ORIGINAL ARTICLE

Comparing the effect of cup placement between true and false acetabula in total hip arthroplasty in patients with Crowe type 3 dysplastic hip: A randomized clinical trial

Mehdi Motififard[1], Mohammad Mir Miran Yazdi[2], Mehdi Teimouri[1], Saeed Hatami[2], Moslem Rafiee[2], Arash Toghyani[3], Ali Andalib[2]

[1]Department of Orthopedic Surgery, School of Medicine, Kashani University Hospital, Isfahan University of Medical Sciences, Isfahan, Iran, [2]Department of Orthopedic Surgery, School of Medicine, Isfahan University of Medical Sciences, Isfahan, Iran, [3]School of Medicine, Isfahan University of Medical Sciences, Isfahan, Iran

Background: Hip dysplasia is one of the most widespread hip disorders. Total hip arthroplasty (THA) is the preferred treatment in patients with cup placement choices in true or false acetabulum. The objective of this research was to compare the effectiveness of the two mentioned procedures. **Materials and Methods:** This study was a randomized, open-label, parallel-group clinical trial, in which 46 patients/51 hips with Crowe type 3 dysplastic hip having THA were assigned to two groups: Group 1 – patients who had cup placement in the true acetabulum and Group 2 – patients who underwent cup placement in the false acetabulum. The variables that were evaluated and analyzed included severity of pain using the visual analog scale (VAS), range of motion (ROM), gait ability, the need for repeated joint replacement, and the Harris Hip Score (HHS). **Results:** Forty-six patients/51 hips were included in the present study. The patients who were evaluated included 30 (65.2%) males and 16 (34.8%) females. The mean age in the population under study was 71.0 ± 10.22, and the mean body mass index of participants was 26.34 ± 2.22 kg/m^2. The basic parameters in the two research groups were similar ($P > 0.05$). There were no significant differences between the two groups in terms of the mean values of VAS and ROM ($P > 0.05$); however, the mean HHS was significantly higher in the true acetabulum group, 57.90 ± 18.47 versus 48.29 ± 13.80 ($P = 0.04$). **Conclusion:** The effectiveness of cup placements both in the true and false acetabula was similar in all of the evaluated variables in terms of clinical outcomes except for HHS which was higher in the true acetabulum group. To further support the results of this research, it is recommended that more research be done on a greater population.

Key words: Acetabulum, general surgery, hip dislocation

How to cite this article: Motififard M, Mir Miran Yazdi M, Teimouri M, Hatami S, Rafiee M, Toghyani A, *et al*. Comparing the effect of cup placement between true and false acetabula in total hip arthroplasty in patients with Crowe type 3 dysplastic hip: A randomized clinical trial. J Res Med Sci 2022;27:72.

INTRODUCTION

Hip dysplasia is a relatively widespread disorder among children with a prevalence rate of 0.5%–4%.[1] Though patients are diagnosed in early ages, they may be missed[2] and consequently hip joint inappropriate weight distribution may cause symptomatic dysplasia.[3] It has been observed that total hip arthroplasty (THA) meaningfully improves the quality of life among these patients.[4] In dysplastic hips with false acetabulum formation, THA is performed by placing the cup in the true (original) acetabulum.[5] True acetabulum cup placement provides a more functional anatomical center of rotation, but leads to less wall coverage. As in many cases if the dimensions of the cup and femoral head which are utilized are smaller, cup loosening and hip dislocation might be more prevalent with deteriorating postoperative clinical outcomes. Regarding better bone stalk, the false acetabulum provides larger femoral heads and may reduce hip dislocation but changes the hip rotation axis.[5,6]

Access this article online

Quick Response Code:

Website: www.jmsjournal.net

DOI: 10.4103/jrms.jrms_766_21

Address of correspondence: Dr. Ali Andalib, Department of Orthopedic Surgery, School of Medicine, Isfahan University of Medical Sciences, Hezar Jarib Blvd, Isfahan, Iran. E-mail: draliandalib@gmail.com

Submitted: 31-Aug-2021; **Revised:** 16-May-2022; **Accepted:** 04-Jul-2022; **Published:** 27-Sep-2022

To reduce the risk of osteoarthritis in the future, prompt therapy of the dysplastic hip should be undertaken. On the other hand, if the Developmental Dysplasia of the Hip (DDH) is overlooked or neglected during the infantile and early adulthood period, the method of choice of therapy is THA. Studies have shown that in patients with osteoarthritis due to hip dysplasia, THA improved the quality of life meaningfully.[4] In a dysplastic hip that forms a false acetabulum, the head of the femur is displaced superiorly and laterally; therefore, the anterior and superior acetabulum wall is defected. Another defect that is noticed in these patients is that the muscular structures and surrounding soft tissue are exceedingly contracted requiring major release of the soft tissue, capsulotomy, and release of the iliopsoas tendon.[7,8] There are different techniques of THA which can be done in dysplastic hips with false acetabulum formation ("highly dislocated hips"), including positioning the cup of prosthesis in the true (original) or false (dislocated) acetabulum or in the middle of both.[5] The advantage of placing the cup in the true acetabulum is that more anatomical reduction can be provided in comparison to placing the cup in the false one creating a more functional anatomical center of rotation for the patient's hip. Nevertheless, placing the position of the cup prosthesis in a hypoplastic acetabulum may lead to less bone coverage, particularly in the medial wall, as a result, applying higher pressure to the bones and implants. Therefore, a small-sized cup and subsequently smaller femoral head should be used, but this in turn could be associated with elevated risks of cup loosening and postoperative dislocations. In addition, a small-sized cup restricts our choice in using variable cups, which may be a technical limitation for the surgeon. In the procedure with true acetabulum cup positioning, concomitant surgical procedures such as subtrochanteric or supracondylar osteotomy and femoral shortening may be necessitated, which, in turn, may in theory need more soft tissue releasing. Such procedures are associated with longer surgery times and subsequently higher levels of blood loss. In a publication, in which the acetabular cup was placed in the true acetabulum, subtrochanteric or supracondylar osteotomy was found to be essential in nearly half of the patients under the study (18). While the procedure of subtrochanteric femoral shortening osteotomy is known to be an effective and dependable method with minimum occurrence of nonunion,[9,10] the risk of the need for concomitant surgery and the likelihood of nonunion should be taken into account.

In patients with DDH, one more surgical procedure that can be done is the placement of the cup in the false the acetabulum. This procedure can reduce the possibility of postoperative dislocation since it provides better bone stalk compared to cup placement in the true hypoplastic acetabulum. On the other hand, this technique may be linked with minor variations in the axis of hip rotation.[5] In addition, the length of operation is shorter in this technique. When there is an inadequate amount of bone coverage, bone grafts can be used to make a correction. Although there have been various studies regarding the efficacy of cup placement in the true or false acetabulum in patients with hip dysplasia, the results have been conflicting.[11,12]

During recent times, the types of prosthesis that have been used and the techniques for cup positioning have transformed enormously, and therefore, more research should be performed to make comparisons in the effectiveness of these techniques. The previously conducted clinical trials aiming to make comparisons between the results of cup positioning in the true or false acetabulum in patients with DDH who require THA have been very few,[9,13] with the majority of research being conducted in the form of retrospective cohort studies. Our objective was to assess and compare the efficacy and side effects of these two principal and well-known cup positioning methods for THA in patients who suffer from high dislocated developmental hip dysplasia. In addition, we assessed the results of these two different methods from a clinical point of view.

MATERIALS AND METHODS

Study design and participants

The study, which was a randomized, open-label, controlled, parallel-group clinical trial, was performed on patients who attended the Orthopedic Clinic of Saadi and Kashani Hospitals, affiliated with the Isfahan University of Medical Sciences, Isfahan, Iran. The research was approved by the Ethics committee of the Isfahan University of Medical Sciences (IR.MUI.MED.REC.1397.072) and also by the Iranian Registry of Clinical Trials (IRCT20200217046523N5). The patients underwent primary cementless THA between 2013 and 2018 and satisfied the inclusion criteria of the study. In total, 46 patients/51 hips who filled out a written consent form to participate in the study were selected and randomly allocated into two intervention groups, i.e., one group with the THA method using cup positioning in the true acetabulum technique and the other group with cup positioning in the false acetabulum. The randomization was performed using the Random Allocation Software.

The required sample size was calculated by utilizing the formula for sample size estimation. In this study, the means were compared when considering the 95% confidence level, 80% test power, standard deviation (SD) of mean blood pressure in controlled hypotension which was about 1.5 (15), and the effect size which was 0.8 in 23 patients in each group. In addition, the person who collected the data

and the person who made the statistical analysis were not aware of the dose of fentanyl administered to patients. After the data were analyzed, the codes were revealed and comparisons were made between the groups. The sampling method was the convenient method.

The patients who were included in the study were those with hip dysplasia with a Crowe type III and IV classification[14] who had THA. The Crowe index is measured using anteroposterior (AP) radiographs of the hip centered on the pubic symphysis and including the iliac wings and indexes which are: (1) the pelvic height; (2) the medial head–neck junction in the afflicted hip; and (3) the inferior margin of the acetabulum (the teardrop). Crowe score 1 is considered to have smaller than 50% partial dislocation. Crowe score 2 is considered to show 50%–75% partial dislocation, whereas Crowe score 3 is known to have 75%–100% partial dislocation. Type 4 is considered higher than 100% partial dislocation.[15] Additional inclusion criteria were the absence of any other skeletal deformities, having hip dysplasia, with both the true and false acetabula present in their hip, and signing the written informed consent. Patients who refused to participate in the study, who had a history of ipsilateral pelvic trauma and associated surgeries, a history of ipsilateral hip infection or tumor, lack of data on main study outcomes during follow-up, any other Crowe types including type 1, 2, and 4, having neuromuscular diseases, lumbar spine stiffness or severe spinal deformity were excluded from the study.

Study procedures and evaluation of outcomes

The approach that was used for all patients without trochanteric osteotomy was the direct lateral approach. In addition, any osteophytes or soft tissues that interfered with the techniques were removed. To expose the true acetabulum and proximal femur, resection of the hypertrophic capsule and femoral head was done. A contact surface of the bone cup location which was higher that than 70%–75% was an indication of joint stability during the THA operation. Throughout every stage of the operation, stability of the cup and superolateral side of the rim was evaluated, and in cases of insufficient bone coverage, structural bone grafts were utilized if it was deemed essential. However, in our research, there was no need to use any bone grafts. The devices that were routinely used for the patients were the Trilogy Acetabular System, M/L Taper Prosthesis, Aqulad wedge femoral stem, and Corail Total Hip System. The information about the types of prostheses used in this research are available in detail but not elaborated since this was not one of the objectives of the research in question.

Placement at true acetabulum

The approach that was used was the direct lateral approach, which was done in all the patients by a single surgeon. When considering the fact that the neurovascular bundle may be dislocated from their original anatomical location, soft tissue dissection was done with care. While radiographs can be used to determine the exact position of the acetabular section preoperatively, an image intensifier can be used to monitor the complete course of determining the true acetabulum. To gradually deepen and enlarge the acetabulum, once the soft tissue was dissected adequately, serial reaming at the preferred angle of abduction and anteversion was done until the anterior and posterior walls appeared. Then, the cementless element was suitably fixed (used size was 40–44 mm) (21). No structural bone grafts were utilized.

Placement at false acetabulum

In each hip, the approach that was employed was the direct lateral approach. Joint capsulectomy, gluteal sling release, and iliopsoas tenotomy were completed. The cup (range, 44–52 mm) was embedded at the nonanatomic or "false" position. For increasing the primary stability of the cup, screws were applied. During the operation, stability was checked, and if needed additional bone grafts were utilized, but in our study, there was no need for bone grafts.

Placement of femoral prosthesis

After the cup was implanted, the femoral canal was arranged using the dedicated reamer for the stem. With trial placed in the femur, the final vertical distance from the femoral head to the cup was measured. A subtrochanteric or supracondylar osteotomy could be completed for femoral shortening if it was not possible to make a hip reduction with a femoral trial stem. In our research, there was no need for shortening.

Postoperative assessment

The visual analog scale (VAS) was used to evaluate the severity of pain, which had a range from 0 to 10 with no pain scored (0) and highest level of pain scored at 10. Pain was assessed during the hospitalization period with an average score being obtained. It is worth mentioning that immediately after surgery, the patients were encouraged to be mobilized as soon as possible. In addition, on the day after surgery, weight-bearing as tolerated was done, and if it was needed, a physiotherapist was summoned. In the 1st, 3rd, 6th, and 12th months after the operation, the immediate postoperative AP radiographs of the pelvis were taken and repeated. If there was a change in alignment of >4° or migration of >3 mm present in the radiographic evaluation, the acetabular component was deemed to be loose.[16] Physical examinations 1 year after the surgery was used to assess the range of motion (ROM) of the involved joints, which included average degrees of hip extension, flexion, abduction, adduction, external rotation, and internal rotation. The Harris Hip Score (HHS) was measured for each patient after 1 year of surgery and scored from 0 to 100.[17] Further complications such as the occurrence of infection,

necessity for revision, and hip dislocation were evaluated and analyzed in the course of the research.

Basic data assessment of patients

The information that was gathered from the patients included age, sex, weight, height, body mass index (BMI) and involved side, and gait type. The gait of the patients was assessed and scored from 1 to 6, in which normal gait scored 6 and mild claudication but no usage of a cane scored 5. In addition, patients with the ability to walk a long distance with a single cane and mild disability of walking without a cane scored 4. Patients who had a limitation in walking with a single cane and serious problems when walking without a cane or standing up for a while scored 3. Having a severe disability when walking with or without a single cane scored 2 and patients who could only walk for 2–3 meters or had a disability when walking or those who needed to use 2 canes scored 1.[18] In the study, patients who had a score of 4–6 in gait and those with a Crowe type 3 were included in the study population. In addition, the involved side was recorded, which included left, right, and both sides. Patients who had both sides involved were not compared to patients with only one side involved. Loosening was evaluated during the postoperative visits and intervals with an X-ray of the joints and using physical examinations.

Statistical analysis

Continuous and categorical data were reported as mean ± SD and frequency (percentage), respectively. Normality of continuous was evaluated using the Kolmogorov–Smirnov test and Q-Q plot. Continuous data were compared between the groups using the independent samples *t*-test and analysis of covariance (ANCOVA). ANCOVA was used when adjustment was required for potential confounding variables. Categorical data were compared between the groups using the Chi-squared or Fisher's exact tests. All statistical analyses were completed using SPSS 20 (IBM Corp. Released 2011. IBM SPSS Statistics for Windows, Version 20.0. Armonk, NY, USA: IBM Corp.).

RESULTS

In total, 96 patients were observed, 31 of which did not meet the inclusion criteria. In addition, 9 of the patients did not express consent to participate in the research. On the other hand, after meticulous examination before the initiation of the research, six patients were excluded since they suffered from comorbidities affecting the main study outcome variables. Finally, 50 patients with unilateral/bilateral hip dysplasia were included in the study. However, four patients exited during the follow-up period. Eventually, the data from 22 patients/25 hips in the true and 24 patients/26 hips in the false groups were analyzed [Figure 1].

The population under the study consisted of 30 (65.2%) males and 16 (34.8%) females. The mean age of our patients was 71.0 ± 10.22, and the mean BMI of patients was 26.34 ± 2.22 kg/m^2. The majority of those who participated in the research had involvement of the limb on one side, which included 22 (47.8%) with right side and 19 (41.3%) with left side involvement and the remaining (5 patients, 10.9%) with involvement on both sides. The study groups were similar regarding basic characteristics with no statistically significant differences between the groups ($P > 0.05$) [Table 1].

All the predefined main outcomes between the two groups were compared. The difference in the mean values of VAS were not statistically significant between the two study groups, which did not change after adjustment for age and BMI ($P = 0.86$). The difference in the ROM was not significant between the groups, after adjusting the confounding effects of age and BMI ($P = 0.26$). The mean HSS scores of the two groups were compared, which showed a statistically significant difference before and after adjustment for confounders ($P = 0.04$). Similar results were witnessed for all of the main outcomes of the research in subgroup analyses by gender, except in HHS that was not significantly different between two groups in any female and male subgroups [Table 2].

The length of hospital stay for the patients was from 2 to 4 days. The method of choice for performing anesthesia for all patients was spinal anesthesia, although among the patients a total of nine patients had to have general anesthesia in the two groups because of the increased duration of operation. Subsequently, one patient in the false acetabulum group and one patient in the true acetabulum group showed radiologic signs of acetabular loosening after the operation. The method of treatment was to receive

Table 1: Basic demographic and clinical characteristics of patients in the two study groups

Variable	True (*n*=22), *n* (%)	False (*n*=24), *n* (%)	*P**
Age (year)	69.13±10.09	72.75±9.26	0.24
Sex			
Male	15 (68.2)	15 (62.5)	0.68
Female	7 (31.8)	9 (37.5)	
BMI	26.95±2.57	25.79±1.72	0.08
Limb involved side			
Right	11 (50.0)	11 (45.8)	0.75
Left	8 (34.6)	11 (45.8)	
Both	3 (13.6)	2 (8.3)	
Gait type			
4	3 (13.6)	3 (12.5)	0.93
5	10 (45.5)	11 (45.8)	
6	9 (40.9)	10 (41.7)	

*Results from independent samples test and Chi-squared test for continuous and categorical data, respectively. Data are reported as mean±SD and frequency (%). BMI=Body mass index; SD=Standard deviation

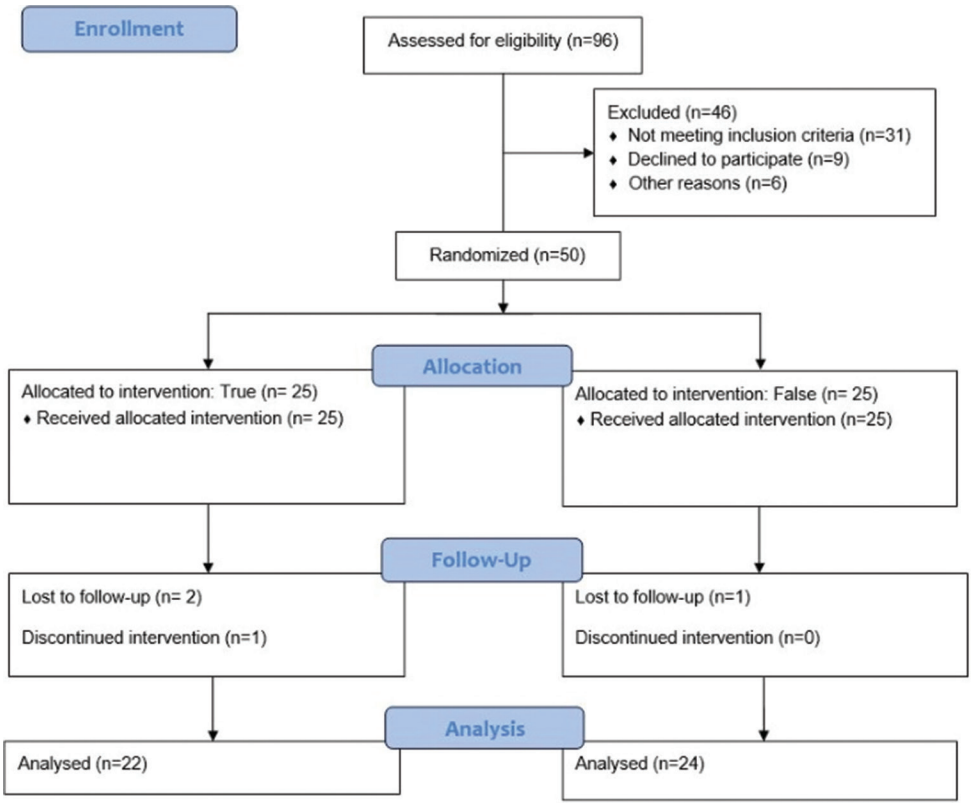

Figure 1: The CONSORT flow diagram of the patient's recruitment

Table 2: Comparison of main study outcomes between the two study groups

Variable	Total sample		*P**	Female		*P**	Male		*P**
	True	False		True	False		True	False	
VAS	3.45±0.73	3.41±0.71	0.86	3.57±0.78	3.33±0.86	0.58	3.40±0.74	3.46±0.64	0.79
ROM	105.00±13.18	108.75±9.23	0.26	102.14±12.53	109.44±10.13	0.21	106.33±13.68	108.33±8.99	0.64
Harris Hip Score	57.90±18.47	48.29±13.80	0.04	56.71±13.51	47.88±14.96	0.24	58.46±20.80	48.53±13.59	0.13

*Resulted from independent samples test and Chi-squared (or Fisher's exact) test for continuous and categorical data, respectively. Data are reported as mean±SD and frequency (%). VAS=Visual analog scale; ROM=Rang of motion; SD=Standard deviation

observational evaluations, in which they showed no signs of any clinical difficulty by the conclusion of the research. In terms of the length of hospital stay and need to switch the anesthesia method from spinal to general, there were no significant differences witnessed between the two groups ($P > 0.05$). There was no need to use structural bone grafts in any of the groups. In addition, there was no subtrochanteric or supracondylar osteotomy performed on any of the patients.

After 1 year from the operations, there was one patient from the false acetabulum group, one patient from the true acetabulum group, and one patient from the bilateral THA who suffered from mild claudication; nevertheless, they described major improvements after surgery. In addition, there was no noteworthy heterotopic ossification observed in hip periarticular tissues. Furthermore, there was no incidence of immediate or delayed wound dehiscence or infection. In terms of iatrogenic vascular injury to the femoral artery and need for repeated surgeries, no cases were reported either. The only case of paresthesia with signs of sciatic nerve palsy during the follow-up visits was just one case in the true acetabulum group. These symptoms showed improvement spontaneously without any additional therapy.

DISCUSSION

If acetabulum malformation occurs in patients with asymptomatic mild DDH, since the medial and superolateral sides of the acetabulum are weak, THA may be associated with more surgical problems. In a research done by Widmer in 2007, the zones for placing the cup were assessed in patients who had THA. The results showed that most patients had suitable coverage and symmetric load transfer. As a result, long-term stability was acceptable. Placing the cup in the true or false acetabulum showed quite a similar prognosis in the patients. In addition, it

was recommended that a safe zone should be taken into consideration.[15] On the other hand, our clinical research is about the results of the Crowe type 3 dysplastic hip patients who received hip arthroplasty. The patients in the true acetabulum group showed superior results in their function.

By comparing the cup placement in the true or false acetabulum in this research, a preference from the HHS viewpoint was shown in the true acetabulum group. A study performed by Zheng *et al*.[19] showed that cup medialization was a method to obtain superior bone coverage. In addition, subtrochanteric or supracondylar shortening osteotomy was done and widespread soft tissue release was avoided, if leg lengthening was to be more than 4 cm after hip reduction.[20,21] This was to reduce the possibility of dislocation in patients. In a recent publication, there was no need to perform an osteotomy since the hip deformity was deemed minor based on the Crowe classification and preoperative gait type.

Seagrave *et al*., who published a systematic review in 2017, reviewed 28 previous articles, in which a safe zone for cup placement during THA was evaluated. In their article, they stated that determining a safe zone was nearly impossible because of varying findings in previous articles. In addition, the surgical methods may have no significant differences because of the multifactorial characteristic of THA dislocation. As a result, they suggested that additional research must take place to evaluate the relationship between cup positioning and degrees of dislocation.[22,23] According to other researches, factors affecting the increased likelihood of dislocation after THA include small size of femoral head (<32 mm), soft tissue tension, and higher ages. Nevertheless, in this study, there was no indication of dislocation in the true or false acetabulum groups. However, since the follow-up period was short and the sample size was limited, no definite conclusion could be made in this regard. On the other hand, the likelihood of dislocation in the false acetabulum group could be increased due to the changes in the center of the hip rotation axis, because a larger cup size was utilized. In this research, the position of the true acetabulum limited the choice of acetabular cup and liner that was utilized, but there was no incidence of dislocation in our short-term follow-up duration in any of the groups.

Moreover, as it is indicated in our research, significantly higher HHSs are recorded in the true acetabulum group, but no significant difference in ROM and incidence of femoroacetabular impingements between the groups is seen. One explanation for such results could be the increased lateralization of the acetabular component in the false acetabulum group, which might elevate the possibility of creating femoroacetabular impingement, abduction restriction, reduction in mean ROM, and decreasing HHSs.

In a study by Murayama *et al*., radiological and clinical findings of THA for patients with type 1–3 Crowe hip dysplasia were evaluated. They studied 43 hips and stated that moderate high cup placement without bulk bone grafting at a horizontal locus placed more medially than that of a normal hip is associated with a better prognosis.[24] These results are somewhat coherent with our findings because we prevented lateralization of cup placement. In another study, Stans *et al*. assessed 90 hips in 82 patients having THA for Crowe type 3 hip dysplasia. They showed that 25.7% of cups had been placed in the false acetabulum and stated that 83.3% of cups in the false acetabulum had loosening, while 42.3% of cups in the true acetabulum loosened. Finally, they recommended that cup placement in the true acetabulum may have more beneficial effects,[25] which are somewhat coherent with our study, since we found significant differences between the two surgical approaches from a clinical point of view. However, Stans *et al*. assessed loosening according to radiographic findings. Nevertheless, in our short-term clinical follow-up, no loosening was found, but the HHS was significantly improved in the true acetabulum group. In the short-term follow-up the HHS the priority was found to be significant in the true acetabulum group but this was not observed for clinical factors. There were paradoxical results in previous studies mostly because of the study design and populations under study.

In this research, the patients received THA because of DDH. The factors that were assessed included postoperative clinical hip functions such as HHS, VAS, and ROM. These variables are imperative from a clinical point of view because they are related to the patient's satisfaction. One of the measures that is not evaluated in this research is the SF-36. On the other hand, the research that was done previously has mainly concentrated on nonclinical variables. The restrictions of our research are a small sample size, short follow-up period, and deficiency of calculating perioperative complications such as bleeding and surgery/anesthesia duration.

In addition, evaluation of the results in a short-term period and lack of a long-term follow-up were also limitations of our study. It is worth mentioning that in this study, the operations were performed by a single orthopedic surgeon in a high-volume hospital. However, it is recommended that future studies take into account the outcomes of surgery by less experienced surgeons. In our research, the results from using different types of prostheses and their subsequent complications were not assessed and reported.

CONCLUSION

The principal objective of this research was assessment and comparison of measures that are clinically imperative such as HHS, VAS, and ROM in dysplastic hips that received THA. By comparing these measures in this study, it is shown that there are no significant differences between cup placement in the false or true acetabulum except for the HHS which is higher in the true acetabulum group. According to the results of this study, cup positioning in the true acetabolumn is preferred; however, there is a need for more clinical trials with long-term follow-up and larger sample size taking into account important clinical outcomes.

Financial support and sponsorship

The current research was granted by the Isfahan University of Medical Sciences.

Conflicts of interest

There are no conflicts of interest.

REFERENCES

1. Nelson SE, DeFrancesco CJ, Sankar WN. Operative reduction for developmental dysplasia of the hip: Epidemiology over 16 years. J Pediatr Orthop 2019;39:e272-7.
2. Pollet V, Percy V, Prior HJ. Relative risk and incidence for developmental dysplasia of the hip. J Pediatr 2017;181:202-7.
3. Acuña AJ, Samuel LT, Mahmood B, Kamath AF. Systematic review of pre-operative planning modalities for correction of acetabular dysplasia. J Hip Preserv Surg 2019;6:316-25.
4. Garbuz DS, Awwad MA, Duncan CP. Periacetabular osteotomy and total hip arthroplasty in patients older than 40 years. J Arthroplasty 2008;23:960-3.
5. Andalib A, Etemadifar MR, Zadeh AR, Moshkdar P. Treatment of pilon fractures with low profile plates. Int J Burn Trauma 2021;11:486.
6. Motififard M, Hatami S, Rafiee M, Toghyani A, Andalib A. Cup Positioning in True or False Acetabulum in Total Hip Arthroplasty: Which One is More Effective: A Randomized Clinical Trial on Patients with Crowe Type 3 and 4 Dysplastic Hip; 2021.
7. Gala L, Clohisy JC, Beaulé PE. Hip dysplasia in the young adult. J Bone Joint Surg Am 2016;98:63-73.
8. Ekhtiari S, de Sa D, Haldane CE, Simunovic N, Larson CM, Safran MR, *et al.* Hip arthroscopic capsulotomy techniques and capsular management strategies: A systematic review. Knee Surg Sports Traumatol Arthrosc 2017;25:9-23.
9. Perka C, Fischer U, Taylor WR, Matziolis G. Developmental hip dysplasia treated with total hip arthroplasty with a straight stem and a threaded cup. J Bone Joint Surg Am 2004;86:312-9.
10. Sener N, Tözün IR, Aşik M. Femoral shortening and cementless arthroplasty in high congenital dislocation of the hip. J Arthroplasty 2002;17:41-8.
11. Domb BG, Chaharbakhshi EO, Perets I, Yuen LC, Walsh JP, Ashberg L. Hip arthroscopic surgery with labral preservation and capsular plication in patients with borderline hip dysplasia: Minimum 5-year patient-reported outcomes. Am J Sports Med 2018;46:305-13.
12. Lerch TD, Steppacher SD, Liechti EF, Tannast M, Siebenrock KA. One-third of hips after periacetabular osteotomy survive 30 years with good clinical results, no progression of arthritis, or conversion to THA. Clin Orthop Relat Res 2017;475:1154-68.
13. Sakellariou VI, Christodoulou M, Sasalos G, Babis GC. Reconstruction of the acetabulum in developmental dysplasia of the hip in total hip replacement. Arch Bone Jt Surg 2014;2:130-6.
14. Samani RE, Ebrahimi H, Zadeh AR, Safaee M. Evaluation of relative abundance of lymphedema after reverse axillary mapping in patients with breast cancer. Adv Biomed Res 2022;11:36.
15. Ma HY, Zhou YG, Zheng C, Cao WZ, Wang Sen, Wu WM, *et al.* New classification of Crowe type IV developmental dysplasia of the hip. Zhongguo Gu Shang 2016;29:119-24.
16. Kosashvili Y, Backstein D, Safir O, Lakstein D, Gross AE. Acetabular revision using an anti-protrusion (ilio-ischial) cage and trabecular metal acetabular component for severe acetabular bone loss associated with pelvic discontinuity. J Bone Joint Surg Br 2009;91:870-6.
17. Mahomed NN, Arndt DC, McGrory BJ, Harris WH. The Harris hip score: Comparison of patient self-report with surgeon assessment. J Arthroplasty 2001;16:575-80.
18. Charnley J. The long-term results of low-friction arthroplasty of the hip performed as a primary intervention. J Bone Joint Surg Br 1972;54:61-76.
19. Zheng LL, Lin YY, Zhang XY, Ling QH, Liao WM, Wu PH. Best bone of acetabulum for cup component placement in Crowe types I to III dysplastic hips: A computer simulation study. Chin Med J (Engl) 2019;132:2820-6.
20. Ding ZC, Zeng WN, Mou P, Liang ZM, Wang D, Zhou ZK. Risk of dislocation after total hip arthroplasty in patients with Crowe type IV developmental dysplasia of the hip. Orthop Surg 2020;12:589-600.
21. Galea VP, Laaksonen I, Donahue GS, Fukui K, Kaneuji A, Malchau H, *et al.* Developmental dysplasia treated with cementless total hip arthroplasty utilizing high hip center reconstruction: A minimussm 13-year follow-up study. J Arthroplasty 2018;33:2899-905.
22. Seagrave KG, Troelsen A, Malchau H, Husted H, Gromov K. Acetabular cup position and risk of dislocation in primary total hip arthroplasty. Acta Orthop 2017;88:10-7.
23. Komiyama K, Fukushi JI, Motomura G, Hamai S, Ikemura S, Fujii M, *et al.* Does high hip centre affect dislocation after total hip arthroplasty for developmental dysplasia of the hip? Int Orthop 2019;43:2057-63.
24. Murayama T, Ohnishi H, Okabe S, Tsurukami H, Mori T, Nakura N, *et al.* 15-year comparison of cementless total hip arthroplasty with anatomical or high cup placement for Crowe I to III hip dysplasia. Orthopedics 2012;35:e313-8.
25. Ghadimi K, Motififard M, Mohammadi R. Complete bilateral knee arthroplasty in staged or simultaneous surgeries in patients with osteoarthritis. Int J Burn Trauma 2022;12:59.