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Original Research

Handheld Navigation Improves Accuracy in Direct Anterior Total Hip Replacement

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ABSTRACT

Background: This study sought to determine the accuracy in placing the acetabular component, estimation of leg length, offset, radiation time and dose, and operative time using a handheld navigation device compared to conventional anterior total hip arthroplasty (THA). It also examined the learning curve of the handheld navigation device.

Methods: Data were prospectively collected for a consecutive series of 159 THAs; 99 THAs with handheld navigation and 60 conventional THAs. Thresholds of <5°, ≥5° to <10°, and ≥10° for acetabular inclination and version and thresholds of <5 mm, ≥5 mm to <10 mm, and ≥10 mm for leg-length and combined offset discrepancy were used to assess accuracy. Fluoroscopy time and exposure, operative time, and complications were compared. Learning curve was determined using operative time. Statistical analysis was performed for the different accuracy thresholds with P values set a <0.05 for significance.

Results: The handheld navigation device demonstrated a mean accuracy of 3.2° and 1.8° for version and inclination, respectively. The handheld navigation group had significantly fewer outliers in version (P < .001), inclination (P < .001), leg-length discrepancy (P < .001), and offset discrepancy (P < .001). Fluoroscopic dose and time (P < .001) were lower in the handheld navigation cohort. The learning curve for handheld navigation was 31-35 cases. The mean operative time after the learning curve was similar to that in the conventional fluoroscopy group (P = .113).

Conclusions: Handheld navigation technology provided more accurate results while mitigating radiation exposure to the surgeon and patient. There were fewer outliers in the handheld navigation group. After the learning curve, all metrics improved in accuracy, and operative time was similar to that of the conventional technique.

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Introduction

Total hip arthroplasty (THA) is a highly successful operation that has enjoyed continued success in regard to treating pain and improving function [1]. The direct anterior approach (DAA) for THA has become popular in recent years, which may be in part due to its purported benefits including early recovery, less postoperative pain, shorter length of stay, and decreased cost [2,3]. Additionally, the supine patient positioning allows for relatively easy incorporation of intraoperative fluoroscopy leading to a more accurate acetabular cup position after surgeon learning curve than posterior approach [4,5]. While the use of intraoperative fluoroscopy has benefits, it increases radiation exposure, is another source for contamination of the sterile field, and finally can lead to misleading information provided to the surgeon [6–8].

Technologies including robot-assisted surgery and computer navigation have been introduced to mitigate fluoroscopy use [9]. These technologies also aim to improve accuracy of prosthesis placement, which may improve longevity of the implant and patient outcomes [10–12]. Further, handheld navigation technologies have been introduced which mitigate the need for preoperative

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imaging instead of using patient anatomy and intraoperative landmarks to assist in acetabular cup placement, leg length restoration, and restoration of combined offset [13].

The primary objective of this study was to explore the accuracy of a disposable, hand-held navigation system in clinical use to guide acetabular cup placement, assess leg length restoration, and combined offset restoration for THA using a DAA. The use of the hand-held navigation system was compared to conventional fluoroscopy-assisted DAA THA. We hypothesized that the use of the hand-held navigation system would be more accurate than conventional fluoroscopy-assisted DAA THA. Secondary objectives included comparison of intraoperative time, fluoroscopy time, and radiation dose between the hand-held navigation group and the conventional fluoroscopy group. Lastly, the use of the hand-held navigation system after completion of a learning curve from its initial use was evaluated.

Material and methods

Subjects

After institutional review board approval, data were prospectively collected and retrospectively reviewed for 159 hips in 158 patients who underwent DAA THA by a single fellowship-trained surgeon between 2018 and 2021. Patients were classified into 2 separate cohorts: 99 hips (98 patients) underwent surgery with the hand-held navigation system (HipAlign; OrthAlign, Inc., AlisoViejo, CA), and 60 hips (60 patients) underwent surgery with conventional fluoroscopy assistance. All patients undergoing primary anterior total hip replacement for osteoarthritis, inflammatory arthritis, and post-traumatic arthritis were included. Exclusion criteria for the study were patients who underwent any other approach, those undergoing revision surgery, or those with known infection.

Offset was introduced in late 2020, and intraoperative offset measurements were collected from that time forward. Post hoc power analysis revealed we would need 30 cases to achieve a proper power analysis for offset. This number was increased (47 offset cases) in our collection to ensure we achieved accurate results.

Preoperative and postoperative protocols

Preoperative templating used standing anteroposterior (AP) pelvic radiographs obtained at a preoperative visit. Individualized component positioning was determined preoperatively based on the patient's anatomy. The preoperative and 6-week postoperative radiographs were used to gather measurements. Postoperative measurement of acetabular component inclination and anteversion was taken from the AP pelvis radiograph and cross-table lateral radiograph, respectively. AP pelvis radiograph was used to measure postoperative leg length and was compared to the preoperative AP pelvis radiograph. Finally, combined offset was measured both preoperatively and postoperatively using the AP pelvis radiograph. This was measured with a line up the pubic symphysis to the center of the sacrum and lines drawn up the central axis of each femur in the center position. The combined offset was calculated as the distance from the central symphysis-sacral line to the line in the center of each femur at the level of the tip of the greater trochanter (Fig. 1). For the navigation group, reported discrepancies are from intraoperative measurements, while conventional surgeries report the discrepancy between planned and postoperative measured values. This technique of differing references for comparison is based on previous studies [14] where the accuracy of the navigation is a metric. The goal of this paper is to report on the ability to trust

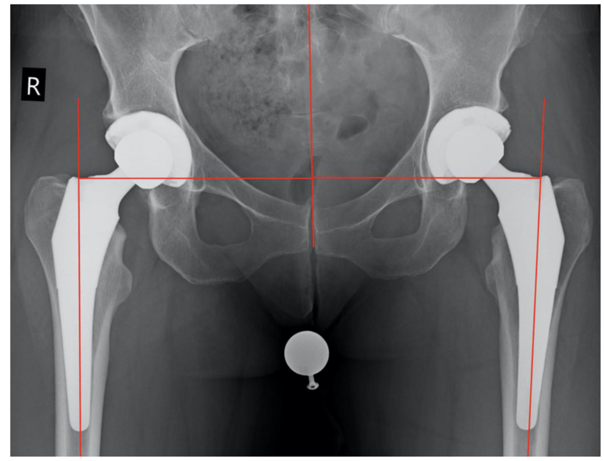

Figure 1. The method used to calculate combined offset measurement on AP pelvis radiograph.

and reproduce intraoperative measurements. For this reason, we chose to report intraoperative vs postoperative measurements for the navigation group. For the conventional group, surgeons utilize preoperative templating for planning, so we compared postoperative measurements of the conventional group to the preoperative plan.

Surgical technique

The surgical technique was similar in both groups. All surgeries were performed on the Hana Table (Mizuho OSI, Union City, CA).

Preoperative templating for all cases was performed by standard digital templating using the Merge PACS software (Merge Healthcare, Chicago, IL). Preoperative leg length and combined offset were measured for each case. Planned acetabular abduction and anteversion, along with leg length and offset, were made in each case. In the conventional group, abduction and anteversion were planned for 40° and 15°, respectively. Leg length and offset were planned individually.

In the navigation group, prior to making the skin incision for the THA, the surgeon placed 2 pins in the iliac crest just lateral and posterior to the anterior superior iliac spine (ASIS). The surgeon utilized a standard anterior approach for all cases, with the incision being based 2-3 cm distal and 2-3 cm lateral to the ASIS. Incision was made with a slight lateral angle measuring about 6-8 cm. Dissection to the tensor fascia lata (TFL) was made, and the medial border of the TFL fascia was incised sharply. Next, the rectus was retracted medial, and TFL lateral. The circumflex vessels were cauterized, and capsule exposed. Capsulectomy was performed in all cases. At this point for the navigation group, a static pin was placed on the lateral greater trochanter as a landmark for leg length and offset. The landmarks on the pelvis (bilateral ASIS and pubic symphysis) and femur (static pin) were captured. These landmarks allow the navigation unit to estimate the plane of the pelvis and leg length. Offset was added in 2020, and at that time, the unit began measuring offset. Next, in both groups, the femoral neck was osteotomized under visual guidance. Acetabulum was reamed under visual guidance in both groups, and an acetabular component was placed with fluoroscopic guidance in the conventional group and with the navigation unit and fluoroscopic confirmation in the navigation group. Anteversion was assessed in the conventional group using the method proposed by Boettner et al. [15]. This technique was used in the initial cases using the handheld navigation as the surgeon became comfortable with the technology. Femoral preparation was similar in both groups. Once the trial was assembled, the navigation group was assessed with the navigation unit for leg length then confirmed with fluoroscopy. Navigated offset was introduced in late 2020, and offset was collected and assessed from that point on. In the conventional group, fluoroscopic guidance was used to assess leg length and offset. Stability was confirmed with testing the range of motion of the hip; specifically lowering the leg 45° then externally rotating to 110°. Changes in cup position, leg length, and offset were made in the conventional group based on fluoroscopic guidance and stability testing. Both, along with navigation, were used to guide cup position, leg length, and offset. All wounds were copiously irrigated with a betadine/saline solution then normal saline. All wounds were closed with deep Vicryl (Ethicon, Bridgewater, NJ) sutures and Monocryl (Ethicon, Bridgewater, NJ) and Dermabond (Johnson and Johnson, New Brunswick, NJ) for the skin. Poke holes for the navigation pins were all closed with Dermabond and steristrips.

Data collection

For the handheld navigation system group, the intraoperative and postoperative measurements were compared, and in the conventional fluoroscopy group, the planned (preoperative templated) and postoperative measurements were compared with the absolute difference between the intraoperative and actual postoperative outcome for cup position, leg length discrepancy (LLD), and offset discrepancy (OD) recorded for each group. Intraoperative measurements were used in the handheld navigation group as the surgeon made intraoperative adjustments to the preoperative plan based on patient anatomy. Thresholds of <5° (no outlier), ≥5° to <10° (mild-moderate outlier), and ≥10° (significant outlier) for acetabular inclination and version and thresholds of <5 mm (no outlier), ≥5 mm to <10 mm (mild-moderate outlier), and ≥10 mm (significant outlier) for leg-length and combined OD were used to assess accuracy. These cutoffs were chosen based on the Lewinnek safe zone [15], clinical tolerance of LLD and OD [16–18], and prior use in the literature [5,11,14,19–22]. Fluoroscopy time and dosage were recorded from the fluoroscopic C-arm for each surgery. Operative time in minutes was recorded for all cases. Complications, both intraoperative and postoperative, were recorded.

Learning curve

Operative time was used to determine the learning curve for the handheld navigation system, as has been used in numerous studies [23–29]. This was chosen as previous studies have demonstrated little to no learning curve in achieving accurate implant positioning when using robotic and navigation technology [14,23,30]. The learning curve was considered completed when the 5-case mean operative time was maintained within the 95% confidence interval of the mean operative time for conventional DAA THA. A subgroup analysis using the prelearning curve and postlearning curve handheld navigation group compared to the conventional fluoroscopy group was performed.

Statistical analysis

The intraoperative navigation system data and postoperative radiographic data were compared using Bland-Altman plots [31], absolute mean differences, and the previously described thresholds. The handheld navigation group and the conventional fluoroscopy group were compared using t-test for continuous variables and chi-square or Fisher exact tests for the different accuracy thresholds with *P* values set at <0.05 for significance. A post hoc power analysis was performed with the alpha set at 0.05 for mean version, inclination, LLD, and OD and found the study was adequately powered (power >80%).

Results

Study cohort

There were a total of 159 hips (158 patients) included in this study: 99 hips (98 patients) were designated to the handheld navigation cohort, and 60 hips (60 patients) were designated to the conventional surgery cohort. The sex (*P* = .288), body mass index (*P* = .533), and preoperative absolute LLD (*P* = .151) were similar between cohorts (Table 1). The age was significantly lower in the handheld navigation group, 61.7 vs 66.6 years (*P* = .008) (Table 1).

Primary outcomes

Regarding the handheld navigation, Bland-Altman analysis of intraoperative navigation and postoperative radiographic measurements demonstrated excellent agreement (Fig. 2). For version and inclination, 95% and 94% of pairings, respectively, were within the statistical limit of agreement (Fig. 2a and b); 96% of LLD and 98% of OD were in statistical agreement (Fig. 2c and d). Table 2 demonstrates outliers in the handheld navigation and conventional techniques for implant positioning as no outlier, mild-moderate outliers, and significant outliers. A comparison of implant position, operative time, and fluoroscopy use between handheld navigation and conventional fluoroscopic techniques is seen in Table 3. Overall, the handheld navigation was significantly more accurate for version (3.2° vs 5.8°, *P* < .001), inclination (1.8° vs 5.4°, *P* < .001), leg length measurement (1.6 mm vs 3.4 mm, *P* < .001), and combined offset (1.4 mm vs 6.1 mm, *P* < .001). One-hundred percent of cups in the handheld group were accurate within 10° for inclination, and 92% were within 5°; for version, 95% of cups were within 10°, and 71% were within 5° of intraoperative measurement (Table 3). The mean difference for handheld navigation was 1.6 mm for LLD and 1.4 mm for OD, with 100% accuracy within 10 mm and 95% and 93% accuracy for LLD and OD, respectively, within 5 mm of the postoperative radiograph (Table 3).

The handheld navigation cohort achieved acetabular cup placement closer to the planned position for both version (*P* < .001) and inclination (*P* < .001) than conventional fluoroscopy (Table 3). There were fewer ≥10° outliers from the planned position for version (*P* = .002) and inclination (*P* < .001) in the handheld navigation cohort than those in the conventional fluoroscopy cohort

Table 1
Preoperative patient characteristics.

Variable	Direct anterior approach		*P* value
	Handheld navigation	Conventional fluoroscopy	
Number of cases	99	60	
Age (y)	61.7 (11.9)	66.6 (9.7)	.008[a]
Sex			.288
Female	54 (54.5%)	27 (45.8%)	
Male	45 (45.5%)	33 (54.2%)	
Body mass index (kg/m^2)	27.1 (4.7)	26.5 (5.8)	.533
Preoperative absolute leg length discrepancy (mm)	3.6 (3.5)	4.6 (5.2)	.151
Preoperative absolute offset discrepancy (mm)	4.8 (3.9)	5.8 (4.4)	.382

Categorical data presented as n (%); continuous data presented as mean (standard deviation).
[a] Statistically significant difference.

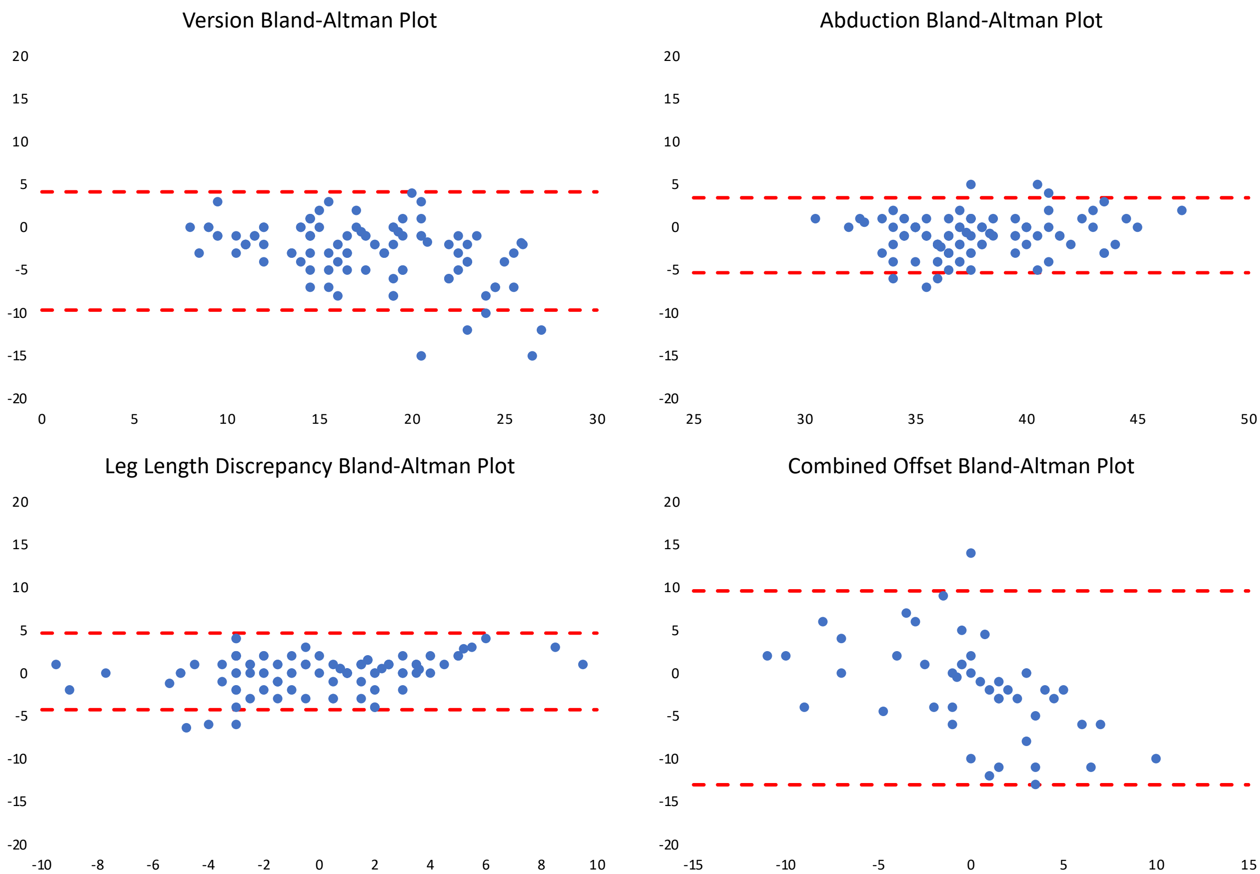

Figure 2. Bland-Altman plots demonstrating agreement between handheld navigation and postoperative radiographic measurements.

(Table 3). The mean LLD was less in the handheld navigation cohort ($P < .001$), and additionally 96% of the handheld navigation group had LLD <5 mm compared to 70% in the conventional fluoroscopy group ($P < .001$, Table 3). Lastly, the OD was less in the handheld navigation cohort measuring 1.3 mm ($P < .001$, Table 3) with no >10-mm outliers, while 13% of the conventional fluoroscopy group had OD >10 mm (Table 3). When considering the no-outlier threshold of <5° for inclination and version and <5 mm for LLD and OD, the handheld navigation group had significantly more patients that were not outliers for version ($P = .002$), inclination ($P < .001$), LLD ($P < .001$), and OD ($P < .001$).

Table 2
Outliers in acetabular and femoral component positions.

Variable	Handheld navigation	Conventional fluoroscopy
Acetabular cup version		
No outlier	74%	52%
Mild-moderate outlier	21%	28%
Significant outlier	5%	20%
Acetabular cup inclination		
No outlier	90%	58%
Mild-moderate outlier	10%	27%
Significant outlier	0%	15%
Leg length discrepancy		
No outlier	93%	70%
Mild-moderate outlier	7%	25%
Significant outlier	0%	5%
Offset discrepancy		
No outlier	94%	39%
Mild-moderate outlier	6%	48%
Significant outlier	0%	13%

No outlier is <5° or <5 mm discrepancy, mild-moderate outlier is 5°-<10° or 5-<10 mm discrepancy, and significant outlier is >10° or >10 mm discrepancy.

Secondary outcomes

For the entire cohort, the operative time was similar in the handheld navigation group at 75 compared to 72 minutes ($P = .305$, Table 3). There was a trend of decreasing operative time for the handheld navigation group (Fig. 3). The fluoroscopic dose (1.01 mGy vs 2.08 mGy, $P < .001$) and fluoroscopic time (11.2 seconds vs 19.1 seconds, $P < .001$) were both lower in the handheld navigation cohort (Table 3). Few complications were seen in either group. For the handheld navigation group, there were 3 cases of Booker 1 heterotopic ossification, 2 cases of lateral femoral cutaneous neuropraxia (resolved within 6 months of surgery), and 1 case of iliopsoas tendonitis. For the conventional fluoroscopic group, there were 2 cases of Booker 1 heterotopic ossification, 2 cases of lateral femoral cutaneous neuropraxia (resolved within 6 months of surgery), and 1 postoperative hematoma requiring aspiration.

Learning curve of handheld navigation system

The learning curve for use of the handheld navigation device was determined using operative time, comparing the mean operative time from 5 cases with the handheld navigation to the 95% confidence interval for the mean conventional fluoroscopy operative time. It was determined that the operative surgeon completed the learning curve for handheld navigation at 31 to 35 cases (Fig. 3). Therefore, the handheld navigation cohort was split into 2

Table 3
Handheld navigation and conventional component position, operative time, and fluoroscopy use.

Variable	Direct anterior approach		*P* value
	Handheld navigation (n = 99)	Conventional fluoroscopy (n = 60)	
Acetabular cup version			
Mean difference in degrees	3.2 (3.1)	5.8 (4.6)	<.001[b]
Outlier ≥5°	24 (24%)	29 (48%)	.002[b]
Outlier ≥10°	5 (5%)	12 (20%)	.003[b]
Acetabular cup inclination			
Mean difference in degrees	1.8 (1.6)	5.4 (4.1)	<.001[b]
Outlier ≥5°	8 (8%)	25 (42%)	<.001[b]
Outlier ≥10°	0 (0%)	9 (15%)	<.001[b]
Leg length discrepancy			
Mean difference in mm	1.6 (1.7)	3.4 (3.0)	<.001[b]
Outlier ≥5 mm	5 (5%)	18 (30%)	<.001[b]
Outlier ≥10 mm	0 (0%)	3 (5%)	.052
Offset discrepancy[a]			
Mean difference in mm	1.4 (1.7)	6.1 (4.5)	<.001[b]
Outlier ≥5 mm	3 (7%)	14 (61%)	<.001[b]
Outlier ≥10 mm	0 (0%)	3 (13%)	.032[b]
Operative time (min)	75 (17)	72 (24)	.305
Fluoroscopic dose (mGy)	1.01 (0.89)	2.08 (2.10)	<.001[b]
Fluoroscopic time (s)	11.2 (8.8)	19.1 (8.4)	<.001[b]

Categorical data presented as n (%); continuous data presented as mean (standard deviation).
[a] Intraoperative offset measurement available in 47 navigation cases.
[b] Statistically significant *P* value.

subgroups: the first 30 cases (prelearning curve) and the last 64 cases (postlearning curve) for analysis. OD was only available in postlearning curve cases. The results of subgroup analysis are seen in Table 4.

Prior to completion of the learning curve, the handheld navigation technique displayed similar accuracy to conventional fluoroscopy in obtaining planned cup version (5.8° vs 5.8°, $P = 1.000$) and leg length (2.3 mm vs 3.4 mm, $P = .087$, Table 4); it demonstrated better accuracy in obtaining planned inclination (2.9° vs 3.4°, $P = .011$, Table 4). In the prelearning curve subgroup, the handheld navigation avoided >10° and >10 mm outliers for version in 83%, inclination in 100%, and LLD in 100% of cases (Table 4). There was no difference in fluoroscopy time (20.4 seconds vs 19.1 seconds, $P = .477$) or fluoroscopy dose (1.64 mGy vs 2.08 mGy, $P = .284$) between the prelearning curve and conventional fluoroscopy groups (Table 4). In the prelearning curve subgroup, the handheld navigation had a significantly longer operative time ($P < .001$, Table 4).

In the postlearning curve subgroup, the handheld navigation was extremely accurate in the placement of components and at avoiding outliers. The handheld navigation produced significantly lower differences in version (2.0° vs 5.8°, $P < .001$), inclination (1.3° vs 5.4°, $P < .001$), and LLD (1.0 mm vs 3.4 mm, $P < .001$) than the fluoroscopy-guided cup placement. Offset was only available after the learning curve, and results remained the same as previously mentioned (1.4 mm vs 6.1 mm, $P < .001$). There were no cases with significant outliers (≥10° or ≥10 mm) in cup version, inclination, LLD, or OD from planned (Tables 3 and 4). The mean intraoperative

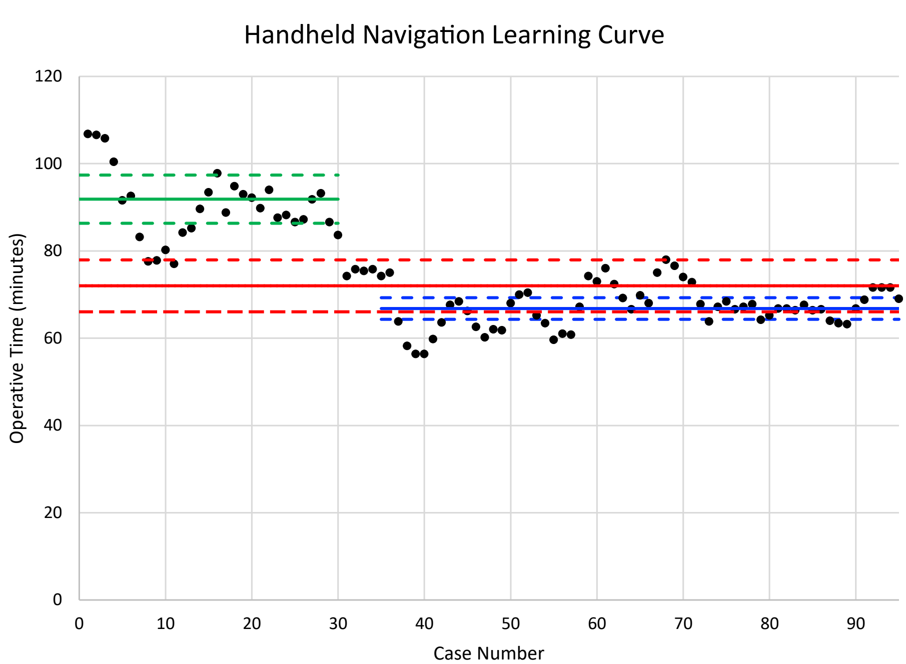

Figure 3. Plot demonstrating the operative time and case number relationship.

Table 4
Prelearning and postlearning curve handheld navigation outcomes compared to conventional fluoroscopic THA.

Variable	Conventional fluoroscopy (n = 60)	Prelearning curve (n = 30)	*P* value[a]	Postlearning curve (n = 64)	*P* value[a]
Acetabular cup version					
Mean difference in degrees	5.8 (4.6)	5.8 (4.1)	1.000	2.0 (1.4)	<.001[b]
Outlier ≥5°	29 (48%)	17 (57%)	.454	4 (6%)	<.001[b]
Outlier ≥10°	12 (20%)	5 (17%)	.699	0 (0%)	<.001[b]
Acetabular cup inclination					
Mean difference in degrees	5.4 (4.1)	2.9 (1.9)	.011	1.3 (1.0)	<.001[b]
Outlier ≥5°	25 (42%)	7 (23%)	.087	0 (0%)	<.001[b]
Outlier ≥10°	9 (15%)	0 (0%)	.027	0 (0%)	.001[b]
Leg length discrepancy					
Mean difference in mm	3.4 (3.0)	2.3 (1.8)	.087	1.0 (1.1)	<.001[b]
Outlier ≥5 mm	18 (30%)	3 (10%)	.034	1 (2%)	<.001[b]
Outlier ≥10 mm	3 (5%)	0 (0%)	.326	0 (0%)	.11
Operative time (min)	72 (24)	92 (15)	<.001	66 (10)	.113
Fluoroscopic dose (mGy)	2.08 (2.10)	1.64 (0.94)	.280	0.56 (0.48)	<.001[b]
Fluoroscopic time (s)	19.1 (8.4)	20.4 (7.5)	.477	5.3 (3.3)	<.001[b]

Categorical data presented as n (%); continuous data presented as mean (standard deviation).
[a] Compared to conventional fluoroscopy.
[b] Statistically significant *P* value.

fluoroscopy time for the postlearning curve group was 5.3 seconds, and the fluoroscopy dose was 0.56 mGy, which were both lower than those of the conventional fluoroscopy group ($P < .001$, Table 4). The mean operative time in the postlearning curve group was similar to that in the conventional fluoroscopy group (66 minutes vs 72 minutes, $P = .113$) with less variability in operative time (standard deviation 10 vs 24 minutes). In the postlearning curve group, more components were positioned <5° and <5 mm from planned for version ($P < .001$), inclination ($P < .001$), LLD ($P < .001$), and OD ($P < .001$). Using handheld navigation, the surgeon was accurate to <5° and <5 mm in all measured component position variables in 93% of cases.

Discussion

One of the goals of THA is to restore native hip kinematics. Traditionally, surgeons have used target safe zones [15] to define the acceptable placement of total hip components. However, more recent publications have questioned the utility of the Lewinnek safe zone and have suggested smaller safe zones or individualized safe zones [32–34]. Therefore, increasing the precision and accuracy in which surgeons can place the acetabular cup is increasingly important.

In this study, the handheld navigation device produced significantly more accurate results in allowing the surgeon to place the acetabular component in the position desired and also to recreate proper leg length and offset than conventional THA methods. These findings corroborate recent literature comparing manual THA to computer navigation or robot-assisted THA [24,35,36]. The handheld navigation cohort clearly demonstrated the accuracy of its intraoperative assessment, with cup placement within 1.8° for inclination and 3.2° for version of the postoperative assessment. These results suggest similar accuracy compared to a study involving the Intellijoint navigation system (Intellijoint HIP; Intellijoint Surgical, Inc., Waterloo, ON, Canada), which found differences of 4.3° and 4.2° of inclination and version, respectively, between intraoperative and postoperative assessments [11]. Redmond et al. found a similarly low rate of outliers with >10° for cup inclination (7.3%) and version (3.4%) using robot-assisted THA [22]. They also reported similar accuracy in restoration of leg length and offset [22]. There are few studies reporting on the decreased radiation exposure or learning curve associated with this handheld navigation system.

The use of intraoperative fluoroscopy is common during DAA THA and has been associated with decreased variance in cup positioning [4,5]. However, there remain issues with distortion and variability in patient position affecting its accuracy. Carlson et al. [37] found that distortion with intraoperative fluoroscopy can lead to inaccuracy in determining LLD of up to 20 mm and that the amount of distortion in a given case is unpredictable. Another study found that changes in patient positioning led to unrecognized increases in inclination and version in about 95% of cases [8]. One of the benefits in using navigation technology in arthroplasty surgery is to reduce or eliminate the use of intraoperative fluoroscopy. Previous studies have shown the various negative effects of radiation exposure including increased risks of cataracts and cancer [38,39]. While radiation doses in DAA THA are low, [6] eliminating intraoperative fluoroscopy will decrease the cumulative radiation dose to the surgeon and staff. Additionally, avoiding the use of a fluoroscopic c-arm can decrease the risk of surgical field contamination [7]. The current study clearly demonstrated a significant reduction in fluoroscopy time ($P < .001$) and fluoroscopy dose ($P < .001$) with the use of handheld computer navigation. Similarly, Morgenstern and Su recently published results of 50 anterior THAs using HipAlign (OrthAlign, Inc., AlisoViejo, CA) navigation and demonstrated a significant reduction of 45% in fluoroscopy time [13]. Interestingly, our study showed a decrease of approximately 67% in fluoroscopy time in the postlearning curve cohort.

Operative time using intraoperative navigation and robot-assisted surgery is an important consideration. A recent metanalysis found that robot-assisted surgeries took over 23 minutes longer than the conventional arthroplasty surgeries [40]. Studies of imageless navigation systems demonstrated smaller increases in operative time of 2.9-10 minutes [13,41,42]. Although our data demonstrated the operative time was significantly higher in the navigation group initially, the operative time decreased to a shorter (66 minutes vs 75 minutes) but statistically similar time as the conventional technique after the learning curve. Furthermore, there was less variability in the operative time in the postlearning curve handheld navigation cohort, which is important for operating room scheduling.

The learning curve associated with adoption of new surgical approaches, robot-assisted and navigation-assisted THA, has been assessed in several ways in the literature. The most common method used in the literature involves grouping cases in sequential groups, as seen in the studies by Redmond et al. [26], Kamara et al. [23], and York et al. [27]. Our study demonstrates that it took 31-35 cases for the surgeon to become equally skilled in the use of the handheld navigation compared to the surgeon's conventional fluoroscopic technique using time as the metric. The learning curve found in this study is similar to that reported in a recent meta-analysis on learning curve in robot-assisted THA [24]. Additionally, this study demonstrates that the handheld navigation system allows equivalently accurate component positioning to conventional techniques during the learning curve, with improved accuracy and precision in component placement after passing the learning curve.

This study is not without limitations. First, it represents cases performed by a single surgeon and may not be generalizable to all orthopedic surgeons. The study also lacks randomization, which may be a source of selection bias. Finally, there is a cost associated with all technologies. The navigation used in this study requires no significant capital cost, and the entire cost of the unit is lower than the cost of many of the disposables associated with other technologies. It is important to discuss that we are not certain long-term outcomes are affected by technology utilization. However, despite these limitations, it provides further evidence supporting the increased accuracy in component placement attainable with handheld navigation technology and offers invaluable insight into the learning curve a surgeon can expect when adopting this technology.

Conclusions

In conclusion, this study established that the handheld navigation system provides accurate intraoperative information during DAA THA regarding LLD, combined offset, and acetabular cup position. The use of the handheld navigation system was more accurate and resulted in fewer outliers in LLD, combined offset, and acetabular cup position than conventional fluoroscopy-aided DAA THA, while mitigating radiation time and dose. The learning curve for this handheld navigation system was 31-35 cases. After completion of the learning curve, the use of the handheld navigation system offered extremely accurate cup placement and recreation of leg length and offset, decreased operative time, and significantly fewer outliers in implant position.

Conflict of interest

Dr Waddell is now a paid consultant for OrthAlign. The authors declare there are no conflicts of interest.

For full disclosure statements refer to https://doi.org/10.1016/j.artd.2022.06.016.

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