An audit on the accuracy of freehand acetabular cup positioning in total hip arthroplasty with the direct lateral approach at a tertiary institution over seven years

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Abstract

Background

The direct lateral approach for total hip replacement has been traditionally reserved and described for neck of femur fractures. Advantages of this approach include technically easy access to the acetabulum and femur and low incidence of hip dislocation. Imperfect positioning of the acetabular component leads to increased risk for dislocations, accelerated wear, reduced range of motion and increased revision rate. Freehand technique has been the gold standard for many decades, but newer technologies like computer navigation and robotic-assisted surgery have shown to improve the accuracy of cup placement. This study reports on the accuracy of freehand cup positioning via the direct lateral approach with mention of the dislocation rate.

Methods

We retrospectively reviewed 253 patients who had total hip replacements done via the direct lateral approach. The patients' files were evaluated for patient parameters, demographic details, aetiology of hip pathology, confirmation of approach used, comorbidities and history of previous relevant surgery. The postoperative radiographs were analysed for acetabular component position inclination and anteversion. Dislocation rates were calculated as a secondary objective.

Results

The radiographic analysis was performed using the Liaw method based on trigonometry of the eclipse generated. This showed a mean cup inclination of 42.3° (95% CI: 41.3–43.3°) and anteversion of 12.7° (95% CI: 12.0–13.7°). A total of 57% of the acetabular cups were within the safe zones described by Lewinnek. Of them, 78% were in the 30–50° range for inclination and 73% in the 5–25° range for anteversion. There were ten dislocations within one year from the index procedure: a dislocation rate of 4.0% (95% CI: 2.8–8.5%).

Conclusion

The freehand technique using the direct lateral approach for acetabular cup placement produces a poor overall accuracy of only 57%. Although our study only commented on ten dislocations, the rate (4%) is significantly worse compared to the 0.43% reported in literature for the direct lateral approach. The radiographic results for inclination and anteversion are comparable to other freehand techniques, regardless of the approach used, but significantly worse than results achieved with navigation and robotics.

Level of evidence: Level 4

Keywords: lateral approach, total hip arthroplasty, cup positioning

Introduction

Total hip arthroplasty (THA) is regarded as the most successful operation of the 20th century.[1] A projected 572 000 THAs are expected to be performed over the next 20 years.[2] Postoperative complications such as dislocation, polyethylene liner fracture, osteolysis, impingement, limb length discrepancy, reduced range of motion and increased wear are attributable to various patient and surgical factors.[3] Patient factors include body mass index, age, sex and primary diagnosis for the THA.[3] Surgical factors include surgeon experience, surgical approach, prosthetic design, acetabular component fixation method and orientation of the acetabular cup.[3]

Although different factors affect the success of the procedure, the four basic principles defining success are still pain relief, stability, range of motion and survivorship.[2] Acetabular cup orientation is defined by acetabular inclination and acetabular anteversion angles.[4] Lewinnek et al. described a safe zone of acetabular cup placement: anteversion of 15° ± 10° and inclination of 40° ± 10°; cups outside this safe zone are associated with a higher dislocation rate.[5] One of the most important surgical factors contributing to complications is accuracy of acetabular cup placement.

The freehand technique is the most common method in performing this surgery. Newer techniques include computer-assisted navigation, robotic-assisted surgery and computer tomography-assisted navigation. Alternative options to approach include anterior (Smith-Petersen), anterolateral (Watson-Jones) and direct lateral (Hardinge). The posterior approach is associated with a higher dislocation rate compared with the other approaches, and the newer technologies are time-consuming and not always cost-effective, leaving much to be investigated with regard to the clinical results.

Dislocation is one of the most common complications seen after THA, having an incidence of 1–5%; 50% of dislocations occur within three months and 75% occur within the first year of the index procedure.[3,6] Dislocation after THA is the most common cause of revision surgery in the first two years.[6] Revision surgery, however, has had variable success.[6]

At our institution, Steve Biko Academic Hospital, we make use of the direct lateral approach to the hip as our primary approach in elective and emergency hip replacements. The aim of this study was to determine the accuracy of freehand acetabular cup placement using the direct lateral (Hardinge) approach and to determine our dislocation rate and how cup placement relates to this dreaded complication.

Materials and methods

A total of 388 primary total hip replacements were performed between 2009 and 2015 at our institution. Twenty-five were excluded as the indication for surgery was unknown. A further 110 were excluded as it was not known whether dislocations occurred within a year of the hip replacement; either no follow-up radiographs were available on our patient archiving and communication system (PACS), inadequate radiographs taken postoperatively, or follow-up at the clinic was incomplete. We performed a retrospective chart and radiographic review of 253 primary total hip replacements. At our institution, we position our patients in the lateral decubitus position, keeping the pelvis stable with hip positioners. The Hardinge approach and trial implants are used, aiming for 15° anteversion and 40° inclination; we also reference according to the transverse acetabular ligament as a collateral guide. The cup is then impacted and the femur addressed.

The files of the study group were retrieved from our records department to obtain patient parameters, demographic details, aetiology of hip pathology, confirmation of the Hardinge approach, associated comorbidities, and history of previous pelvic or hip surgery.

The theatre register for the period between 2009 and 2015 was also retrieved, and information was gathered regarding the size of the acetabular component and the surgeons involved. Immediate postoperative anteroposterior pelvic radiographs were used for analysis of component positioning on our PACS. These were true anteroposterior views of the pelvis, centred over the pubis.

The inclination was measured using the ischial tuberosity line and a line connecting the most medial and lateral points of the cup. The anteversion was calculated using the Liaw method: version = $\sin^{-1} \tan \beta$, where β angle is the angle between the long axis of the component (AB in *Figure 1*) and the line connecting the end of AB with the end-point of the ellipse (C in *Figure 1*).[7] Angle β is used to calculate the anteversion. Line DC is a perpendicular line at the midpoint of AB.

All the hips were measured by the main author and co-author. Interobserver reliability was calculated for anteversion and inclination. Given a reliability of above 0.8, the averaged value across raters was used. The accuracy of three groups was determined: group 1 (the consultant was the main surgeon and the registrar assisted); group 2 (the registrar was the main surgeon and the consultant assisted); and group 3 (the registrar was the main surgeon and another registrar assisted). Information regarding dislocations was gathered by reviewing the patients' files and assessing radiographs of each patient on our PACS. All information was recorded in a data sheet in Microsoft Excel. To calculate our dislocation rate, the patient records and follow-up radiographs on PACS up until a year postoperatively were analysed.

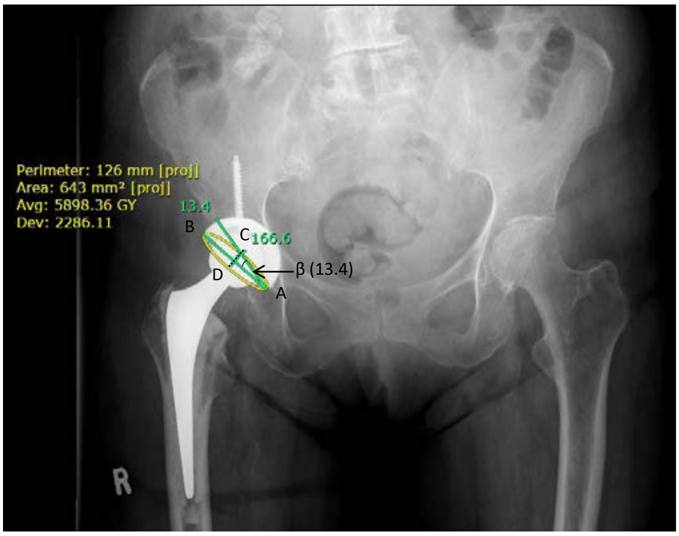

Figure 1. Depiction of the method of Liaw et al.

Statistical analysis

Categorical variables were described using frequencies and proportions. The complication rate was estimated with a 95% confidence interval (CI). Continuous variables were described using mean and standard deviation. Scatterplots were constructed to visually assess points within the safe zones. The chi-square test was used to test associations between categorical variables. Fisher's exact test was used when expected frequencies were below 5, as in the case of the dislocation rate. The t-test was used to compare means between groups. Interobserver reliability was evaluated using the intraclass correlation coefficient (ICC), where above 0.8 is accepted as strong reliability. Statistical significance was set at 5%. Statistical analysis was conducted using StataCorp. 2019, Strata Statistical Software: Release 16, College Station, TX: StrataCorp LLC.[7]

Results

We reviewed 253 total hip replacements performed using the direct lateral approach. The mean (SD) patient age at time of surgery was 62.4 years (SD 12.7 years). There were 160 (63%) female patients and 93 (36%) male patients. One hundred and twenty-five were left hip replacements, while the remaining 128 were right hip replacements. The vast majority (120 hips; 47%) presented with neck of femur fractures, 77 (30%) with osteoarthritis, 51 (20%) with avascular necrosis and five (2%) with dysplasia (*Table I*).

The acetabular cups used during these procedures were uncemented in 220 cases (87%) and cemented in 33 cases (13%). Cup sizes ranged from 36 mm to 64 mm, the most common being 50 mm. The acetabular liner was of polyethylene in all cases.

The radiographic analysis was performed using the Liaw method based on the trigonometry of the eclipse generated. An ICC of 0.98 for both anteversion and inclination indicated strong reliability between raters. Therefore, the values were averaged across

Table I: Patient demographics

Variable		n	%
Age (in years; mean)		62.4	
Sex	Male	93	37
	Female	160	63
Aetiology	Neck of femur	120	47
	Osteoarthritis	77	30
	Avascular necrosis	51	20
	Dysplasia	5	2
Side of pathology	Left	125	49
	Right	128	51

Table II: Relationship between accuracy and dislocation

Range of acetabular anteversion	Range of acetabular inclination	Not dislocated	Dislocated	Total
		n (%)	n (%)	n (%)
< 5°; > 25°	< 30°; > 50°	14 (6)	1 (10)	15 (6)
5–25°	< 30°; > 50°	39 (16)	2 (20)	41 (16)
< 5°; > 25°	30–50°	49 (20)	4 (40)	53 (21)
5–25°	30–50°	141 (58)	3 (30)	144 (57)
Total		243 (100)	10 (100)	253 (100)

raters. The mean cup anteversion was 12.7° (95% CI: 12.0–13.7°) and mean cup inclination was 42.3° (95% CI: 41.3–43.3°).

In *Figure 2*, we present the cases according to anteversion and inclination in relation to the demarcated safe zone. More than half (144; 57%) of the acetabular cups were inserted within the safe zone described by Lewinnek et al., with 73% in the 5–25° range for anteversion and 78% in the 30–50° range for inclination. The relationship between accuracy of cup positioning and dislocations can be seen in *Table II.* There were ten dislocations within a year of the index procedure, resulting in a dislocation rate of 4.0% (95% CI: 2.8–8.5%).

There were 82 hips (32%) in group 1, 83 (33%) in group 2 and 88 (35%) in group 3. Group 1 had a mean cup anteversion of 10.5° (95% CI: 8.5–12.4°) and a mean cup inclination of 43.4° (95% CI: 41.6–45.3°). Group 2 had a mean cup anteversion of 14.5° (95% CI: 12.6–16.4°) and a mean cup inclination of 41.5° (95% CI: 39.8–43.3°). Group 3 had a mean cup anteversion of 13.0° (95% CI: 11.4–14.6°) and a mean cup inclination of 42.0° (95% CI: 40.3–43.6°; *Table III*).

Discussion

Hassan et al. reviewed the radiographs of 50 patients treated using a lateral approach. They used a trigonometric measurement to calculate the accuracy of cup placement according to Lewinnek et al.'s safe zones and reported an accuracy of 58% for anteversion and inclination together, of 68% for anteversion alone and of 84% for inclination alone, and no dislocations.[8]

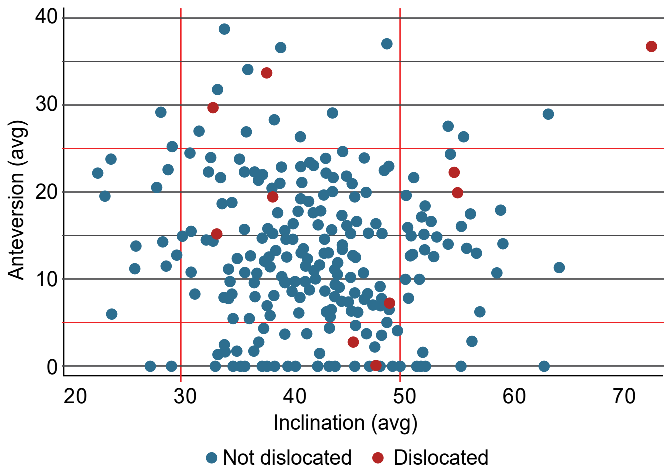

Figure 2. Scatterplot showing cases according to anteversion and inclination (in degrees) and indicating cases of dislocation

Hohmann et al. compared the accuracy of cup placement between imageless navigation and the freehand technique. All 30 patients in the freehand technique group were operated on via a lateral approach in a supine position. Accuracy was determined using postoperative CT scans of all patients. According to the Lewinnek et al. criteria, 20 of the 30 (66.7%) were in the safe zone for anteversion and 18 (60.0%) for inclination, while only six (20.0%) were in the safe zone for both. Navigation, however, improved the accuracy for anteversion and inclination to 86.7%.[9]

In a groundbreaking study, Callanan et al. compared the accuracy of freehand techniques using different approaches. Applying Lewinnek et al.'s criteria, they reported an accuracy of 57.3% (670 of 1 170 patients) for the posterolateral approach, an accuracy of 37.0% (207 of 560) for the anterolateral approach, and an accuracy of 32.0% (16 of 50) for the Hardinge lateral approach.[3]

Similar to the posterolateral group in the Callanan et al. study, we achieved an accuracy of 57% and improved results compared with the Hardinge lateral approach group for cups inserted in the Lewinnek et al. safe zones for anteversion and inclination. Although the literature has shown that inclination of less than 30° reduces range of motion, can cause impingement of the femoral neck on the cup and can lead to dislocation, none of the dislocations in our study occurred with regard to this inclination.[10]

CT scans remain the gold standard for true measurement of anteversion and inclination angles.[11] Radiographs can also be used to determine cup orientation; however, pelvic tilting and the difference between radiographic and anatomical landmarks can affect calculations. Radiographs are accepted as a postoperative control after total hip replacement; they are much cheaper and do not expose the patient to high levels of radiation compared with CT scans.[12]

Alzohiry et al. recommend the Lewinnek et al. and Liaw methods for determining the anteversion angle on anteroposterior pelvis or anteroposterior hip radiographs.[13] *Figure 3* is an X-ray of a patient that sustained a right neck of femur fracture. In the Liaw method, a line is drawn across the maximal diameter of the ellipse (AB) on the anteroposterior radiograph, and another point

Table III: Mean cup anteversion and inclination by surgical group

Surgical group	n (%)	Anteversion		Inclination		Anteversion and inclination
		Mean (95% CI)	n (%) in 5–25°	Mean (95% CI)	n (%) in 30–50°	n (%) in safe zone
Group 1	82 (32)	10.5° (8.5–12.4°)	50 (61)	43.4° (41.6–45.3°)	64 (78)	39 (48)
Group 2	83 (33)	14.5° (12.6–16.4°)	61 (73)	41.5° (39.8–43.3°)	63 (76)	45 (54)
Group 3	88 (35)	13.0° (11.4–14.6°)	74 (84)	42.0° (40.3–43.6°)	70 (80)	60 (68)

Figure 3. Neck of femur fracture

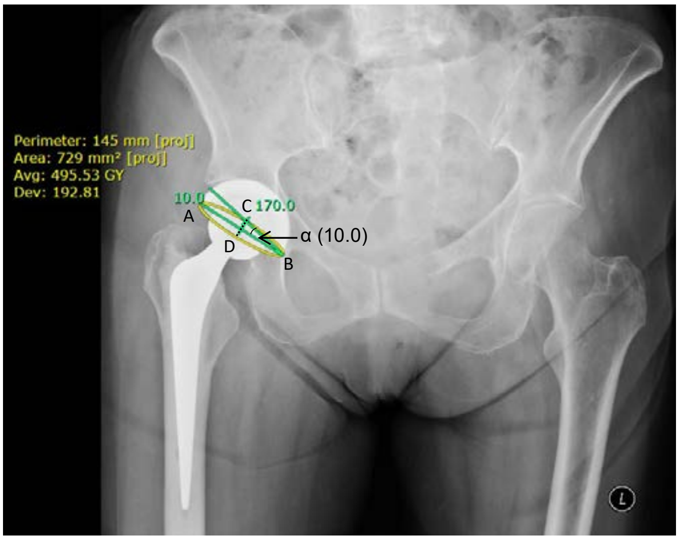

Figure 4. Anteversion

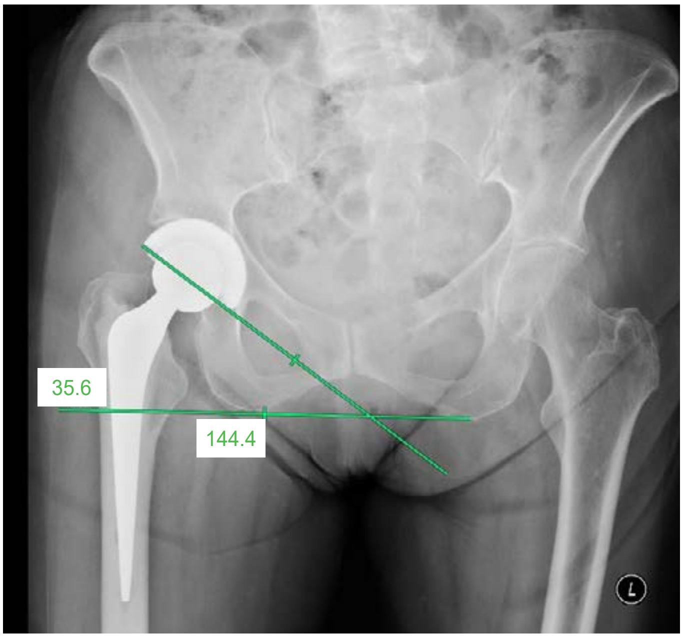

Figure 5. Inclination

(C) midway on the ellipse, which is the intersection of the ellipse, and a line perpendicular to and going through the midpoint of AB is determined.[13] Another line from the apex (B) to the point (C) is then drawn.[13] The angle between lines BC and AB is then measured (α), and the anteversion is calculated according to $\sin^{-1} \tan \alpha$ (*Figure 4*).[13] Inclination is measured by the angle between the ischial tuberosity line and a line connecting the medial and lateral borders of the cup *(Figure 5).* Alzohiry et al. found no statistical difference between CT measurements and the Liaw method.[13] Park et al. showed that the Liaw method is the most accurate method with reference to the anteversion obtained from the PolyWare software program.[7] PolyWare is a better reference for radiographic anteversion, while CT better reflects anatomical anteversion.[7] Bayraktar et al. used a similar software program to assess acetabular cup orientation, and they found that the mean values for absolute differences between CT and radiographs were 7.2° for anteversion and 3.1° for inclination.[11]

Newer technologies to improve cup positioning include computer-assisted navigation, consisting of active, semi-active and passive navigation.[14] Active navigation employs robots to implant cups, and semi-active systems allow the surgeon to move the robotic arms but do not allow the arms to move beyond a milling boundary determined by preoperative three-dimensional imaging.[14] Passive navigation only guides the surgeon in implanting in the correct position and consists of three types of navigation: imageless navigation, CT-based navigation and fluoroscopic navigation.[14] Imageless navigation uses optical sensors as 3D-position sensors to track the target bones and surgical tools or implants and then gives feedback on anteversion and inclination of the acetabular cup, relative to the anterior pelvic plane.[1]

In their comparison of the freehand technique with computer-assisted navigation, Parratte and Argenson found no differences between treatment groups with regard to the mean cup abduction and anteversion angles.[15] However, the computer-assisted surgery system significantly reduced the percentage of outliers according to the criteria described by Lewinnek et al. from 57% (17 of 30) in the freehand placement group to 20% (6 of 30) in the computer-assisted group using an anterolateral approach, and there were no dislocations in either group.[4, 15]

Dorr et al. compared imageless computer-assisted navigation and the freehand technique regarding the accuracy of cup placement in terms of anteversion and inclination, verifying component placement by CT.[16] With imageless computer-assisted navigation, the variability was 4.1° for anteversion and 4.4° for inclination, whereas with the freehand technique, the variability was 12.3° for anteversion and 11.5° for inclination.[16]

We detected ten dislocations within the first year of the index procedure, resulting in a dislocation rate of 4%. We observed from our study that we did not have any dislocations if inclination was between 20–30°, regardless of the anteversion. On the other hand, we do not know how this affects wear of components, and prospective studies would be beneficial to provide more information. Kwon et al. in their meta-analysis reported a dislocation rate of 0.43% (10 of 2 309) of THAs performed via the direct lateral approach compared with a dislocation rate of 1.01% (21 of 2 084) of THAs performed via the posterior approach.[17]

Among the limitations of our study is that we used radiographs on our PACS to determine the anteversion and inclination, and radiographic measurements are subject to human error. These measurements were not calibrated against a CT scan. Secondly, pelvic tilt or rotation may also have influenced the measurements. Thirdly, the discretion of the surgeons was trusted in that all cups would be placed in anteversion, as cups that measured more than 5° theoretically could be retroverted, but this cannot reliably be confirmed unless CT scans are employed. We, however, argue that this does not detract from the main findings of the study, as these associations do not affect the estimate of the dislocation rate, nor the overall accuracy of the surgical procedures.

Conclusion

In our study, the freehand technique using a direct lateral approach for acetabular cup placement achieved an accuracy of only 57% regarding the safe zones of Lewinnek et al. It is still a recognisable approach for neck of femur fractures, with 47% of our study population falling into this group. Our study reported ten dislocations, a rate (4.00%) significantly worse than the 0.43% reported in the literature for the direct lateral approach.

Navigation and robotic surgery are developing fields within orthopaedics. Improvements in accuracy of cup placement are evident. However, these newer technologies can be time-consuming initially and expose patients to additional radiation and are not always cost-effective. Prospective studies are needed to determine whether they are functionally significant and whether they reduce complications and secondary revision surgery.

Ethics statement

The author/s declare that this submission is in accordance with the principles laid down by the Responsible Research Publication Position Statements as developed at the 2nd World Conference on Research Integrity in Singapore, 2010.

Prior to the commencement of the study, ethical approval was obtained from the following ethical review board: Faculty of Health Sciences Research Ethics Committee, University of Pretoria, Reference no. 440/2019

Declaration

The authors declare authorship of this article and that they have followed sound scientific research practice. This research is original and does not transgress plagiarism policies.

Author contributions

RDE: primary author, study design, data collection, data analysis
PJF: co-author, data collection
CJvR: information technology and analysis
HWJ: conceptualisation, study design, manuscript revision and supervision

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References

1. Snijders T, Van Gaalen SM, De Gast A. Precision and accuracy of imageless navigation versus freehand implantation of total hip arthroplasty: A systematic review and meta-analysis. Int J Med Robot. 2017;13(4).
2. Soderquist MC, Scully R, Unger AS. Acetabular placement accuracy with the direct anterior approach freehand technique. J Arthroplasty. 2017;32(9):2748-54.
3. Callanan MC, Jarrett B, Bragdon CR, et al. The John Charnley Award: risk factors for cup malpositioning: quality improvement through a joint registry at a tertiary hospital. Clin Orthop Relat Res. 2011;469(2):319-29.
4. Moskal JT, Capps SG. Improving the accuracy of acetabular component orientation: avoiding malposition. J Am Acad Orthop Surg. 2010;18(5):286-96.
5. Lewinnek GE, Lewis JL, Tarr R, et al. Dislocations after total hip-replacement arthroplasties. J Bone Joint Surg Am. 1978;60(2):217-20.
6. Abdel MP, Von Roth P, Jennings MT, et al. What safe zone? The vast majority of dislocated THAs are within the Lewinnek safe zone for acetabular component position. Clin Orthop Relat Res. 2016;474(2):386-91.
7. Park YS, Shin WC, Lee SM, et al. The best method for evaluating anteversion of the acetabular component after total hip arthroplasty on plain radiographs. J Orthop Surg Res. 2018;13(1):66.
8. Hassan DM, Johnston GH, Dust WN, et al. Accuracy of intraoperative assessment of acetabular prosthesis placement. J Arthroplasty. 1998;13(1):80-84.
9. Hohmann E, Bryant A, Tetsworth K. A comparison between imageless navigated and manual freehand technique acetabular cup placement in total hip arthroplasty. J Arthroplasty. 2011;26(7):1078-82.
10. Deacon M, De Beer J, Ryan P. Radiological analysis of component positioning in total hip arthroplasty using the anterior approach. SA Orthop J. 2016;15(3):38-45.
11. Bayraktar V, Weber M, Von Kunow F, et al. Accuracy of measuring acetabular cup position after total hip arthroplasty: comparison between a radiographic planning software and three-dimensional computed tomography. Int Orthop. 2017;41(4):731-38.
12. Haenle M, Heitner A, Mittelmeier W, et al. Assessment of cup position from plain radiographs: impact of pelvic tilting. Surg Radiol Anat. 2007;29(1):29-35.
13. Alzohiry MA, Abdelnasser MK, Moustafa M, et al. Accuracy of plain antero-posterior radiographic-based methods for measurement of acetabular cup version. Int Orthop. 2018;42(12):2777-85.
14. Bhaskar D, Rajpura A, Board T. Current concepts in acetabular positioning in total hip arthroplasty. Indian J Orthop. 2017;51(4):386-96.
15. Parratte S, Argenson JN. Validation and usefulness of a computer-assisted cup-positioning system in total hip arthroplasty. A prospective, randomized, controlled study. J Bone Joint Surg Am. 2007;89(3):494-99.
16. Dorr LD, Malik A, Wan Z, et al. Precision and bias of imageless computer navigation and surgeon estimates for acetabular component position. Clin Orthop Relat Res. 2007;465:92-99.
17. Kwon MS, Kuskowski M, Mulhall KJ, et al. Does surgical approach affect total hip arthroplasty dislocation rates? Clin Orthop Relat Res. 2006;447:34-38.