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Original Research

Accuracy and Precision of Acetabular Component Position Does Not Differ Between the Anterior and Posterior Approaches to Total Hip Arthroplasty With Robotic Assistance: A Matched-Pair Analysis

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ABSTRACT

Background: Deviation from planned component placement with robot-assisted total hip arthroplasty (RA-THA) may differ based on surgical approach. The purpose of this study was to compare radiographic accuracy and precision of acetabular component position using RA-THA with the direct anterior approach (DAA) or posterior approach (PA).

Methods: Between 2016 and 2019, 134 PA RA-THA patients were matched to 134 DAA RA-THA patients based on age (±10 years), body mass index (±5 kg/m^2), and sex (exact). Acetabular component position was assessed using (1) planned position on preoperative computed tomography, (2) intraoperative position, and (3) position on 6-week postoperative radiographs using the digital Ein Bild Röntgen Analyse system.

Results: Accuracy of acetabular component inclination in the PA cohort was lower than that in the DAA cohort (PA: 4.3° ± 2.8° vs DAA: 3.1° ± 2.4°, $P = .001$). Inclination precision was not statistically different (PA: 3° ± 2.4° vs DAA: 2.5° ± 1.8°, $P = .071$). Anteversion accuracy was not statistically different (PA: 4.1° ± 3.7° vs DAA: 3.5° ± 2.5°, $P = .091$). Acetabular component anteversion was more precise with DAA (PA: 4.1° ± 3.7° vs DAA: 2.9° ± 2.0°, $P = .001$). Radiographic outliers (anteversion or inclination was >10° or <−10° from the planned target) were significantly more prevalent in the PA cohort than in the DAA cohort (12 vs 3, $P = .016$).

Conclusions: The acetabular component can be positioned with excellent precision and accuracy when using RA-THA regardless of approach. Although the DAA resulted in a slight increase in precise placement of cup anteversion and more accurate placement of cup abduction with fewer outliers, these small differences may not be clinically meaningful.

Introduction

Numerous studies have investigated potential differences in clinical, functional, and radiographic outcomes between the direct anterior (DAA) and posterior approach (PA) in primary total hip arthroplasty (THA). The majority of this literature has been conflicting, suggesting that there may be no clinically meaningful differences in length of hospital stay, [1,2] complication rates, [3,4] or early postoperative patient-reported outcomes and pain [5–11]. As it pertains to radiographic outcomes, a recent randomized control trial reported that acetabular components placed with the DAA trended towards being outside of the Lewinnek safe zone and had more acetabular anteversion than the PA although this was not statistically significant [12]. Additional studies of various qualities have corroborated these findings, concluding that radiographic differences such as target inclination and anteversion may not exist between these approaches [13–15]. However, none of these studies have implicated robotic assistance for component placement, which in recent years has become widely used across many institutions [16–18].

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Robot-assisted THA (RA-THA) may enhance the reproducibility of technique and outcomes with the proposed benefits of increased precision and accuracy of acetabular cup version and inclination along with more consistent restoration of leg length and offset [16,19–22]. Consequently, this may help avoid complications, such as component malpositioning, dislocation, and accelerated bearing wear, all of which play a considerable role in the long-term success of THA [19]. This is an especially pertinent concern when performing the DAA, where a learning curve exists, and most surgeons use fluoroscopic guidance in order to confirm acetabular component positioning [23]. Although several studies have reported that RA-THA using the PA confers more accurate and precise acetabular component placement than conventional THA, [24–26] a paucity of literature with small samples sizes has proposed that RA-THA using the DAA may offer improved implant placement [27]. Just as it has been imperative to compare the conventional PA and DAA in order to augment shared decision-making, provide appropriate patient guidance, and optimize patient outcomes, so too would it be of great clinical benefit to ascertain whether radiographic outcomes are comparable when these approaches are performed with robotic assistance given that component position may influence THA success.

The purpose of the current study was to investigate whether differences exist in the radiographic accuracy and precision of acetabular component position in patients who underwent DAA vs PA RA-THA. Since access to the anatomy necessary for bony registration during DAA THA may be limited in comparison to PA THA, the authors hypothesized that DAA RA-THA may confer less-accurate and precise acetabular component placement than PA THA.

Material and methods

Patient selection

This study was approved through the institutional review board prior to being conducted. A retrospective review of 349 patients who underwent primary RA-THA from 4 surgeons at the Hospital of Special Surgery between 2016 and 2019 was performed. Patients who underwent RA-THA using the MAKO Total Hip 3.0 system (Stryker, Kalamazoo, MI) and for whom postoperative supine anteroposterior (AP) pelvis radiographs were available were included. Exclusion criteria consisted of patients whose postoperative AP radiographs were not amenable to analysis with Ein Bild Röntgen Analyse (EBRA) measurements due to poor x-ray technique with excessive pelvic rotation or tilt. This resulted in exclusion of 33 PA patients (from an initial 167 PA patients), after which the remaining PA patients ($n = 134$) were matched 1-to-1 to DAA patients ($n = 134$) using the greedy matching algorithm [28] based on age (±10 years), body mass index (±5 kg/m^2), and exact sex with equal weightings. A post-hoc power analysis was performed in G*Power (version 3.1.9.4) based on the differences observed in acetabular component abduction. The difference in a 2-dependent-means statistical test with 2 tails was utilized with an alpha error probability of 0.05 and a total sample size of 268. These parameters demonstrated that the statistical power of the current study was 99.96%.

Surgical approach with robotic assistance

For the DAA approach, the patient was placed in the supine position on a modified traction table. An oblique, 10-cm incision was made beginning 2 cm posterior and distal to the anterior superior iliac spine and continued distally. Dissection continued to the tensor fascia latae, which was subsequently retracted laterally, and a retractor placed superior and inferomedially to the femoral neck. The rectus femoris and iliocapsularis were elevated, after which a c-retractor was placed deep and over the anterior wall of the acetabulum. An H-shaped capsulotomy was created, after which attention as turned to registration of the Mako computer navigation system. Three pins were placed in the contralateral iliac crest, and the pelvic array introduced, while a checkpoint was placed on the greater trochanter. Initial offset and leg-length measurements were taken from this marker, and an additional marker on the patella. After calibration, the femoral neck osteotomy was performed, and the femoral head was removed. The labrum was excised, and an acetabular checkpoint was placed superiorly in the bone above the acetabulum. Registration of the MAKO computed tomography (CT) scan was performed by registering multiple bony landmarks around the acetabulum. A Reamer was placed on the haptic arm of the robot, and reaming was performed, followed by placement of the planned acetabular component in appropriate inclination and anteversion. The haptic arm was removed, and 5 points were taken from the rim of the acetabulum to confirm the position of abduction and anteversion. Supplemental fixation screws were placed, if necessary, followed by a 0-degree highly cross-linked polyethylene liner. The locking mechanism was tested, remaining osteophytes removed, and attention turned to the femur. Additional capsular release was performed as needed, and the femur was exposed for preparation. Sequential broaching was performed based on preoperative templating. A trial neck and head were placed, and the hip was reduced. Leg-length and offset measurements were taken with the navigation system. Final components were implanted, and the wound was copiously irrigated. Capsular closure was performed, followed by closure of the tensor epimysium, and the remaining layers in a standard fashion.

For the PA procedure, patients were placed in the lateral decubitus position, and an incision centered over the posterior corner of the greater trochanter was made. Dissection was performed down to the short external rotators, of which the piriformis and conjoint tendons were released and tagged for later repair. The gluteus minimus tendon was elevated, and a capsulotomy performed. Three pins were placed in the ipsilateral iliac crest, and the pelvic array was introduced, while a checkpoint was placed on the greater trochanter. Initial offset and leg-length measurements were taken from this marker and an additional marker on the patella. The hip was subsequently dislocated, and femoral neck osteotomy was performed. An acetabular checkpoint was placed superiorly in the bone above the acetabulum. The labrum was excised. Registration of the MAKO CT scan was performed by locating multiple points around the acetabulum. Reaming and component placement were performed with haptic arm assistance, after which abduction and anteversion were confirmed. The femur was prepared according to pretemplating sizing, and leg-length and offset measurements were taken again. After trialing and final component placement, the final leg length and offset were obtained, and the capsule and short external rotators repaired. The fascia and soft tissue were repaired in a standard fashion. For both procedures, patients were made immediately weight-bearing as tolerated, received antibiotic prophylaxis, and were started on deep venous thrombosis prophylaxis.

Radiographic analysis

Metrics used to determine acetabular component abduction and anteversion angles included the surgeon's intraoperative planned component position, leg-length goal, and the component position measured on 6-week postoperative AP radiographs (Fig. 1) using digital Ein Bild Röntgen Analyse (EBRA-Digital, 2012). The EBRA software has been shown to be an effective tool for both measurement of component head migration and measurement of

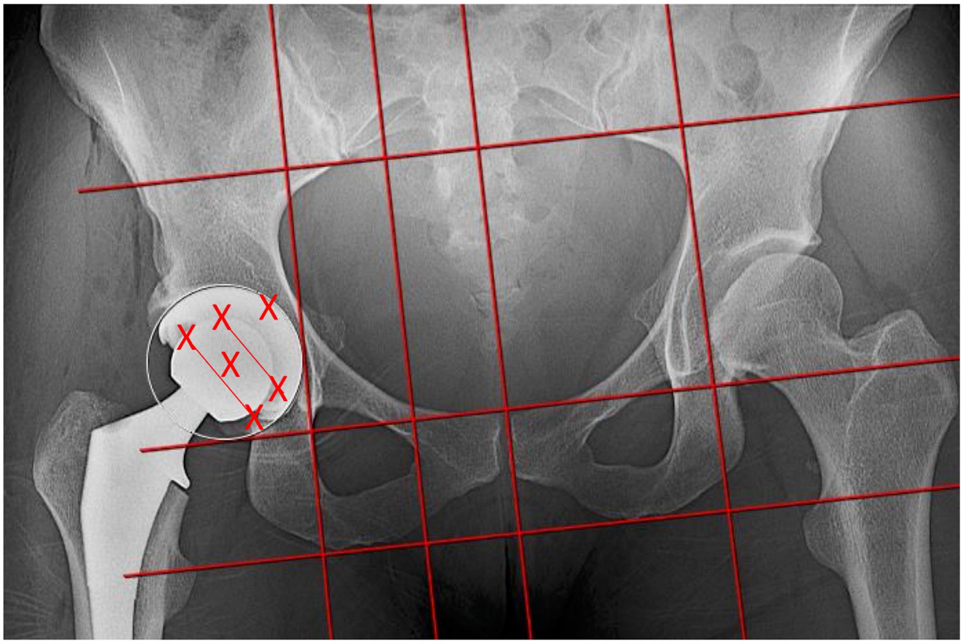

Figure 1. Supine anteroposterior pelvic radiograph with Ein-Bild-Rontgen-Analyse (EBRA) grid lines and landmarks. As determined by the EBRA software, acetabular inclination was 42.2° and anteversion 25.2°.

anteversion and abduction [29–31]. While a variety of hip sockets are supported in the EBRA software, type 1 hip sockets and polyethene cups with circular contrast wire were utilized in the current study. This hip socket type had (1) head and cup integration, (2) acetabular component inclination, and (3) acetabular component anteversion as available parameters.

For each radiograph, a 25-mm reference sphere was measured along its diameter to scale the image, after which the patient's acetabular cup and prosthetic head diameter were entered into the software. One of the 3 sets of suggested reference lines were utilized as illustrated in Figure 1. Three horizontal reference lines were then drawn: (1) tangential to the distal aspect of the obturator foramen, (2) tangential to the distal aspect of the pubic ramus, and (3) tangential to the proximal horizontal border of the greater sciatic notch. In addition, 3 vertical reference lines were drawn: (1) center of the pubic symphysis, (2) at the medial border of each greater sciatic notch, and (3) at the lateral aspect of each of the greater sciatic notch. After the reference lines were established, a circular outline of the head component was created by labeling the perimeter of the component with at least 4 points. An ellipse along the cup was then defined by labelling the vertices of the cup ellipse using at least 3 more points.

Statistical analysis

Accuracy was defined as the absolute difference between the intraoperative planned position and postoperative position measured on the AP radiographic pelvic film using the digital EBRA technology. Precision was measured by calculating the absolute difference between (1) the average of the difference in planned and measured component positions and (2) the difference of planned and measured positions for each cohort. Outliers were defined as patients with a final acetabular inclination or anteversion value greater than or less than 10 degrees of the initial plan based on preoperative imaging. Continuous variables with normal distribution were presented as means with standard deviations and were compared by independent sample t-tests. Categorical variables were presented as frequencies with percentages and were compared using the chi-squared test or the Fisher exact test where appropriate. Significance was defined as 2-tailed P value of $< .05$. Statistical analysis was performed in SAS for Windows 9.4 (SAS Institute Inc., Cary, NC).

Results

A total of 268 patients with a mean (± standard deviation) age of 61.4 ± 8.7 years and BMI of 25.2 ± 3.6 kg/m^2 were included. A total of 150 (55.9%) patients were female. Following stratification and matching, a total of 134 patients composed the DAA and PA cohorts. Matching was deemed appropriate as comparisons did not reveal statistically significant differences in any demographic variables collected (Table 1).

Registration accuracy

Registration accuracy among all patients on average was 0.34 ± 0.09 mm. In the PA cohort, the mean registration accuracy was 0.33 ± 0.09 mm while that of the DAA cohort was 0.36 ± 0.09 mm, representing a statistically significant difference favoring the PA cohort ($P = .008$).

Acetabular component position

The mean postoperative measured inclination among all patients was 43.2° ± 3.6° (Table 2). The mean inclination in the PA cohort was 44.2° ± 3.8°, which was significantly higher than that of the DAA cohort (42.3° ± 3.2°, $P < .001$). Accuracy of the acetabular component placed with the PA with respect to inclination was significantly lower than that of the DAA (4.3° ± 2.8° vs 3.1° ± 2.4°, $P = .001$). No statistically significant differences were observed between the 2 cohorts when comparing precision of inclination although inclination in the DAA trended towards being more precise (3° ± 2.4° vs 2.5° ± 1.8°, $P = .071$).

Table 1
Patient demographics.

Variable	All	Posterior approach	Anterior approach	*P* value
N	268	134	134	
Age, y	61.44 ± 8.7	60.86 ± 8.46	62.03 ± 8.93	.271
BMI, kg/m^2	25.24 ± 3.64	25.54 ± 3.62	24.95 ± 3.65	.183
Sex				.999
Male	118 (44)	59 (44)	59 (44)	
Female	150 (56)	75 (56)	75 (56)	
Laterality				.142
Left	124 (46.3)	68 (50.7)	56 (41.8)	
Right	144 (53.7)	66 (49.3)	78 (58.2)	
Diagnosis				.999
Hip OA	256 (95.5)	128 (95.5)	128 (95.5)	
Other	12 (4.5)	6 (4.5)	6 (4.5)	
Specific diagnosis				.052
Avascular necrosis	1 (0.4)	0 (0)	1 (0.7)	
Osteonecrosis	2 (0.7)	2 (1.5)	0 (0)	
Posttraumatic arthritis	3 (1.1)	3 (2.2)	0 (0)	
Hip dysplasia	6 (2.2)	1 (0.7)	5 (3.7)	
Hip OA	256 (95.5)	128 (95.5)	128 (95.5)	

BMI, body mass index; OA, osteoarthritis.
Values presented as mean (± standard deviation) or frequency (percentage).

The mean postoperative measured anteversion among all patients was 22.2° ± 4.9° (Table 2). The mean anteversion in the PA cohort was 23.3° ± 5.5°, which was significantly higher than that of the DAA cohort (21.0° ± 4.0°, $P < .001$). Although the DAA cohort demonstrated better accuracy for anteversion, this difference was not statistically significant (4.1° ± 3.7° vs 3.5° ± 2.5°, $P = .091$). Placement of the acetabular component with respect to anteversion was less precise in the PA cohort than that in the DAA cohort (4.1° ± 3.7° vs 2.9° ± 2.0°, $P = .001$).

Leg-length discrepancy

The mean planned and actual change in leg length was 3.3 ± 3.4 and 4.0 ± 3.3 mm, respectively (Table 2). The mean planned leg-length change for the PA cohort (3.7 ± 3.3 mm) was not significantly different from that of the DAA cohort (2.9 ± 3.5 mm, $P = .052$). Furthermore, the actual leg-length change for the PA cohort (4.2 ± 3.3 mm) was not significantly different from that of the DAA cohort (3.9 ± 3.2 mm, $P = .60$).

Agreement and outliers

Overall, agreement between intraoperative targets and postoperative EBRA measurements was within 10° for 98.5% of components for inclination and within 10° of the target range for 95.8% of components for anteversion (Figs. 2-4). A total of 15 outliers were identified: 10 in which the inclination was >10° or <−10° from the planned target, and 5 in which the anteversion was >10° or <−10°. Twelve of these outliers were found in the PA cohort (n = 8 for inclination and n = 4 for anteversion), while the remaining 3 were found in the DAA cohort (n = 2 for inclination and n = 1 for anteversion). Chi-squared analysis of association confirmed that the number of outliers was associated with surgical approach, with the PA cohort containing a higher frequency of outliers than the DAA cohort (12 vs 3, $P = .017$).

Of the patients considered outliers, there were a total of 6 patients with acetabular components outside the traditional Lewinnek safe zone. Of the 10 outliers based on inclination, a total of 6 of these patients had an acetabular inclination value outside of the traditional Lewinnek safe zone (range, 50.1-53.1). All 6 patients underwent THA via PA, representing a statistically significant difference ($P < .001$). Of the 5 outliers based on anteversion, no patients had an anteversion value that exceeded the limits of the traditional Lewinnek safe zone.

Discussion

The main finding of the current study was that acetabular component positioning using RA-THA is both accurate and precise in the majority of cases regardless of whether surgeon preference is for using a DAA or PA to the hip. However, DAA RA-THA conferred significantly better precision in acetabular anteversion and better

Table 2
Preoperatively planned, intraoperative (actual), and measured (6 wk) radiographic measures.

Radiographic variable	All	Posterior approach	Anterior approach	*P* value
N	268	134	134	
Planned inclination, °	40.41 ± 1.03	40.79 ± 1.33	40.02 ± 0.29	**<.001**
Planned anteversion, °	23.16 ± 2.05	22.95 ± 1.98	23.38 ± 2.11	.084
Planned leg length, mm	3.32 ± 3.43	3.72 ± 3.26	2.91 ± 3.56	.052
Actual inclination, °	40.49 ± 2.19	40.83 ± 2.40	39.97 ± 1.88	**.001**
Actual anteversion, °	23.33 ± 2.64	22.39 ± 2.30	24.27 ± 2.64	**<.001**
Actual leg length, mm	4.05 ± 3.28	4.15 ± 3.34	3.94 ± 3.23	.600
Measured inclination, °	43.23 ± 3.62	44.16 ± 3.82	42.31 ± 3.16	**<.001**
Measured anteversion, °	22.16 ± 4.93	23.33 ± 5.50	20.99 ± 3.96	**<.001**
Registration accuracy, mm	0.34 ± 0.09	0.33 ± 0.09	0.36 ± 0.09	**.008**
Inclination accuracy, °	3.66 ± 2.66	4.25 ± 2.80	3.06 ± 2.37	**<.001**
Anteversion accuracy, °	3.77 ± 3.17	4.10 ± 3.74	3.45 ± 2.46	.091

Values presented as mean (± standard deviation) or frequency (percentage).
Bolded values indicated statistical significance at $P < .01$ level.

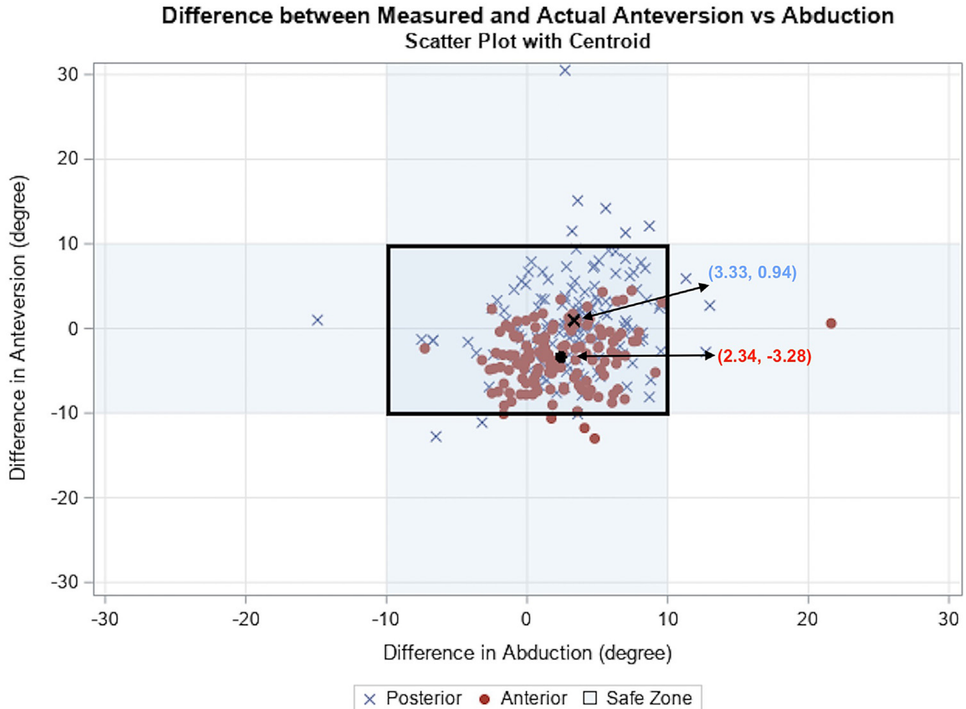

Figure 2. Differences between measured and actual anteversion vs abduction values. The first value in each bracket represents the mean difference in abduction, whereas the second value represents the mean difference in anteversion.

accuracy for cup inclination than PA RA-THA. It is unclear whether the magnitude of these differences is clinically significant. Furthermore, the number of outliers in the PA cohort was significantly greater than that in the DAA cohort. Finally, there were no differences in the planned or actual leg-length changes based on surgical approach.

Registration accuracy was significantly better using the PA than that with the anterior approach although this difference was only

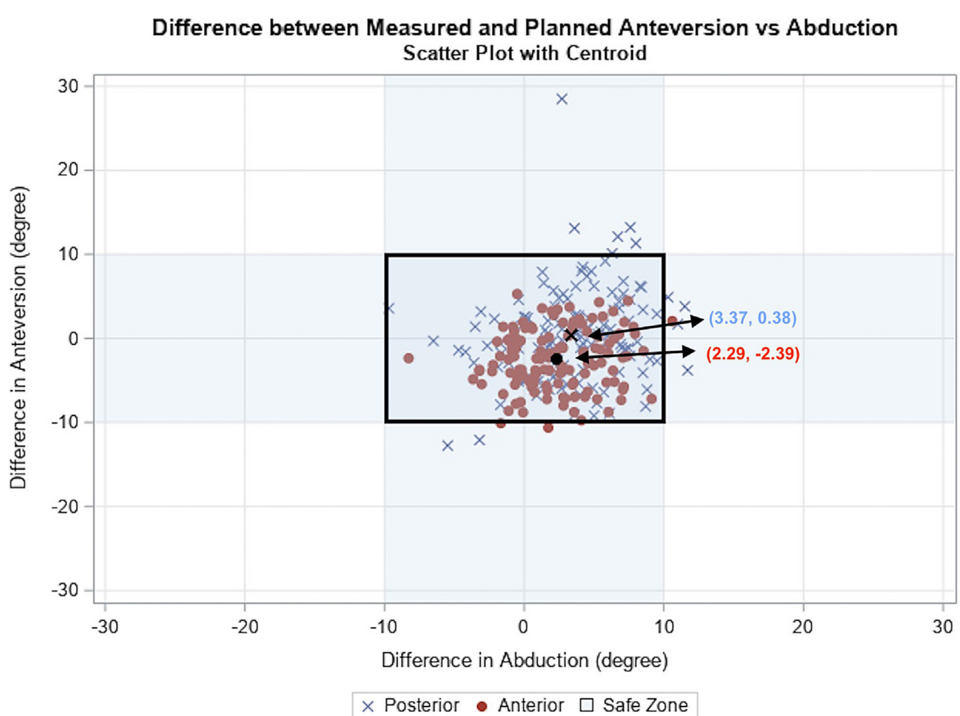

Figure 3. Differences between measured and planned anteversion vs abduction values. The first value in each bracket represents the mean difference in abduction, whereas the second value represents the mean difference in anteversion.

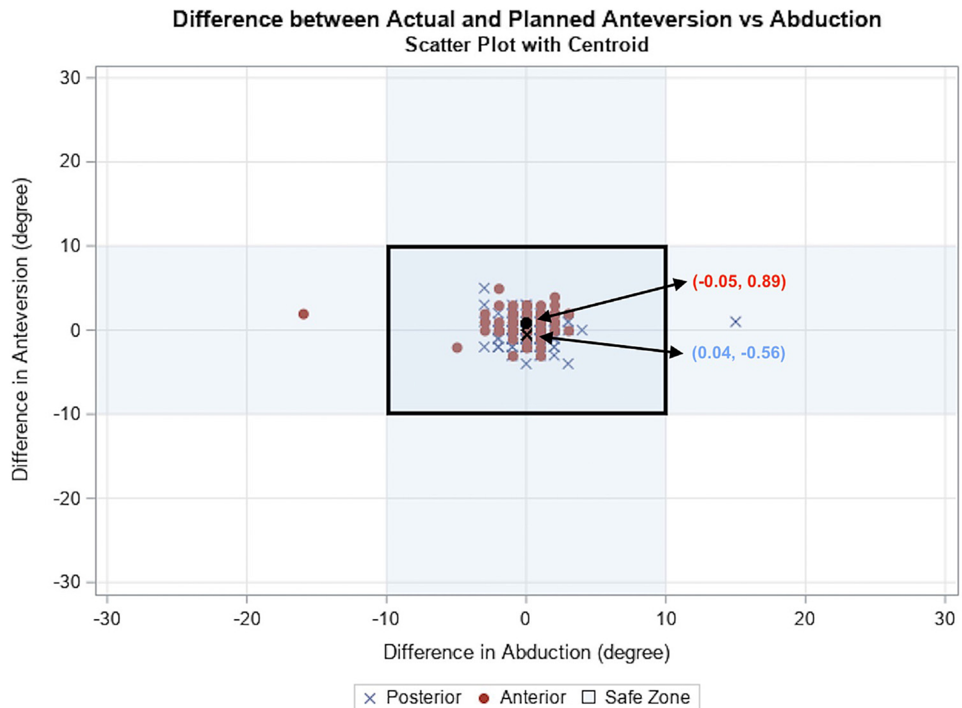

Figure 4. Differences between actual and planned anteversion vs abduction values. The first value in each bracket represents the mean difference in abduction, whereas the second value represents the mean difference in anteversion.

by a margin of 0.03 mm. Although this finding is in accordance with the hypothesis that challenges in acetabular exposure inherent to the anterior approach to the hip may result in more difficulty performing intraoperative registration based on preoperative CT scans, this difference is small, and the clinical meaning unknown. As such, although this finding met statistical significance, it should be emphasized that a difference of 0.03 mm in registration is unlikely to influence acetabular component angulations of 10 degrees, and such outliers are likely due to other currently unknown factors. Therefore, there is a lack of clinical relevance as it pertains to this finding given the current data, and future studies are warranted to establish what would define a clinically meaningful difference in registration accuracy. It is also notable that the MAKO system does not necessitate that the process of registration intraoperatively be accurate for all registration points in order to proceed with acetabular reaming and cup placement, and therefore may contribute the variation in this observation as this likely differs among the 4 surgeons in the current study.

When comparing the accuracy and precision of acetabular component anteversion, it was found that cup anteversion when performed with RA-THA using the DAA conferred better precision than with the RA-THA using the PA. However, the mean difference in precision was 1.25° and is likely not clinically significant. Additionally, there was not a significant difference based on approach in the overall accuracy of cup anteversion. This finding is in accordance with the study by Rathod et al. [32], where the authors reported that the use of fluoroscopy with the DAA decreased the variability in acetabular cup anteversion in comparison to PA cases although the authors could not draw inferences as to whether this difference was attributed to the use of fluoroscopy or due to the approach and whether it was clinically significant. In a smaller study consisting of 30 DAA supine position patients, 46 DAA lateral position patients, and 33 PA patients, Maeda et al. [33] compared cup alignment using CT-based navigation with the CT Hip 1.1 (Stryker, Mahwah, NJ). The authors reported that there were no significant differences in the accuracy or precision of cup inclination based on approach; however, cup anteversion was significantly larger in both DAA groups when compared to PA, with anteversion in the PA group being 6° smaller on average than the target angle of the mechanical guide of 14° radiographic anteversion. A recent meta-analysis of 7172 THAs suggested that although the acetabular component was more often positioned in a predefined safe zone with the DAA, no differences in cup inclination or anteversion were found when compared to the PA, and dislocation rates did not differ based on approach or cup position [34]. The results of the current study build upon these previous findings and suggest that performing RA-THA with either the DAA or PA approach will result in final cup anteversion position that is either close to or identical to the preoperatively planned position. However, it is important to note that in the MAKO 3.1 workflow (used in this study), the DAA approach uses a superior rough registration point placed near the anterior inferior iliac spine, which is easily identified and registered when compared to the superior rough registration point that, in some cases, may be randomly placed on the ilium superior to the acetabulum when using the PA. This may predispose the PA surgeon to perform a misleading registration and verification, which led to the development of the MAKO 4.0 registration pattern, and therefore may partially explain why some of the differences in the current study were observed.

The current study determined that performing RA-THA with the DAA results in better accuracy as it pertains to cup inclination when compared to RA-THA with the PA. However, this difference in accuracy was marginal at 1.19° on average, and the precision of cup inclination was not significantly different based on approach. Rathod et al. [32] compared cup placement variability in a series of 825 patients and found that target inclination was achieved better in the DAA cohort than in the PA cohort (97% vs 77%, respectively). Interestingly, in cases performed during the surgeon's learning curve, achievement of target inclination was found to be statistically similar. Belyea et al. [35] compared acetabular cup inclination among patients who underwent THA with the DAA and fluoroscopy (n = 35), PA with fluoroscopy (n = 44), and PA without fluoroscopy (n = 18). The authors reported that the use of PA with fluoroscopy significantly increased accuracy of cup inclination compared to PA without fluoroscopy and DAA with fluoroscopy. Although dissimilar in methodology and use of additional technology, these studies suggest that the use of imaging guidance may help reduce the variability in component positioning and may also explain why the difference observed in the current study was marginal. Redmond et al. [36] compared the DAA and PA in RA-THA in a smaller cohort of 146 patients and determined that the average difference in inclination between groups was $3.3^\circ \pm 3.1^\circ$, which was not significantly different. In the current matched-pair study with appropriate statistical power, the mean difference was 2.11° smaller on average, which may better represent the true relationship between approach and accuracy and precision of cup placement. This is clinically important for surgeons who perform THA using the DAA or PA and would like to incorporate robotics into their surgical planning, as the current results suggest that they may continue to perform their preferred approach without sacrificing the accuracy and precision of acetabular component placement. Future studies are warranted to continue to compare the use of both approaches using robotic assistance to determine whether clinically significant differences in component positioning exist although our results suggest that either approach can be used to reproducibly achieve a preoperatively planned cup orientation based on patient-specific CT imaging.

Leg-length discrepancy was not significantly different based on approach when considering both planned and actual leg-length changes. Redmond et al. [36] retrospectively identified 41 DAA and 105 PA cases which were performed using the MAKO robotic system with the purpose of investigating whether intraoperative measurement data correlated to postoperative radiographic data and determined that in all cases, final radiographic leg-length discrepancies were less than 1 cm radiographically. Furthermore, they noted that there were no significant differences in leg-length discrepancies based on approach for the number of patients with changes greater than 1 cm. However, the goal of their study was to confirm the correlation of data from the robotic navigation system with findings on postoperative imaging as opposed to being powered to directly compare acetabular component orientation or leg length like the current study. Nam et al. [37] compared computer-navigated PA, conventional PA, and DAA approaches and found that the mean leg-length discrepancies in each group were 3.9 ± 2.7, 3.9 ± 3.0, and 3.8 ± 3.9 mm, respectively, which were not significantly different.

Importantly, goals for anteversion and leg length were captured based on preoperative CT plans and compared to the actual intraoperative targets. This is an important component of the current study as targets may be outside of a traditional “safe zone” depending on combined anteversion. For example, in the presence of low femoral anteversion or retroversion, cup anteversion may intentionally be increased to improve overall combined anteversion. Consequently, the authors did not use the Lewinnek safe zone as a primary outcome measure as it may not be the best position for an acetabular component for all patients, particularly in those with spinopelvic pathology such as a stiff lumbar spine or prior fusion [38]. This may also partially explain why the PA cohort had a greater number of “outliers” than the DAA cohort. Despite reaching statistical significance, the outliers in both groups were few (12 vs 3), and whether these influenced the propensity of a clinically meaningful outcome is unknown. Future studies examining the effect of radiographic outliers on long-term clinical and functional outcomes using these 2 approaches may be of interest to address this question.

Limitations

The current study is not without limitations. First, sagittal or axial pelvic alignment was not controlled for, and therefore, there is the potential for variability to exist in the postoperative radiographs as a function of varying degrees of pelvic rotation on radiographs. This theoretically could influence the anteversion and abduction results determined by the EBRA software. While CT scan would be more accurate, it is not practical or appropriate to perform routine postoperative CT scans, and prior literature has demonstrated excellent correlation of measurements on radiographs with CT postoperatively [39]. Second, the results of EBRA are user-dependent based on predefined reference points and may be subject to measurement error. However, previous studies have demonstrated that EBRA is a valid and reproducible method to perform these specific measurements, and the variability of measurement error in the current study was low [29–31]. Third, only 1 commercially available robotic system was studied, and it is possible that results may vary with other robotic systems and surgeon experience. Fourth, clinical outcome data, including patient-reported outcomes and adverse events such as incidence of dislocations, were not collected. Future investigations are warranted to determine whether clinically meaningful differences in these outcomes exist based on radiographic differences between these 2 cohorts. Based on the current findings, we anticipate that any differences would be unlikely. Fifth, although EBRA has been demonstrated to confer high intraobserver and interobserver reliability across a range of spinopelvic phenotypes in patients undergoing THA, [40] it is possible that in select patients, the variations in spinopelvic parameters may have influenced some postoperative measurements. Finally, the DAA was routinely performed by one of the senior surgeons, while the PA was performed by 2 additional senior authors, and therefore, surgeon factors and propensity to accept certain degrees of variation from preoperative planning may partially contribute to differences in outcomes.

Conclusion

The acetabular component can be positioned with excellent precision and accuracy when using RA-THA regardless of approach. Although the DAA resulted in a slight increase in precise placement of cup anteversion and more accurate placement of cup abduction with fewer outliers, these small differences may not be clinically meaningful.

Conflicts of interest

S. A. Jerabek is a paid consultant for and received royalties from Stryker and has stock options in Imagen Technologies. All other authors declare no potential conflicts of interest.

For full disclosure statements refer to https://doi.org/10.1016/j.artd.2022.08.004.

References

[1] Wang Z, Hou JZ, Wu CH, Zhou YJ, Gu XM, Wang HH, et al. A systematic review and meta-analysis of direct anterior approach versus posterior approach in total hip arthroplasty. J Orthop Surg Res 2018;13:229.

[2] Moerenhout K, Derome P, Laflamme GY, Leduc S, Gaspard HS, Benoit B. Direct anterior versus posterior approach for total hip arthroplasty: a multicentre, prospective, randomized clinical trial. Can J Surg 2020;63:E412–7.

[3] Maratt JD, Gagnier JJ, Butler PD, Hallstrom BR, Urquhart AG, Roberts KC. No difference in dislocation seen in anterior vs posterior approach total hip arthroplasty. J Arthroplasty 2016;31(9 Suppl):127–30.

[4] Tissot C, Vautrin M, Luyet A, Borens O. Are there more wound complications or infections with direct anterior approach total hip arthroplasty? Hip Int 2018;28:591–8.

[5] Barrett WP, Turner SE, Leopold JP. Prospective randomized study of direct anterior vs postero-lateral approach for total hip arthroplasty. J Arthroplasty 2013;28:1634–8.
[6] Bergin PF, Doppelt JD, Kephart CJ, Benke MT, Graeter JH, Holmes AS, et al. Comparison of minimally invasive direct anterior versus posterior total hip arthroplasty based on inflammation and muscle damage markers. J Bone Joint Surg Am 2011;93:1392–8.
[7] Zhao HY, Kang PD, Xia YY, Shi XJ, Nie Y, Pei FX. Comparison of early functional recovery after total hip arthroplasty using a direct anterior or posterolateral approach: a randomized controlled trial. J Arthroplasty 2017;32:3421–8.
[8] Martusiewicz A, Delagrammaticas D, Harold RE, Bhatt S, Beal MD, Manning DW. Anterior versus posterior approach total hip arthroplasty: patient-reported and functional outcomes in the early postoperative period. Hip Int 2020;30:695–702.
[9] Christensen CP, Jacobs CA. Comparison of patient function during the first six weeks after direct anterior or posterior total hip arthroplasty (THA): a randomized study. J Arthroplasty 2015;30(9 Suppl):94–7.
[10] Rodriguez JA, Deshmukh AJ, Rathod PA, Greiz ML, Deshmane PP, Hepinstall MS, et al. Does the direct anterior approach in THA offer faster rehabilitation and comparable safety to the posterior approach? Clin Orthop Relat Res 2014;472:455–63.
[11] Taunton MJ, Mason JB, Odum SM, Springer BD. Direct anterior total hip arthroplasty yields more rapid voluntary cessation of all walking aids: a prospective, randomized clinical trial. J Arthroplasty 2014;29(9 Suppl):169–72.
[12] Cheng TE, Wallis JA, Taylor NF, Holden CT, Marks P, Smith CL, et al. A prospective randomized clinical trial in total hip arthroplasty-comparing early results between the direct anterior approach and the posterior approach. J Arthroplasty 2017;32:883–90.
[13] Shemesh SS, Robinson J, Keswani A, Bronson MJ, Moucha CS, Chen D. The accuracy of digital templating for primary total hip arthroplasty: is there a difference between direct anterior and posterior approaches? J Arthroplasty 2017;32:1884–9.
[14] Lin TJ, Bendich I, Ha AS, Keeney BJ, Moschetti WE, Tomek IM. A comparison of radiographic outcomes after total hip arthroplasty between the posterior approach and direct anterior approach with intraoperative fluoroscopy. J Arthroplasty 2017;32:616–23.
[15] Tripuraneni KR, Munson NR, Archibeck MJ, Carothers JT. Acetabular abduction and dislocations in direct anterior vs posterior total hip arthroplasty: a retrospective, matched cohort study. J Arthroplasty 2016;31:2299–302.
[16] Sousa PL, Sculco PK, Mayman DJ, Jerabek SA, Ast MP, Chalmers BP. Robots in the operating room during hip and knee arthroplasty. Curr Rev Musculoskelet Med 2020;13:309–17.
[17] Jacofsky DJ, Allen M. Robotics in arthroplasty: a comprehensive review. J Arthroplasty 2016;31:2353–63.
[18] Wasterlain AS, Buza 3rd JA, Thakkar SC, Schwarzkopf R, Vigdorchik J. Navigation and robotics in total hip arthroplasty. JBJS Rev 2017;5:e2.
[19] Domb BG, El Bitar YF, Sadik AY, Stake CE, Botser IB. Comparison of robotic-assisted and conventional acetabular cup placement in THA: a matched-pair controlled study. Clin Orthop Relat Res 2014;472:329–36.
[20] Gupta A, Redmond JM, Hammarstedt JE, Petrakos AE, Vemula SP, Domb BG. Does robotic-assisted computer navigation affect acetabular cup positioning in total hip arthroplasty in the obese patient? A comparison study. J Arthroplasty 2015;30:2204–7.
[21] Nakamura N, Sugano N, Nishii T, Kakimoto A, Miki H. A comparison between robotic-assisted and manual implantation of cementless total hip arthroplasty. Clin Orthop Relat Res 2010;468:1072–81.
[22] DiGioia AM, Jaramaz B, Blackwell M, Simon DA, Morgan F, Moody JE, et al. The Otto Aufranc Award. Image guided navigation system to measure intra-operatively acetabular implant alignment. Clin Orthop Relat Res 1998;355:8–22.
[23] Meermans G, Konan S, Das R, Volpin A, Haddad FS. The direct anterior approach in total hip arthroplasty: a systematic review of the literature. Bone Joint J 2017;99-B:732–90.
[24] Perets I, Walsh JP, Mu BH, Mansor Y, Rosinsky PJ, Maldonado DR, et al. Short-term clinical outcomes of robotic-arm assisted total hip arthroplasty: a pair-matched controlled study. Orthopedics 2020;1:e236–42.
[25] Han PF, Chen CL, Zhang ZL, Han YC, Wei L, Li PC, et al. Robotics-assisted versus conventional manual approaches for total hip arthroplasty: a systematic review and meta-analysis of comparative studies. Int J Med Robot 2019;15:e1990.
[26] Chen X, Xiong J, Wang P, Zhu S, Qi W, Peng H, et al. Robotic-assisted compared with conventional total hip arthroplasty: systematic review and meta-analysis. Postgrad Med J 2018;94:335–41.
[27] Xu S, Bernardo LIC, Yew AKS, Pang HN. Robotic-arm assisted direct anterior total hip arthroplasty; improving implant accuracy. Surg Technol Int 2020;38:347–52.
[28] Bergstralh E, Kosanke J. GMATCH. In: Biomedical statistics and informatics software packages. Rochester, MN: Department of Quantitative Health Sciences, Mayo Clinic; 2007.
[29] Langton DJ, Sprowson AP, Mahadeva D, Bhatnagar S, Holland JP, Nargol AV. Cup anteversion in hip resurfacing: validation of EBRA and the presentation of a simple clinical grading system. J Arthroplasty 2010;25:607–13.
[30] Wilkinson JM, Hamer AJ, Elson RA, Stockley I, Eastell R. Precision of EBRA-Digital software for monitoring implant migration after total hip arthroplasty. J Arthroplasty 2002;17:910–6.
[31] Biedermann R, Krismer M, Stockl B, Mayrhofer P, Ornstein E, Franzen H. Accuracy of EBRA-FCA in the measurement of migration of femoral components of total hip replacement. Einzel-Bild-Rontgen-Analyse-femoral component analysis. J Bone Joint Surg Br 1999;81:266–72.
[32] Rathod PA, Bhalla S, Deshmukh AJ, Rodriguez JA. Does fluoroscopy with anterior hip arthroplasty decrease acetabular cup variability compared with a nonguided posterior approach? Clin Orthop Relat Res 2014;472:1877–85.
[33] Maeda Y, Sugano N, Nakamura N, Hamawaki M. The accuracy of a mechanical cup alignment guide in total hip arthroplasty (THA) through direct anterior and posterior approaches measured with CT-based navigation. J Arthroplasty 2015;30:1561–4.
[34] Huerfano E, Bautista M, Huerfano M, Nossa JM. Use of surgical approach is not associated with instability after primary total hip arthroplasty: a meta-analysis comparing direct anterior and posterolateral approaches. J Am Acad Orthop Surg 2020;29:e1126–40.
[35] Belyea CM, Lansford JL, Yim DG. Utility of intraoperative fluoroscopic positioning of total hip arthroplasty components using a posterior and direct anterior approach. Mil Med 2020;187:e11–6.
[36] Redmond JM, Gupta A, Hammarstedt JE, Petrakos A, Stake CE, Domb BG. Accuracy of component placement in robotic-assisted total hip arthroplasty. Orthopedics 2016;39:193–9.
[37] Nam D, Sculco PK, Abdel MP, Alexiades MM, Figgie MP, Mayman DJ. Leg-length inequalities following THA based on surgical technique. Orthopedics 2013;36:e395–400.
[38] Snijders TE, Schlosser TPC, van Stralen M, Castelein RM, Stevenson RP, Weinans H, et al. The effect of postural pelvic dynamics on the three-dimensional orientation of the acetabular cup in THA is patient specific. Clin Orthop Relat Res 2020;479:561–71.
[39] Widmer KH. A simplified method to determine acetabular cup anteversion from plain radiographs. J Arthroplasty 2004;19:387–90.
[40] Grammatopoulos G, Gofton W, Jibri Z, Coyle M, Dobransky J, Kreviazuk C, et al. 2018 frank stinchfield award: spinopelvic hypermobility is associated with an inferior outcome after THA: examining the effect of spinal arthrodesis. Clin Orthop Relat Res 2019;477:310–21.