Leg-length Inequalities Following THA Based on Surgical Technique

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abstract

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Leg-length inequality after total hip arthroplasty (THA) is a source of patient morbidity and concern, potentially contributing to nerve palsies, low back pain, and abnormal gait mechanics. The purpose of this study was to compare the degrees of leg-length inequality in patients undergoing primary THA via 3 surgical approaches: anterior, conventional posterior, and posterior-navigated (ie, using computer navigation).

The authors reviewed the most recent 90 patients who underwent primary unilateral THA performed by a senior surgeon using an anterior, conventional posterior, or posterior-navigated approach. Measurements of leg-length inequality of the operative extremity were performed using interischial and interteardrop reference lines. One-way analysis of variance demonstrated no statistical difference in postoperative absolute leg-length inequality using interischial ($P = .11$) and interteardrop ($P = .90$) reference lines between the 3 approaches. In addition, no significant difference existed in the number of outliers in each cohort when measured relative to the interteardrop reference line. When a leg-length inequality more than 5 mm was considered an outlier, 31.1%, 20.0%, and 23.3% of patients in the anterior, conventional posterior, and posterior-navigated groups, respectively, were outliers ($P$ values range, .12 to .71). Mean±SD absolute-leg-length inequality relative to the interteardrop reference line in the anterior, conventional posterior, and posterior-navigated groups were 3.8±3.9, 3.9±3.0, and 3.9±2.7 mm, respectively. The anterior and posterior-navigated approaches demonstrated no superiority over the conventional posterior approach; all methods provided reliable leg-length equalization.

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Although primary total hip arthroplasty (THA) provides reliable pain relief and improves mobility, concerns remain regarding the accuracy of intraoperative leg-length equalization. Leg-length inequality following THA is a significant cause of patient morbidity and concern because it is associated with complications, such as sciatic, femoral, and peroneal nerve palsy, low back pain, and abnormal gait mechanics.\textsuperscript{1-7} Although the reported value of clinically significant leg-length inequality varies (range, 5-15 mm), patient dissatisfaction with leg-length inequality after THA has been reported as the most common reason for litigation against orthopedic surgeons.\textsuperscript{8}

Numerous methods have been reported to assist with the intraoperative assessment of leg-length inequality during THA. Ranawat et al\textsuperscript{9} reported using a vertical Steinmann pin at the infractroyloid groove of the acetabulum in 100 consecutive THAs and demonstrated a mean postoperative radiographic lengthening of 7.4 mm. McGee and Scott\textsuperscript{10} reported the use of a bent Steinmann pin impacted on the ilium and pointing toward the femur to measure the starting and postarthroplasty leg-length inequality. Computer navigation techniques have been implemented, with numerous studies reporting improved leg-length correction and acetabular component positioning.\textsuperscript{11-13} However, most commonly, preoperative templating of the proposed acetabular cup position, the level of femoral neck resection, and the implant sizes are solely used to assist surgeons in achieving leg-length equalization postoperatively.\textsuperscript{1,14}

The anterior approach to THA has increased in popularity, with proposed benefits including improvements in acetabular component positioning, leg-length equality, and offset restoration through the use of intraoperative fluoroscopy.\textsuperscript{15} In addition, the ability to place patients in the supine position and perform direct clinical comparisons of both lower extremities is another proposed benefit. However, no study has reported the anterior approach to be superior to the conventional posterior or the posterior-navigated (ie, posterior approach using computer navigation) approach with regard to leg-length inequality correction.

The purpose of this study was to compare the degrees of leg-length inequality in patients undergoing primary THA via 3 surgical approaches: anterior, conventional posterior, and posterior-navigated. The hypothesis was that using the posterior-navigated approach and using intraoperative fluoroscopy via the anterior approach would result in improved leg-length equalization when compared with the conventional posterior approach.

**Materials and Methods**

The authors performed a retrospective review of the radiographic results of 3 high-volume arthroplasty surgeons (M.M.A., M.P.F., D.J.M.) from an institutional review board–approved database. Each surgeon exclusively uses the direct anterior (M.M.A), conventional posterior (M.P.F.), or posterior-navigated approach (D.J.M.) for each THA. All 3 surgeons perform more than 200 THAs annually. The most recent 90 patients for each surgeon who met the inclusion criteria were included. Inclusion criteria were patients with a primary diagnosis of osteoarthritis, rheumatoid arthritis, posttraumatic arthritis, avascular necrosis, or developmental hip dysplasia (Crowe I or II) who underwent primary unilateral THA (Table 1). Exclusion criteria were patients who underwent single-stage bilateral THA or revision THA or had developmental hip dysplasia (Crowe III or IV).

The anterior approach cohort consisted of 37 men and 53 women (47 left hips, 43 right hips), the conventional posterior cohort consisted of 36 men and 54 women (43 left hips, 47 right hips), and the posterior-navigated cohort consisted of 49 men and 41 women (41 left hips, 49 right hips). The primary diagnoses for each respective cohort are presented in Table 1. All patients in the anterior and posterior-navigated cohorts underwent uncemented fixation of the acetabular and femoral components; 15 patients in the conventional posterior cohort underwent cement fixation of the femur and uncemented acetabular fixation.

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For each patient, preoperative leg-length inequality was radiographically assessed using anteroposterior radiographs of the pelvis. Leg-length inequality was measured using either an interteardrop reference line or an interischial tuberosity reference line. All radiographs were digitally measured using a picture archiving and communication system (PACS) (Sectra Imtec AB, Linköping, Sweden). A horizontal line was drawn passing through the inferior aspects of the teardrop for the left and right hips. As reported by Ranawat et al, the vertical distance between the most prominent point of each lesser trochanter

<table>
<thead>
<tr>
<th>Primary Diagnosis</th>
<th>Anterior</th>
<th>Conventional Posterior</th>
<th>Posterior-navigated</th>
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<tbody>
<tr>
<td>Osteoarthritis</td>
<td>86</td>
<td>83</td>
<td>77</td>
</tr>
<tr>
<td>Rheumatoid arthritis</td>
<td>1</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Developmental dysplasia of the hip (Crowe I or II)</td>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Avascular necrosis</td>
<td>2</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Prior femoral neck or intertrochanteric fracture</td>
<td>0</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

Table 1: Primary Diagnoses for the Anterior, Conventional Posterior, and Posterior-navigated Cohorts
and the interteardrop line was measured on both sides. The difference between the 2 sides was recorded as the preoperative leg-length inequality (Figure 1). For convention, values were recorded relative to the operative extremity (eg, if the operative extremity was short, the leg-length inequality was given a negative value). A second reference line, that was drawn across the most inferior aspects of the ischial tuberosities was also used. Leg-length inequality was then measured in a similar way (Figure 2).

Preoperative templating of the femoral and acetabular components was performed for all patients. In the anterior approach cohort, patients were placed in the supine position with both legs steriley prepared and draped. Intraoperative fluoroscopy was used to determine the appropriate location for femoral neck resection and alignment, the appropriate medialization of the acetabular component, and the size and fit of the femoral component. During trial reductions, fluoroscopy was used to align a metal rod across the inferior aspects of the ischial tuberosities, and its relation relative to the lesser tuberosities of each lower extremity was assessed to determine the presence of leg-length inequality. Both lower extremities were internally rotated to the same degree while these measurements were performed. The same method was used after placing the final implants. An additional clinical assessment was performed via direct comparison of the leg lengths and heel locations of both lower extremities.

In the conventional posterior cohort, preoperative planning was performed to determine the center of rotation of the femoral head and its distance from the top of the lesser trochanter. Appropriate acetabular and femoral component position and size were planned to equalize preoperative leg-length discrepancies. Intraoperatively, after dislocating the femoral head, the center of the femoral head was marked using electrocautery, and the distance between the center and the top of the lesser trochanter was determined before the femoral neck resection. Based on the preoperative plan, the appropriate amount of femoral neck resection relative to the lesser trochanter was chosen. After acetabular and femoral component preparation, the distance from the center of the femoral head to the lesser trochanter was reassessed to determine whether the extremity had been lengthened or shortened appropriately.

In the posterior-navigated cohort, an imageless computer-assisted surgery system (AchieveCAS; Smith & Nephew Inc, Memphis, Tennessee) was used intraoperatively in all patients. Prior to placing the patient in the lateral decubitus position, 2 Steinmann pins were placed in the iliac crest for the placement of a pelvic array, and the anterior superior iliac spines and the pubic symphysis were landmarked to define the anterior pelvic plane. In addition, an electrode sticker was placed on the lateral epicondyle of the ipsilateral femur prior to preparing and draping the lower extremity. After performing the surgical approach, a 10×3.5-mm cortical screw was inserted on the greater trochanter and prior to dislocating the femur. The greater trochanteric screw and the distal electrode were landmarked prior to dislocation of the femoral head to determine the initial femoral offset and leg length. After all trial implants were inserted, repeat registration of the greater trochanter screw and electrode was performed to determine the change in leg length and the femur offset. The same method was used after placing the final implants to assess the appropriate lengthening or shortening of the operative extremity based on preoperative templating.

For each patient, postoperative leg-length inequality was radiographically assessed using anteroposterior radiographs of the pelvis (Figures 3, 4) at first follow-up, typically 6 weeks postoperatively. All radiographic measurements of leg-length inequality were independently measured by 2 observers (D.N., P.K.S.) who were blinded to the treatment arm groups. and the results were assessed for interobserver reliability.

Statistical Methods
All data were collected and analyzed using Microsoft Excel software (Microsoft Corporation, Redmond, Washington). Statistical comparisons between the 3 cohorts were performed using 1-way analysis of variance, with statistical significance set at a P value less than .05. The number of outliers in each cohort was determined, with outlier levels set at a leg-length inequality of greater than 5 mm and a leg-length inequality of greater than 10 mm. Fischer’s exact tests were used to compare the number of outliers in each cohort, with statistical significance set at a P value less than .05.
Interclass correlation coefficients for postoperative radiographic measurements were graded using previously reported semiquantitative criteria: excellent for .9 < P < 1.0, good for .7 < P < .89, fair for .5 < P < .69, low for .25 < P < .49, and poor for .0 < P < .24.17

RESULTS

A comparison of preoperative variables, including mean age, body mass index, and preoperative leg-length inequality are presented in Table 2. Absolute preoperative leg-length inequality values account for extremities that were short or long with regard to the contralateral extremity. Mean patient age in the posterior-navigated cohort was significantly younger than the other 2 cohorts (P < .01). Using the interteardrop and interischial reference lines, no statistically significant difference existed between mean body mass index and mean preoperative leg-length inequality among the 3 cohorts.

In addition, no statistically significant difference existed in absolute postoperative leg-length inequality between the 3 cohorts. Mean postoperative leg-length inequalities relative to the interteardrop reference line in the anterior, conventional posterior, and posterior-navigated cohorts were 3.8 ± 3.9, 3.9 ± 3.0, and 3.9 ± 2.7 mm, respectively (P = .99). Mean postoperative leg-length inequalities relative to the interischial reference line in the anterior, conventional posterior, and posterior-navigated cohorts were 6.2 ± 4.4, 5.1 ± 4.2, and 5.0 ± 4.1 mm, respectively (P = .10). However, when 1-way analysis of variance analysis was performed for leg-length inequality without taking the absolute values of the measurements, a significant difference existed between the anterior and posterior-navigated groups. Mean leg-length inequalities relative to the interteardrop reference line in the anterior, conventional posterior, and posterior-navigated cohorts were 1.7 ± 4.4, 1.1 ± 4.8, and −1.4 ± 5.4 mm, respectively (P < .01). Therefore, the mean value in the anterior cohort indicated a tendency toward a lengthened operative extremity, whereas patients in the posterior-navigated cohort more often had a shortened operative extremity.

No significant difference existed in the number of outliers in each cohort when measured relative to the interteardrop reference line. When a leg-length inequality more than 5 mm (short or long) was considered an outlier, the percentage of patients in the anterior, conventional posterior, and posterior-navigated cohorts was 31.1%, 20.0%, and 23.3%, respectively (P value range, .12–.71). When a leg-length inequality more than 10 mm (short or long) was considered an outlier, 2.2%, 4.4%, and 4.4%, patients in the anterior, conventional posterior, and posterior-navigated cohorts, respectively, were considered outliers (P value range, .68–1.0).

The interobserver correlation coefficient for the measurement of postoperative leg-length inequality relative to the interischial reference line was good (r = 0.89), as was the leg-length inequality relative to the interteardrop reference line (r = 0.85).

DISCUSSION

Leg-length inequality following THA is a significant source of patient dissatisfaction and concern because patients can detect subtle discrepancies in leg lengths postoperatively.18 The reported incidence of patients detecting leg-length inequality following THA varies significantly but can be as high as 32%.19 Several surgical techniques have been implemented to improve leg-length equalization accuracy, including several commercially available leg-length calipers, variations in surgical

Table 2

Preoperative Demographic Variables and Leg-length Inequalities

<table>
<thead>
<tr>
<th>Variable</th>
<th>Approach, Mean ± SD</th>
<th>1-way ANOVA, P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y</td>
<td>67.5 ± 10.7</td>
<td>&lt; .01</td>
</tr>
<tr>
<td>BMI, kg/m²</td>
<td>28.7 ± 5.4</td>
<td>.56</td>
</tr>
<tr>
<td>Preop interischial LLI, mm</td>
<td>6.6 ± 5.9</td>
<td>.93</td>
</tr>
<tr>
<td>Preop interteardrop LLI, mm</td>
<td>5.7 ± 5.4</td>
<td>.47</td>
</tr>
</tbody>
</table>

Abbreviations: BMI, body mass index; LLI, leg-length inequality; Preop, preoperative.
technique, the use of computer navigation, and the application of intraoperative fluoroscopy when using the direct anterior approach. However, the current study demonstrates that neither using intraoperative fluoroscopy with the anterior approach nor computer navigation via the posterior approach is superior to the conventional posterior approach in restoring leg-length equality following THA.

Proposed benefits of using computer navigation in THA are improved accuracy in acetabular component positioning and improved restoration of leg-length equality and femoral offset. Manzotti et al performed a match-paired analysis of 48 patients undergoing computer-assisted THA vs 48 patients undergoing traditional THA, both via the posterolateral approach. They reported a statistically significant improvement in the computer-assisted group, with a mean postoperative leg-length discrepancy of 5.06±2.99 mm compared with 7.64±4.36 mm in the traditional group (P = .04). Similarly, it has been suggested that the anterior approach to THA leads to more accurate leg-length equalization compared with traditional approaches because it allows the use of intraoperative fluoroscopy and direct comparison of leg lengths between the 2 extremities.

Matta et al retrospectively reviewed 494 primary THAs performed through an anterior approach. They achieved a mean postoperative leg-length discrepancy of 3±2 mm and concluded that the anterior approach allows accurate restoration of leg lengths in THA. In the current study, mean postoperative leg-length inequalities for all groups were similar, with mean values of 3.8±3.9, 3.9±3.0, and 3.9±2.7 mm for the anterior, conventional posterior, and posterior-navigated cohorts, respectively. Therefore, all 3 surgical techniques in the current study were equally and highly accurate in achieving acceptable leg-length equalization postoperatively.

The most likely reason all 3 groups in the current study were highly accurate but still at risk of having outliers is that each method is susceptible to several error sources. In the anterior approach, subtle rotations of the pelvis and extremities can affect the intraoperative fluoroscopic views obtained. Also, it is difficult to obtain a single fluoroscopic view of the entire pelvis, and simultaneous radiographic comparison of both extremities can be difficult. In addition, direct visual comparison of the location of the calcanei of each extremity is subject to error. Regarding the use of computer navigation, although systems may be able to accurately show how much the operative extremities have been lengthened or shortened relative to the starting position, surgeons still rely on preoperative templating to determine the amount to lengthen or shorten. In addition, as with all navigation systems, appropriate registration of anatomic landmarks is crucial and subject to variability. Regarding the posterior approach, the accuracy of measuring and recreating the distance from the lesser trochanter to the center of the femoral head is highly user-dependent, and this approach depends on preoperative templating, which can be subject to magnification errors.

Although no significant difference existed between the 3 approaches to THA regarding postoperative leg-length inequality, several limitations existed to the current study. First, although the preoperative goal of each THA was to achieve leg-length equalization, intraoperatively, surgeons may have to decide whether to lengthen the operative extremities for improved stability. Whether this was considered intraoperatively was not recorded. Second, each cohort consisted of a single surgeon; thus, the reproducibility of these results is questionable. All 3 surgeons specialize in adult reconstruction and solely perform primary THAs using their respective approaches. Therefore, reviewing the results of these high-volume arthroplasty surgeons was the best indicator of whether a difference existed in the accuracy of leg-length equalization via each approach.

**CONCLUSION**

Based on the current findings, surgeons who are less experienced should not choose a specific surgical approach with the belief that it will improve leg-length correction following THA. Although each surgical approach has its benefits, the authors found no leg-length correction to be different among the 3 approaches analyzed. All postoperative measurements were performed using anteroposterior pelvic radiographs, which are subject to rotational and magnification error. All radiographs were calibrated to the same degree of magnification, as is the institution’s standard, but the presence of flexion contractures of the hip and rotational abnormalities of the femur can also affect the accuracy of radiographic measurements. Despite these limitations, this study demonstrated that neither the anterior nor posterior-navigated approach is superior to the conventional posterior approach in achieving leg-length equalization after THA.

**REFERENCES**

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