Orthopaedic Surgery

CLINICAL ARTICLE

Long-Term Clinical Outcomes and Survivorship of Total Hip Arthroplasty for Pyogenic Arthritis: A Retrospective Cohort Study of 168 Hips

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Objective: The aim of the present study was to evaluate the 10-year outcomes of cementless total hip arthroplasty (THA) in adult patients with the late sequelae of septic arthritis of the hip.

Methods: We followed 166 consecutive patients (168 hips) who underwent cementless THA between March 2001 and December 2011. There were 79 men and 87 women, with a mean age of 50.4 years (range 21–76 years) at the time of index THA, all of whom had hip osteoarthritis secondary to hip pyogenic infection. The average duration of follow up was 10.6 years (range 6.9–17.2 years). Preoperative and postoperative clinical ratings were evaluated, including the hip dysfunction and osteoarthritis outcome score (HOOS), the Harris hip score (HHS), range of motion, a 100-point visual analog scale for hip pain, and the severity of limp and limb length discrepancy (LLD). The anteroposterior and lateral radiographs of the hip and full-length view of the lower extremities were obtained to assess the position of the components, radiolucent lines, osteolysis, loosening of components, and heterotopic ossification. The intraoperative and postoperative complications were also recorded.

Results: The mean HSS and hip pain score were 44.2 points (range 29–66 points) and 42.5 points (range 32–64 points), respectively, before the index surgery and significantly improved to 88.1 points (range 78–96 points) and 15.1 points (range 10–26 points), respectively, at final follow-up examination. The HOOS and range of motion also improved significantly. The mean limb length discrepancy was reduced from 2.6 to 0.8 cm. The limp at last follow-up examination was moderate in 3 cases because of hip osteoarthritis in the other limb, slight in 26, and absent in 137. A radiolucent line was observed in 12 hips (7.1%) around the acetabular or femoral components. A progressive radiolucent line around the undersized femoral stem in all zones was seen in 1 hip, resulting in aseptic loosening and breakage of the femoral component. There were 8 cases of intraoperative fracture, 7 cases of dislocation, and 7 cases of transient nerve palsy. Recurrence of infection occurred in 2 hips. Revision surgery was conducted in 2 hips because of isolated loosening of the acetabular cup and the femoral stem, respectively. Kaplan–Meier survival was 97% at 10 years, with revision for any reason with any component as an end-point.

Conclusion: Improved surgical techniques and development of components with various sizes provided favorable results for cementless THA conducted for late sequelae of sepsis in these young and active patients. Although the incidence of complications was relatively high, the complications were treated successfully.

Key words: Childhood sepsis; Clinical outcomes; Long-term survivorship; Radiographic outcomes; Total hip arthroplasty

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Introduction

Infective arthritis of the hip joint mainly occurs in relatively young patients (peak incidence is in kids < 3), especially in economically less-developed countries, which may lead to the sequelae of suppurative arthritis of the hip (i.e. avascular necrosis of the femoral head, slipped upper femoral epiphysis, or joint stiffness) if untreated or if treatment is untimely[1–3]. Total hip arthroplasty (THA) is the most successful method for treating sequelae of suppurative arthritis of the hip. However, THA for the treatment of the late sequelae of septic arthritis of the hip is technically demanding because of abnormal bone development, severe flexion deformities resulting from severe soft tissue contractures, the relatively young age of patients, potential risk of reinfection, and higher complication rates[2,4–9]. For instance: femur canal preparation is difficult for a narrow femoral intramedullary canal and increased anterior bowing; smooth and stable fixation of the acetabular component is difficult for a shallow dysplastic acetabulum with superior and anterolateral deficiencies; and previous infection and repeated surgeries cause severe soft tissue contractures, anatomic distortion in the femoral artery, vein, and nerve, and alters the orientation of hip abductor muscles[9].

Total hip arthroplasties with cemented acetabular and femoral components in patients with septic arthritis of the hip are associated with high rates of revision[7,10], osteolysis[1,6,7,11], and postoperative complications[1,6,8]. Hybrid or cemented THA could also pose special problems in subsequent revision surgeries, including inadequate bone stock and difficulty in removing these prostheses[2,7,11]. With the development of the cementless femoral and acetabular components and improved surgical techniques, cementless THA could been performed in these young and active patients[2,12–14]. However, to the best of our knowledge, only short-term or mid-term results of THA in patients with quiescent infection of the native hip have been documented[1,2,5–8,10–12]. Some prior reports have included cemented[7], cementless[7,8,10], or hybrid components[1,2,5,6,11,12], while others have included a modest number of hips that were treated with mixed groups with different anatomic levels and surgical techniques[7,12].

We hypothesized that the cementless THA would have satisfactory long-term outcomes for patients with the late sequelae of septic arthritis of the hip. Thus, the purpose of this study was: (i) to determine the efficiency of cementless THA for patients with suppurative arthritis of the hip; (ii) to evaluate the long-term clinical and radiographic outcomes of patients; and (iii) to evaluate patient complications.

Materials and Methods

Inclusion and Exclusion Criteria

After obtaining approval from the institutional review board of our hospital, this retrospective study was conducted using a single institution's total joint registry. The work has been reported in line with the STROCSS criteria[15]. The protocol of the study was registered in the Chinese Clinical Trial Registry. Written informed consent was obtained from all participants. Our study included any patient who underwent cementless THA in the setting of late sequelae of septic arthritis of the hip. Pyogenic arthritis was diagnosed according to the patient's history and clinical and radiological findings.

Inclusion criteria were: (i) patients older than 18 years; (ii) THA performed between March 2001 and December 2011; (iii) patients with late hip osteoarthritis secondary to hip pyogenic infection; (iv) an infection quiescent period >10 years; (v) cementless THA; and (vi) patients who were retrospectively recruited and provided informed consent. The exclusion criteria were: (i) recent pyogenic arthritis of the hip; and (ii) THA with cemented or hybrid components. A total of 176 patients (178 hips) fit our inclusion criteria and were eligible for inclusion in this study. Ten patients were excluded due to unrelated death (5 patients) or loss of follow up (5 patients). Two patients received bilateral THA. This resulted in 166 patients (168 hips) being included as the subjects of this study (Fig. 1). The infecting organism of the original infection was *Staphylococcus aureus* in 149 hips (88%), *Streptococcus* in 5 (3%), *Pseudomonas aeruginosa* in 4 (2%), *Escherichia coli* in 2 (2%), *Salmonella* spp. in 2 (1%), and *Hemophilus influenzae bacillus* in 1 (1%). Information regarding the causative microorganism was not available in the remaining 5 hips.

Clinical Data and Perioperative Management

The eligible patients included 79 men and 87 women, with a mean age of 50.4 years (range 21–76 years) at the time of index THA. The mean body mass index was 23.6 kg/m^2 (range 16.1–33.8 kg/m^2). The average duration of follow up was 10.6 years (range 6.9–17.2 years). The average time interval between the resolution of active infection of the hip and the index THA was 34.4 years (range 6.9–58 years). Only 1 hip had a quiescent period of less than 10 years after the infection. The demographic data for patients are summarized in Table 1. Before surgery, all patients were evaluated for continuing infection with use of technetium-99 and gallium bone scans, erythrocyte sedimentation rate (ESR), concentration of C-reactive protein (CRP), and complete blood cell count. During the operation, smears, aspirates, synovial tissues, and excised specimens were cultured for aerobic, anaerobic, and tuberculous bacilli. Moreover, frozen sections were taken for suspicious tissue for evidence of bacterial or tuberculous infection. After obtaining deep tissue samples for culture, cefuroxime (1500 mg, every 8-h interval) was administered intravenously and was continued for 1 day[16].

The surgery process was as follows: (i) all THA procedures were performed under general anesthesia and with patients placed in lateral position; (ii) all THA procedures were performed using a posterolateral approach; (iii) the acetabulum was reamed gradually to reach the medial wall of the true acetabulum, starting with very small reamers; and (iv) the preoperative templating and insertion of acetabular

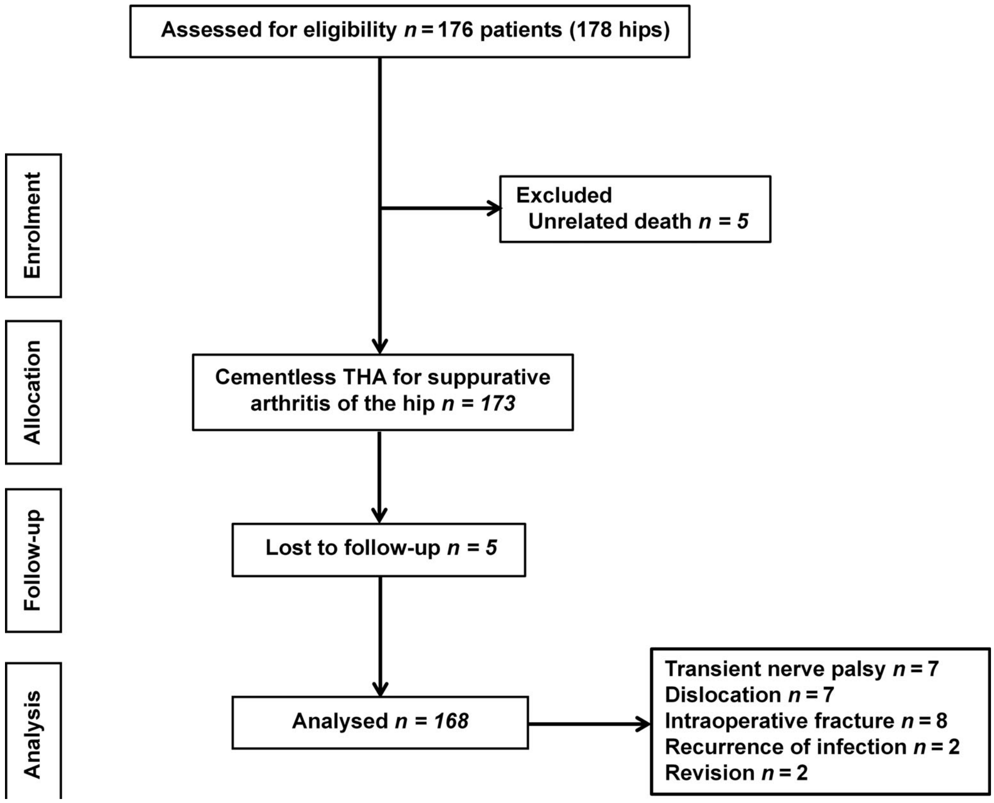

Fig 1 Flow diagram for the retrospective cohort study.

and femoral components were as described in a previous study[13]. If the acetabular recess could accommodate the acetabular cup, a cementless Duraloc or Pinnacle (DePuy Orthopaedics, Warsaw IN, USA) acetabular component was press-fit with the target position of 40° ± 10° abduction and 15° ± 10° anteversion and/or was fixed with screws to ensure immediate stability. In cases of insufficient coverage (<70%) of the acetabular cup or severe acetabular bone defects, a structural femoral head allograft or porous tantalum augment (Ti-alloy; Zimmer) combined with bulk bone grafting from the femoral head was used to ensure adequate bony cover.

The acetabular component was fixed by press-fit and/or screws in 66 hips (39.3%), allografting and multiple screws in 97 hips (57.7%), and Ti-alloy mesh and impaction bone grafting in 5 hips (2.9%). The median acetabular cup diameter was <52 mm in 137 patients (139 hips) and >52 mm in 29 patients (29 hips). Four different types of hip resurfacing were used: metal-on-metal bearing in 9 hips, metal-on-polyethylene bearing in 29 hips, ceramic-on-polyethylene bearing in 7 hips, and ceramic-on-ceramic bearing in 123 hips.

After insertion of the acetabular component, attention was redirected to the femoral side. In these hips, 25 hips (14.9%) were classified as Crowe type III and 31 (18.5%) as Crowe type IV according to Crowe classification[17]. The deformity seen around the acetabulum or femur is due to the sequelae of infection. An osteotomy at 1–2 cm beneath the lesser trochanter was conducted in 27 hips (Crowe type III in 3 hips and Crowe type IV in 24 hips) to restore the anatomical hip rotation center[14]. Four different types of cementless femoral prostheses (DePuy Orthopadics) were used: a CORAIL component in 68 hips, a SUMMIT component in 17 hips, an S-ROM component in 61 hips, and a Tri-Lock component in 22 hips. The types of femoral stems were decided on the basis of preoperative templating, morphology of the medullary cavity, and whether subtrochanteric femoral shortening resection was needed. S-ROM stems were applied in patients who needed femoral osteotomy or had excessively anteverted femoral neck[13,14]. Postoperatively, all patients were encouraged to conduct isometric exercises on a bed immediately. The patients walked with partial weight-bearing on two crutches for approximately 2 weeks, and gradually progressive full weight-bearing was allowed as tolerated[14].

Hip Dysfunction and Osteoarthritis Outcome Score and Harris Hip Score Assessment

The HOOS was used to evaluate symptoms and functional limitations related to the hip. The HOOS consists of 40 items, selected from 51 original items, assessing five separate patient-relevant dimensions: pain (P) (10 items); symptoms (S) including stiffness and range of motion (5 items); activity limitations-daily living (A) (17 items); sport and recreation function (SP) (4 items); and hip related quality of life (Q) (4 items).

TABLE 1 Demographic data

Variable	166 patients (168 hips)
Age (year)*	50.4 (21–76)
Gender (male/female)†	79 (47.6%)/87(52.4%)
Height (m)*	1.59 (1.48–1.77)
Weight (kg)*	60.4 (40–101)
BMI (kg/m^2)*	23.6 (16.1–33.8)
Trendelenburg sign (number of hips)†	
Yes	46
No	120
Operated side (R/L) (%)†	70 (41.7%)/98 (58.3%)
ASA†	
Status I–II	129 (77.7%)
Status ≥III	37 (22.3)
Interval between resolution of active infection and THA (years) (number of hips)*	34.4 (7–58)
<10†	1 (1)
10–20†	17 (17)
20–30†	47 (47)
>30†	101 (103)
Follow up (years)*	10.6 (6.9–17.2)
Prosthesis (number [%] of hips)†	
Cementless Corail	66 (68)
Cementless S-ROM	61 (61)
Cementless Tri-Lock	22 (22)
Cementless Summit	17 (17)

The Corail, S-ROM, Tri-Lock, and Summit prostheses are manufactured by Depuy (DePuy, Warsaw, IN); ASA, American Society of Anesthesiologists; BMI, body mass index.; * The values are given as the mean and range.; † The values are given as the number of patients.

The HHS was used to evaluate postoperative recovery of hip function in an adult population. The HHS score system includes four aspects: pain, function, absence of deformity, and range of motion. The score standard had a maximum of 100 points (best possible outcome). A total score <70 is considered a poor score, 70–80 fair, 80–90 good, and 90–100 excellent.

Clinical Assessment

Range of motion, a 100-point visual analog scale for hip pain, severity of limp, and limb length discrepancy (LLD) were documented. Intraoperative and postoperative complications were recorded. To evaluate any LLD, we measured the difference between the anterior superior iliac spine and the medial malleolus[13]. Recurrence of infection, survivorship, and complications were also recorded.

Radiographic Assessment

Anteroposterior (AP) and lateral radiographs of the hip and full-length view of the lower extremities were obtained under fluoroscopic control for all patients by a well-trained radiographer to ensure reproducibility. Two observers, who were not involved with the surgery, assessed the radiographs for the position of the components, radiolucent lines, osteolysis, loosening of components, and heterotopic ossification. Abduction of the acetabular cup was calculated according to the system of Engh *et al.*[18], and anteversion of the component was measured according to the system of Woo *et al.*[19]. On the AP radiograph, the coverage of the acetabular cup was measured using the method of Wilson *et al.*[20]. The presence of radiolucent lines and osteolytic lesions was recorded around the acetabular component based on the three-zone system of Cherney and Amstutz[21] and around the femoral component based on the seven-zone system of Gruen *et al.*[22]. Fixation of the acetabular and femoral component was classified according to the method of Engh *et al.*[23] and Latimer *et al.*[24] (including ingrown, stable fibrous ingrown, or unstable). If there was definite evidence of migration or progressive subsidence in the femoral canal, the radiographic result of the femoral stem was defined as unstable[25]. The loosening of the acetabular cup had the following radiological signs: a change in the position of the cup, breakage of screws used for fixation, progressive radiolucent lines of >2 mm around the cup, or migration[26]. Heterotopic ossification was evaluated according to the system of Brooker *et al.*[27].

Statistical Analysis

The two-sided paired Student *t*-test was used to compare clinical continuous variables measured preoperatively and at the follow up. The χ^2-test was used for comparison between categorical variables. A *P*-value of <0.05 was considered significant. The data were presented as mean values with ranges. Kaplan–Meier survival models were constructed for survival estimates and conducted with the following study end points for survival: (i) revision for any reason with any component; and (ii) revision for recurrence of infection. All analysis was performed with use of SPSS Statistics software version 19.0 (SPSS, Chicago, IL, USA).

Results

Hip Dysfunction and Osteoarthritis Outcome Score and Harris Hip Score Improvement

The mean HSS and hip pain were 44.2 points (range 29–66 points) and 42.5 points (range 32–64 points) before the index surgery and significantly improved to 89.2 points (range 79–96 points) and 15.6 points (range 12–26 points) at 5 years follow up, then 88.1 points (range 78–96 points) and 15.1 points (range 10–26 points) at final follow-up examination, respectively. The difference in the range of motion between preoperatively and at the time of the final follow up was significant ($P < 0.01$). The HOOS improved at the final follow-up visit compared with preoperatively, and these improvements were significant ($P < 0.01$).

Clinical Evaluations

The preoperative technetium-99 and gallium bone scan, the level of ESR and CRP, and the complete blood cell count were normal in all patients. Moreover, the results of cultures and frozen sections were negative for bacterial and tuberculous infections in all hips. The clinical evaluations were significantly improved at 5 year follow up and at final follow up (Table 2).

The mean preoperative and postoperative LLD in the unrevised hips was 2.6 cm (range 0–7.5 cm) and 0.8 cm (0–1.9 cm), respectively. This change was statistically significant ($P < 0.01$). Moreover, the limp at the 5-year follow-up examination was moderate in 3 cases, slight in 28, and absent in 137, while moderate in 3 cases, slight in 26, and absent in 139 at last follow-up examination (Table 2). At the final follow up, 3 patients (3 hips) had severe pain in the other limb because of hip osteoarthritis, resulting in a moderate limp.

Recurrence of infection after THA was found in 2 patients. The 2 hips with a recurrent infection had a quiescent period of 6.9 years and 23 years, respectively. The organism of the recurrent infection was different from the original organism, and the 2 hips had a new infection (*Staphylococcus haemolyticus*) with no association with previous pyogenic infection (*Streptococcus* and *Escherichia coli*, respectively). The 2 hips underwent two-stage THA and chronic antibiotic suppressive therapy. The new hip components were stable without any loosening or infection at the final follow-up visit. The remaining acetabular cups and femoral stems were embedded firmly in a satisfactory position (Fig. 2).

At 10 years after surgery, Kaplan–Meier survival for revision for any reason with any component was 97% (95% confidence intervals, 91 to 99). With recurrence of infection as an end-point, survival was 98% at 10 years (95% confidence intervals, 93 to 99).

Radiographic Evaluations

The mean coverage of the acetabular cup was 96.2% (87.6% to 100%). The mean abduction and anteversion of the acetabular cup were 42.2° (24° to 54°) and 26.9° (12° to 39°), respectively (Fig. 3). At the final follow up, a radiolucent line (0.3 mm-1.2 mm) was observed in 12 hips (7.1%) around the acetabular (DeLee and Charnley zone I: 3 hips, zone II: 4 hips, and zone III: 2 hips, respectively) or femoral components (Gruen zone 1: 1 hip and zone 7: 2 hips). A progressive radiolucent line around the undersized femoral stem in all zones was seen in 1 hip, resulting in aseptic loosening and breakage of the femoral component. A larger Solution cementless femoral stem (DePuy) was used to revise this femoral stem 2.2 years after surgery (Fig. 4). One hip with metal-on-metal hip bearing (MoMHR) surface had pseudotumors around the acetabulum and a peri-acetabular radiolucent line (2.4 mm) in zones I to III, which resulted in the loosening and a change of the inclination angle of the acetabular cup. An acetabular-only revision was conducted, and the new acetabular component was fixed firmly at final follow-up.

Complications

Heterotopic ossification was seen in 13 hips: there was 1 case of Brooker grade I, 7 of grade II, and 5 of grade III. Dislocation of the femoral head (22–28 mm) occurred in 7 hips

TABLE 2 Clinical outcomes

Variable	Preoperative	Five-year follow-up	Statistical value*	*P*-value*	Last follow up	Statistical value†	*P*-value†
Harris hip score	44.2 (29–66)	89.2 (79–96)	−43.46	**<0.01**	88.1 (78–96)	−43.23	**<0.01**
HOOS							
Symptoms	9.0 (4–12)	15.9 (13–18)	−30.33	**<0.01**	16.1 (14–19)	−35.04	**<0.01**
Pain	13.4 (3–21)	28.9 (26–32)	−38.04	**<0.01**	29.3 (27–32)	−40.71	**<0.01**
Daily living	29.4 (19–37)	61.8 (59–67)	−75.48	**<0.01**	60.6 (57–66)	−69.59	**<0.01**
Sports and recreational activities	5.2 (4–9)	12.5 (10–15)	−32.34	**<0.01**	12.0 (9–15)	−28.79	**<0.01**
Quality of life	4.8 (1–7)	13.4 (12–15)	−52.98	**<0.01**	13.2 (11–15)	−46.19	**<0.01**
Range of motion							
Permanent flexion	11.1 (0–40)	0 (0–0)	23.30	**<0.01**	0 (0–0)	23.30	**<0.01**
Flexion	85.7 (10–120)	110.8 (95–130)	−17.83	**<0.01**	111.4 (96–130)	−18.07	**<0.01**
Abduction	20.2 (−20–50)	44.5 (30–60)	−18.82	**<0.01**	43.9 (30–60)	−18.77	**<0.01**
Hip pain	42.5 (32–64)	15.6 (12–26)	35.56	**<0.01**	15.1 (10–26)	35.68	**<0.01**
Limp (number of hips)			228.45	**<0.01**		232.67	**<0.01**
Severe	38 (22.6%)	0 (0%)	NA	NA	0 (0%)	NA	NA
Moderate	54 (32.1%)	3 (1.8%)	NA	NA	3 (1.8%)	NA	NA
Slight	72 (42.9%)	28 (17.5%)	NA	NA	26 (15.5%)	NA	NA
None	4 (2.4%)	137 (85.6%)	NA	NA	139 (82.7%)	NA	NA
Limb length discrepancy (cm)	2.6 (0–7.5)	0.8 (0–1.9)	16.40	**<0.01**	0.8 (0–1.9)	16.33	**<0.01**
Crowe III	3.5 (2.5–6)	1.0 (0.4–1.8)	36.30	**<0.01**	1.0 (0.4–1.8)	35.30	**<0.01**
Crowe IV	5.2 (3–7.5)	1.3 (0.5–1.8)	36.37	**<0.01**	1.3 (0.5–1.8)	36.28	**<0.01**

* Comparison between preoperation and 5-year follow up.; † Comparison between preoperation and final follow-up.
[1] HOOS, hip dysfunction and osteoarthritis outcome score.

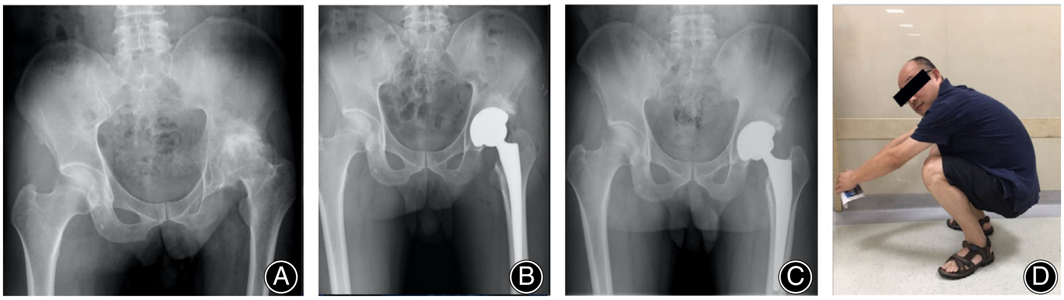

Fig 2 Radiographs of a 42-year-old man with osteoarthritis secondary to infection of the hip in childhood in the left hip. (A) Preoperative anteroposterior view. (B) Postoperative radiographic image at 1-week follow up. (C) Postoperative radiographic image at 8-year follow up with appropriate implant position and stable fixation. (D) The postoperative hip function at 8-year follow-up examination.

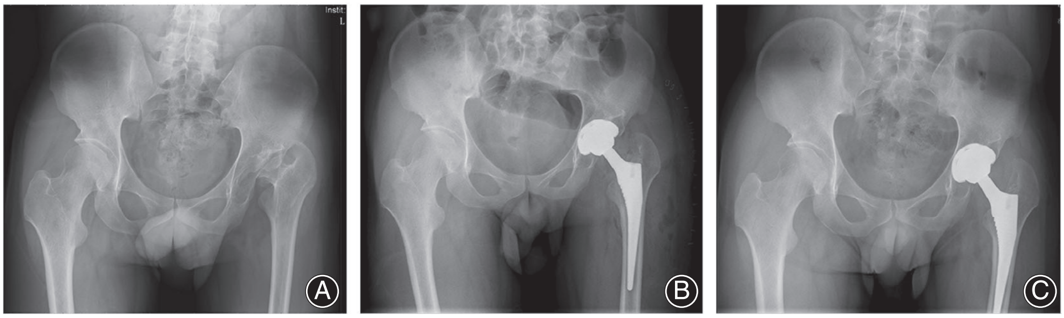

Fig 3 Radiographs of a 24-year-old man with osteoarthritis secondary to infection of the hip in childhood in the left hip. (A) Preoperative anteroposterior view. (B) Postoperative radiographic image at 1-week follow up. (C) Postoperative radiographic image at 7-year follow-up examination.

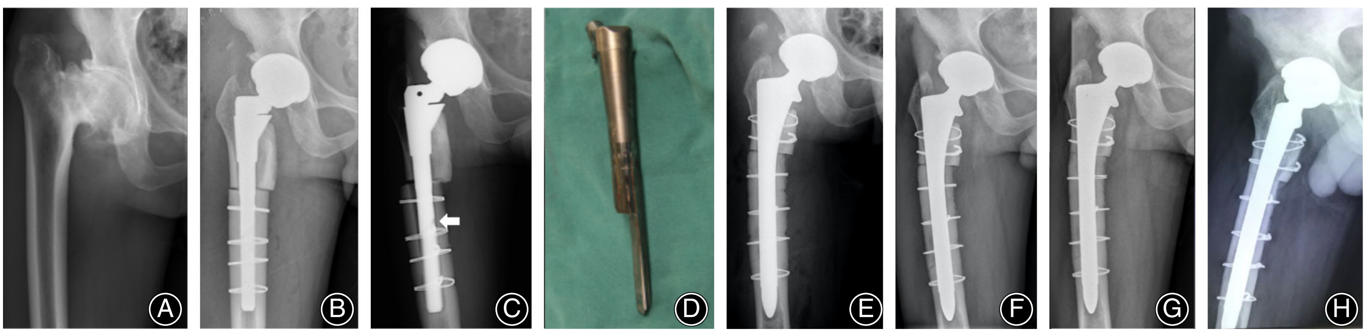

Fig 4 Radiographs of a 50-year-old man with osteoarthritis secondary to infection of the hip in childhood in the right hip. (A) Preoperative anteroposterior view. (B) Postoperative radiographic image at 1-week follow up. (C) Postoperative radiographic image at 2-year follow up. The hip had aseptic loosening of the femoral stem, resulting in local stress concentration at the distal end of the femoral component and breakage. (D) The fractured femoral stem intraoperatively. (E) Postoperative radiographic image at 1-week follow up. The hip underwent cementless total hip arthroplasty with Solution femoral stem (DePuy). (F) Postoperative radiographic image at 1-year follow up. The acetabular and femoral components were stable and in a satisfactory position. (G) Postoperative radiographic image at 2-year follow up. The acetabular and femoral component were fixed firmly. (H) Postoperative radiographic image at 5-year follow-up. The acetabular and femoral components were stable without radiolucent line.

(4.2%). These hips were successfully treated with closed reduction and confinement to bed for 3 weeks without additional recurrence. Transient sciatic nerve palsy occurred in 7 patients (7 hips; 4.2%) who had leg lengthening of 3.68 cm (range 2.9 to 3.9 cm) (Crowe type III in 1 hip, Crowe type IV in 4 hips, and other types in 2 hips). These patients recovered fully within 8 months after receiving medication and undergoing rehabilitation exercise. In 8 hips (4.8%), intraoperative fractures occurred in the femur (6 hips: 2 in the distal and 4 in the proximal femur) and in the greater

TABLE 3 Previous studies of THA in patients with childhood sepsis

Study	THA	Mean age	Quiescent period (years)	Hip function scores		Stem type	Acetabular type	Mean follow up (years)	Revision rate	AL rate	Complication	Repeated infection	Survival
				Preoperative	Postoperative								
Jupiter *et al*	24	NA	27.3	NA	NA	16 Cemented/ 8 Cementless	16 Cemented/ 8 Cementless	3.6	4.2%	0%	4.2%	4.2%	95.8%
Laforgia *et al*	42	NA	33.2	NA	NA	32 Cemented/ 10 Cementless	32 Cemented/ 10 Cementless	5	9.5%	0%	7.1%	9.5%	90.5%
Dudkiewicz *et al*	7	19.1 (14–25)	NA	58.4	94.1	2 Cemented/ 5 Cementless	2 Cemented/ 5 Cementless	8.1	42.8%	Acet AL: 2/ Fem AL: 2	Femoral fracture: 1	14.3%	58.2%
Park *et al*	49	50.8 (24–73)	36.3 (16–61)	62.4 (41–79)	91.1 (74–98)	All Cementless	All Cementless	5.8	2.1%	0%	SNI: 1; Intraop FF: 1	0%	97.9%
Kim *et al* (1)	47	41.9 (18–60)	34.9	50	85 (61 to 97)	All Cemented	All Cemented	9.8	17%	Acet AL/ Fem AL: 8	Osteolysis: 25; Nonunion:7; Heterotopic ossification: 4; SNI: 1	4.2%	83%
Kim *et al* (2)	123	42.7 (19–48)	31.9–34.9	50	89 (61 to 100)	All Cementless	All Cementless	10.8	15%	Acet AL/ Fem AL: 18	Osteolysis: 72; Nonunion: 2; Heterotopic ossification: 10; SNI: 1; Femoral fracture: 1	0%	85%
Bauer *et al*	9	60 (29—92)	5 (2–18)	58	91 (75—100)	NA	NA	10.3	5%	0%	11.1%	0%	95%
Zhang *et al*	19	40.7 (34–52)	29.5 (22–41)	47.3 (27–63)	89.7 (75–96)	0 Cemented/ 19 Cementless	2 Cemented/ 17 Cementless	2.8	0%	0%	Femoral fracture: 2; SNI: 1	0%	100%
Papanna *et al*	7	58 ± 11	4	NA	NA	2 Cemented/ 5 Cementless	2 Cemented/ 5 Cementless	5.5	0%	0%	Dislocation: 1; Heterotrophic ossification: 2	0%	100%
Current study	168	50.4 (21–76)	34.4 (7–58)	44.2 (29–66)	88.1 (78–96)	All Cementless	All Cementless	10.6 (6.9–17.2)	2.4%	1.2%	Dislocation: 7; Intraoperative fracture: 9; Transient nerve injury: 8	1.2%	97.6%

acet AL, acetabulum aseptic loosening; fem AL, femoral component aseptic loosening; intraop FF, intraoperative femoral fracture; SNI, sciatic nerve injury; THA, total hip arthroplasty.

trochanter (2 hips), which were successfully treated with a cerclage cable. Intraoperative fractures occurred in 5 hips that underwent subtrochanteric osteotomy. One patient had a wound infection and skin-edge necrosis, which was healed completely after debridement and closure. Three patients (1.8%) had thigh swelling due to additional adductor tenotomy. No deep venous thrombosis, nonunion at femoral osteotomy site, and polyethylene wear were seen during follow-up evaluation. Based on the patients in this study, a significant association was observed between intraoperative fractures and transverse subtrochanteric osteotomy (P = 0.019) and prophylactic cable fixation in the femur (P = 0.034).

Discussion

Total hip arthroplasty is a challenging procedure in hips that have had a previous bacterial infection due to the severe anatomical deformities, scarred soft tissue, and leg length discrepancy[3,8,28,29]. However, most prior reports of THA in such patients included mixed groups of patients with cementless and cemented components or different surgical techniques with small sample sizes (Table 3)[1,2,5–8,10–12]. To our knowledge, this is the largest reported series in which the clinical and radiological results of cementless THA for the treatment of late sequelae of septic arthritis of the hip are assessed.

Placement and Survivorship of Prosthesis

Pyogenic arthritis results in undergrowth and destruction of anatomic structures and a hypoplastic femur with a small proximal diameter, which may limit the size and shape of the stem[8]. Previously, small-diameter stems were typically used in these reconstructions as they could be more easily positioned in the straight and small medullary canal[1,6]. However, previous studies indicated that the mismatch of stem size with the femoral canal could lead to a high rate of aseptic loosening, osteolysis, and stem revision[8]. In previous series, aseptic loosening of the femoral stem occurred in 2 of the 62 hips with high dislocations after sepsis due to use of undersized stems[10], which were thought to be a risk factor in the failure of fixation of the femoral components[7]. In our series, only 1 patient with an undersized prosthesis to fill in a small femoral canal had aseptic loosening of the femoral stem, which resulted in local stress concentration at the distal end of the femoral component and breakage, requiring femoral-only revision. Therefore, as the special cementless femoral components (i.e. a modular design with various sizes) have been designed to adjust for differences in cortical width at the isthmus of affected femurs, we recommend that appropriate femoral stems should be fixed by tight press-fit to achieve rigidly rotational stability. However, tight press-fit of the prosthesis into the small canal may cause hoop strains in the medial and anteromedial femoral cortex and femoral fracture. Rates of intraoperative femoral fracture of 5.2% to 26.8% during insertion of the stem have been reported among patients undergoing cementless THA for Crowe IV developmental dysplasia of the hip (DDH)[13,30,31]. In our current series, most of the intraoperative fractures (5 hips) were in patients with Crowe group III and IV hip dysplasia needing subtrochanteric shortening osteotomy. There may be a long learning curve for these technically difficult THA in such patients. Moreover, a prophylactic cable fixation was not used, which is common practice to prevent femoral fractures. It has been demonstrated to be a protective factor for intraoperative fractures[14]. Thus, these fractures may be attributed to less experience and no correspondent measurements to decrease the risk of this complication. Although all fractures were stabilized with a cable system and completely healed without any further complications by the latest follow-up evaluation, surgeons should take correspondent measurements to prevent this complication. First, a cerclage band was prophylactically placed before implant insertion. Second, the surgeons were on the lookout for femoral fracture signs, such as sudden subsidence and rotational instability of the stem[13].

Considering the good bone quality in these relatively young patients, the acetabular cup was mainly fixed by press-fit, multiple screws, or/and a structural femoral head allograft so that at least 70% of the porous surface was in contact with viable host bone. In Zahar *et al*., stable fixation of a cementless acetabular cup was achieved using bulk autograft and multiple screws in hips with severe acetabular dysplasia at the midterm follow up; however, the long-term results are questionable[32]. In Kim *et al*., a structural femoral head allograft was performed to provide 60% of the porous surface covered by host bone, which provided long-term stability of the acetabular component with partial resorption of the allograft[10]. We observed one acetabular component loosening at the latest follow up, which was due to a pseudotumor resulting from the use of large-diameter MoMHR designs. The wear and corrosion at the femoral head interface as well as at the bearing surface may result in pseudotumor formation[33]. In 1 study, poor implant survivorship with large-diameter MoMHR was identified at a median of 10 years[34]. We elected to retain well-fixed and adequately positioned femoral components and conducted acetabular-only revisions when dealing with this failed MoMHR, which provided good subsequent implant survivorship and patient-reported outcomes. This finding was parallel with the previous report[35]. However, we recommended in our follow-up protocols that these patients should receive regular clinical surveillance (typically annually). The remaining acetabular components were embedded firmly at the final follow-up examination. As for the less than 70% of the acetabular cup covered by host bone, we believe the bone grafting in such young patients could provide structural support to the acetabulum and additional pelvic bone stock for subsequent revision.

Recurrence of Infection

One hip that had a 6.9-year interval between infection and index arthroplasty had recurrence of infection. Although this hip had a new infection with no association with the original sepsis, we recommended that the quiescent period after active infection be >10 years before THA is performed at our center. The other hip that had a 23-year interval between resolution of active infection in the hip and THA had recurrence of infection. The patient developed severe pneumonia and sepsis, and the type of infecting organism was *Staphylococcus haemolyticus* after THA, which was a new infection. Postoperative pneumonia and sepsis were found to be risk factors for periprosthetic joint infection (PJI)[36]. We should avoid these risk factors for PJI to decrease the risk of reactivation of the infection. Moreover, bacteriologic sampling should be extensive to maximize the chances of identifying residual bacteria.

Nerve Injury

Compared with the placement at the non-anatomic hip center, restoration of the anatomical hip rotation center can provide adequate coverage and restore abductor muscle function, which may promote long-term stability of acetabular and femoral components[13,30,37]. However, the reduction of the femoral head into the true acetabulum may excessively lengthen the limb and result in nerve injury in patients with high dislocations of the hip[10,13,30,38]. Wang *et al.* retrospectively reviewed 76 consecutive patients with Crowe IV DDH who underwent cementless THA with transverse subtrochanteric shortening osteotomy, and intraoperative fracture occurred in 2 hips[13]. Femoral osteotomy appears to represent an effective way to facilitate reduction without increasing the risk of nerve injury [39]. The prevalence of nerve palsy has been reported as between 5.5% to 16% in patients who had childhood pyogenic arthritis[5,6,8,10]. Nerve injury rates ranging from 5% to 11.3% were reported in patients with Crowe type IV DDH[30,37,38,40]. In the current series, the majority of nerve injuries occurred in 5 hips with high dislocations (Crowe III and IV), which had leg lengthening of >3.5 cm. We believe that leg lengthening of >3.5 cm may increase the risk of nerve injury, which concurs with the findings of a previous report for severe DDH[13]. Transient nerve injuries also occurred in 2 hips with Crowe I dysplasia of the hip. The hips had severe soft-tissue contracture and needed extensive soft tissue release, which may lead to these neurological complications in such patients. Therefore, careful soft tissue release and subtrochanteric resection with appropriate length (leg lengthening of <3.5) to reduce the femoral head into the acetabular cup easily was valuable to avoid nerve injury.

Limitations

Our study has some limitations. First, it was not a randomized controlled study and was conducted at a single center, which may limit the applicability of the findings to other centers. However, given the limited long-term data reported for the late sequelae of septic arthritis of the hip, our study included a large series of patients with this uncommon diagnosis. Second, all operations were conducted by five senior surgeons, which may affect the validity of our findings. However, all surgical techniques for osteotomy and fixation were identical for all THA in our series. Third, there was no sufficient data to analyze the outcomes between unilateral and bilateral cementless THA. Thus, a prospective randomized controlled study of cementless THA in a much larger group of patients with late sequelae of septic arthritis of the hip should be carried out in future.

Conclusion

Cementless THA with placement of the cup at the anatomic hip center in the setting of the late sequelae of septic hip arthritis continues to be a challenging problem with an increased risk of complications. However, with improved surgical techniques and development of the cementless implants, significant long-term improvements in function and pain relief, high rates of stable fixation of cementless components, and restoration of normal limb lengths can be obtained in this setting.

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