CLINICAL ARTICLE

Clinical and Radiological Outcomes of Revision Total Hip Arthroplasty for Patients with Prior Hartofilakidis Type C Hip Dysplasia

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Objective: To investigate the clinical and radiological results of revision total hip arthroplasty (THA) for patients with previously diagnosed Hartofilakidis type C hip dysplasia, which is technically challenging and lacks literature.

Methods: We enrolled 20 patients with previously diagnosed Hartofilakidis type C hip dysplasia who underwent revision THA between November 2008 and July 2015 at our hospital. Patients were followed up for an average of 87 months. Data pertaining to the Harris hip score (HHS), modified Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC), general satisfaction, and the level of satisfaction related to 16 hip functions or issues experienced after revision THA were collected. The vertical and horizontal center of rotation (COR) of the hips were measured bilaterally based on preoperative and postoperative anteroposterior radiographs. Categorical variables were analyzed by the chi-square test. Continuous variables were analyzed using the student's t test or non-parametric Wilcoxon Rank Sum test.

Results: There were significant postoperative improvements in the HHS (47.4 ± 31.6 *vs* 70.1 ± 39.0), modified WOMAC (48.5 ± 27.9 *vs* 75.7 ± 36.8), and the vertical (45.7 ± 33.7 mm *vs* 21.6 ± 21.8 mm) and horizontal (41.8 ± 17.0 mm *vs* 31.4 ± 14.7 mm) offset of the COR after revision THA ($P < 0.05$). Fifteen (75.0%) patients were satisfied with the procedure. The satisfaction rate for each of the 16 items ranged from 45% to 100%. The top three dissatisfactory items were squatting, getting into/out of cars, and leg-length discrepancy. Postoperatively, dissatisfied patients had a significantly higher visual analogue scale pain score and lower WOMAC pain, HHS pain, WOMAC total, and HHS total scores, a lower satisfaction rate for pain relief, and a higher vertical COR.

Conclusion: There is a high rate (25%) of dissatisfaction with the outcome after revision THA for patients with prior Hartofilakidis type C hip dysplasia. The most likely reasons for dissatisfaction were inadequate pain relief and a higher vertical COR measured on radiography.

Key words: Hip dysplasia; Pain; Radiography; Rotation; Total hip arthroplasty

Introduction

Developmental dysplasia of the hip (DDH) is a common cause of degenerative hip disease in Asia.[1] Features of Hartofilakidis type C hip dysplasia include high-riding dislocation of the femoral head and very shallow true acetabulum and pseudo-acetabulum, and the disease is not uncommon in China due to neglected or untreated hip dislocation during childhood.[2] Hartofilakidis type C hip dysplasia often leads to hip osteoarthritis at an early age of 30–40 years and typically requires total hip arthroplasty (THA), which is the most effective treatment option.[3,4]

However, the treatment of end-stage hip arthritis after Hartofilakidis type C dysplasia is challenging for surgeons performing hip arthroplasty because of the lack of bone stock in the acetabular side, femoral canal stenosis, soft tissue contracture, and surgical scarring from previous childhood

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salvage operations.[5,6] These difficulties encountered in young patients with high functional demands could lead to high failure rates.[7,8] It is commonly reported that THA for Hartofilakidis type C hip dysplasia is associated with much higher postoperative complication rates, including those related to dislocation, component loosening, periprosthetic fracture, infection, and non-union of the subtrochanteric osteotomy, leading to an increased revision rate of 14%–18%, which is much higher than the average revision rate for THA.[9–13]

After the primary surgeries, it is even more challenging to perform revision THA in patients with prior Hartofilakidis type C hip dysplasia, as one would expect to encounter more severe acetabular bone defects, soft tissue tightness, femoral-side bone loss and deformity, abductor dysfunction, and leg-length discrepancy (LLD).[4,14–17] On the acetabular side, it is biomechanically more favorable to restore the center of rotation (COR) to the normal level, which often requires strut bone grafts or metal augments, especially in those with a high-riding COR in the primary procedure.[5,15] On the femoral side, the revision options include strut bone grafting, the application of an allograft prosthesis composite, or a long-stem or megaprosthesis to reconstruct the femoral bone defects.[18] Despite the complexity of these techniques, there has been a lack of literature reporting the outcomes of revision THA in patients with prior Hartofilakidis type C hip dysplasia.

To determine the mid-term clinical and radiological outcomes of revision THA for patients with prior Hartofilakidis type C hip dysplasia, we aimed to answer the following four major questions: (i) what are the mid-term survival outcomes, complications, and radiological results of revision THA?; (ii) what is the overall level of satisfaction for these patients, and what are the reasons for overall dissatisfaction?; (iii) what is the postoperative functionality of the hip?; and (iv) how satisfied are these patients regarding each particular hip function or issue?

Methods

Patients

With the approval of the Beijing Jishuitan Hospital Institutional Review Board (IRB) (No. JST201803-02), we conducted a retrospective survey study to answer those four aforementioned questions. We reviewed the data of 398 eligible patients (408 hips in total) who underwent revision THA between November 2008 and July 2015 in our hospital. We enrolled 20 patients who underwent revision THA for whom Hartofilakidis type C hip dysplasia was the etiology leading to the primary THA. Four senior surgeons in our department conducted the surgeries. The criteria for inclusion were as follows: (i) age > 18 years, undergoing revision THA; (ii) a minimum follow-up of 24 months; and (iii) a diagnosis of Hartofilakidis type C hip dysplasia before undergoing primary THA. We excluded patients who underwent primary hip arthroplasty for the following etiologies: (i) avascular necrosis (178 hips); (ii) non-union after femoral neck fracture (63 hips); (iii) Hartofilakidis classification1 or type 2 hip dysplasia (59 hips), post-infection arthritis (21 hips), femoroacetabular impingement (20 hips), sequelae of childhood Perthes disease (14 hips), post-traumatic hip arthritis (12 hips), rheumatoid arthritis (12 hips), ankylosing spondylitis (four hips), systemic lupus erythematosus (four hips), and synovial chondromatosis of the hip (one hip).

The enrolled cohort had an average age of 51 years (range, 24–66 years) and a mean duration of follow-up of 87 months (range, 38–195 months). Of the entire cohort, 13 (65%) patients were women. The average body mass index (BMI) was 24.2 kg/m^2 (range, 18.7–28.1 kg/m^2). All patients underwent unilateral revision THA. Thirteen patients (65%) were gainfully employed. The indications for revision THA were as follows: eight patients (40%) experienced loosening of acetabular components; one patient (5%) experienced loosening of the femoral component; two patients (10%) exhibited loosening of both the acetabular and femoral components; four patients (20%) experienced early postoperative dislocation within 6 months after the primary surgery; two patients (10%) required treatment because of periprosthetic fracture of the femur; and three patients (15%) developed late periprosthetic infections. Among the three patients with periprosthetic infections, one (5%) underwent revision through single-stage surgery, and two patients (10%) had staged revision THA operations. The two patients who underwent staged revision were found to be infected with methicillin-resistant Staphylococcus aureus *via* preoperative culture, and the other was infected with methicillin-sensitive Staphylococcus aureus. Among the group of hips, 16 (80%) had no other symptomatic or successfully reconstructed joints (Charnley type A),

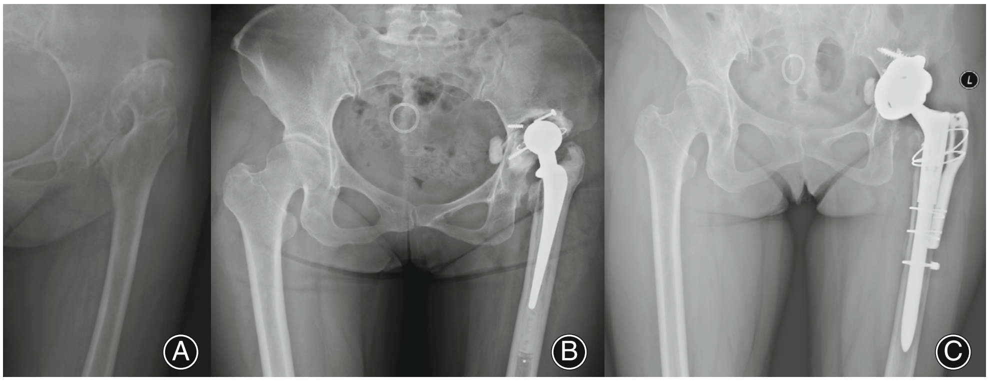

Fig. 1 Anterior–posterior view radiographies of the hip of a patient before (A) first total hip arthroplasty, and before (B) and after (C) the revision total hip arthroplasty

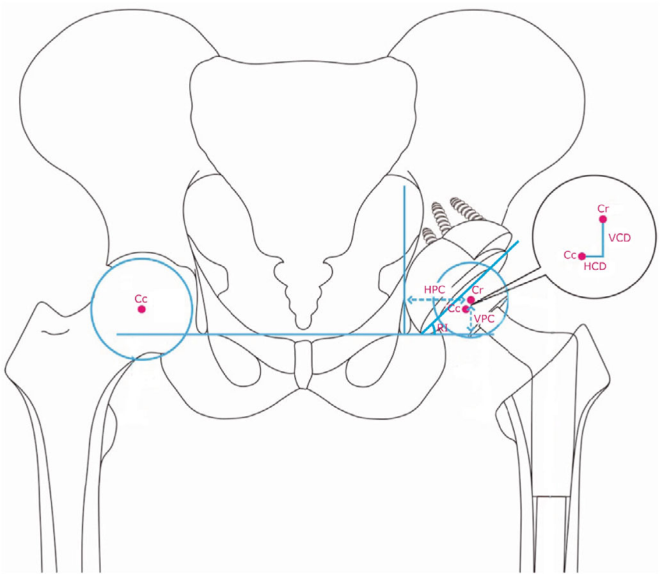

Fig. 2 Radiographic measurements of biomechanical parameters. Cr—reconstructed COR; Cc—contralateral COR; HPC—horizontal position of COR; VPC—vertical position of COR; VCD—vertical COR discrepancy; HCD—horizontal COR discrepancy; RI—radiographic inclination

two (10%) had a symptomatic contralateral hip at the time of surgery (Charnley type B), and two (10%) had symptomatic knee joints in addition to a symptomatic contralateral hip (Charnley type C).

This cohort of patients had undergone previous operations an average of 1.4 times (range, 1–3 times). Three (15.0%) patients underwent cemented femoral and acetabular fixation for the primary THA, whereas the other 17 (85%) underwent cementless femoral and acetabular fixation. Among the patients with cementless femoral components, 11 (55%) were treated with S-ROM modular femoral stems, and the other six (30%) underwent reconstruction with monoblock Wagner cone femoral stems. Seven (35%) patients underwent subtrochanteric shortening osteotomy in the primary THA. At the time of revision THA, seven (35%) patients had Paprosky type IIA acetabular bone defects, five (25%) had Paprosky type IIB acetabular bone defects, and eight (40%) had Paprosky type IIIA acetabular bone defects. On the femoral side, five patients (25%) had Paprosky type I femoral bone defects, 13 (65%) patients had Paprosky type II femoral bone defects, and two patients (10%) had Paprosky type IIIA femoral bone defects.

Surgical Technique

All revisions were performed through a posterior approach to the hip. The original incisions for the primary THA were incorporated into any new incisions as much as possible. Three patients were treated *via* an anterior-lateral approach for the primary THA and revised with another incision suitable for a posterior approach. Failed acetabular implants and fibrous membranes and cement (if present) were removed without causing additional bone loss. The acetabulum was then reamed sequentially into an approximately hemispherical shape until reaching the viable host bone. For severe superior or medial bone loss, two patients (10%) were treated with a bulk allograft to provide structural support for the cementless cups, and eight patients (eight hips, 40%) were treated with porous metal augments to reconstruct bone defects. All patients were treated with

TABLE 1 Comparisons between preoperative and postoperative factors (n = 20, mean ± SD)

Variables	Preoperative	Postoperative	*t*-value[a]	*P*-value[b]
Radiological measurement				
Vertical COR (mm)	45.7 ± 33.7	21.6 ± 21.8	3.843	0.002
Horizontal COR (mm)	41.8 ± 17.0	31.4 ± 14.7	3.633	0.003
Radiological LLD (mm)	23.9 ± 16.1	12.4 ± 7.9	4.395	0.001
Vertical COR discrepancy/LLD (%)	117.3 ± 160.9	56.7 ± 49.5	3.430	0.004
Acetabular cup inclination (°)	51.7 ± 34.1	39.5 ± 13.6	2.608	0.001
Acetabular cup anteversion (°)	17.0 ± 11.7	11.4 ± 5.8	1.795	0.004
Modified WOMAC score				
WOMAC Pain score	47.5 ± 28.7	80.8 ± 54.5	4.148	0.001
WOMAC Stiffness score	71.9 ± 46.3	78.9 ± 57.9	0.764	0.454
WOMAC Function score	46.0 ± 29.6	73.8 ± 34.4	4.617	0.000
Total WOMAC score	48.5 ± 27.9	75.7 ± 36.8	4.455	0.000
HHS score				
HHS Pain score	25.0 ± 17.4	36.0 ± 26.4	3.101	0.006
HHS Function score	18.1 ± 21.6	28.5 ± 19.1	3.696	0.002
HHS Deformity score	2.9 ± 3.6	2.8 ± 3.7	0.089	0.930
HHS ROM score	1.4 ± 1.6	2.9 ± 2.4	4.313	0.000
Total HHS score	47.4 ± 31.6	70.1 ± 39.0	4.354	0.000

Notes: [a] Paired *t*-test.; [b] *P*-values <0.05 were considered to be statistically significant.; Abbreviations: COR—center of rotation; HHS—Harris hip score; LLD—leg length discrepancy; WOMAC—Western Ontario and McMaster Universities Osteoarthritis Index.

TABLE 2 Comparisons of the preoperative demographic, radiological, and clinical factors between the satisfied and dissatisfied patients. (mean ± SD or percentages)

Variables	Satisfied group (n = 15)	Dissatisfied group (n = 5)	*t* value/χ^2 value	*P*-value[a]
Age (years)	49.5 ± 21.7	57.6 ± 17.0	1.476	0.157
Female	11 (73.30%)	2 (40.00%)	1.832	0.290
Left side	11 (73.3%)	4 (60.0%)	0.317	1.000
BMI (kg/m^2)	24.4 ± 4.7	23.9 ± 8.1	0.308	0.761
Number of previous surgeries	1.3 ± 1.2	1.6 ± 1.8	−0.750	0.463
Indications for revision				
Dislocation	2 (13.3%)	2 (40.0%)		
Periprosthetic infection	2 (13.3%)	1 (20.0%)		
Periprosthetic fracture	2 (13.3%)	0 (0.0%)		
Component loosening	9 (60.0%)	2 (40.0%)	3.111	0.816
Conditions in primary THA				
Cementless cup	12 (80.0%)	5 (100.0%)	1.176	0.539
Cementless stem	12 (80.0%)	5 (100.0%)	1.176	0.539
Subtrochanteric osteotomy	6 (40.0%)	1 (20.0%)	0.659	0.613
Paprosky classification of bone defect				
Acetabular side				
IIA	6 (40.0%)	1 (20.0%)		
IIB	4 (26.7%)	1 (20.0%)		
IIIA	5 (33.30%)	3 (60.00%)	1.162	0.684
Femoral side				
I	5 (33.3%)	0 (0.0%)		
II	9 (60.0%)	4 (80.0%)		
IIIA	1 (6.7%)	1 (20.0%)	2.564	0.300
Modified WOMAC score				
WOMAC Pain score	47.7 ± 29.4	47.0 ± 29.9	0.086	0.933
WOMAC Stiffness score	74.2 ± 47.6	65.0 ± 43.8	0.743	0.467
WOMAC Function score	47.0 ± 30.0	42.9 ± 31.0	0.515	0.613
Total WOMAC score	49.4 ± 28.2	45.6 ± 29.1	0.508	0.618
HHS score				
HHS Pain score	25.3 ± 19.4	24.0 ± 10.7	0.283	0.780
HHS Function score	19.3 ± 22.5	14.4 ± 18.7	0.862	0.400
HHS Deformity score	3.0 ± 3.4	2.4 ± 4.3	0.630	0.537
HHS ROM score	1.3 ± 1.6	1.6 ± 1.8	0.619	0.544
Total HHS score	49.0 ± 34.7	42.4 ± 19.6	0.785	0.443
Radiological measurement				
Preoperative vertical COR (mm)	47.8 ± 35.9	37.2 ± 19.4	0.951	0.359
Preoperative horizontal COR (mm)	40.9 ± 18.0	45.8 ± 11.2	0.869	0.401
Radiological LLD (mm)	24.0 ± 29.9	23.3 ± 45.3	0.062	0.952
Vertical COR discrepancy/LLD (%)	116.7 ± 176.0	120.0 ± 103.7	0.061	0.953
Acetabular cup inclination (°)	51.8 ± 39.9	51.5 ± 16.5	0.030	0.977
Acetabular cup anteversion (°)	18.1 ± 26.5	14.5 ± 11.5	0.562	0.582

Abbreviations: BMI—body mass index; COR—center of rotation; HHS—Harris hip score; LLD—leg length discrepancy; THA—total hip arthroplasty; WOMAC—Western Ontario and McMaster Universities Osteoarthritis Index.; *Notes*: [a] *P*-values < 0.05 were considered to be statistically significant. Values are presented as n (%) or as mean ± standard error of the mean.

non-cemented prostheses. Among the 20 hips, the bearing surfaces utilized in the revision were as follows: four (20%) involved ceramic-on-ceramic; and 16 (80%) involved ceramic-on-polyethylene.

For metal augment cases, the acetabulum was reamed one or two sizes higher at the anatomic level, with the final reamer positioned at the anatomic level as a trial fitting of the cup. The bone defect was then reassessed, and the augment's shape and size were determined according to the shape and extent of the defects around the trial fitting. Appropriate metal augments were then used to restore the acetabular rim or to reconstruct points for mechanical support. In severe superior bone loss cases, fixation to the ilium was achieved with either a buttress augment (three hips, 15%) or slope augments (five hips, 25%). Bone cement was used in the interface between the cup and augments before final cup implantation.

Clinical Outcome Assessment

Clinical and radiological results were available for all 20 patients. The registry center collected preoperative and postoperative information on the patients treated in our hospital. The preoperative Harris hip score (HHS) values and the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) values were recorded by physicians and their full-time assistants in our hospital during the follow-up

TABLE 3 Comparison of postoperative radiological and clinical factors between the satisfied and dissatisfied patients. (mean ± SD or percentages)

Variables	Satisfied group	Dissatisfied group	*t* value/χ^2 value	*P*-value[a]
Radiological measurement				
Acetabular cup diameter (mm)	47.4 ± 7.9	44.0 ± 0.0	1.842	0.084
Postoperative vertical COR (mm)	17.9 ± 17.8	36.2 ± 7.0	3.342	0.005
Postoperative horizontal COR (mm)	30.4 ± 15.8	35.4 ± 3.7	1.029	0.322
Radiological LLD (mm)	11.4 ± 13.2	16.3 ± 25.0	0.956	0.357
Vertical COR discrepancy/LLD (%)	54.2 ± 53.8	66.7 ± 22.6	0.755	0.464
Acetabular cup inclination (°)	39.3 ± 14.2	38.7 ± 13.7	0.160	0.875
Acetabular cup anteversion (°)	12.7 ± 11.0	8.2 ± 8.9	1.610	0.125
VAS score of pain	2.5 ± 4.7	6.8 ± 2.6		0.001
Modified WOMAC score				
WOMAC Pain score	90.0 ± 39.9	53.0 ± 59.9	3.114	0.006
WOMAC Stiffness score	84.3 ± 51.9	62.6 ± 69.5	1.461	0.161
WOMAC Function score	77.0 ± 32.5	64.2 ± 36.4	1.454	0.163
Total WOMAC score	80.3 ± 31.8	61.6 ± 40.6	2.095	0.041
HHS score				
HHS Pain score	40.4 ± 16.9	22.8 ± 34.5	3.029	0.007
HHS Function score	29.7 ± 19.0	24.8 ± 19.5	0.967	0.346
HHS Deformity score	2.9 ± 3.6	2.4 ± 4.3	0.539	0.597
HHS ROM	2.9 ± 2.6	2.8 ± 2.1	0.103	0.919
Total HHS score	75.9 ± 27.3	52.8 ± 52.0	2.548	0.020
Satisfaction with 16 functions and issues				
Pain relief	13 (86.7%)	0 (0.0%)	12.381	0.001
Walking on a flat surface	10 (66.70%)	2 (40.0%)	1.111	0.347
Ascending stairs	9 (60.0%)	2 (40.0%)	1.667	0.249
Descending stairs	13 (86.7%)	3 (60.0%)	1.667	0.249
Getting into/out of cars	7 (46.7%)	2 (40.0%)	0.067	1.000
Squatting	7 (46.7%)	1 (20.0%)	1.111	0.603
Rising after squatting	9 (60.0%)	2 (40.0%)	0.606	0.617
Abnormal feeling in the hip	11 (73.3%)	4 (80.0%)	0.089	1.000
Muscle weakness when walking	13 (86.7%)	4 (80.0%)	0.131	1.000
Putting on and tying up shoes	15 (100.0%)	5 (100.0%)	-	1.000
Walking fast or jogging	12 (80.00%)	2 (40.0%)	2.857	0.131
LLD	5 (33.30%)	4 (80.0%)	3.300	0.127
Hip squeaking	15 (100.00%)	4 (80.0%)	3.158	0.250
Hip stiffness	11 (86.7%)	3 (60.0%)	1.667	0.249
Hip numbness	13 (86.7.0%)	4 (80.0%)	0.131	1.000
Discomfort in cold weather	11 (73.3%)	4 (80.0%)	0.089	1.000

Abbreviations: COR—center of rotation; HHS—Harris hip score; LLD—leg length discrepancy; VAS—visual analogue scale; WOMAC—Western Ontario and McMaster Universities Osteoarthritis Index.; *Notes*: [a] *p*-values <0.05 were considered to be statistically significant. Values are presented as n (%) or as mean ± standard error of the mean.

period. The HHS values were collected in the following categories as previously described:[19,20] pain, function, deformity, range of motion, and total score. The modified WOMAC scores were calculated as the total score and as subscores of pain, stiffness, swelling, and function, with a higher score being indicative of better outcomes and ranging from 0 to 100.[21] Postoperative complications leading to readmission, including deep venous thrombosis and pulmonary embolism, sciatic nerve injury, periprosthetic fracture, component migration, dislocation, and periprosthetic infection, were recorded (Fig. 1).

A senior surgeon evaluated the radiographs. Preoperative and postoperative anteroposterior (AP) radiographs of bilateral hips were reviewed. All measurements were conducted using Mimics version 16.0 software (Materialise, Leuven, Belgium). The magnification was determined by normalizing the femoral head size for the pre-revision and post-revision radiographs. The vertical and horizontal positions of the COR of the hip were measured about the interteardrop line and the vertical line through the teardrop. The preoperative COR and reconstructed COR were determined using a best-fit circle aligned with the femoral head margin.[22] As subtrochanteric osteotomy caused a change in leg length below the lesser trochanter, the radiological LLD was determined by calculating the difference between the distance from the COR to the tip of the medial malleolus on the full-length view radiographs. The contribution percentage of the acetabular side to the LLD was defined as the quotient of the vertical COR discrepancy and the radiological LLD (Fig. 2). Signs including radiolucent lines, radioactive lines, osteolysis, stress shielding, and pedestals were noted according to the Gruen and DeLee zone method. Other radiological signs of polyethylene wear, component dissociation, and prosthesis failure were also recorded.

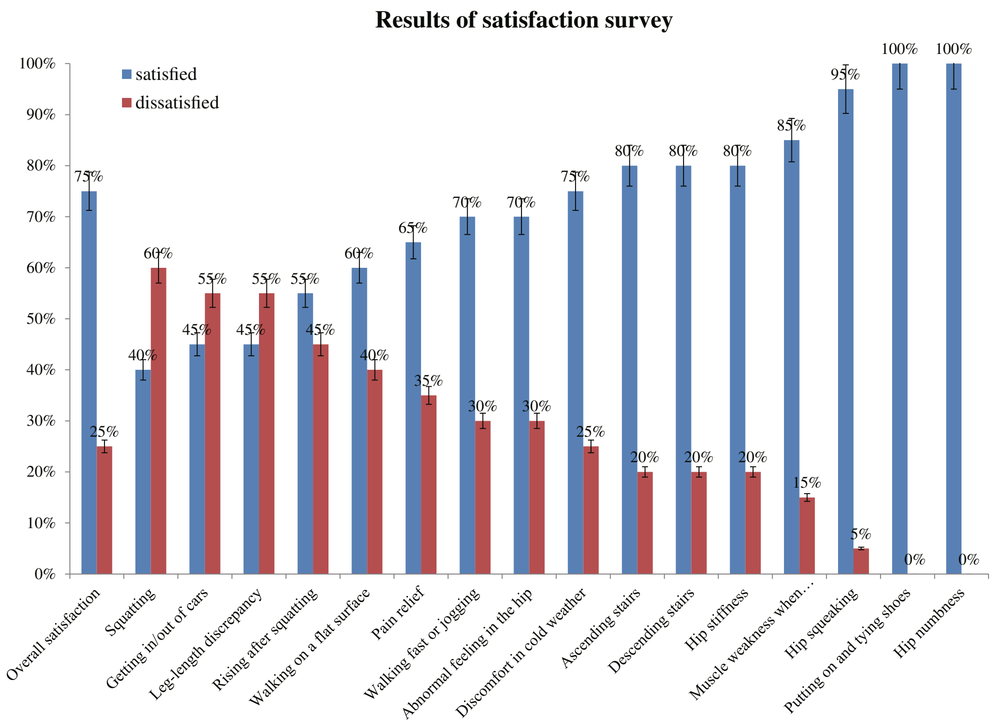

Fig. 3 Results of satisfaction survey. Specific functions or issues are arranged in ascending order by percentage of patients satisfied with each item

Patient Satisfaction Assessment

We evaluated the patients' level of satisfaction with the revision surgery at the final follow-up assessment using a previously reported satisfaction questionnaire for THA.[21] The questionnaire assessed the general level of satisfaction after revision THA and the level of satisfaction related to the following 16 specific hip functions or issues after revision THA: pain relief, walking on a flat surface, ascending stairs, descending stairs, getting into/out of cars, squatting, rising after squatting, putting on shoes and tying laces, walking fast or jogging, LLD, hip squeaking, hip stiffness, abnormal sensation in the hip, muscle weakness when walking, hip numbness, and discomfort in cold weather.

For each item, patients were asked to designate their level of satisfaction based on the following five categories: very dissatisfied, dissatisfied, neutral, satisfied, or very satisfied. Subsequently, a binary satisfaction outcome was determined for each item by combining patients who answered "very dissatisfied," "dissatisfied," or "neutral" into the "dissatisfied" group and combining those who answered "satisfied" or "very satisfied" into the "satisfied" group.[23,24] These two categories were used for all statistical analyses.

Statistical Analysis

Categorical variables (sex, affected side, employment status, primary diagnosis, bearing surfaces, femoral head diameter, and Charnley classification) were analyzed by cross-tabulation using the chi-square test (Table 1). Continuous variables (age, BMI, preoperative and postoperative HHS values) were analyzed using the student's t test or the non-parametric Wilcoxon rank sum test, if approximate (Table 1). All statistical analyses were conducted using Statistical Package for the Social Sciences (SPSS) software (version 15.0; IBM, Armonk, NY, USA), and P values <0.05 were considered significant.

Results

Clinical and Radiological Results

There were significant postoperative improvements in the average HHS, modified WOMAC, and pain visual analogue scale (VAS) scores compared with the preoperative measurements ($P < 0.05$, Table. 1). There were also significant differences between the preoperative and postoperative radiographs in terms of the vertical and horizontal offset of the COR, radiological LLD, and percentage of the vertical COR discrepancy/LLD (Table. 2). Two patients exhibited radiolucent lines <1 mm in width in the Gruen and DeLee zone 1 of the acetabular side. No signs of loosening, excessive polyethylene wear, or osteolysis were noted. One patient experienced deep venous thrombosis at the bilateral popliteal veins, without symptoms of pulmonary embolism, 5 days after revision THA. No patients had revisions of the hip joint furthermore.

Overall Satisfaction and Reasons for Overall Dissatisfaction

Of the 20 patients, 15 (75%) patients were classified as being satisfied with revision THA, seven (35%) of whom were "very satisfied" and eight (40%) of whom were "satisfied."

Of the remaining five (25%) patients who were classified as being dissatisfied with surgery, three (15%) were "neutral" and two (10%) were "dissatisfied." The comparison of the preoperative factors revealed no significant differences between the binary satisfied and dissatisfied classification groups (Table 2). The dissatisfied patients exhibited a significantly higher postoperative VAS pain score than the satisfied patients (2.5 ± 4.7 *vs* 6.8 ± 2.6), a lower postoperative modified WOMAC pain score (90.0 ± 39.9 *vs* 53.0 ± 59.9), HHS pain score (40.4 ± 16.9 *vs* 22.8 ± 34.5), WOMAC total score (80.3 ± 31.8 *vs* 61.6 ± 40.6), and HHS total score (75.9 ± 27.3 *vs* 52.8 ± 52.0), a lower satisfaction rate related to pain relief (86.7% *vs* 0.0%), and a higher vertical COR (17.9 ± 17.8 *vs* 36.2 ± 7.0) ($P < 0.05$, Table. 3).

Dissatisfaction Related to Hip Functions or Issues

The satisfaction rate for each of the 16 items ranged from 45% to 100% (Fig. 3). The top three dissatisfactory functions or issues were squatting (dissatisfaction rate, 60%), getting into/out of cars (dissatisfaction rate, 55%), and LLD (dissatisfaction rate, 55%). Functions and symptoms are ranked in descending order by the level of dissatisfaction (Fig. 3).

Discussion

This study investigated the clinical and radiological outcomes of revision THA among patients with prior Hartofilakidis type C hip dysplasia. To our knowledge, there has been a paucity of literature reporting results after revision THA among patients for whom previous Hartofilakidis type C hip dysplasia was the etiology leading to the primary THA. Our data revealed significant improvements in the radiological COR, HHS scores, and modified WOMAC scores after revision (Table 1). The overall satisfaction rate was 75%, with squatting, getting into/out of cars, and LLD being the top three hip functions or issues with the greatest dissatisfaction rates (Fig. 3).

Overall Satisfaction Rate and Reasons for Overall Dissatisfaction

Our investigation revealed that the postoperative satisfaction rate among patients with prior Hartofilakidis type C hip dysplasia who underwent revision THA was 75%, with 35% being "very satisfied" and 40% being "satisfied." However, patients' satisfaction rates varied for specific items, ranging from 45% to 100% (Fig. 3). Our data showed that revision THA for patients with prior Hartofilakidis type C hip dysplasia resulted in less satisfactory outcomes than those of previous reports involving other revision THA populations.[25,26] For example, Barrack *et al.* reported a satisfaction rate of 82% among 320 patients undergoing revision hip arthroplasty,[27] Jibodh *et al.* reported an average satisfaction score of 8.7 ± 2.1 for 78 patients after revision THA,[28] and Turnbull *et al.* reported that 79% of patients remained satisfied or very satisfied following revision THA.[26] The reason that revision THA in those with a prior DDH diagnosis resulted in lower satisfaction rates might be due to difficulties related to inadequate bone stock, soft tissue tightness caused by long-term dislocation and repeated surgeries, and adjacent joint problems.[5,6] In our current cohort, the most likely reasons for dissatisfaction were inadequate pain relief and a higher vertical COR measured on radiography (Table 3).

The current study showed that pain relief following revision THA was not as effective as that following primary THA, which can result in satisfactory pain relief in 89.8% to 90.6% of cases.[21,23] Anakwe *et al.* have shown that pain relief is directly associated with general satisfaction with a procedure.[29] Espehaug *et al.* investigated 1618 patients and reported less favorable postoperative improvements in pain relief after revision THA than after primary THA.[30] Postler *et al.* also reported less pain relief after revision THA than after primary THA.[31] Compared with the results reported in the literature from other populations who underwent revision THA, the level of pain relief following revision THA was comparable in patients who experienced a prior high hip dislocation.[26,31] The reasons patients experienced less effective pain relief after revision THA are complex and remain unclear, although repeated surgeries might cause pain sensitization, leading to a lower threshold for pain sensation.[32] The complex surgery might lead to less favorable biomechanical reconstruction and a higher intraarticular joint reaction force, which might also explain the residual pain.

Our data showed that dissatisfied patients had a higher vertical COR after revision THA compared with that of the satisfied group. Morag *et al.* reported that patients with a COR higher than 35 mm from the interteardrop line experienced significantly worse survival outcomes than those with a COR < 35 mm among patients with prior DDH who undergo revision THA.[5] Other researchers have found that a superiorly and laterally placed COR significantly increased the joint reaction force and subsequent loosening rate of components.[33–35] The poorer functional outcomes associated with a higher COR might be due to the lower range of motion resulting from impingement.[36] The present study revealed a trend toward lower HHS and modified WOMAC functional scores (Table 3), although neither reached statistical significance. This might be due to the fact that there was no lateralization of the COR (30.4 ± 15.8 mm *vs* 35.4 ± 3.7 mm of the horizontal COR), and the superior placement was not severe enough (17.9 ± 17.8 mm *vs* 36.2 ± 7.0 mm of the vertical COR) in the current cohort. According to the computerized model reported by Delp *et al.*, the moment arm of abductors could be compensated for by increasing the neck length in high COR instances, only without lateralization of the COR.[34]

Dissatisfaction Related to Specific Hip Functions or Issues

The top three dissatisfactory functions were squatting, getting into/out of cars, and rising after squatting (Fig. 3); this indicates that hip function was limited in the performance of high-flexion activities. Koyanagi *et al.* found that the mean maximum ROM for hip flexion after arthroplasty *in vivo* was 86.2° (range, 55.1°–117.4°).[37] However, numerous studies have shown that hip flexion of more than 120° is required for squatting.[38–40] Our data revealed that 60% of the patients were not satisfied with their squatting ability after the procedure, which reflected the importance of high-flexion postures in Asian cultures,[39,40] as many Asians squat while eating, resting, or using the toilet. Our data showed that the dissatisfied group exhibited a higher COR after revision THA, which might be one of the causes of inadequate flexion.[36] Another possible reason for the limited range of motion is the tightness in soft tissues caused by previous surgical scarring and joint capsule contracture. As pointed out by Barrack *et al.*, patients who undergo revision THA commonly have high functional expectations. It is essential to educate patients preoperatively about the typical postoperative functional outcomes, especially for patients with a previous history of DDH.[27]

Previous studies have shown that LLD played an essential role in patient satisfaction after THA. The current investigation revealed that the average radiological shortening improved from 23.9 ± 16.1 mm to 12.4 ± 7.9 mm after revision THA for patients with prior Hartofilakidis type C DDH; these changes corresponded with the 55% rate of dissatisfaction related to the LLD (Table 1, Fig. 3). Achieving an equal leg length is difficult in patients with severe bone loss, in those who have undergone repeated surgeries, and in individuals with a prior high-riding hip dislocation. Our data showed that 56.7% of the postoperative radiological LLD came from the acetabular side, compared with 117.3% in the preoperative radiographs; these values suggested that the normalization of the COR helped reduce LLD (Table 1). This factor might have played an important role in the higher dissatisfaction rate reported by patients with a higher COR.

Limitations and Strengths

Our study had several limitations. First, this is a retrospective study with a small sample size, which might have increased the likelihood of selection bias. Second, the revision surgeries were conducted by four different surgeons at our institute, which may have been a potential confounding factor in the study. Third, the present study did not include a matched comparison group comprising patients who underwent revision THA without a prior diagnosis of Hartofilakidis type C hip dysplasia. Further studies are required to compare the outcomes of revision THA among patients undergoing primary THA due to diseases with other etiologies. Besides, the radiological evaluation was completed by only one author. However, the long-term clinical experience of the senior author improved the reliability.

Despite these limitations, the current study reports a series of revision THA patients with prior Hartofilakidis type C hip dysplasia, which was seldom reported in the literature. Our clinical and radiological results showed promising outcomes for this category of challenging disease and illustrated key factors influencing the treatment outcome.

Conclusion

This study found that patients with prior Hartofilakidis type C hip dysplasia who underwent revision THA reported an overall level of satisfaction of 75%, with squatting, getting into/out of cars, and LLD being the top three hip functions or issues with the greatest levels of dissatisfaction. The most likely reasons for dissatisfaction were inadequate pain relief and a higher vertical COR measured on radiography.

Authors' Contributions

All authors (YXZ, SJG, HT, Y, and ZYM) made substantial contributions to the design, data processing, and interpretation. YXZ, SJG and HT conceived the study. YH and ZYM coordinated data collection. HT and YH performed the analyses. SJG and HT drafted the article, and all other authors revised it critically for important intellectual content. All authors read and approved the final manuscript.

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