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Comparison of High Hip Center versus Anatomical Reconstruction Technique in Crowe Types II and III Developmental Dysplasia of the Hip: a Retrospective Clinical Study

Porovnání technik High Hip Center a anatomické rekonstrukce v léčbě VDK typu Crowe II a III: retrospektivní klinická studie

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ABSTRACT

PURPOSE OF THE STUDY

The literature is conflicting as to whether the high hip center (HHC) reconstruction in total hip arthroplasty (THA) is an ideal option for patients with severe developmental dysplasia of the hip (DDH).

This study aimed to compare the mid-term functional and radiographic outcomes of THA using HHC versus anatomical hip center (AHC) technique in Crowe types II and III DDH. Our hypothesis was that there may be no differences in terms of functional and radiographic outcomes between patients who underwent THA using HHC or AHC.

MATERIAL AND METHODS

Fifty-seven patients who underwent a primary THA due to Crowe type-II or type-III DDH were retrospectively reviewed and included. Patients were divided into two groups as per the hip center reconstruction: Group A (AHC technique) and group H (HHC technique). A cementless cup was inserted in 25 hips (19 female, 6 male; mean age = 51 years, age range = 28-67)) at near-AHC in group A and 32 hips (22 female, 10 male; mean age = 53 years, age range = 29-68) at HHC position in group H. To assess clinical status, the Harris Hip Score (HHS) was used at the final follow-up. In radiographical assessment, component loosening and osseointegration of the acetabular cup were examined on follow-up radiographs. Complications were also recorded.

RESULTS

The mean follow-up was 41 months (range, 25–84) in group A and 40 months (range, 24–86) in group H. The mean HHS was 83 (range, 74-91) in group A and 83.6 (range, 73-94) in group H ($p = 0.741$). Osteolysis was determined in three patients from each group. The other 51 cups demonstrated a minimum of one radiographic sign of osseointegration. Although the overall complication rate was higher in group A (64%) than in group H (46%), this difference reached no statistical significance ($p = 0.11$).

CONCLUSIONS

The HHC technique using cementless acetabular fixation seems to be a valuable alternative option to AHC technique in cases of Crowe types II and III DDH.

Key words: High hip center; anatomical hip center; center of rotation; total hip arthroplasty; dysplastic hip; developmental dysplasia of the hip; Crowe type II; Crowe Type III.

INTRODUCTION

Acetabular reconstruction in patients with severe developmental dysplasia of the hip (DDH) remains a technically demanding procedure for orthopedic surgeons (21). Although the primary aim is to place the acetabular cup in the anatomic position, it is frequently difficult in such patients due to deficiency of periacetabular bone stock secondary to the altered acetabular morphology (13, 16). Thus, to reconstruct the cup in the anatomical hip center, structural or morselized bone grafting can be applied. However, bone grafts may be collapsed and diminish the contact area between the bone and implant which is fundamental to achieve biological fixation with a cementless acetabular cup (17).

To avoid the problem with bone grafting and enhance host bone-implant contact, placement of the cementless cup using the high hip center (HHC) technique has been suggested as a critical alternative with the presence of better periacetabular bone stock than an anatomic position (18, 27). Although several studies found HHC associated with higher rates of aseptic loosening, dislocation, limb-length inequality as well as an increased hip joint reaction force (9, 10, 26) some studies have recently reported satisfactory results with the high placement of the cup (5, 6, 24, 25). To our knowledge, the literature seems to be controversial regarding the effects of HHC on results of total hip arthroplasty (THA) in patients with DDH, and there is still a lack of evidence directly comparing the two techniques to determine the more advantageous one (6, 15).

Therefore, this study aimed to compare the mid-term functional and radiographic outcomes of THA using HHC versus anatomical hip center (AHC) technique in patients with Crowe types II and III DDH. We hypothesized that there may be no differences in terms of functional and radiographic outcomes between patients who underwent THA using HHC or AHC.

MATERIAL AND METHODS

The medical records of 65 consecutive patients in whom Crowe type-II or type-III DDH (7) (Fig. 1) was diagnosed and treated by one-stage THA from 2012 to 2017 at our institution were retrospectively reviewed. All patients were assessed based on the eligibility criteria (inclusion and exclusion) given in Table 1. After excluding 8 patients, the remaining 57 patients who met the inclusion criteria were included in the study and invited to a final follow-up examination (Fig. 2). Informed consent was obtained from all subjects, and the institutional review board approval was obtained prior to data collection.

Patients were then categorized into two groups according to the technique of hip center reconstruction: Group A (AHC technique) and group H (HHC technique). To determine the AHC, initial postoperative radiographs were analyzed as described by Pagnano et al. and a vertical distance of 15 mm from AHC was defined as HHC (26). The cup was inserted in 25 hips (25 patients; 19 female, 6 male) at near-AHC in group A and in 32 hips (32 patients; 22 female, 10 male) at HHC position at a distance of 15.00 to 36.90 mm (mean = 19.18 mm) from the AHC in group H.

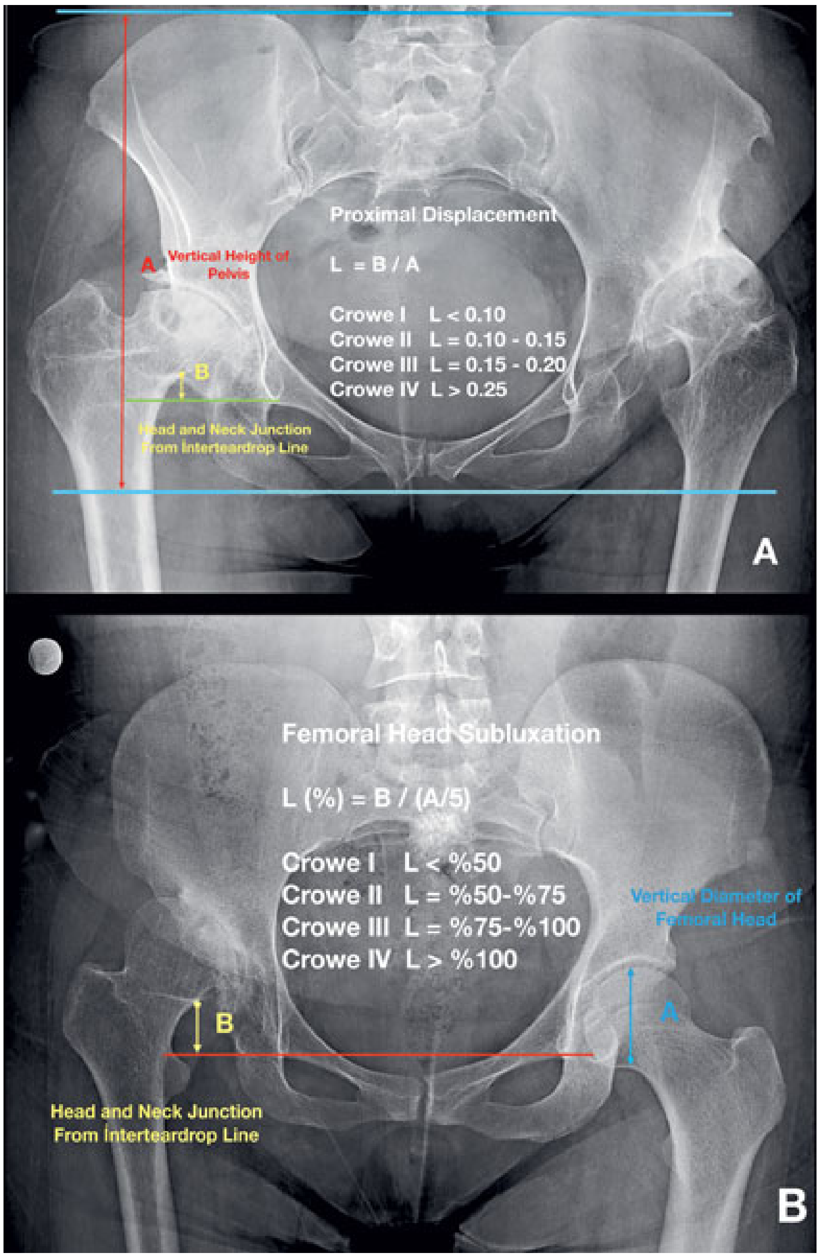

Fig. 1. Crowe's Classification is based on the proximal displacement (A) and femoral head subluxation (B).

Table 1. Eligibility criteria for inclusion and exclusion of the study participants

Inclusion criteria	Exclusion criteria
– A diagnosis of Crowe type-II or type-III DDH – Complete medical records and radiographic images – A minimum of two-year-follow-up – Being willing to participate the study	– Lost to follow-up – Inadequate medical records – Presence of a concomitant rheumatoid, neurologic, or malignant disease – Being unwilling to participate the study

Clinical outcome measures

Clinical status of the patients was measured and graded based on the Harris Hip Score (HHS) at the final follow-up. HHS provides assessments about pain (1 item, 0–44 points), function in the performance of gait and daily activities (7 items, 0–47 points), absence of deformity (1 item, 4 points), and range of motion (2 items, 5 points): the grading is poor (<70), fair (70-79), good (80-89), excellent (90–100) (12).

Visual analogous scale (VAS) was also measured to assess thigh pain at the final follow-up. VAS score used in the current study is a modified and simplified measure in which pain intensity during daily activity is rated on a scale of 0–10, where 0 indicates no pain and 10 indicates the worst pain (19).

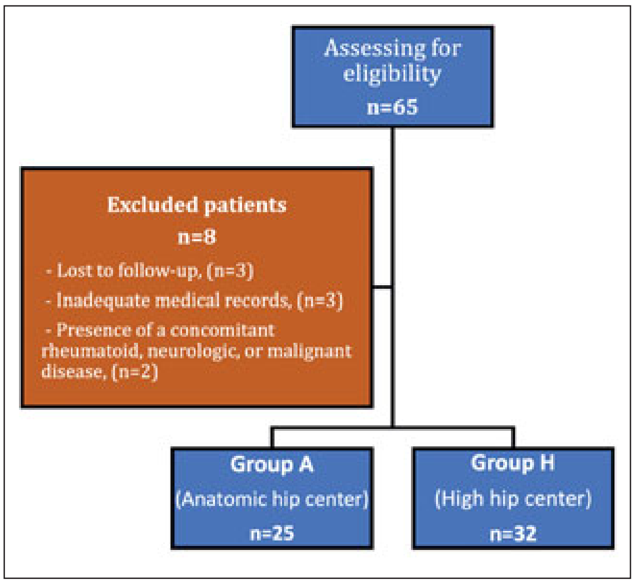

Fig. 2. Flow chart of the study participants.

Implants and surgical technique

A standard protocol was applied in all operations, which comprised spinal or general anesthesia, thrombosis prophylaxis, an appropriate perioperative antibiotic regimen for infection prophylaxis, and rehabilitation. Low–molecular-weight heparin was started 12 hours before the operation for thrombosis prophylaxis and terminated when patients were completely mobile. None of the patients underwent prophylaxis for heterotopic ossification.

All THAs were performed by two orthopedic surgeons who specialized in arthroplasty. Direct lateral (modified Hardinge) approach was used without trochanteric osteotomy. Sharp dissection was used to split and elevate the anterior third of the gluteus medius tendon. Following antero-inferior capsulectomy hip was dislocated and femoral neck osteotomy was performed two centimeters above the lesser trochanter. After proper acetabular exploration, reaming was first started with postero-medialization then expanded to periphery. Location of the acetabular cup placement was determined by the responsible surgeon aiming for the highest primary stability that can be achieved. In both groups, a cementless porous coated titanium acetabular cup (REFLECTION™, Smith and Nephew, Memphis, USA) was used aiming primary stability with screws. Metaphyseal fitting type femoral stem was used aiming press-fit fixation in all patients. None of the patient needed structural bone graft. Table 2 details the instrumental characteristics in the two groups.

All patients were encouraged to ambulate with immediate unrestricted weight bearing according to what they could tolerate with two crutches first postoperative day. Under the supervision of physiotherapists, a standardized, daily functional exercise program which include range of motion and muscle strength were initiated before discharge from the hospital.

Table 2. Demographic and surgical variables of the study participants

		Group A	Group H	P-value
Age at surgery (year)	Mean min–max	51 28–67	53 29–68	*0.732*
Gender	(Female/ Male)	19/6	22/10	*0.624*
Follow-up (month)	Mean min–max	41 25–84	40 24–86	*0.486*
BMI (kg/m²)	Mean min–max	33 25–40	32 24–39	*0.456*
Crowe type 2 3	N (%)	 17 (68%) 8 (32%)	 20 (63%) 12 (37%)	*0.623*
Cup size (mm)	Median min–max	46 42–54	52 42–62	*0.041**
Cup type Reflection R3 Zimmer Depuy	N (%)	 21 (84%) 3 (12%) 1 (4%) 0	 30 (94%) 0 1 (3%) 1 (3%)	*0.414*
Number of screws 0 1 2 3	N (%)	 0 8 (32%) 16 (64%) 1 (4%)	 2 (6%) 11 (34%) 19 (60%) 0	*0.527*
Femoral stem type Synergy Polar Depuy Zimmer SL plus	N (%)	 19 (76%) 2 (8%) 0 3 (12%) 1 (4%)	 27 (85%) 2 (6%) 1 (3%) 1 (3%) 1 (3%)	*0.739*
Acetabular liner Polyethylene Ceramic	N (%)	 21 (84%) 4 (16%)	 25 (78%) 7 (22%)	*0.549*

*BMI: body mass index; ASA: American Society of Anesthesiologists Classification class, *p < 0.05*

Radiographic outcome measures

Component positioning was assessed based on the following radiographic parameters on final follow-up anteroposterior pelvic radiographs:

- *Vertical center of rotation (V-COR) (mm) was calculated as* the vertical distance from the center of the femoral head to the interteardrop line (Fig. 3A) (22, 25, 27).
- *Horizontal center of rotation (H-COR) (mm)* was calculated as the horizontal distance along the interteardrop line extending laterally from the inferior tip of the teardrop to a perpendicular line dropped from the center of the femoral head (Fig. 3A) (22).
- *Cup inclination* (°) was defined as the abduction angle between the interteardrop line and the tangent to the cup (Fig. 3C) (1, 23).
- *Femoral offset (mm)* was calculated as the perpendicular distance between the center of rotation and the axis of femoral shaft (Fig. 3A) (2, 29).

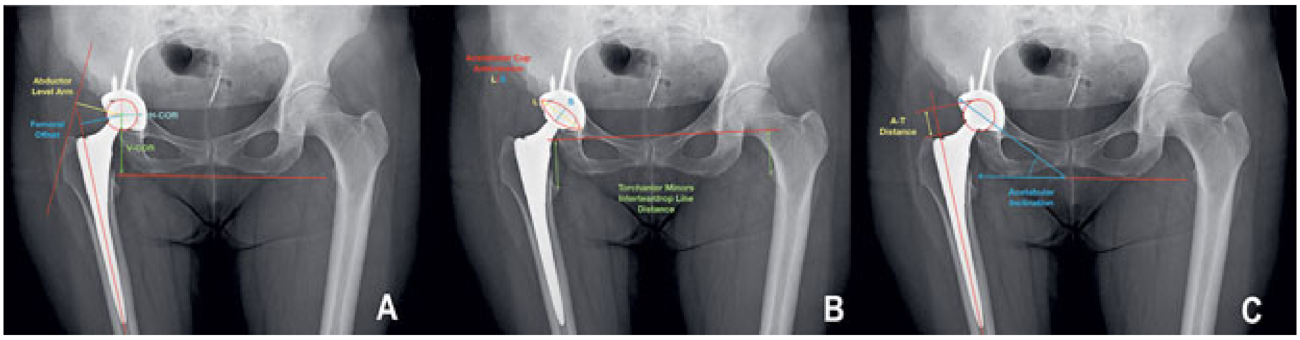

Fig. 3. Representative radiographic measurements of component positioning parameters: A –vertical center of rotation (V-COR), horizontal center of rotation (H-COR), abductor muscle lever arm, and femoral off-set; B – cup anteversion and leg length inequality measurements; C – cup inclination measurement.

- *Abductor muscle lever arm (mm)* was calculated as the perpendicular distance between the center of the femoral head and the line extending from the greater trochanter to the anterior superior iliac spine (Fig.3A) (29).
- *Cup anteversion* (°) was measured using the method of Lewinnek et al. (Fig. 3B) (20).
- *Leg length inequality (mm)* was measured by calculating the difference between both sides in the vertical distance from the interteardrop line to the tip of the lesser trochanter (Fig. 3B) (1, 29).

Component loosening was examined on final follow-up radiographs. Radiolucency was defined as a lesion with a clear sclerotic border a minimum of 1mm in width; osteolysis was defined as a radiolucency larger than 2 mm in width (11). The location of radiolucent lines or osteolysis around the acetabular cup was recorded based on three zones described by DeLee and Charnley (8). The cup was deemed as loosened in presence of osteolysis and migration over 5 mm detected on serial follow-up radiographs (29).

Osseointegration of the acetabular cup was evaluated according to the five radiographic signs of osseointegration described by Moore et al. (23): 1) the absence of radiolucent lines, 2) the presence of a superolateral buttress, 3) the presence of medial stress-shielding, 4) the presence of radial trabeculae, and 5) the presence of an inferomedial buttress (Fig. 4).

Complications

Intraoperative, early, and late postoperative complications were documented. *Heterotopic ossification* was examined using the Brooker classification on final follow-up radiographs (3).

Statistical analyses

IBM SPSS Statistics software, version 20.0 (IBM Corp., Armonk, New York, NY, USA), was used for statistical analysis. A $p < 0.05$ was considered statistically significant. Normality tests were conducted using the Shapiro–Wilk test and histogram graphics. Data are presented as “minimum”, “maximum”, “arithmetic mean” or “median”, “number” and “percentage”. Between-group comparisons were performed using the Student t-test for parametric variables and the Mann–Whitney U test for nonparametric variables. For categorical variables, Pearson’s chi-square test, Fisher’s exact test, or Fisher–Freeman–Halton’s exact test was used.

RESULTS

Patients in both groups were comparable in terms of the demographic and surgical variables (Table 2) (p >

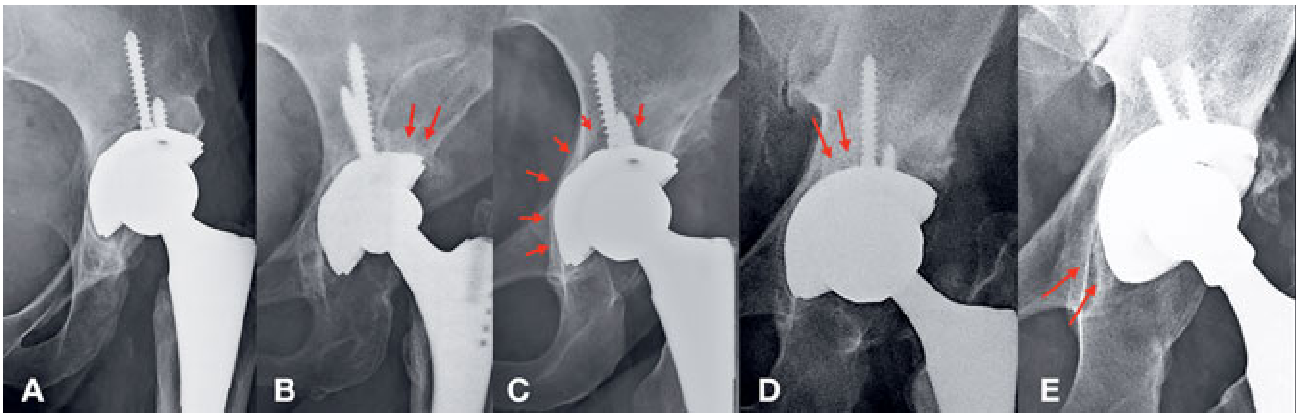

Fig. 4. Five radiographic signs of osseointegration described by Moore et al.: A – absence of radiolucent lines, B – presence of a superolateral buttress, C – presence of medial stress-shielding, D – presence of radial trabeculae, E – presence of an inferomedial buttress.

0.05). The mean age at the time of the surgery was 51 years (range, 28–67) in group A and 53 years (range, 29–68) in group H. The mean follow-up was 41 months (range, 25–84) in group A and 40 months (range, 24–86) in group H.

Clinical outcomes

Table 3 shows comparative results of clinical outcome measures. There were no differences in both HHS and VAS at the final follow-up between the two groups. According to HHS, most the patients in both groups exhibited good functional status while no poor results were recorded.

Table 3. Comparative results of clinical outcome measures

		Group A (n= 25)	Group H (n = 32)	P-value
Harris Hip Score mean (min–max)		83 (74–91)	83.6 (73–94)	*0.741**
Poor (< 70) Fair (70–79) Good (80–89) Excellent (90–100)	N (%)	0 5 (20%) 16 (64%) 4 (16%)	0 5 (16%) 23 (71%) 4 (13%)	*0.778*
Visual Analogous Scale mean (min–max)		1.32 (0–4)	0.75 (0–5)	*0.146*
	p < 0.05			

Radiographic outcomes

In the analyzes of component positioning, although V-COR and H-COR were both significantly greater in group H than in group A ($p < 0.001$), there were no significant differences in the other radiographic variables (Table 4).

In the assessment of component loosening, final follow-up radiographic examination revealed osteolysis in three patients from each group. Of these patients, one patient in each group who exhibited extensive osteolysis all around the cup surface was diagnosed with aseptic loosening of the acetabular cup. Other patients showed osteolysis in only one of DeLee and Charnley zones and thus were not considered as aseptic loosening.

Apart from the loosened cups mentioned above, the other 51 cups demonstrated a minimum of one radiographic sign of osseointegration. 51 acetabular cups were evaluated according to the classification described by Moore et al. (23). There were no radiolucent lines in 5 acetabular cups, superolateral buttress appearance in 12 acetabular cups, medial stress-shielding appearance in 14 acetabular cups; radial trabecular pattern in 14 acetabular cups; In the 6 acetabular cups, the appearance of the inferomedial strut was found (Fig. 4).

Table 4. Comparative analyzes of component positioning using anatomical versus high hip center techniques

*Variables**	Group A	Group H	P-value
V-COR (mm)	69.6 (52.7–87.6)	84.1 (56.1–114)	*< 0.001***
H–COR (mm)	25.3 (38–13.8)	31.8 (23.2–51.2)	*< 0.001***
Cup inclination (°)	39.2 (24.8–52.5)	39.7 (23–54.1)	*0.956*
Cup anteversion (°)	11.4 (3–41)	10.5 (2–41)	*0.696*
Femoral offset (mm)	37.4 (15.8–48.5)	37.1 (23.9–57.6)	*0.642*
Abductor muscle lever arm (mm)	45.3 (35–55.9)	42.4 (21.6–70.9)	*0.223*
Leg length inequality (mm)	12.5 (2–44.7)	13.2 (0–38)	*0.798*

V-COR: Vertical center of rotation; H-COR: Horizontal center of rotation
**Data are given as mean (min–max).*
***p < 0.01*

Complications

Table 5 illustrates intra-and post-operative complication rates and comparative statistical results. No significant differences were observed in terms of each complication between the two groups. Although the overall complication rate was higher in group A (64%) than in group H (46%), this difference reached no statistical significance ($p = 0.11$).

Proximal femur metaphyseal fracture occurred intraoperatively in two patients from group A and three patients from group H. These complications were managed by cable fixation, and bone union was achieved three to six months after the operation. One patient with Crowe III DDH in group A developed sciatic nerve paralysis that resolved spontaneously within the first year of the operation. One patient in group A and one patient in group H experienced dislocation of THA secondary to trauma 18 days and two months after surgery, respectively. The patients were treated successfully by closed reduction under general anesthesia with no recurrence of the dislocation.

Table 5. Intra- and post-operative complication rates in both groups

Complications	Group A (n = 25)	Group H (n = 32)	P-value
Intraoperative Proximal femur metaphyseal fracture	2 (8%)	3 (9%)	*0.856*
Early postoperative Sciatic nerve paralysis Superficial hematoma Superficial infection	 1 (4%) 1 (4%) 1 (4%)	 0 1 (3%) 1 (3%)	*0.446*
Late postoperative Dislocation Heterotopic ossification Stage 1 Stage 2 Stage 3 Osteolysis Aseptic loosening of the acetabular cup	 1 (4%) 2 (8%) 1 (4%) 3 (12%) 3 (12%) 1 (4%)	 1 (3%) 2 (6.25%) 1 (3%) 2 (6.25%) 3 (9%) 1 (3%)	*0.197*
Overall complication rate	64%	46%	*0.11*

Data are given as N (%).
**p < 0.05*

Two patients with aseptic acetabular cups mentioned above were treated by a revision THA. Other patients with osteolysis did not suffer from any complaint; therefore, the decision for close follow-up with no intervention was made.

DISCUSSION

One of the major concerns with the elevated hip center is the increased risk of component loosening. Theoretically, the ideal location for placement of the acetabular cup is the anatomic position in the true acetabular region of a dysplastic hip, as non-anatomical positioning of the COR causes increased joint reaction forces and jeopardizes survival of the prosthesis (2). Supporting this notion, earlier results with cemented fixation (4, 26, 27) demonstrated higher acetabular loosening rates varying from 16% to 42% as a result of superior cup placement. In contrast, with the use of newly designed cementless cups, more recent studies (14, 24) have revealed excellent survivorship approaching 100% at a minimum of 10 to 15 years follow-up in THAs with HHC for Crowe I to III DDH. Nonetheless, controversy remains as to whether HHC reconstruction, especially without bone grafting, is an ideal option for patients with severe DDH because of the lack of comparative data. To our knowledge, only few studies (6, 24, 25, 27) directly compared HHC with anatomic cup placement for such patients in the literature. Therefore, the current study provides additional evidence that AHC and HHC techniques could confer similar radiographical results for patients with Crowe type-II and-III DDH at mid-term follow-up.

In one of the comparative studies on the issue, Russotti et al. (27) determined that isolated high positioning of hip center without lateral displacement has no negative effect on the long-term survival of the cemented acetabular components in challenging cases of the acetabular reconstruction such as high dislocation of the hip or revision THA. In another comparative study, Murayama et al. (24) found excellent survivorship rates of cementless THA using AHC (100%) or HHC (97%) in patients with Crowe I to III DDH. In their case series, superior placement of the acetabular cup from the interteardrop line was not greater than 35 mm (mean, 24.5 mm) in all patients treated by HHC technique, and the authors suggested that moderate superior cup placement without bone grafting at a more medial position than that of a normal hip is an alternative durable solution. In a recent comparative study, Nawabi et al. (25) concluded that fixation of cementless acetabular cup without bone grafting at a HHC could provide high survivorship and excellent hip scores for patients with Crowe II and III DDH at a minimum of 10 year follow-up. The common finding of the above comparative studies is that HHC reconstruction can provide as high survivorship and favorable clinical scores as AHC reconstruction in cementless acetabular cup fixation for patients with DDH. For both AHC and HHC, rates of acetabular loosening (8% and 3%, respectively) obtained in this study are consistent with those in the literature, although longer-term follow-up is needed to determine the exact profile of HHC effects.

Moreover, comparative reports available emphasized the importance of medialization of the acetabular cup when performing HHC reconstruction to warrant the long-term durability of the acetabular component (24, 25, 27). In the current study, although H-COR was higher in HHC group than in AHC group, our senior surgeons have routinely sought to medialize acetabular cups to the inner table to obtain sufficient bony coverage without structural bone grafts. Therefore, we support the notion that placing the cup at a more superior but not more lateral position could ensure as stable fixation as placement of the cup at the anatomical position.

One of the major limitations of comparative studies available is their heterogeneous patient population including different severity of DDH and lack of a control group with similar disease severity. To avoid a potentially biased conclusion as to whether HHC is the ideal option for severe DDH, we attempted to analyze more homogenous patient populations in terms of DDH severity (Crowe II to III DDH). Further, differently from the previous reports, (24, 25, 27) we set a control group including patients with similar DDH severity treated by AHC reconstruction.

Another important issue that may affect the results of HHC reconstruction is the definition of HHC. In an early report which set out to investigate the results of the high placement of cementless acetabular cups in complex total hip arthroplasty, Schutzer and Harris (28) defined an HHC as 35 mm from the interteardrop line. The authors determined only a 6% rate of acetabular loosening at 5 years. Otherwise, most recent studies (14, 24) have demonstrated excellent results with nearly 100% survivorship of the cementless acetabular cup in cases Crowe I to III DDH treated by HHC reconstruction. In these studies, the mean vertical distance of hip center from interteardrop line ranged from 25.5 mm to 30.3 mm (14, 24). In our series, the mean vertical distance was 35.59 mm. Values from our study and the above studies are lower than those reported by Schutzer and Harris. This may be one of the reasons why we observed high survivorship with lower loosening rates.

In addition to the two signs of acetabular loosening (radiolucent lines and cup migration), we radiographically examined osseointegration of the acetabular cup in order to improve clinical assessment of acetabular components. In both groups, as a complementary result to lower rates of acetabular loosening, acetabular cups that radiographically demonstrate no signs of acetabular loosening illustrated one or more signs of osseointegration. In addition, there is no study in the literature reporting a relationship between cup size and osseointegration.

Furthermore, the clinical outcomes and complication rates should also be discussed. The current study has demonstrated good clinical condition based on Harris Hip and VAS scores with comparable lower rates of major and minor complications for HHC reconstruction comparable to AHC at the final follow-up. These results are consistent with other authors who have analyzed the clinical results of HHC in Crowe II and III DDH (14, 24, 25).

When interpreting the findings in this study, some limitations should be considered. The major limitations of the study were its retrospective nature, limited sample size, and short-to mid-term follow. Furthermore, the current study is a non-randomized, surgeon dependent study where three different surgeons performed all the operations. This may have biased the results because of the surgeon's preference and experience. Despite these limitations, our study is one of few studies that compare the HHC versus AHC technique in cases of Crowe types II and III DDH (24, 25, 27).

CONCLUSIONS

The HHC technique using cementless acetabular fixation without structural bone graft appears to be a valuable alternative option to AHC technique in cases of Crowe types II and III DDH. With both techniques, favorable clinical and radiographical results can be obtained at mid-term follow-up.

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