position in 200 patients (group I, posterior approach without fluoroscopy; group II, anterior supine approach with fluoroscopy) who underwent primary THA. Mean limb length discrepancy was 2.7 mm (SD, 5.2 mm; range, -9.8 to 20.9 mm) and 0.7 mm (SD, 3.7 mm; range, -11.8 to 10.5 mm) for groups I and II, respectively (P=.002). In group I, 7% of hips had limb length discrepancy greater than 1 cm compared with 3% in group II. Mean cup inclination measured 40.8° (SD, 5.0°; range, 26.1°-53.7°) in group I and 43.4° (SD, 5.6°; range, 31.3°-55.9°) in group II (P=.008). In group I, 96% of cups had inclination within 10° of the mean compared with 92% in group II (P=.24). Mean anteversion measured 35.3° (SD, 7.1°; range, 17.8°-60.7°) in group I and 25.9° (SD, 8.2°; range, 1.5°-44.8°) in group II (P=.0001). In group I, 87% of hips exhibited anteversion within 10° of the mean compared with 76% in group II (P=.045). Although the anterior approach with intraoperative fluoroscopy reduced mean limb length discrepancy, the clinical significance of this reduction is unclear. Fluoroscopy reduced the incidence of limb length discrepancy greater than 1 cm. However, the use of fluoroscopy did not help to improve the precision of cup positioning. [Orthopedics. 2015; 38(5):e380-e386.]
Total hip arthroplasty (THA) is one of the most successful interventions in orthopedic surgery. However, malpositioning of either the cup or the stem can lead to devastating complications, including limb length discrepancy, liner fracture, increased wear,2 pain, and dislocation.2-4 Orthopedic surgeons have used various techniques to optimize implant positioning, including preoperative templating, intraoperative computer-assisted navigation, and a variety of intraoperative calipers.5 Although some of these measures (ie, preoperative templating)6 led to consistent improvement of implant positioning, others showed user-dependent success rates.8

Targeted safe zones, described for both inclination and version of the acetabular component, were implemented in an attempt to reduce dislocation rates. The most commonly used recommendations for optimal inclination and version are 30° to 50° and 5° to 25°, respectively.9 The exact “safe zone” for anteversion is controversial because it is widely known that surgeons who use a posterior approach tend to place the cup in more anteversion than surgeons who use a lateral approach or an anterior approach. Recent publications advocated new safe zones of between 15° and 35° of cup anteversion;10 or even between 5° and 35°.11 Combined anteversion (anteversion of the cup and stem) for each hip differs, and thus the surgeon must be aware that cup position is only 1 of several factors (offset, limb length, and femoral anteversion) that influence hip stability.12

With alternative bearing surfaces gaining more interest because of the potential for reduction in wear rates, acetabular and femoral component positioning requires greater accuracy to minimize complications associated with edge loading and impingement. It is now accepted that hard-on-hard (ceramic and metal) bearings are less tolerant of malposition than metal-on-ultra-high-molecular-weight polyethylene bearings.13 Modalities that may improve acetabular component positioning should be investigated.

Intraoperative fluoroscopy is a widely accepted modality in all subspecialties of orthopedic surgery. It has proven to be user-friendly, accurate, and reproducible.14 This study compared limb length discrepancy and cup position produced with the posterior approach and the anterior approach with intraoperative fluoroscopy.

**Materials and Methods**

**Study Groups**

After institutional review board approval was obtained, a retrospective radiographic review was carried out on 200 consecutive primary THA procedures performed by 2 fellowship-trained orthopedic surgeons (M.J.B., J.I.H.) who were in practice for at least 9 years each and were beyond their “learning curve.” Each surgeon performed the procedure with his desired approach. Group I included 100 patients who underwent THA through a posterior approach and the anterior approach in the lateral decubitus position. The surgeon used preoperative digital templating, posterior capsular flap length, soft tissue tension, and an intraoperative jig (to measure relative positions of the patellae) to assess limb length discrepancy. Group II included 100 patients who underwent THA performed through an anterior supine approach with intraoperative fluoroscopy. All patients were treated for osteoarthritis, rheumatoid arthritis, or osteonecrosis. No patient had preoperative limb length discrepancy greater than 15 mm or significant acetabular bone loss. The surgeon’s goal was to equalize limb length for each patient. Anteverision targets were 30° for surgeon I and 20° for surgeon II, with a target range of 15° to 35° for both surgeons. Inclination targets were 40° for surgeon I and 45° for surgeon II, with a target range of 30° to 50° for both surgeons. All cups and femoral stems were cementless.

Group I included 57 women and 43 men, with an average age of 60.3 years (SD, 13.4; range, 24-86 years). Average body mass index for patients in group I was 28.9 kg/m² (SD, 7.1 kg/m²; range 18-50 kg/m²). Group II included 52 women and 48 men, with an average age of 59.3 years (SD, 13.6 years; range, 13-84 years). Fifty-five patients underwent right THA and 45 underwent left THA. Average body mass index in group II was 28.3 kg/m² (SD, 5.5 kg/m²; range, 15-46 kg/m²) (Table I). Patient demographics, age, and body mass index did not significantly differ according to a nonparametric Kruskal-Wallis test. One postoperative dislocation occurred in each group. Both of these patients were treated with closed reduction, and neither patient received an abduction brace. Neither patient had a second dislocation. No patient had a periprosthetic infection at a minimum of 2 years of follow-up. No patient in group II had audible squeaking.

**Surgical Procedure for the Posterolateral Approach**

All 100 hips in group I underwent templating preoperatively with commercially available templating software (Orthoview, Jacksonville, Florida). All 100 patients had spinal anesthesia in addition to general anesthesia. Patients were positioned in the lateral decubitus position and secured with a pegboard. After sterile preparation and draping, preoperative limb length was determined with the help of a mechanical guide on the cup inserter. After trial placement, leg length was again determined with the jig, soft tissue tension, and the relationship of the edge of the posterior capsular flap to 2 fixed points on the
intertrochanteric ridge. No intraoperative radiographs were obtained. Adjustments in stem size, head length, and stem offset were made as needed to optimize offset, limb length, and ultimately stability. After implantation of the real femoral component, final head length was determined by repeating the measurements discussed earlier. All patients received a Zimmer (Warsaw, Indiana) M/L taper stem or Versys Fiber Metal MidCoat (Zimmer) stem with 32- or 36-mm heads on highly cross-linked polyethylene liners in a Zimmer Trilogy or Continuum socket.

Surgical Procedure for the Anterior Supine Approach

All 100 patients in group II underwent templating preoperatively with acetate templates provided by the implant manufacturer on standard calibrated anteroposterior pelvis radiographs. The patients were positioned supine on a fracture table (Hana Hip and Knee Arthroplasty Table; Mizuho OSI, Union City, California) with both lower extremities secured in traction boots. The pelvis was stabilized with a well-padded perineal post. After sterile preparation and draping, an anterior approach to the hip was performed with the interval between the tensor fascia lata and the rectus femoris. After exposure of the anterior femoral neck, a neck cut was performed under fluoroscopic guidance. The acetabulum was then reamed, and the cup was placed under fluoroscopic guidance. Next, the femur was prepared and broached and a trial was inserted. After reduction, a single anteroposterior radiograph of the pelvis was obtained with the C-arm. For this image, both legs were placed in similar adduction-abduction and internal-external rotation. Images used to determine limb length discrepancy had to be of good quality and had to include both hips and both lesser trochanters. Once this was achieved, the interteardrop line was used to measure limb length discrepancy (discussed later). Adjustments to head length, stem offset, and/or stem size were made as needed. After implantation of the stem, another trial reduction was performed and limb length discrepancy was measured. Adjustments were made if needed, but never for instability because the patient’s legs were secured on the fracture table. For all patients, the Corail Total Hip System (DePuy, Warsaw, Indiana), was used, with ceramic-on-ceramic bearings with 32- or 36-mm heads.

Radiographic Measurements

An independent author (P.L.) performed all measurements on the 6-week postoperative radiographs using a picture archiving and communication system. All measurements were performed twice, with a 4-week interval between the 2 measurements. Limb length discrepancy and cup inclination were measured on a calibrated anteroposterior radiograph (beam centered over the symphysis, patellae pointing upward). Cup anteversion was measured on a calibrated cross-table lateral radiograph because a recent study showed strong correlation between anteversion measured on cross-table lateral radiographs and computed tomography scans. Three standardized, reproducible lines were used to determine limb length discrepancy. One radiographic line was drawn through the inferior border of the radiographic teardrops (interteardrop line), the second was drawn through the inferior border of the obturator foramina (interobturator line), and the third was drawn through the inferior border of the ischial tuberosities (isertuberosity line). The distance between this line and the most medial aspect of the lesser trochanters was recorded. Thus, 3 values for limb length discrepancy were recorded on each postoperative radiograph. Negative measurements indicated a shortened extremity, whereas positive measurements indicated a lengthened extremity. Cup inclination was determined by measuring the angle between a tangential line across the cup and the interteardrop line. Similarly, anteversion was calculated as the angle between a tangent of the cup face and a vertical line on cross-table lateral radiographs. Measurements were chart-

<table>
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<tr>
<th>Table 1 Demographics</th>
<th>Posterolateral Approach</th>
<th>Anterior Approach</th>
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ed with an Excel (Microsoft, Redmond, Washington) spreadsheet for further analysis. For each patient, limb length discrepancy was obtained by calculating the mean of the 3 values from the interteardrop line, interobturator line, and intertuberosity line.

**Statistics**

Data were analyzed with paired t test for continuous variables and Kruskal-Wallis test for nonparametric values. Power analysis showed that with an alpha of 0.05, a power of 0.8, and a difference in means of 1 mm, 100 patients would be needed in each group.

**RESULTS**

**Limb Length Discrepancy**

Mean limb length discrepancy was 2.7 mm and 0.7 mm for groups I and II, respectively (Table 2). In group I, 7% of hips had limb length discrepancy greater than 1 cm compared with 3% in group II. Limb length discrepancy for hips implanted with the posterolateral approach ranged from -9.8 to 20.9 mm, with a total spread of 30.7 mm. In comparison, limb length discrepancy for hips implanted under fluoroscopic guidance with an anterior approach ranged from -11.8 to 10.5 mm, with a total spread of 22.4 mm.

**Acetabular Component Position**

Mean inclination was 40.8° (SD, 5.0°) in group I and 43.4° (SD, 5.6°) in group II (P=.008) (Figure 1). In group I, 96% of cups showed inclination within 10° of the mean compared with 92% in group II (P=.24). Mean anteverision measured 35.3° (SD, 7.1°) in group I and 25.9° (SD, 8.1°) in group II (P=.0001). In group I, 87% of hips showed anteverision within 10° of the mean compared with 76% in group II (P=.045).

The authors compared cup position in the 2 groups with the safe zones defined by Lewinnek et al.⁹ They found that 96 of 100 (96%) posterior hips and 89 of 100 (89%) anterior hips were positioned in the safe zone for inclination (P=.97). In addition, 7 of 100 (7%) cups in group I and 45 of 100 (45%) cups in group II showed anteverision within the described safe zone (P=.001). Overall, 7% of cups implanted without fluoroscopy were inside the safe zone for both inclination and anteverision, compared with 40% of cups in group II (Figures 2A-B) (P=.001).

The authors also compared the percentage of cups placed in the modified safe zone of 15° to 35°. Data were plotted into this zone and showed that 58% of cups in group I and 80% of cups in group II were positioned within this modified safe zone (P=.02). When the safe zone for inclination and the modified anteverision zone were compared, 57% of cups in group I and 73% of cups in group II fell into this area (Figures 2C-D) (P=.02).

**DISCUSSION**

The primary goal of THA is restoration of normal, functional mechanics of the

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**Table 2**

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Limb Length Discrepancy, mm</th>
<th>Cup Inclination</th>
<th>Cup Anteversion</th>
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<td>Anterior THA</td>
<td>Posterior THA</td>
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<tr>
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<td>22.4</td>
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</tr>
<tr>
<td>Minimum</td>
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<td>-11.8</td>
<td>26.1°</td>
</tr>
<tr>
<td>Maximum</td>
<td>20.9</td>
<td>10.5</td>
<td>53.7°</td>
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Abbreviation: THA, total hip arthroplasty.

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**Figure 1:** Graph showing the inclination (A) and anteverision (B) of hips undergoing total hip arthroplasty (THA) performed with a posterolateral approach (red) and an anterior supine approach (blue).
hip joint. Reestablishment of physiologic joint function is the basis for pain relief, improved mobility, and stability. Many studies provided evidence that satisfactory hip function requires optimal implant position of both the acetabular and femoral components. This study showed that an anterior approach with intraoperative fluoroscopy helped to minimize limb length discrepancy. Although the statistically significant reduction in mean limb length discrepancy may be of limited clinical benefit, the substantial reduction in limb length discrepancy greater than 1 cm is clinically significant. An anterior approach with fluoroscopy did not yield more precise cup positioning.

Limitations

This study had several limitations. First, measurements of inclination and anteversion on plain radiographs do not consider pelvic tilt, which has been shown on computed tomography scan to significantly change functional angles. Second, the authors did not measure femoral component version. Current research shows that isolated evaluation of cup anteversion does not predict dislocation rates as reliably as combined version does. Combined version describes the sum of acetabular component anteversion and femoral stem anteversion. Optimal combined anteversion is believed to be 40° to 45° in women and 35° to 40° in men. Possibly, the higher anteversion angles measured in this study compared with the literature were combined with overall lower femoral anteversion angles. This could result in combined anteversion that is within a safe zone. Third, the best way to assess the influence of fluoroscopy on limb length discrepancy and cup position would be with a randomized trial with the same surgical approach. Despite the lack of randomization and the use of 2 surgical approaches, the authors believe that these data are useful because this situation represents modern surgical practice in the United States, with 2 experienced surgeons performing the same operation (THA) with the technique of their choice. Finally, the study was powered to detect differences in mean limb length discrepancy. Thus, the data may have yielded a statistically significant difference in the incidence of cup inclination outliers had there been more observations.

A difficulty in comparing these outcomes with 2 different approaches is that the targets for socket positioning may be different. Because of destabilization of the posterior soft tissues (short external rotator muscles and capsule), surgeons who use a posterior approach seek to optimize stability by placing the cup in more anteversion than when an anterior or anterolateral approach is used. Alternatively, surgeons who use an anterior or anterolateral approach prefer less cup anteversion to minimize the possibility of anterior dislocation. This discrepancy explains why the 2 surgeons had different anteversion targets. In group I, the surgeon aimed for 40° of inclination to minimize wear with a highly cross-linked polyethylene bearing. In group II, the surgeon aimed for 45° of inclination because he was less worried about wear and more concerned with impingement and edge loading with ceramic-on-ceramic bearings.

Although most patients with minor limb length discrepancy are asymptomatic, those with symptomatic moderate discrepancy can be helped with a shoe lift. However, a small minority of patients with limb length discrepancy have substantial disability as a result of pain, paresthesia, and gait instability. Bhave et al documented measurable and significant stance-time asymmetry in the gait of patients with limb length discrepancy of greater than 1 cm. Operative or nonoperative correction of this limb length discrepancy led to relief of back pain that was caused by pelvic obliquity. If implant positioning could be optimized to achieve more accurate and precise limb length equality, the number of unsatisfied patients may be minimized. Although the difference in mean limb length discrepancy in the current study (statistically significant) may not be relevant clinically, the reduction in outliers is likely to be clinically significant.

Figure 2: Scatter diagram showing the distribution of hips undergoing total hip arthroscopy (THA) with cup position within the safe zone described by Lewinnek et al (A, B) and within the modified safe zone of 15° to 35° (C, D).
Rates of dislocation and accelerated wear are influenced by both surgical and patient factors. It is well known that patient factors are inherently difficult to modify. Therefore, the authors’ goal is to optimize surgical factors in an attempt to reduce the overall complication rate. Malpositioned cups lead to higher dislocation rates\(^{11}\) and increased wear.\(^{21}\) The latter is especially critical with the use of hard-on-hard bearings, including metal-on-metal and ceramic-on-ceramic types. With these bearing combinations, suboptimal positioning can lead to edge loading, with catastrophic failure of the components. Morlock et al.\(^{22}\) established a 21- to 27-fold higher wear rate in implants that showed edge loading. These failed cups showed a steeper inclination angle than their counterparts without edge loading.\(^{22}\)

This study was designed to assess whether an anterior approach with fluoroscopy would eliminate outliers. The data showed a very high number of acetabular components implanted within the inclination safe zone for both groups (group I, 96%; group II, 89%). Anteversion, however, is a persistent challenge because patient position and the anatomy of the pelvis may not provide consistent landmarks. Intraoperative fluoroscopy may offer considerable guidance from both the anatomy of the involved hip and the contralateral side. The current results showed a significantly higher number of cups with anteversion within the safe zone in the fluoroscopically assisted patient cohort (group I, 7%; group II, 45%, \(P \leq 0.001\); or group I, 58%; group II, 80% for the modified safe zone, \(P = 0.02\)). The anteversion targets for the 2 approaches differed slightly. However, fluoroscopy did not reduce the number of anteversion outliers because 87% of hips in group I showed anteversion within 10° of the mean compared with 76% in group II (\(P = 0.045\)).

The anterior approach for THA has gained popularity over the past decade. Concerns about high complication rates in patients treated by surgeons with little experience\(^{23}\) may decrease as surgeons become more familiar with this technique. A recent multicenter cohort study involving 9 clinical sites in the United States and 1152 patients suggested similar complication rates compared with traditional approaches for THA.\(^{24}\) In addition, this study showed that surgeons with a volume of more than 100 cases per year have decreased complication rates. This finding is consistent with data from Katz et al.,\(^{25}\) who showed a decreased complication rate in Medicare beneficiaries treated by high-volume surgeons (>100 THA cases/y) vs low-volume surgeons (<50 THA cases/y). An average cup inclination of 42.1° and an anteversion angle of 19.2° have been reported.\(^{26}\) These measurements are similar to the current findings; however, limb length discrepancy was significantly lower in the current patient group treated with the anterior approach. Average limb length discrepancy in the multicenter study population was 4.0 mm compared with 0.7 mm in the current study group.

**CONCLUSION**

The use of an anterior supine approach with intraoperative fluoroscopy reduced limb length discrepancy but did not improve the precision of cup positioning.

**REFERENCES**


20. Bhave A, Paley D, Herzenberg JE. Improve-


