



Original research

Anatomic Total Hip Component Position Is More Reproducible With the Direct Anterior Approach Using Intraoperative Fluoroscopy

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ABSTRACT

Background: Total hip arthroplasty (THA) has demonstrated excellent results regardless of the surgical approach. However, the approach used may be a factor in final positioning of implants. We hypothesized that the direct anterior approach (DAA) with fluoroscopy would be associated with more anatomic implant positioning than the posterior approach (PA).

Methods: A retrospective review of 200 patients was performed. One hundred patients underwent THA utilizing the PA, and 100 patients, with the DAA. All patients had an anterior-posterior pelvis radiograph preoperatively and postoperatively with a magnification marker present to standardize each radiograph. Exclusion criteria included contralateral THA or any pelvic or femoral deformity.

Results: Preoperative radiographs demonstrated identical cohorts with respect to leg length, femoral offset, and total offset. Postoperatively, the DAA achieved more accurate anatomic restoration of leg length (1.6 mm vs 5.5 mm; $P < .0001$), femoral offset (4.8 mm vs 9.3 mm; $P < .0001$), and total offset (0.5 mm vs 4.7 mm; $P < .0001$) compared with the PA. Ideal cup abduction and anteversion were significantly superior to the DAA (96% vs 78%, $P = .0002$, and 69% vs 24%, $P < .0001$, respectively).

Conclusions: This study is the first to compare anatomic implant positioning between patients undergoing THA with these 2 approaches. All parameters were significantly closer to anatomic implant positioning with the DAA. There are at least 2 potential explanations for this: (1) The DAA implant positioning was performed under fluoroscopic guidance, whereas the PA was not. (2) The PA disrupts the posterior capsule and external rotators, and therefore, increased offset or leg length may be necessary to achieve comparable hip stability with the DAA.

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Introduction

Total hip arthroplasty (THA) is a highly successful surgical procedure, with numerous studies demonstrating excellent clinical outcomes [1–3]. Although the results of THA are generally good, there remains substantial debate regarding which surgical approach is superior for primary THA [4,5]. There are 2 principal methods for accessing the hip joint for THA, the posterior approach (PA) and the direct anterior approach (DAA). In the United States, the PA has been the dominant choice for surgeons. However, recent adoption of the DAA has resulted in a substantial shift from the PA

to the DAA. Studies have evaluated clinical outcomes after PA vs DAA THAs, and the results have been mixed with no clear consensus to support one approach over the other [6,7].

Most studies comparing the PA and DAA focus on clinical results, while there are fewer studies evaluating radiographic outcomes [4,8]. Lower dislocation rates and improved wear rates have been identified in implants that are more anatomically positioned regardless of the approach [9–11]. It should be noted that most of the comparative studies have focused on cup position but have largely ignored the femoral component with the exception of leg length. Femoral offset and/or total offset can substantially affect the function of the hip abductor muscles [12,13]. During hip replacement, most surgeons attempt to position the acetabular component in a relative “safe zone” and utilize the femoral component to recreate leg length and offset. Therefore, the goal of either approach is to achieve ideal implant position, which encompasses a safe

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Table 1
Patient demographics.

| Patient demographics | Anterior N = 100 | Posterior N = 100 | P-value ^a | Overall N = 200 patients |
|-------------------------------|-------------------|-------------------|----------------------|--------------------------|
| Sex, n (%) | | | .4777 | |
| Female | 57 (57.0%) | 52 (52.0%) | | 109 (54.5%) |
| Male | 43 (43.0%) | 48 (48.0%) | | 91 (45.5%) |
| Age (y) at surgery, mean (sd) | 59.8 (10.7) | 61.7 (12.7) | .2473 | 60.8 (11.7) |
| Age groups, n (%) | | | .2753 | |
| <60 y | 47 (47.0%) | 42 (42.0%) | | 89 (44.5%) |
| 60–<70 y | 38 (38.0%) | 34 (34.0%) | | 72 (36.0%) |
| 70+ y | 15 (15.0%) | 24 (24.0%) | | 39 (19.5%) |
| BMI at surgery, median (IQR) | 28.3 (25.4, 31.9) | 28.7 (25.7, 32.3) | .6093 | 28.5 (25.6, 32.0) |
| BMI WHO categories, n (%) | | | .9047 | |
| Underweight | 1 (1.0%) | — | | 1 (0.5%) |
| Normal weight | 23 (23.0%) | 22 (22.0%) | | 45 (22.5%) |
| Preobesity | 38 (38.0%) | 39 (39.0%) | | 77 (38.5%) |
| Obesity class I | 25 (25.0%) | 23 (23.0%) | | 48 (24.0%) |
| Obesity class II | 9 (9.0%) | 10 (10.0%) | | 19 (9.5%) |
| Obesity class III | 4 (4.0%) | 6 (6.0%) | | 10 (5.0%) |
| Operative side, n (%) | | | .0324 | |
| Left | 51 (51.0%) | 36 (36.0%) | | 87 (43.5%) |
| Right | 49 (49.0%) | 64 (64.0%) | | 113 (56.5%) |
| Diagnosis, n (%) | | | .4480 | |
| Degenerative arthritis | 85 (85.0%) | 84 (84.0%) | | 169 (84.5%) |
| Osteonecrosis | 6 (6.0%) | 10 (10.0%) | | 16 (8.0%) |
| Other | 9 (9.0%) | 6 (6.0%) | | 15 (7.5%) |

Add as legend: ^aP = .05.

range of cup abduction and anteversion, as well as to restore leg length and offset to the patient's normal anatomy (represented by the contralateral hip).

The ability to achieve anatomic implant positioning using either surgical approach is largely unknown. To our knowledge, no study has evaluated how often this combination of radiographic parameters (acetabular and femoral implant position) is comparatively achieved. Specifically, is one approach better at achieving anatomic implant position, which includes cup position, as well as restoring leg length and offset to the patient's normal anatomy? Therefore, the following study was designed to compare these radiographic parameters between 2 cohorts: (1) A cohort of THAs performed through the PA without intraoperative imaging; (2) A cohort of THAs performed through the DAA with intraoperative fluoroscopy.

Material and methods

After obtaining institutional review board approval, the following study was performed. This consisted of a retrospective review of our total joint replacement database. The following screening criteria were used to select the 2 cohorts of patients: (1) 100 consecutive PA patients, (2) 100 consecutive DAA patients, (3) unilateral hip replacement, (4) no pelvic or femoral hardware, (5) no developmental hip dysplasia or protrusio deformity. Patients were enrolled contemporaneously into each cohort.

The PA cohort consisted of 100 consecutive patients who underwent a PA THA between 3–2010 and 12–2011. All patients underwent primary THA by one of 5 fellowship-trained surgeons. All procedures were performed in the lateral decubitus position. Only

Table 2
Preoperative radiographic review.

| Radiographic variables, mean (sd) | Anterior N = 100 | Posterior N = 100 | P-value ^a | Overall N = 200 patients |
|-----------------------------------|------------------|-------------------|----------------------|--------------------------|
| Pre-operative leg length (mm) | –1.3 (4.3) | –2.2 (5.5) | .2253 | –1.8 (5.0) |
| Pre-operative femoral offset | 37.7 (6.4) | 36.0 (7.2) | .0827 | 36.8 (6.8) |
| Pre-operative total offset | 68.9 (9.0) | 68.1 (10.3) | .5594 | 68.5 (9.6) |

Add as legend: ^aP = .05.

one surgeon in this cohort obtains routine intraoperative imaging. The external rotators and the posterior capsule were repaired in each case. Implant positioning was based on preoperative templating and intraoperative stability assessments.

The DAA cohort consisted of 100 consecutive patients treated by 2 fellowship-trained total joint replacement surgeons during the same time interval as the PA cohort. All surgeries were performed in the supine position on a Hana table (Mizuho OSI, Union City, CA) with fluoroscopic guidance for implant placement. Each surgeon matched the intraoperative anteroposterior (AP) pelvis fluoroscopic view to the preoperative AP standing pelvis radiograph before implant positioning. The capsule was routinely repaired in all cases. Implant positioning was based on preoperative imaging, intraoperative imaging, and stability assessments.

Radiographic assessment

A preoperative AP pelvis standing radiograph was obtained on all patients with a 25-mm magnification marker ball for radiographic standardization. All radiographs were performed by the same radiology team. Radiographs were initially reviewed to confirm the previously specified inclusion/exclusion criteria. Subsequently, femoral offset, total offset, and leg length were recorded

Table 3
Postoperative radiographic review.

| Radiographic variables, mean (sd) | Anterior N = 100 | Posterior N = 100 | P-value ^a |
|-------------------------------------|------------------|-------------------|----------------------|
| Post-operative leg length (mm) | 0.3 (1.1) | 3.3 (5.7) | <.0001 |
| Δ (leg length), mean (sd) | 1.6 (4.3) | 5.5 (5.7) | <.0001 |
| (range) | (–9.7, 18.9) | (–6.7, 23.1) | |
| Ideal leg length (±5 mm), n (%) | 77 (77%) | 49 (49%) | <.0001 |
| Post-operative femoral offset | 42.5 (7.0) | 45.3 (7.0) | .0059 |
| Δ (femoral offset), mean (sd) | 4.8 (5.1) | 9.3 (5.8) | <.0001 |
| (range) | (–6.6, 17.3) | (–3.7, 26.0) | |
| Ideal femoral offset (±5 mm), n (%) | 49 (49%) | 21 (21%) | <.0001 |
| Post-operative total offset | 69.3 (9.0) | 72.7 (8.5) | .0064 |
| Δ (total offset), mean (sd) | 0.5 (5.0) | 4.7 (6.2) | <.0001 |
| (range) | (–12.9, 16.5) | (–8.9, 21.0) | |
| Ideal total offset (±5 mm), n (%) | 77 (77%) | 45 (45%) | <.0001 |

Add as legend: ^aP = .05.

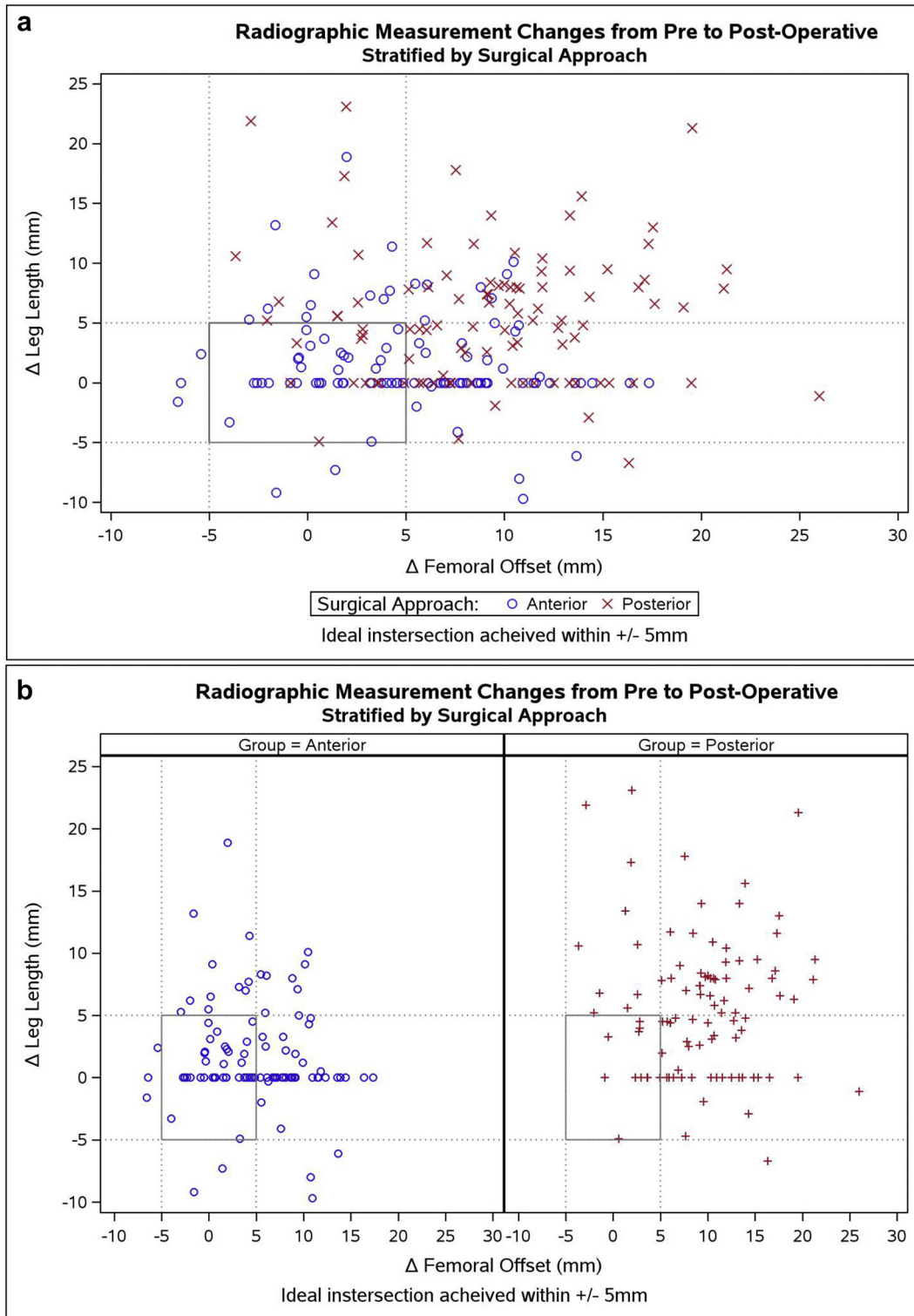


Figure 1. (a) Radiographic measurement changes from before to after surgery stratified by surgical approach. (b) Radiographic measurement changes from before to after surgery stratified by surgical approach, individually represented.

on each patient on the contralateral hip as described by Brun [14] using TraumaCad (Brainlab, Westchester, IL). Postoperatively, a standing AP pelvis radiograph was obtained with a 25-mm magnification marker ball present again. Femoral offset, total offset, leg length, and cup abduction and anteversion were recorded. Femoral offset, total offset, and leg length were determined using the same technique preoperatively. Acetabular component

abduction and anteversion were recorded for each cohort. “Ideal” abduction was defined as 30°-50° of inclination based on the “safe zone” described by Lewinnek [15]. “Ideal” anteversion was defined as a cup position between 5° and 25° of anteversion as described by Liaw [16]. Ideal leg length and femoral and total offset were confirmed if the postoperative measurement was within ± 5 mm of the contralateral “normal” hip [17]. We defined anatomic implant

Table 4
Abduction and anteversion (overall and stratified by group).

| Component position | Stratified by group | | P-value ^a | Overall N = 200 Patients |
|--------------------------|---------------------|-------------------|----------------------|-----------------------------|
| | Anterior N = 100 | Posterior N = 100 | | |
| Ideal abduction, n (%) | 96 (96.0%) | 78 (78.0%) | .0002 | 174 (87.0%) |
| Ideal anteversion, n (%) | 69 (69.0%) | 24 (24.0%) | <.0001 | 93 (46.5%) |
| Ideal, n (%) | 66 (66.0%) | 16 (16.0%) | <.0001 | 82 (41.0%) |
| Abduction, mean (sd) | 39.0 (5.2) | 41.7 (7.7) | .0041 | 40.3 (6.7) |
| Anteversion, mean (sd) | 23.4 (6.5) | 30.3 (7.0) | <.0001 | 26.8 (7.6) |

Add as legend: ^aP = .05.

position to be the combination of ideal abduction (30°–50°), ideal anteversion (5°–25°), and restoration of leg length and offset to within ±5 mm of the contralateral normal hip.

Statistical analysis

All data underwent descriptive statistical analysis using SAS, version 9.4 (SAS Institute, Cary, NC; <http://www.sas.com/software/sas9>). Chi-square or Fisher's exact tests, where appropriate, were used for categorical variables and t-tests for normally distributed or Wilcoxon 2-sample tests for non-normally distributed data were used for continuous variables to compare the anterior approach group with the PA group at an alpha level of 0.05. Paired t-tests were used to test the measurement changes from before to after surgery.

Results

Patient demographics

The final cohort consisted of 200 patients, 100 in the DAA cohort and 100 in the PA cohort. There were no statistically significant differences between the 2 cohorts when comparing age, gender, BMI, or preoperative diagnosis (Table 1). The average patient age was approximately 60 years in each cohort with an average BMI of approximately 28 kg/m². The most common predisposing condition was osteoarthritis.

Preoperative radiographs

All preoperative radiographs were reviewed on the contralateral "normal hip" to determine leg length, femoral offset, and total offset (Table 2). These parameters were used to establish the anatomic implant position at the time of hip replacement for the involved hip. There were no statistically significant differences for any of the parameters between these 2 cohorts.

Postoperative radiographs

All postoperative radiographs were reviewed and compared with the contralateral hip. We identified statistically significantly improved restoration of leg length, femoral offset, and total offset in the DAA cohort. In addition, the DAA cohort was statistically more likely to achieve "ideal" leg length as well as femoral and total offset (Table 3).

A scatter plot of each patient's change in leg length and femoral offset from preoperative to postoperative was then constructed. The "ideal" (±5mm) change was also included to demonstrate how accurate each method was in achieving this change (Fig. 1).

Utilizing an "ideal" position for acetabular component inclination between 30° and 50°, the DAA achieved this change significantly more frequently than the PA. Similarly, utilizing an "ideal" position for cup anteversion between 5° and 25°, the change was

achieved significantly more frequently with the DAA. The DAA also had significantly fewer outliers in anteversion (Table 4).

A similar scatter plot of each patient was then constructed, this time including abduction and anteversion of the acetabular component. The Lewinnek "safe zone" was also included to demonstrate how accurate each method was in achieving this (Fig. 2). Excessive anteversion was significantly more common with the PA than with the anterior approach ($P < .0001$).

Finally, we determined the probability of achieving anatomic implant position. This group included patients who had acetabular inclination from 30° to 50°, anteversion from 5° to 25°, and leg length and total and femoral offset within 5 mm (Table 5). The DAA achieved anatomic implant position 26% of the time vs one percent for the PA cohort ($P < .0001$).

Discussion

Achieving anatomic implant position is one of the primary goals of THA. Ideal implant position has mainly focused on cup position as a means of decreasing dislocation and wear rates [15]. It is well established that increased acetabular component anteversion and abduction have been associated with increased wear [10] and instability [9]. However, there are recent data to suggest that anatomic restoration of leg length and both femoral and total offset can achieve better hip kinematics [18], as well as improved wear rates [11], stability [19], and abductor muscle function [17]. Most surgeons utilize a combination of acetabular and femoral parameters to achieve anatomic restoration of the hip joint. However, before this study, we are unaware of any comparative study that has assessed the ability to achieve anatomic implant position.

Our study was specifically designed to determine if the DAA, with fluoroscopic guidance, achieved more anatomic implant positioning than the PA without image guidance. The DAA had statistical improvements in placement of the acetabular component and restoring leg length and femoral and total offset. We believe that this may be related to several factors. First, the routine use and ease of incorporation of intraoperative fluoroscopic implant positioning likely decreases outliers in implant position and can aid in more accurately "fine-tuning" implant position [20,21]. Second, disruption of the posterior capsule and external rotators decreases stability of the hip joint and increased offset and/or leg length may be necessary to improve stability [22,23]. Finally, the lateral decubitus position with the leg freely mobile allows for easier assessment of stability with the PA than with the DAA. It is possible that more emphasis is placed on achieving intraoperative stability with the PA for fear of dislocation. Although the goal initially for the PA might be to achieve anatomic implant position, an intraoperative assessment of stability that demonstrates early impingement will typically prompt a change in implant positioning or an increase in offset/leg length.

There are several potential benefits of achieving anatomic restoration of leg length, offset, and cup abduction/anteversion. Decreasing femoral offset by greater than 5 mm has been

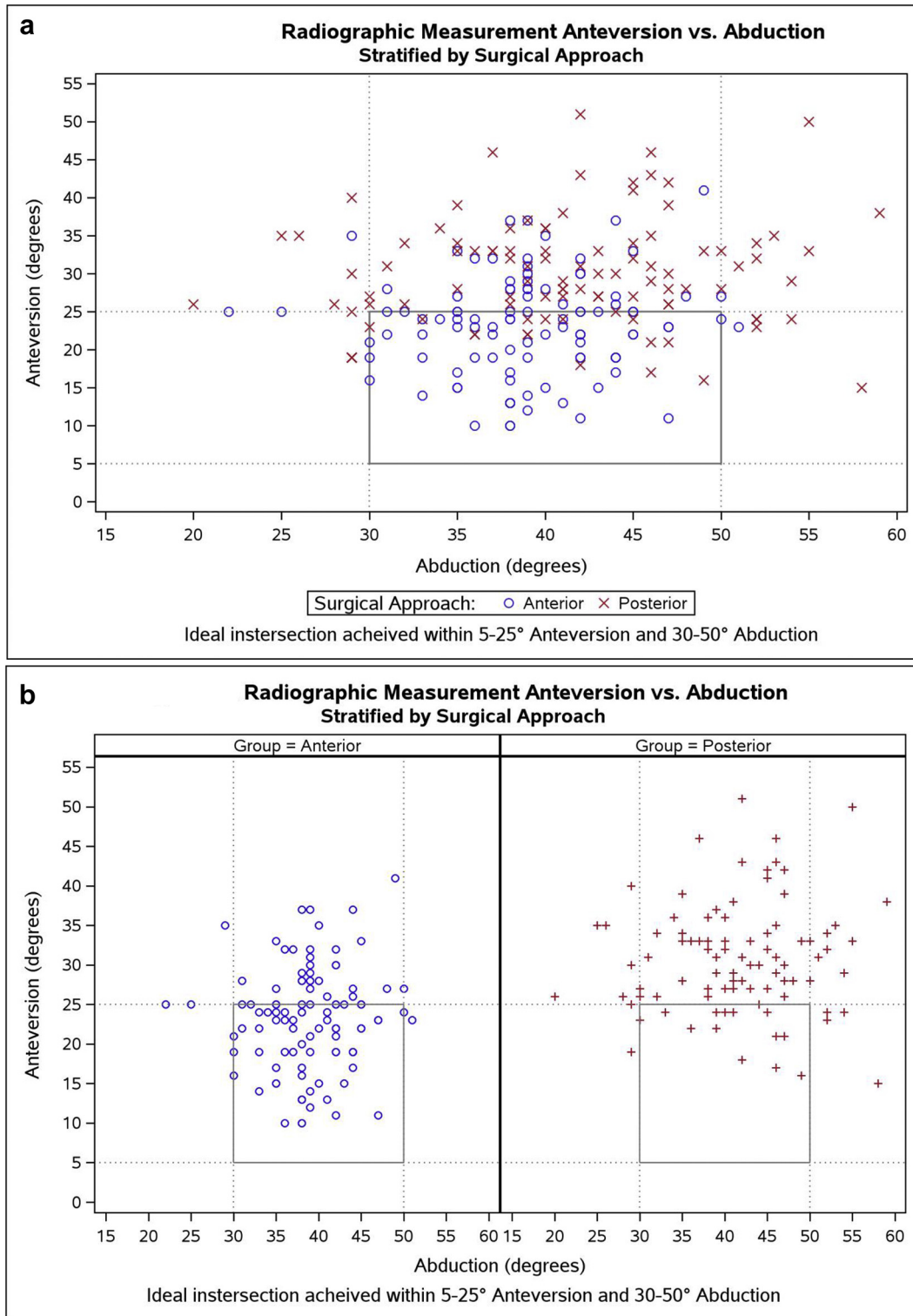


Figure 2. (a) Radiographic measurement anteversion vs abduction stratified by surgical approach. (b) Radiographic measurement anteversion vs abduction stratified by surgical approach.

associated with a significant reduction in abductor muscle strength [12]. However, increasing offset or leg length by greater than 5 mm is associated with significant negative change in gait pattern and walking speed [17]. In our study, the PA increased offset and leg length by about 5 mm on average (range: -4 to 26 mm). This could potentially result in a higher incidence of altered gait mechanics, implant wear, and worse abductor function for this patient

population [12,13]. In addition, implant position, specifically cup abduction and anteversion angles, has been a focus of optimization to increase hip stability and decrease implant wear [9,24]. However, Abdel et al. [25] have recently called into question the so-called “safe zone” for hip abduction and anteversion. They demonstrated that most hip dislocations (58%) occur within this “safe zone.” Numerous studies have demonstrated increased instability

Table 5
Ideal implant position.

| Recall variables plus new ideal variable | Stratified by group | | P-value ^a | Overall N = 200 patients |
|---|---------------------|-------------------|----------------------|--------------------------|
| | Anterior N = 100 | Posterior N = 100 | | |
| Ideal, n (%) | 66 (66.0%) | 16 (16.0%) | Table 3 | 82 (41.0%) |
| Ideal leg length (± 5 mm), n (%) | 77 (77%) | 49 (49%) | Table 2 | 126 (63%) |
| Ideal femoral offset (± 5 mm), n (%) | 49 (49%) | 21 (21%) | Table 2 | 70 (35%) |
| Ideal implant position, n (%) | 26 (26%) | 1 (1%) | <.0001 | 27 (13.5%) |

^a Chi-square test was used for categorical data to determine statistical significance between groups at an alpha level of 0.05.

in patients with spinopelvic disease ranging from prior lumbosacral fusions to hypermobility [26–28]. Although spinopelvic relationships certainly can impact hip stability, traditional targets in implant positioning have not changed drastically. It should be noted that the DAA with fluoroscopy achieved the “ideal” abduction and anteversion angles significantly more consistently than the PA, and this may become increasingly important when executing operative plans.

This study used strict inclusion and exclusion criteria. It was believed that the contralateral hip would serve as the reference point for anatomic implant position. Therefore, a large portion of patients were excluded to achieve a patient population of one hundred patients in each cohort with isolated unilateral hip arthritis and no severe deformities. By eliminating potential confounding variables, it was believed that implant position would be more dependent on the approach and image guidance and less so on anatomical variations or bony deficiencies that might alter implant position. During this study, implant position, regardless of the approach, aimed at anatomic restoration of leg length and offset as well as following similar “safe zones” for each approach.

Although this study represents one of the first attempts to define and compare anatomic implant positioning between the DAA and PA THA, there remain several limitations. First, this study is a retrospective cohort analysis with inherent limitations. However, in the setting of a prospective study, increased attention to implant position and “fine-tuning” may produce bias. Second, the PA was not routinely performed by intraoperative imaging. We have shown that the use of intraoperative fluoroscopy with the DAA significantly improves implant position. Third, femoral anteversion was not accounted for in this study. Determining offset utilizing a 2-dimensional image can be dramatically different depending on the anteversion of the femoral stem or internal/external rotation of the femur. However, we believe that this limitation would impact each group equally and therefore is only a minor limitation. In addition, we standardized foot positioning when obtaining our standing AP pelvis radiograph that may also decrease variance in femoral anteversion in this study. Fourth, no clinical outcomes were included. It should be noted that one surgeon in the posterior cohort used intraoperative radiograph for implant positioning. Even excluding this surgeon, we identified significantly more anatomic position in the DAA cohort than in the PA cohort. Our primary focus was to determine if the anterior approach with fluoroscopic guidance achieved better implant position than the PA. Finally, the cases included in the study were routine primary THAs. It is possible that the results may differ as the complexity of the cases increases. In this study, the more complex cases were removed to allow a more uniform cohort of patients.

Conclusion

Anatomic implant position, consisting of ideal leg length and offset as well as achieving precise cup position, is a primary goal of THA. This study demonstrated that the DAA with intraoperative

fluoroscopy was associated with significantly improved attainment of these goals. There are several possibilities that may explain the improved implant position of the DAA over the PA. Routine use of intraoperative fluoroscopy, lack of disruption of the posterior capsule and external rotators, and less emphasis on intraoperative stability assessments likely explain these differences in implant position with the DAA. Although no direct clinical comparisons were made between these cohorts, we believe that anatomic implant position may result in improved long-term clinical outcomes.

Conflict of interest

J.L. Masonis receives royalties from Medacta, Smith & Nephew, and Zimmer; is a paid consultant for Smith & Nephew and Zimmer; holds stock or stock options in Orthogrid; receives research support as a principal investigator from DePuy Synthes, A Johnson & Johnson Company, Smith & Nephew, and Zimmer; receives royalties, financial or material support from Medacta; is a board member for Anterior Hip Foundation. J.B. Mason receives royalties from DePuy and A Johnson & Johnson Company; is a paid consultant for DePuy Synthes A Johnson & Johnson Company; receives research support as a principal investigator from DePuy Synthes A Johnson & Johnson Company; receives royalties, financial or material support from the Journal of Arthroplasty; is a board member for Anterior Hip Foundation. J.R. Martin is a paid consultant for DePuy Synthes A Johnson & Johnson Company.

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