Original Article

Accuracy of Acetabular Cup Alignment and Positioning in Primary THR with Acetabular Center Axis Navigation

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Background: Total hip arthroplasty using imageless computer navigation and the method of registering the anterior pelvic plane [APP], an external bony landmark of the acetabulum, has been found to be unreliable in several studies. An alternative method is the acetabular center axis [ACA], which hip navigation software which uses registered anatomical landmarks of the acetabulum.

Objective: To evaluate the accuracy of acetabular cup position, size, and alignment (inclination and anteversion) after total hip replacement by means of navigation using ACA software.

***Materials and Methods*:** This prospective observational study included 43 patients (50 hips) who had primary total hip replacement [THR] with navigation using ACA software. Data on cup size (real size and navigated size), inclination and anteversion (compared to native data), and final cup position in three dimensions were collected for analysis. CT scans were obtained at two months post-operative for cup anteversion and a standard plain film of both hips in AP for cup inclination. Both radiographic cup anteversion and inclination were applied to the Lewinnek safe zone to evaluate the placement accuracy and to compare anatomical anteversion and inclination of the cup measured from CT scans to that from navigation. Comparison was done using the paired t-test.

Results: Of the 50 hips, 45 (90%) were within the Lewinnek safe zone and it was statistically significant (p<0.05). Comparison of anatomical data on acetabular cup alignment from the CT scans and from intraoperative data from ACA found the mean inclination (cup/anatomy) with ACA was -17.720 (SD 7.431), the mean inclination (cup/anatomy) with CT scans was -10.700 (SD 6.008), the mean anteversion (cup/anatomy) with ACA was -0.560 (SD 6.929), the mean anteversion (cup/ anatomy) with CT was 3.460 (SD 6.658), and the differences were statistically significant (p<0.05). The mean real acetabular cup size was 51.84 mm (SD 3.099, range 48 to 62) and the mean navigated cup size was 50.08 mm (SD 4.145, range 42 to 61). This difference was statistically significant (p<0.05).

Conclusion: The ACA hip navigation software is accurate in the placement of acetabular cups within the Lewinnek safe zone and in setting cup size and cup position in three dimensions.

Keywords: Hip Arthroplasty, Hip navigation, Acetabular cup alignment

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Accuracy of acetabular component orientation after total hip replacement [THR] is essential because inaccurate orientation is a major cause of unstable THR in revision cases (type 1, 33%). It also increases the recurrent dislocation rate, pelvic osteolysis, polyethylene wear, and component migration(1,2). In 1978, Lewinnek described what is now known as the "Lewinnek safe zone" and the dislocation rate for cup orientation with anteversion 15°±10° and lateral opening of 40°±10° was 1.5%, while outside this safe zone was 6.1%(3). Conventional methods of total hip arthroplasty (free-hand methods) are commonly used and have had good results, but a study by Callanan et al reported that alignment of

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acetabular cups after THR in 1,823 cases only 63% in inclination angle and 79% in anteversion angle were in the Lewinnek safe zone[4]. Using a mechanical alignment guide device introduces an error by decreasing anteversion by a mean of about 6° and increasing inclination by a mean of about 2°[5]. The inclination alignment changes recorded after cup insertion using the free-hand technique were a 1% increase and 41% decrease in inclination (in 5° or more maximum deviation inclination) and a 19% increase and 8% decrease in anteversion (in 5° or more maximum deviation anteversion)[6]. The cup alignment change after screw fixation with the free-hand technique was 1.78° in inclination and 1.81° in anteversion[7].

Imageless navigation is a non-invasive and safe technique to precisely position the orientation of the cup to achieve a good alignment. In standard imageless computer navigation, bone registration was performed at the anterior pelvic plane [APP]. APP represents the vertical axis of the body in the standing position and then the cup alignment is done using the APP as a guide. Evidence-based analysis has revealed a statistically significant difference higher incidence of acetabular component placement in the "safe zone", a decrease in the number of outliers and leg length discrepancies, and fewer dislocations with imageless computer navigation compared to non-navigation[8-10]. However, the presence of compression fractures, advanced age, the presence of lumbar spondylolis thesis, and a small S1 anterior tilt angle were found to independently result in change in posterior sacral inclination [PSI] between the supine and standing position. In most cases, some degree of pre-operative pelvic tilt was also found. Of the patients examined, 17% had more than 10° of pelvic tilt in standing pre-operative radiographs. In 38% of patients the pelvic tilt angle was more than 5°, with the vertical plane and more than 10° in 13% of patients. Pelvic tilt has an effect on the accuracy of APP in imageless computer navigation[11-13]. Acetabular center axis [ACA] is an option for hip navigation which does not use the APP plane and registers the patient-specific anatomy of the acetabulum. It uses only one pin site and can be applied with any position and with any surgical approach. The purpose of the present study was to evaluate the accuracy of acetabular center axis [ACA] software in primary hip navigation.

Materials and Methods

This prospective study was conducted from June 2014 through June 2016. The study was approved by Ethic Committee of Phranakorn Si Ayuthaya Hospital. All primary hip disease patients who underwent THR with navigation using ACA software (Orthopilot Hip suite ACA, Aesculap AG) in the true lateral decubitus position and those who received the standard posterolateral approach were treated by a single surgeon [AP]. The inclusion criteria were patients who had hip diseases and suitable indications to undergo primary THR. The exclusion criteria were patients who had not undergone cementless THR and those who had an iliac crest problem that did not allow the use of the pin site for navigation (especially old iliac bone fractures), and those who declined to participate in this study. All cases received a cementless stem (Metha® or Excia®) and a cementless cup (Primafit cup), (B. Braun Aesculap, Tuttlingen, Germany). The operation started with applying two pins at the ipsilateral iliac crest before the femoral head was dislocated. Pre-operative data recorded including registration of the greater trochanter and the midpoint of the patella for determining offset and leg-length (Figure 1). After that, the femoral head was dislocated and the femoral neck was cut using standard procedures. Acetabular registration was done using three points on the superior rim, three points on the anterior rim and three points on the posterior rim of the acetabulum. We determined the superior point as the point of transection of a line from the midpart of the transverse acetabular ligament to the iliac tuberosity using a mechanical guide to set a good alignment of the acetabulum and five points of the teardrop of the acetabulum (Figure 2). Those points were recorded as native data (anatomical data of anteversion, inclination); navigation was used to predict the size of the cup. While reaming, the navigation presented real time data about the size, alignment and position of the cup in three dimensions until the suitable cup size that pre-operative planning. Mechanical guide alignment was used to set the alignment of the cup by comparing to the native data. The cup orientation was 45° inclination and 20° anteversion (Figure 3). Then the final size of the real cup was determined and the cup was implanted. The ACA navigation was used to determine the final position of the cup (Figure 4). Comparative data were collected using navigation about cup size (real size/ navigation size), inclination (compared to native data), anteversion (compared to native data), and final cup position in three dimensions. Femoral stem insertion was done following standard procedures. The size and offset of the stem, the size and neck length of the femoral head, and the set leg-length and offset to the good

Figure 1. Pre-operative registration of greater trochanter and midpart of the patella including limb-length and offset.

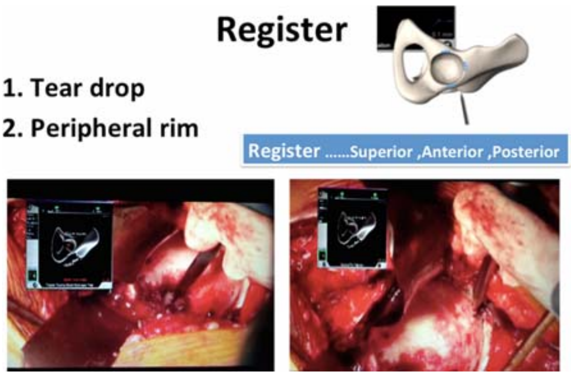

Figure 2. Registration of the acetabular rim and teardrop and recording of native data (anatomical data of anteversion, inclination) and the navigation-predicted size of the acetabular cup.

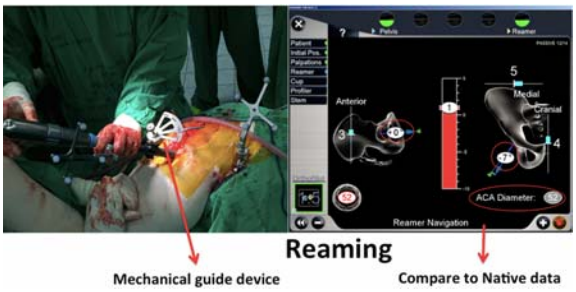

Figure 3. The reaming position was set using a mechanical guide. The alignment of the cup was set using the native data; the acetabular cup orientation was set at 45° inclination and 20° anteversion.

position of the hip from pre-operative planning before reduction and after reduction by ACA navigation were

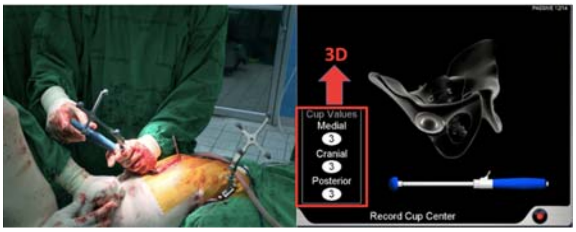

Figure 4. After the real cup was implanted in the proper position, the ACA navigation demonstrated the final position of the cup in three dimensions.

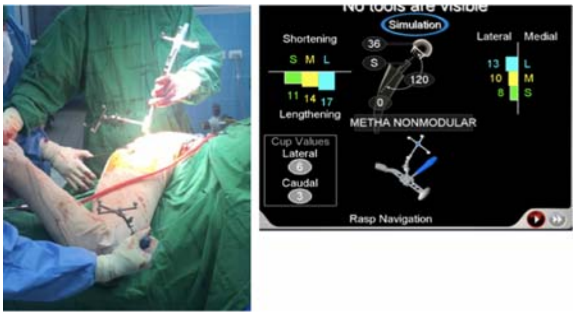

Figure 5. Registration of the hip before reduction to determine the appropriate stem offset, neck size, and head size in planning the offset and limb-length.

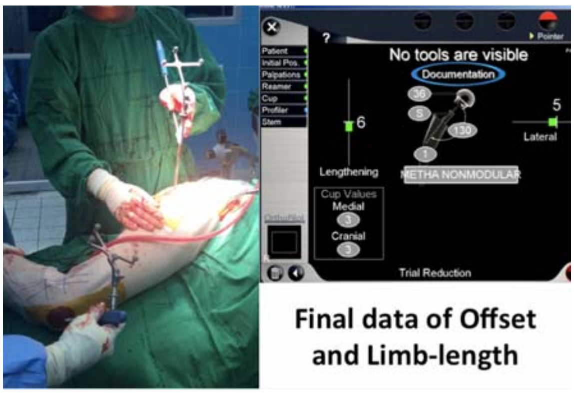

Figure 6. Registration after reduction of the hip to determine final data on limb length and offset and to compare that with pre-operative planning data.

recorded (Figures 5, 6).

A multi-slice computerized tomographic [CT] scan was obtained at 2 months after surgery to measure the anteversion angle of the acetabular cup (Figure 7). That was converted to radiographic anteversion using the Murray equation[14], "Tan (AA) = Tan (RA)/Sin (RI)" then "AA = Tan^{-1} [Tan (RA)/Sin (RI)]" (AA = anatomical anteversion (from CT scan), RA = radiographic anteversion, RI = radiographic inclination). A standard plain film of both hips in AP for radiographic inclination was done in neutral position and the radiation beam was centered on the superior ramus of the pubic symphysis and perpendicular to the patient. The film to beam distance was 110 cm (Figure 8). Both radiographic cup anteversion and radiographic cup inclination were used the Lewinnek safe zone to evaluate the accuracy of ACA navigation and to compare the difference between the acetabular bony alignment (inclination and anteversion) and the acetabular cup alignment with the CT scans and with ACA navigation (Figure 9, 10). All data were measured repeatedly over the next two weeks. Patients were followed up for a minimum of 6 months and Harris hip scores were recorded at pre-op, 2 months, and 6 months post-op.

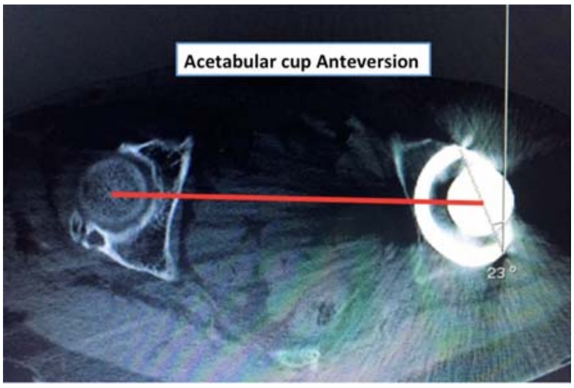

Figure 7. Measurement of the acetabular cup anteversion from CT scans of both hips converted to radiographic anteversion by the Murray equation for applying to the Lewinnek safe zone.

Figure 8. Measurement of the acetabular cup inclination from plain film of both hips for applying to the Lewinnek safe zone.

Statistical analysis

Acetabular cup alignment (inclination and anteversion) within and without the "Lewinnek safe zone" measured by ACA and CT scans were compared by binomial test. Differences in inclination and anteversion between acetabular bony alignment and acetabular cup alignment were compared by paired t-test. The navigation cup size and real cup size were also compared by paired t-test.

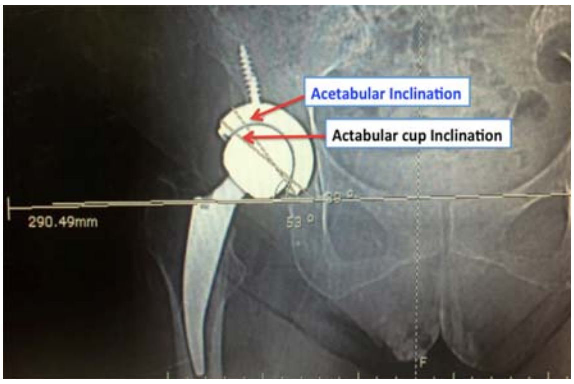

Figure 9. Measurement of the difference in inclination between the bony acetabulum and the acetabular cup from a CT scan of both hips.

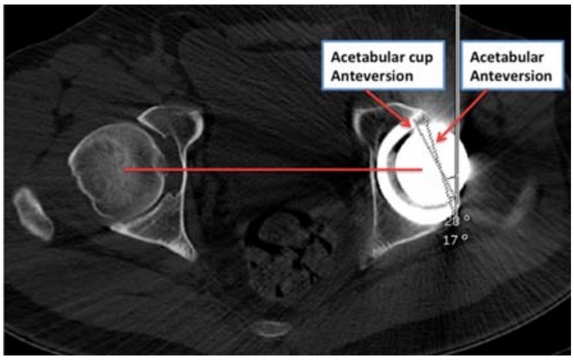

Figure 10. Measurement of the difference in anteversion between the bony acetabulum and the acetabular cup from a CT scan of both hips.

Results

Fifty primary THR (from 43 patients) were included in this study. Demographic data is shown in Table 1. The mean operative time was 104 min (SD 21.12, range 42 to 152 min), the mean of length of hospital stay was 5.28 days (SD 2.12, range 3 to 14 days), and the mean estimated intra-operative blood loss was 407 ml (SD 265.73, range 100 to 1,300 ml). The mean modified Harry hip score pre-operatively was 33.84 (SD 13.89, range 10 to 13.89), at three months post-operative the mean was 80.68 (SD 7.51, range 65 to 91), and at six months post-operative the mean was 87.52 (SD 5.52, range 70 to 96). All patients underwent cementless THR and femoral stem implant (38 Metha®, 12 Excia®) with different offsets, acetabular components (Plasmafit® cup), head sizes, neck sizes, and bearing surfaces (Table 2). There were three cases of post-operative complication (two dislocations and one periprosthetic fracture). All three cases were caused by traumatic events.

Table 1. Demographic data

	n	%
Sex		
Male	23	46
Female	27	54
Age, mean = 52.60, SD = 14.04, max = 79, min = 18		
<40	10	20
41 to 50	9	18
51 to 60	17	34
>60	14	28
BMI, mean = 23.77, SD = 4.19, max = 34.60, Min = 15.63		
<18.50	3	6
18.50 to 22.99 (normal)	27	54
>22.99	20	40
Side		
Right	24	48
Left	26	52
ASA		
1	7	14
2	34	68
3	9	18
Diagnosis		
DDH	7	14
ON	26	52
OA	11	22
Post-trauma ON	4	8
Post-trauma OA	1	2
FX femur neck (OA)	1	2

Acetabular cup anteversion was measured from CT scans of both hips and converted to radiographic cup anteversion using the Murray equation. Radiographic cup inclination was measured from plain film of both hips, then both radiographic cup anteversion and radiographic cup inclination were applied to the Lewinnek safe zone (Figure 11). Forty-five cases (90%) were within the Lewinnek safe zone and five cases were outside the zone (2 DDH, 2 ON, 1 OA). The differences were statistically significant ($p<0.05$).

The differences between acetabular bony alignment (inclination and anteversion) and acetabular cup alignment (inclination and anteversion) data from the CT scans were compared to the intraoperative data from ACA navigation (Figure 12, 13). The mean

Table 2. Implant data

	n	%
Stem		
Metha®	38	76
Excia®	12	24
Stem size (Metha®)		
0	14	28
1	4	8
2	17	34
3	2	4
4	1	2
(Excia®)		
8	2	4
9	4	8
10	2	4
11	1	2
12	2	4
13	1	2
Stem offset (Metha®)		
120	24	48
130	4	8
(Excia®)		
128	12	24
Head size		
32	20	40
36	30	60
Neck length		
S	38	76
M	9	18
L	3	6
Bearing		
M-O-P	31	62
C-O-P	9	18
C-O-C	10	20

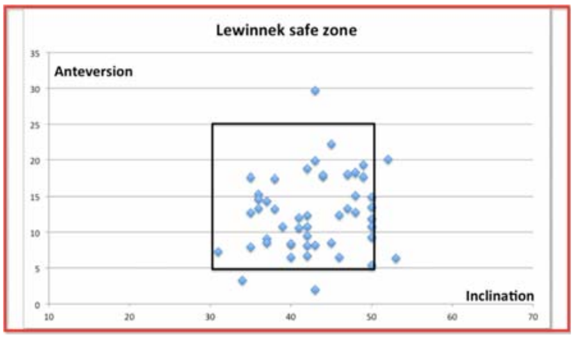

Figure 11. Radiographic cup anteversion and radiographic cup inclination applied to the Lewinnek safe zone. Forty-five cases (90%) were within the Lewinnek safe zone.

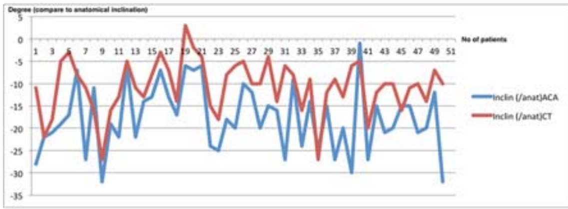

Figure 12. Inclination of the acetabulum and the acetabular cup from ACA navigation and CT scan data.

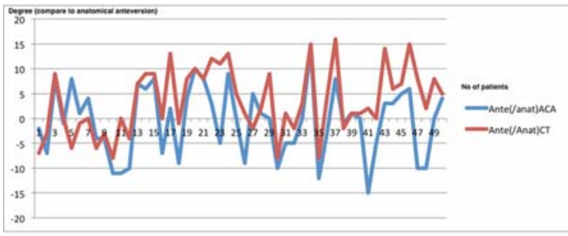

Figure 13. Anteversion of the acetabulum and the acetabular cup from ACA navigation data and CT scan data.

inclination between the acetabulum and the acetabular cup from ACA navigation was -17.720 (SD 7.431), and the mean inclination between the acetabulum and the acetabular cup from the CT scans was -10.700 (SD 6.008). The mean anteversion between the acetabulum and the acetabular cup from ACA navigation was -0.560 (SD 6.929), and the mean anteversion between the acetabulum and the acetabular cup from the CT scans was 3.460 (SD 6.658). The differences in both inclination and anteversion between the ACA navigation data and the CT scan data were statistically significant ($p<0.05$) (Table 3). The five cases with the greatest difference in acetabular cup inclination from the acetabulum (anatomical inclination) included three DDH cases and two ON cases. The real acetabular cup sizes were compared to the navigated cup sizes (Figure 14). The mean real acetabular cup size was 51.84 mm (SD 3.099, range 48-62) and the mean navigated cup size was 50.08 mm (SD 4.145, range 42-61); this difference was statistically significant ($p<0.05$) (Table 4). The final position of the acetabular component in three dimensions was recorded (Figure 15 to 17). The mean of the final position in the anterior/posterior axis was 0.84 mm posteriorly (range 7 mm anterior to 6 mm posterior), the mean of the final position in the medial/lateral axis was 1.74 mm medially (range 17 mm medial to 7 mm lateral), and the mean of the final position in

Table 3. Alignment with ACA navigation and CT scan (statistical data)

Data	Mean	SD	T	*p*-value
Inclin (/anat) ACA	-17.720	7.431	-7.595	<0.001*
Inclin (/anat) CT	-10.700	6.008		
Antev (/anat) ACA	-0.560	6.929	-4.760	<0.001*
Ant (/anat) CT	3.460	6.658		

*$p<0.05$

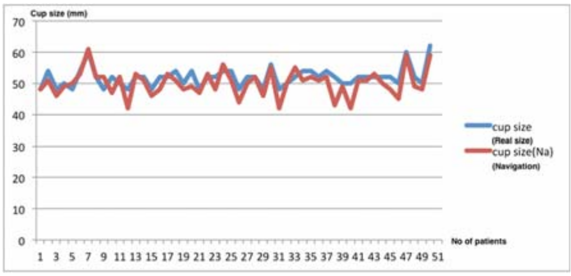

Figure 14. Size of cup from ACA navigation and the real cup.

Table 4. Size of cup from ACA navigation and the real cup (statistical data)

Data	Mean	SD	t	*p*-value
Cup size	51.840	3.099	4.700	<0.001*
Cup size (navigation)	50.080	4.145		

*$p<0.05$

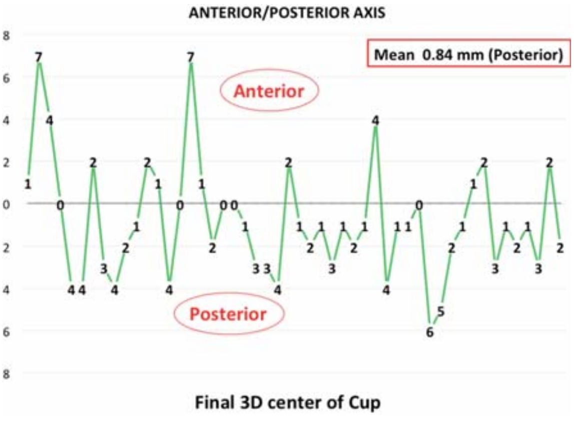

Figure 15. The center of rotation of the acetabular cup in anterior/posterior axis. The mean was 0.84 mm. in posterior axis.

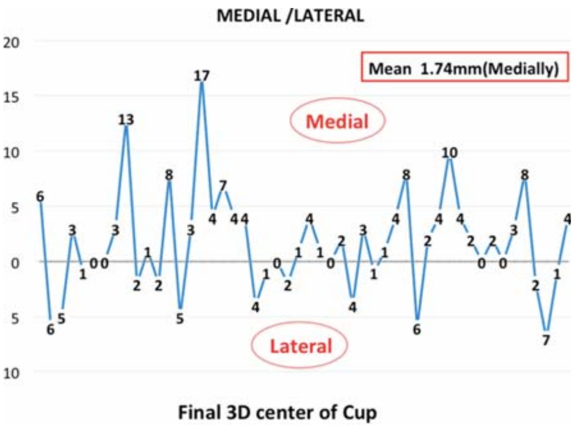

Figure 16. The center of rotation of the acetabular cup in the medial/lateral axis. The mean was 1.74 mm in the medial axis.

the cephalad/caudad axis was 3.12 mm caudad (range 5 mm cephalad to 16 mm caudad).

Discussion

The most common indication for revision THR is recurrent instability and the major cause of this instability is acetabular component malalignment (33%)[1] as it increases recurrent dislocation rate, pelvic osteolysis, polyethylene wear, and component migration. The reported overall dislocation rate after total hip replacement in one study was 3.9%[15]. Many studies have reported more accurate acetabular component alignment with imageless navigation. Moskal et al[8] in an evidence-based analysis found that in nine methodological studies involving 1,479 THR

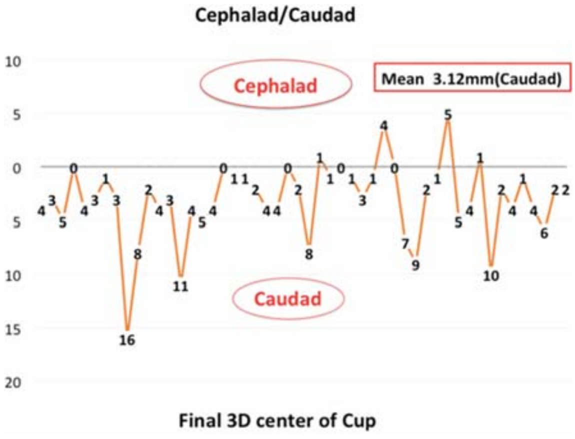

Figure 17. The center of rotation of the acetabular cup in cephalad/caudad axis. The mean was 3.12 mm in the caudad axis.

with a mean age of 59.10 years there were no statistically significant differences in mean acetabular cup inclination or anteversion angle between Navigation and Non-Navigation groups. There was, however, a statistically significant difference in the incidence of acetabular cup alignment in the "safe zone", with the Navigation group having significantly more safe zone alignments than the Non-Navigation group. Xu et al[9] in a systematic review of thirteen studies with a total sample size of 1,071 hips reported that there were statistically significant differences between the Navigation and Non-Navigation groups in acetabular cup placements without the safe zone but no significant differences in either cup inclination or anteversion, indicating that hip navigation in THR improves the precision of acetabular cup placement by decreasing the number of outliers. Paratte et al[16] reported that 57% of conventional freehand technique alignments and 20% of hip navigation set cup alignments were outside the Lewinnek safe zone. Suksathien et al[10] in a comparative study of Navigation and Non-Navigation THR using a cementless short stem reported that the mean inclination was 43.97 (range 33 to 52, SD 4.44) in the Non-Navigation group and 41.37 (range 37 to 45, SD 2.01) in the Navigation group and that the difference was significant (p = 0.004). The mean anteversion was 22.58 (range 2 to 39, SD 10.68) in the Non-Navigation group and 13.57 (range 7 to 18, SD 3.28) in the Navigation group, also a significant difference (p<0.001). In the Non-Navigation group, 96.8% were within the Lewinnek safe zone for inclination, 51.6% for anteversion, and 48.4% for both inclination and anteversion, while in Navigation group, 100% were placed within the safe zone including inclination, anteversion, and both inclination and anteversion.

The anterior pelvic plane [APP], called the Lewinnek plane, is defined using registration points at the bilateral anterior superior iliac spines and the pubic tubercles. It is commonly used as the reference plane to guide acetabular alignment in imageless computer assisted surgery for total hip replacement [THR] because this plane is considered to be the vertical axis of the body in the standing position. However, some studies have demonstrated the unreliability of the APP resulting from pelvic tilt, soft tissue thickening, and spinal problems that made it difficult to identify the point of registration. Malik et al(17) studied the validation of acetabular cup alignment and found that 1° of pelvic posterior tilt increased cup anteversion by 0.8° in the coronal plane. Pinoit et al(13) studied the accuracy of APP in 106 patients using plain lateral x-rays of the pelvis in the standing position and the supine position and found that the orientation of the APP angle was more than 5° from the vertical plane in 38% of patients and more than 10° in 13% of patients. The supine position was found significant as the average orientation of the APP varied from 1.20° to -2.25°; the difference was more than 7° in twelve patients. Joseph et al(12) studied 138 patients who underwent unilateral primary THR and found that 17% had more than 10° additional pelvic tilt in standing pre-operative radiographs. Satoru et al(11) studied spinal factors influencing changes in pelvic sagittal inclination from supine to standing position before THR and found that in compression fractures, the presence of lumbar spondylolisthesis and a small S1 anterior tilt angle were independently affected by posterior change in posterior sacral inclination [PSI] from supine to standing position before THR. Barbier et al(18) using a three dimensional imaging system to analyze the pelvis, evaluated 44 patients in the standing position three months after navigated THR. They reported that the mean cup inclination and mean anteversion were 41.3° and 20.9° intra-operatively and 44.3° and 29.5° post-operatively. The differences between measurements of operative cup inclination using computer assisted navigation and the post-operative imaging system were significant ($p<0.05$). Consequently, the accuracy of APP in hip navigation was seen as questionable with regard to the ability of the axis to detect acetabular cup alignment.

Acetabular center axis [ACA] is software for hip navigation that is independent of the anterior pelvic plane [APP] and can be applied to any patient position and any approach with only a pin site at the iliac crest by registering points at the acetabular rim and the teardrop (anatomical registration), using a mechanical guide device to adjust cup alignment by comparison with native (anatomical) data [*due to the fact that acetabulum had in cases where the acetabulum has some pathologic lesion]. From a comparative study of ACA and APP registration techniques in 36 consecutive patients, Hakki et al(19) concluded that ACA software was statistically superior to APP software in providing anteversion angles of the acetabular cup but that there was no statistically signficant difference in the accuracy of the inclination angles between APP and ACA software. From our study, we found that 45 cases (90%) were within the Lewinnek safe zone and 5 cases were outside and the results were statistically significant ($p<0.05$). The cases that were outside the Lewinnek safe zone consisted of two cases of developmental dysplasia of hip [DDH], two cases of osteonecrosis, and one case of osteoarthritis. It is particularly difficult to set cup alignment in the DDH cases. There were two cases of dislocation (post-op 2 months and 4 months) caused by falling from height, and both cases had acetabular cup alignment within the Lewinnek safe zone. ACA software can estimate cup size after registration. The real cup size tends to be bigger than the estimated size because of reaming to the precise position.

Many studies have discussed the importance of the center of rotation [COR] of the artificial hip. Johnston et al(20) studied the forces on the hip joint using a mathematical model. They found that the forces acting on the hip were lower when the center of rotation was closer to anatomic than to the superior or lateral and posterior. Yoder et al(21) studied factors related to long-term loosening after THR and concluded that hips with the center of rotation placed in a nearly anatomic location had a significantly lower rate of loosening than hips with the center of rotation superior or lateral as that decreased the mechanical forces acting on hips compared to those with a more inferior and medial center of rotation. Karachalios et al(22) suggested that the location of the center of rotation and the horizontal distance from cup to tear-drop were strongly correlated with long-term results such as acetabular and femoral loosening, migration and subsidence of the components, cup wear, and calcar resorption. They reported that occurrence of a 2 mm or more change in the mechanics of the hip may be responsible for long-term unfavorable radiographic signs. Hakki et al(23) collected data from acetabular registration by ACA software and compared it with post-op CT pelvises in

137 cases of hip navigation and found that ACA software was accurate in determining acetabular cup alignment and suggested that the center of rotation should be within 4 mm in three dimensions in order to decrease impingement and to have good stability. That is consistent with our results that the means of the center of rotation [COR] were within 4 mm in three dimensions (0.84 mm posteriorly in A/P axis, 1.74 mm medially in M/L axis, and 3.12 mm caudad in cephalad/caudad axis). The cases which had more outliers outside the acceptable range of the center of rotation [COR] were DDH cases and some cases of ON because DDH cases require reaming medially and caudad which results in a change from the registration data. From our study, we learned to ream the cup with caution along the posterior and caudad axis when using the conventional free-hand technique.

The different data of inclination between acetabulum and acetabular cup from ACA navigation had more degree almost all of the cases and most different in the cases of DDH and some cases of osteonecrosis because the DDH cases had more inclination angle than other cases when setting cup alignment by mechanical device guide, it looked like the upside down of the cup. On the contrary, the differences in anteversion between bony acetabulum and acetabular cup from ACA navigation had vary both more and less degrees and in some cases of DDH, acetabular cup anteversion had less than bony acetabulum. Although comparison of differences in both inclination and anteversion between ACA data and CT scans is statistically significant, the differences tended to be in the same direction. As a consequence, ACA navigation assisted in setting the anatomical cup alignment to the proper position.

Conclusion

The ACA software for hip navigation was significantly more accurate in placing acetabular cups within the Lewinnek safe zone (90%) and in setting cup size and cup position in three dimensions. The advantage of using ACA navigation is that the software assists in setting acetabular cup alignment (inclination and anteversion) and the position of the cup in three dimensions. It can also be used adjust the intra-operative intra-operatively to adjust alignment and position in real time without disturbing the routine operative technique of the surgeon as it can be applied to any position of patient and any surgical approach with accuracy and minimal increase in operating time. However, the disadvantage of ACA software is the necessity to use a mechanical guide device to set the cup alignment, a process which requires putting the patient in a good and stable position and precise registration of points. The weakness of our study is lack of experience with hip navigation as ACA software has not been used routinely in hip navigation.

What is already known on this topic?

Imageless navigation is a safe technique for precisely positioning cup orientation alignment. Standard imageless navigation commonly uses the anterior pelvic plane (APP) as the reference plane to guide acetabular cup alignment because this plane is considered to be the vertical axis of the body in the standing position. However, some studies have demonstrated unreliability of APP resulting from the position of the patient, accuracy of landmarks, and pathologic problems. It is not suitable with the patient in the lateral decubitus position and there are questions about the accuracy of axis to detect acetabular cup alignment.

What this study adds?

This study evaluated the accuracy of acetabular cup orientation using a navigation software of (Acetabular center axis, ACA) that does not use the APP plane and which registers at anatomy of the acetabulum. The results demonstrate that ACA software can assist in setting the acetabular alignment and position of the cup in three dimensions and that it can be used with routine operative techniques, with any patient position, and using any surgical approach. The data on alignment between acetabulum and acetabular cup from ACA navigation help to set cup alignment using a mechanical guide device and by comparison with the anatomical alignment of the acetabulum in cases where there is a pathologic lesion.

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Potential conflicts of interest

The authors declare no conflict of interest.

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