Alumina-on-alumina THA in Patients with Juvenile Idiopathic Arthritis

A 5-year Followup Study

Ana Cruz-Pardos MD, Eduardo García-Rey MD,
Eduardo García-Cimbrelo MD, Jose Ortega-Chamarro MD

Received: 15 April 2011 / Accepted: 12 August 2011 / Published online: 31 August 2011
© The Association of Bone and Joint Surgeons® 2011

Abstract

Background THA is a concern in juvenile idiopathic arthritis (JIA) owing to patients' youth, poor bone stock, and small physical size.

Questions/purposes We asked whether (1) uncemented alumina-on-alumina THAs have good clinical and radiographic results at midterm followup in young patients with inflammatory arthritis and end-stage hip disease secondary to JIA, and (2) the anatomic center of rotation of the hip could be reconstructed in patients with acetabular protrusion. We also assessed the rate of surgical complications.

Patients and Methods We retrospectively reviewed 31 alumina-on-alumina THAs in 21 patients with a mean age of 30.9 years (range, 14–48 years). Minimum followup until the time of revision of any component or the latest evaluation was 16 months. For nonrevised cases, the minimum followup was 60 months (range, 60–108 months). Acetabular protrusion was mild in 17 hips (Group 1) and moderate-severe in 14 (Group 2). Bone autograft was used to reconstruct the acetabulum in Group 2. Acetabular reconstruction was evaluated according to Ranawat et al.

Results One cup was revised owing to aseptic loosening at 16 months; the remaining hips showed good clinical and radiographic results. The mean postoperative horizontal distance and the distance between the center of the head of the prosthesis and the true center of the femoral head improved in Group 2. There were no complications related to alumina.

Conclusions Although THA is a technically demanding procedure in patients with JIA, uncemented alumina-on-alumina THA provides pain relief and improves quality of life. In patients with acetabular protrusion, bone grafts enable anatomic cup positioning. Continued followup will be required to determine whether the alumina-on-alumina bearings in patients with JIA result in less osteolysis and loosening.

Level of Evidence Level IV, therapeutic study. See Guidelines for Authors for a complete description of levels of evidence.

Introduction

JIA is one of the most disabling diseases of children 16 years old and younger [23, 33, 37]. Hip arthritis causes severe destructive joint changes with functional impairment and severe pain in as many as 10% of these young adults [17, 23]. Nonoperative treatment with physical therapy, antiinflammatory medication, corticosteroid therapy, and new immunomodulatory drugs provides acceptable results, but eventually the end-stage hip arthritis may require surgical treatment [3, 37]. THA is one of the most successful orthopaedic procedures and has been associated with good long-term outcomes, even in young patients with inflammatory arthritis and end-stage hip disease; substantial pain

Each author certifies that he or she has no commercial associations (eg, consultancies, stock ownership, equity interest, patent/licensing arrangements, etc) that might pose a conflict of interest in connection with the submitted article.

Each author certifies that his or her institution approved the human protocol for this investigation, that all investigations were conducted in conformity with ethical principles of research, and that informed consent for participation in the study was obtained.

A. Cruz-Pardos (✉), E. García-Rey, E. García-Cimbrelo,
J. Ortega-Chamarro
Department of Orthopaedics, Hospital La Paz, Paseo de la
Castellana 261, 28046 Madrid, Spain
e-mail: anuskacp@yahoo.es

relief and improved ROM, function, and quality of life have been reported [4, 5, 16, 23, 33, 38]. The results of THA reported by many authors for these patients implicate acetabular cup loosening as the major cause of revision [4, 8, 17, 19, 23, 33, 42, 43, 45]. It is known that polyethylene wear causes osteolysis and loosening and its consequences are the limiting factors for THA in younger patients [12]. Although patients with JIA are less active, they are young and it would seem reasonable to test alternative bearing surfaces in this population. The tribologic properties of alumina-on-alumina bearings such as scratch resistance and wettability of the material, and its wear properties are particularly desirable for implants in a young and active population. Although good results have been published with alumina-on-alumina THAs in young people, there are few published with this couple for patients with JIA [3, 15, 32].

Acetabular protrusion, which is a frequent condition in rheumatoid arthritis and other bone deformities, usually requires complex reconstructive techniques that increase surgical difficulties and might affect the survival of the THA in patients with JIA. Different studies report the necessity of restoring the acetabular anatomy and anatomic center of hip rotation to obtain stable fixation of the prosthetic components [1, 34, 44].

In a multicenter study [15], we observed that patients with JIA had several special anatomic characteristics, such as acetabular protrusion, so we decided to analyze these patients in a new study.

We asked whether (1) uncemented alumina-on-alumina THAs have good clinical and radiographic results at mid-term followup in young patients with inflammatory arthritis and end-stage hip disease secondary to JIA, and (2) the anatomic center of rotation of the hip can be reconstructed in patients with acetabular protrusion. Additionally, we assessed the rate of surgical complications in these patients.

Patients and Methods

We retrospectively reviewed 31 consecutive alumina-on-alumina THAs in 21 patients with JIA recruited prospectively over 4 years (March 1999 to May 2003) (Table 1). No patients were excluded from the followup study. There were 12 females and nine males. Their mean age at the time of surgery was 30.9 years (range, 14–48 years) and their mean weight was 61.0 kg (range, 42–82 kg). The minimum followup until the time of revision of any component or the latest evaluation was 16 months (mean, 72 months; range, 16–108 months). For patients without revision surgery, the minimum followup was 5 years. Preoperative activity level was classified according to Devane et al. [7], who classified activity at five levels from sedentary (Level 1) to very active for those who can participate in sports or perform strenuous

manual labor (Level 5). Three patients were Level 1, three were Level 2, two were Level 3, 13 were Level 4, and none were Level 5. Acetabular protrusion, when present, was graded according to the criteria of Sotelo-Garza and Charnley [39], which uses the rim of the pelvis, taken as a projection of the upper margin of the pubic ramus, as a reference, and grades protrusion as follows: I, mild with the hips displaced from 1 to 5 mm; II, moderate with the hips displaced from 6 to 15 mm; and III, severe with the hips displaced more than 15 mm. Seventeen hips had mild acetabular protrusion (Group 1) and 14 had moderate-severe acetabular protrusion (Group 2). Oral and written informed consent was obtained from all patients, and patients were informed before surgery that they might receive a new biomaterial without well-known results (alumina-on-alumina).

Preoperative medical status and immunosuppressive drugs were managed by a rheumatologist in preparation for surgery. A posterolateral approach was used in all hips. In hips with moderate-severe acetabular protrusion, a bone autograft taken from the femoral head was used to reconstruct the medial wall and anatomic center of rotation of the hip before implanting the metallic shell. The metallic shell was implanted after line-to-line reaming. A total of 24 (77.4%) 32-mm and seven (22.6%) 28-mm Al_2O_3 femoral heads were implanted with three neck lengths (Table 2). Cup diameters less than 50 mm require a 28-mm femoral head. The minimum ceramic liner thicknesses are 4.2 mm for 46-mm (28-mm femoral head) and 50-mm (32-mm femoral head) shells and 6.2 mm for 48-mm (28-mm femoral head) and 52-mm (32-mm femoral head) shells. The mean acetabular cup diameter was 51.3 mm (range, 46–60 mm; median, 52 mm), the mean femoral stem width was 8.7 mm (range, 7–14 mm; median, 9 mm), and the mean head diameter was 31.2 mm (range, 28–32 mm; median, 32 mm). Screw use was determined according to the primary stability of the cup. Supplementary screw cup fixation was necessary in 17 cups.

A Cerafit-Triradius press-fit cup (CeraVer-Osteal, Roissy, France), consisting of a fully hydroxyapatite (HA)-coated TiAl_6V_4 rough shell with optional screws fitted with an Al_2O_3 liner, was implanted in every hip. The liner is inserted using a Morse taper shape with an angle of $5^\circ 40'$, so as to achieve better fixation and decrease the risk of liner dislocation. The cup was paired to an uncemented Multicone stem (CeraVer-Osteal), a fully HA-coated tapered straight stem that has a rectangular geometry and is made of TiAl_6V_4 . Characteristics of this alumina are 99.8% purity, 3.98 density, 2- μm grain size, and hot isostatically pressed (HIPed) in all patients. The HA coating was applied by plasma spray according to the manufacturer's specifications, had a relative crystallinity of 37%, thickness of $80 \pm 20 \mu\text{m}$, bond shear strength of 15/25 MPa, and mean roughness of

Table 1. Preoperative details of the 21 patients

Case	Gender	Age (years)	Activity level [6]	Acetabular protrusion	Merle D'Aubigné-Postel score	Horizontal distance (mm)	Vertical distance (mm)	AFHC-CPFH distance (mm)
1	Female	33	4	Yes	9	15	15	5
2	Female	34	4	Yes	9	20	20	6
3	Male	34	4	No	9	35	10	0
4	Female	43	4	No	11	35	10	0
5	Female	38	2	Yes	9	10	35	16
6	Female	39	2	Yes	3	20	5	10
7	Female	20	2	No	3	20	30	7
8	Female	41	4	No	6	30	15	1
9	Female	19	4	Yes	9	2	45	55
10	Female	48	4	Yes	8	40	35	10
11	Female	21	4	No	9	35	25	5
12	Male	18	1	No	3	25	50	32
13	Male	19	1	No	3	35	50	28
14	Male	35	4	No	7	40	15	10
15	Male	40	4	No	6	40	25	1
16	Male	14	1	Yes	3	5	40	30
17	Male	15	1	Yes	9	7	25	25
18	Female	45	2	No	3	15	40	30
19	Female	45	2	Yes	3	15	40	24
20	Female	21	1	Yes	3	15	30	15
21	Female	24	1	Yes	3	10	30	35
22	Male	26	4	Yes	6	25	25	3
23	Male	34	4	No	9	35	25	2
24	Female	16	4	Yes	9	3	50	40
25	Male	48	4	No	6	35	25	1
26	Male	45	4	No	8	25	40	1
27	Male	45	4	No	6	35	25	1
28	Female	18	2	No	3	16	35	10
29	Female	46	4	No	6	30	15	1
30	Female	17	3	Yes	6	22	30	4
31	Female	18	3	No	6	30	65	35

AFHC = approximate center of femoral head; CPHF = center of femoral head.

3 μm . The arithmetic rugosity R_a beneath the HA was 3 to 4 μm for the stem and shell surface finish. Alumina heads were used in all cases.

After surgery, the patients were partially weightbearing for 6 to 8 weeks. The patients received long-term immunosuppressive medications, which had to be discontinued 6 weeks before surgery until 6 weeks afterward. Routine antibiotic prophylaxis consisted of one preoperative dose of 2 g cefazolin intravenously or 1 g vancomycin intravenously in patients with allergy to penicillin and continued for 48 hours after surgery. All patients received thromboembolic prophylaxis consisting of low-molecular-weight heparin subcutaneously beginning the night before surgery and continued for 6 weeks.

Clinical evaluation assessed pain, function, and motion according to the Merle D'Aubigné and Postel scale (range, 1–6) at every followup: 6 weeks, 12 weeks, 6 months, 1 year, and annually thereafter [30]. Levels 5 and 6 were considered a good clinical result and Levels 4 and lower a poor result.

Standard AP and lateral radiographs of the pelvis were obtained for all patients immediately after surgery, at 6 and 12 months, and annually thereafter. All postoperative and followup radiographs were made at our institution according to the same protocol. The patient was positioned supine, with the feet together. The x-ray tube was positioned over the symphysis pubis, 1 m from and perpendicular to the table. Variations in magnification were

Table 2. Operative and postoperative details of the 21 patients

Case	Screws	Cup size (mm)	Stem size (mm)	Head size (mm)	Femoral head autograft	Complications	Acetabular abduction angle (°)	Horizontal distance (mm)	Vertical distance (mm)	AFHC-CPFH distance (mm)	Merle D'Aubigné Postel score	Revision
1	No	46	10	28	Yes		50	35	25	1	17	
2	Yes	50	10	32	Yes		45	35	20	1	17	
3	Yes	50	8	32			40	30	10	1	17	
4	No	50	9	32			45	35	15	1	18	
5	No	52	8	32	Yes		45	25	30	6	18	
6	No	52	8	32	Yes		48	25	20	1	18	
7	Yes	50	7	32			48	25	20	2	18	
8	No	50	8	32		Intraoperative femur fracture	45	25	20	1	18	
9	Yes	48	9	28	Yes		45	30	25	15	18	
10	Yes	54	9	32	Yes		45	35	30	4	18	
11	No	52	9	32			45	35	20	1	18	
12	No	52	7	32			50	25	25	3	18	
13	Yes	54	7	32		Intraoperative femur fracture	60	35	20	15	18	
14	No	54	9	32			45	35	15	1	18	
15	No	60	11	32			45	50	20	10	18	
16	Yes	46	7	28	Yes		42	27	25	1	18	
17	Yes	52	10	32	Yes		45	30	25	3	14	
18	No	50	9	32			45	30	25	1	18	
19	Yes	50	8	32	Yes		75	30	20	20	13	Cup loosening at 17 months
20	Yes	52	8	32	Yes		52	40	20	1	16	
21	Yes	48	8	28	Yes		45	35	20	1	16	
22	Yes	50	9	32	Yes		45	22	25	2	18	
23	No	52	8	32			45	35	20	2	18	
24	Yes	48	9	28	Yes		48	35	15	15	18	
25	No	54	9	32			45	33	25	1	18	
26	No	58	14	32			45	20	40	2	18	
27	No	58	13	32			48	37	25	2	18	
28	Yes	50	7	32			48	25	20	4	18	
29	No	48	7	28			45	25	20	1	18	
30	Yes	46	7	28	Yes		60	25	20	2	18	
31	Yes	50	7	32		Peroneal paralysis and adduction contracture	44	30	20	23	14	

AFHC = approximate femoral head center; CPHF = center of prosthetic femoral head.

corrected using the 32-mm head of the femoral component as an internal reference. Patients' radiographs were assessed and compared by the same observer, who had not been involved in the surgery (ACP). Cup position was assessed by determining the abduction acetabular angle, the vertical distance measured from the center of the femoral head to the ipsilateral teardrop, and the horizontal distance of the cup, measured from the center of the femoral head to the Köhler line [18, 29]. Acetabular reconstruction was

evaluated according to the criteria of Ranawat et al. [13, 25, 35] (Fig. 1). Any radiolucent gap on the initial postoperative radiograph and radiolucent lines and osteolysis at the acetabular bone-prosthesis interface that developed in the subsequent radiographs were recorded in the three DeLee and Charnley zones [6]. Migration of the cup was defined when there had been a change greater than 5° in the abduction acetabular angle or more than 3 mm in either the vertical distance or the horizontal distance of the cup.

Fig. 1A–B (A) A preoperative radiograph shows the method for evaluating the center of rotation of the hip. The true acetabular region (TAR) is measured as the area enclosed by a right-angled triangle, with the height and width equal to 20% of the height of the pelvis. The midpoint of the hypotenuse of the triangle is defined as the approximate center of the femoral head (AFHC) and represents the normal center of rotation of the hip. CPFH = center of the prosthetic femoral head; KK' = Köhler line drawn from the medial border of the ilium to the medial border of the ischium. (B) A postoperative radiograph shows the center of rotation of the hip after THA.

Radiographic cup loosening was defined based on the signs described by Moore et al. [31]. Linear femoral head penetration was recorded according to the method of Kim et al. [20, 22] using scanned digitized radiographs and analyzed with a software package (AutoCAD[®] 2000; Autodesk Inc, Sausalito, CA, USA). The 6-week postoperative radiograph was used as initial reference for subsequent measurements.

Position of the stem was determined as neutral, valgus (lateral deviation of 3 mm or more), or varus (medial deviation of 3 mm or more) [21]. Femoral canal filling was measured as the ratio of stem width to intramedullary canal width and was measured at three levels: Level A, upper border of the lesser trochanter; Level B, middle of the stem; and Level C, 1 cm proximal to the tip [21]. Radiographic femoral component fixation was graded using the criteria for porous prostheses described by Engst et al. [9–11].

Qualitative data (ie, cup diameter, stem diameter, femoral head size) are expressed as counts and quantitative data as a mean $\pm$ SD. Analysis of the reconstruction of the anatomic center of the hips considered the horizontal distance, vertical distance, and approximate center of the femoral head (AFHC)-center of the prosthetic femoral head (CPFH) distance in each group and then between groups. Preoperative and postoperative changes in the horizontal distance, vertical distance, and/or AFHC-CPFH distance were compared between the two groups using two-way repeated-measures ANOVA factoring for patients with and without acetabular protrusion. Preoperative and postoperative changes in pain, function, and motion scores were tested using the Wilcoxon test for paired dates. Statistical analysis was performed using statistical package SAS[®] 9.1 (SAS Institute Inc, Cary, NC, USA).

Fig. 2 Box plots (mean and error bars of SD) of 31 alumina-on-alumina THAs in 21 patients with JIA show preoperative and postoperative Merle-D'Aubigné-Postel values.

Results

The postoperative Merle D'Aubigné and Postel scores were improved compared with preoperative scores ($p < 0.0001$). The mean preoperative scores were 1.9 for pain, 2.2 for function, and 2.1 for ROM (Table 1). The mean scores improved at latest followup to 5.9 for pain, 5.8 for function, and 5.7 for ROM (Table 2; Fig. 2). Slight pain (Level 5) was present in only three hips. One cup was revised owing to aseptic loosening at 16 months after surgery; this cup was implanted with a 75° abduction acetabular angle (Patient 19) and insufficient initial press fit. The cup was revised to a new Cerafit cup with screws with a good result at 3 years. Immediately after surgery, the mean acetabular

Fig. 3A–B (A) A preoperative radiograph shows the hips of a 14-year-old boy with JIA and acetabular protrusion. (B) Radiographic results for the same patient at 6 (left hip) and 5 (right hip) years after THA show the acetabular reconstruction with autograft.

angle was 47.7° (range, 40° – 75°), mean vertical distance was 21.94 mm (range, 10–40 mm), and mean horizontal distance was 30.9 mm (range, 20–50 mm). At latest followup, the mean acetabular angle was 48.8° (range, 42° – 95°), mean vertical distance was 22.74 mm (range, 15–40 mm), and mean horizontal distance was 30.77 mm (range, 20–50 mm). All cups remained stable, except in Patient 19, and no radiolucent lines or osteolysis have been observed around either component. Femoral head penetration was not measurable. No noises or alumina fractures were found in any patient. Postoperatively, there were 29 stems in neutral position, two in varus position, and none in valgus position. Femoral canal filling was 83.27% (range, 60%–98%) at Level A, 89.07% (range, 64%–100%) at Level B, and 83.31% (range, 60%–100%) at Level C. All stems were radiographically osseointegrated and no stem revision in the followup study has occurred in this series (Fig. 3).

We compared hips with mild acetabular protrusion (Group 1) and those with moderate-severe acetabular protrusion (Group 2) reconstructed using bone autograft. The horizontal and vertical distances from the center of the femoral head to the reference points improved after surgery in both groups (Table 3). In hips with moderate-severe acetabular protrusion, the preoperative horizontal distance increased ($p < 0.001$) after surgery. This distance was different ($p < 0.01$) preoperatively between Group 1 and Group 2 but was similar postoperatively (Fig. 4). The vertical distance decreased ($p = 0.002$) in both groups between the preoperative and the immediate postoperative radiograph (Fig. 5). The distance between the CPFH and the AFHC also improved (decreased) ($p < 0.01$) after surgery in hips with moderate-severe acetabular protrusion (Group 2) (Fig. 6); we found differences between both

Table 3. Preoperative and postoperative position of cup

Distance	Group 2 (with AP) (n = 14)	Group 1 (without AP) (n = 17)	p Value*
Horizontal distance (mm)			
Preoperative	15.50 ± 10.8	29.88 ± 7.9	< 0.01
Postoperative	31.00 ± 5.0	30.88 ± 7.1	NS
p Value	< 0.001	NS	
Vertical distance (mm)			
Preoperative	32.96 ± 15.1	27.35 ± 12.5	NS
Postoperative	22.86 ± 4.2	21.18 ± 6.2	NS
p Value	0.002	0.002	
AFHC-CPFH distance (mm)			
Preoperative	22.07 ± 15.4	7.88 ± 11.0	< 0.05
Postoperative	6.71 ± 7.9	2.94 ± 3.8	NS
p Value	< 0.01	NS	

Values are expressed as mean $\pm$ SD; * two-way repeated-measures ANOVA; AP = acetabular protrusion; AFHC = approximate center of femoral head; CPFH = center of prosthetic femoral head; NS = not significant.

groups preoperatively but we did not observe the differences on the immediate postoperative radiographs.

There were two intraoperative femoral fractures. One fracture in a patient with a narrow medullary canal was treated with open reduction and cable fixation. Another patient had an intraoperative calcar fracture observed on the postoperative radiograph. Neither of these fractures required femoral revision and no radiographic loosening was observed. During the postoperative period, an 18-year-old female patient had a transient peroneal paralysis and adduction contracture requiring tenotomy release (Table 2).

Fig. 4 A graph shows preoperative (preop) and postoperative (postop) horizontal distance in Groups 1 and 2. In Group 2, the horizontal distance increased between preoperative and postoperative.

Fig. 6 A graph shows preoperative and postoperative distances from the AFHC to the CPFH in Groups 1 and 2. The decrease in postoperative distance was greater in Group 2 than in Group 1.

Fig. 5 A graph shows preoperative and postoperative vertical distances for Groups 1 and 2. In both groups, this value decreased between preoperative and postoperative.

Discussion

Despite improvements in medical treatment for JIA, progressive joint destruction with serious functional disability and incapacitating pain might make these patients candidates for THA. The frequent existence of anatomic abnormalities and acetabular protrusion in patients with JIA is the main cause for the need for different complex reconstructive techniques and increases surgical difficulty. Polyethylene wear resulting in osteolysis and loosening can limit the use of THA in young patients and has motivated the development of alternative bearing surfaces such as alumina-on-alumina couples. We therefore determined whether (1) uncemented alumina-on-alumina THAs have good clinical and radiographic results at midterm followup

in young patients with inflammatory arthritis and end-stage hip disease secondary to JIA and (2) the anatomic center of rotation of the hip could be reconstructed in patients with acetabular protrusion. We also assessed the rate of surgical complications in these patients.

Our study has limitations. First, the series is small and the followup is short, but this disease has a low incidence (7–20 cases per 100,000 children at risk per year) and not all have hip arthritis severe enough to require THA. Second, we lacked a control group of patients of similar age and different etiology who were operated on with the same techniques that would allow us to evaluate whether the diagnosis had any influence on the result. Third, we do not know whether the same result could be obtained using another couple and another implant.

Different series have found high rates of aseptic loosening of cemented THA for JIA [4, 23, 25, 28, 40], but other series have had excellent results [24, 26, 36, 42, 43] (Table 4). In a midterm followup study, Ruddlesdin et al. [36] reviewed the results of 75 cemented hip arthroplasties in 42 patients; only one hip required revision. In the series of Lachiewicz et al. [24], also at midterm, although two hips were revised, 26% of the acetabular and 8% of femoral components showed radiolucencies and migration. Good results with cementless THA for JIA also have been reported [19, 23, 27]. Odent et al. [33] reported a survival rate of 100% for the femoral component and 90.1% for the acetabular component at 13 years. Our data confirm that alumina-on-alumina THA achieves good clinical results and a low rate of loosening in these patients. At latest followup, the Merle D'Aubigne-Postel scores for pain, function, and ROM were good, allowing our patients to lead a normal life. This outcome was probably attributable to their low activity level compared with the activity level

Table 4. Summary of studies of THAs in patients with JIA

Study	Number of hips/patients	Implant/bearing couple	Average age (years; range)	Followup years (range)	Revisions	Number and percent radiographic loosening (excluding revisions)	Survivorship
Wroblewski et al. [42]	292/195	Charnley THA/metal-polyethylene	38 (12–50)	15 (1–36)	41 revisions (27 loose cups, 9 loose stems, 5 dislocations, 4 infections, 5 fractures, 1 pain)	68 cups and 11 stems	93% at 10 years, 87% at 15 years, 81% at 20 years and 74% at 25 years
Learmonth et al. [25]	14/7	Cemented THA/metal-polyethylene	16 (12–22)	8.5 (4–11)	None	8/57%	
Williams et al. [40]	57/34	Charnley THA/metal-polyethylene	16.4 (13.4–24)	4.6 (1.7–9)	1 cup and 1 stem	14 cups and 4 stems	
Maric and Haynes [28]	17/17	13 cemented THAs and 4 uncemented THAs/metal-polyethylene	18	9, 3	1 cemented cup	5 cemented cups	
Lehtimäki et al. [26]	186/116	Charnley THA/metal-polyethylene	32.1 (12–44)	20	1 stem		91.9% at 10 years and 83.4% at 15 years
Ruddlesdin et al. [36]	75/42	Cemented THA/metal-polyethylene and metal-metal	14 (11–17)	5.4 (1–12)	1 stem	1 cup and 1 stem	
Lachiewicz et al. [24]	62/34	Cemented THA/metal-polyethylene	26 (14–49)	6 (2–11)	2 (3.2%): 1 cup loosening and 1 broken stem	16 (25.8%) acetabular, 4 (6.6%) femoral	
Chmell et al. [4]	55/33	Cemented THA/metal-polyethylene	19.9 (11–29)	7	12 (18%) femoral components and 23 (35%) cups		At 15 years, 85% for femoral component and 70 % for acetabular component
Katsimithas et al. [19]	82/63	HG-I cup with cemented or uncemented stem/metal-polyethylene	54.7 (25–80)	9.1	6 revisions (1 infection and 5 with polyethylene wear)		75% at 12.5 years
Kitisoulis et al. [23]	20/20	Uncemented cup and cemented stem/metal-polyethylene	15.8 (13–24)	9.2 (2–20)	1 cup revision		
Witt et al. [41]	96/54	Cemented THA/metal-polyethylene	16.7 (11.3–26.6)	11.5 (5.3–18.3)	24 (25.0%)	17 (23.6%)	
Haber and Goodman [17]	29/16	Cemented and uncemented THA/metal-polyethylene	20 (14–35)	4.4 (2–8.3)	1 (3.4%) stem	3 (10.2%)	
Odent et al. [33]	62/34	Zweymuller THA/metal-polyethylene	18, 3 (11, 8–31)	6 (3–13)	2 cups	18	At 13 years, 100% for femoral component and 90.1% for acetabular component

expected at their age. The hemispheric cup and tapered stem with the HA coatings provided frequent signs of radiographic osseointegration despite the osteoporotic bone stock. Loosening of the acetabular component remains one of the major long-term problems after THA in patients with rheumatoid arthritis [4, 19, 32]. Only one cup was revised owing to aseptic loosening 17 months after the surgery, a very low rate compared with reported rates [4, 19, 41, 42]. In this case, loosening was attributable to a technical error and poor primary fixation. With cementless cups, Kitsoulis et al. [23] reported only two cup revisions, one at 9 years and another at 12 years after surgery, and Odent et al. [33] also reported two acetabular failures owing to poor primary fixation. Others have documented a high rate of acetabular failure even after short-term followup [8, 41]. A high THA survival rate is necessary for young people given their life expectancy. Polyethylene wear resulting in osteolysis and loosening is a concern in young patients making an alumina-on-alumina THA an option in this population [14, 32]. Most hips with JIA require small implants [17]. The use of an acetabular component with a smaller outer diameter necessitates the use of a thinner polyethylene articular surface. In the series of 82 patients reported by Katsimihas et al. [19], there were five revisions for polyethylene cup wear at 9.1 years. The theoretical advantages of alumina-on-alumina bearings are related to tribologic properties such as the scratch resistance and wettability of the material, and its wear properties are particularly desirable for implants in a young and active population. There is a case report involving a 13-year-old girl with bilateral end-stage JIA using an alumina ceramic-on-alumina ceramic bearing [2]; at 7 and 8 years after THA, the patient has no pain and no limp and is able to walk long distances without difficulty. Radiographs show no signs of implant loosening, osteolysis, or wear of the bearing surface [2]. In our series, we have not observed any complication related to the use of alumina, such as fractures or noises. Good midterm and short-term results with this implant have been reported for other populations and even for young patients [14, 15, 32]. We have not detected femoral head penetration in any hip.

The major technical problem encountered in the performance of THA for JIA is reconstruction of the acetabulum. Many patients have a dysplastic acetabulum and acetabular protrusion is a common condition affecting 14 patients in our series. The location of the center of rotation of the hip affects the weightbearing loading of the hip, so a higher and more medial position will result in greater loads; this is an important factor in loosening [44]. Good results have been recorded after reconstruction with bone graft in patients with acetabular protrusion [29, 38]. In our patients, the use of femoral head bone as autograft in the acetabulum increased the horizontal distance after

surgery and reduced the distance from the CPFH to AFHC, improving the anatomic center of rotation of the hip, according to Ranawat et al. [35]. As acetabular protrusion is a frequent condition in patients with JIA, it is important to keep in mind during preoperative planning and we believe that the acetabulum must be reconstructed to achieve long survival of the THA.

We also noted four (12.9%) complications (two intraoperative femoral fractures, one peroneal paralysis, one adduction contracture), all of which resolved with treatment. Various complication rates have been reported [3, 19, 23, 43]. Only Odent et al. [33] reported two sciatic palsies and one femoral nerve palsy; the femoral nerve palsy occurred after reduction of a 60°-flexion contracture and the two sciatic nerve palsies occurred after implanting the acetabular cup from a superior position to an anatomic position in association with a hip flexion contracture. The nerve palsies recovered spontaneously within 3 months. They also reported an undisplaced femoral shaft fracture occurred during implantation of the stem [33].

Patients with JIA and with advanced hip disease represent a unique population with a need for extremely long-term survivorship of prosthetic reconstructions. The goal of surgical treatment in this patient population is to provide a long-term solution with pain relief and restoration of function. With proper surgical technique and adequate preoperative planning, complications in these patients can be minimized; and although THA is technically more difficult, it provides good medium-term results. Bone grafts enable anatomic positioning of the cup in patients with acetabular protrusion, although a longer followup is necessary to confirm these results. Alumina-on-alumina THA is a good option for patients with JIA. Prospective, multi-center clinical trials to establish large patient cohorts should be considered to investigate THAs in this population.

Acknowledgment We thank Rosario Madero-Jarabo PhD, Mth Statistics, for statistical analysis.

References

1. Busch V, Klarenbeek R, Slooff T, Schreurs W, Gardeniers J. Cemented designs are a reasonable option in young patients. *Clin Orthop Relat Res*. 2010;468:3214–3220.
2. Capello WN, Feinberg JR. Use of an alumina ceramic-on-alumina ceramic bearing surface in THA in a 13 year old with JIA: a single case study. *Bull NYU Hosp Jt Dis*. 2009; 67:384–386.
3. Carl HD, Schraml A, Swoboda B, Hohenberger G. Synovectomy of the hip in patients with juvenile rheumatoid arthritis. *J Bone Joint Surg Am*. 2007;89:1986–1992.
4. Chmell MJ, Scott RD, Thomas WH, Sledge CB. Total hip arthroplasty with cement for juvenile rheumatoid arthritis: results at a minimum of ten years in patients less than thirty years old. *J Bone Joint Surg Am*. 1997;79:44–52.

5. Clohisy JC, Oryhon JM, Seyler TM, Wells CW, Liu SS, Callaghan JJ, Mont MA. Function and fixation of total hip arthroplasty in patients 25 years of age or younger. *Clin Orthop Relat Res.* 2010;468:3207–3213.
6. DeLee JG, Charnley J. Radiological demarcation of cemented sockets in total hip replacement. *Clin Orthop Relat Res.* 1976; 121:20–32.
7. Devane PA, Home JG, Martin K, Coldham G, Krause B. Three-dimensional polyethylene wear of a press-fit titanium prosthesis: factors influencing generation of polyethylene debris. *J Arthroplasty.* 1997;12:256–266.
8. Eskelinen A, Paavolainen P, Helenius I, Pulkkinen P, Remes V. Total hip arthroplasty for rheumatoid arthritis in younger patients: 2557 replacements in the Finnish Arthroplasty Register followed for 6–24 years. *Acta Orthop Scand.* 2006;77:853–865.
9. Engh CA, Bobyn JD, Glassman AH. Porous-coated hip replacement: the factors governing bone ingrowth, stress shielding and clinical results. *J Bone Joint Surg Br.* 1987;69:45–55.
10. Engh CA, Glassman AH, Suthers KE. The case for porous-coated implants: the femoral side. *Clin Orthop Relat Res.* 1990;261: 63–81.
11. Engh CA, Massin P, Suthers KE. Roentgenographic assessment of the biologic fixation of porous-surfaced femoral components. *Clin Orthop Relat Res.* 1990;257:107–128.
12. García-Cimbrelo E, Cruz-Pardos A, Cordero J, Sanchez-Sotelo J. Low-friction arthroplasty in patients younger than 40 years old: 20- to 25-year results. *J Arthroplasty.* 2000;15:825–832.
13. García-Cimbrelo E, Díaz-Martín A, Madero R, Munuera L. Loosening of the cup after low-friction arthroplasty in patients with acetabular protrusion: the importance of the position of the cup. *J Bone Joint Surg Br.* 2000;82:108–115.
14. García-Cimbrelo E, García-Rey E, Murcia-Mazón A, Blanco-Pozo A, Martí E. Alumina-on-alumina in THA: a multicenter prospective study. *Clin Orthop Relat Res.* 2008;466:309–316.
15. García-Rey E, Cruz-Pardos A, García-Cimbrelo E. Alumina-on-alumina total hip arthroplasty in young patients: diagnosis is more important than age. *Clin Orthop Relat Res.* 2009;467: 2281–2289.
16. Goodman SB, Oh K, Imrie S, Hwang K, Shegog M. Revision total hip arthroplasty in juvenile chronic arthritis. *Acta Orthop Scand.* 2006;77:242–250.
17. Haber D, Goodman SB. Total hip arthroplasty in juvenile chronic arthritis: a consecutive series. *J Arthroplasty.* 1998;13:259–265.
18. Johnston RC, Brand RA, Crowninshield RD. Reconstruction of the hip: a mathematical approach to determine optimum geometric relationships. *J Bone Joint Surg Am.* 1979;61:639–652.
19. Katsimihas M, Taylor AH, Lee MB, Sarangi PP, Learmonth ID. Cementless acetabular replacement in patients with rheumatoid arthritis. *J Arthroplasty.* 2003;18:16–22.
20. Kim YH, Kim JS, Cho SH. A comparison of polyethylene wear in hips with cobalt-chrome or zirconia heads: a prospective, randomised study. *J Bone Joint Surg Br.* 2001;83:742–750.
21. Kim YH, Kim VE. Results of the Harris-Galante cementless hip prosthesis. *J Bone Joint Surg Br.* 1992;74:83–87.
22. Kim YH, Kook HK, Kim JS. Total hip replacement with a cementless acetabular component and a cemented femoral component in patients younger than fifty years of age. *J Bone Joint Surg Am.* 2002;84:770–774.
23. Kitsoulis PB, Stafilas KS, Siamopoulou A, Soucacos PN, Xenakis TA. Total hip arthroplasty in children with juvenile chronic arthritis: long-term results. *J Pediatr Orthop.* 2006;26:8–12.
24. Lachiewicz PF, McCaskill B, Inglis A, Ranawat CS, Rosenstein BD. Total hip arthroplasty in juvenile rheumatoid arthritis: two to eleven-year results. *J Bone Joint Surg Am.* 1986;68:502–508.
25. Learmonth ID, Heywood AW, Kaye J. Radiological loosening after cemented hip replacement for juvenile chronic arthritis. *J Bone Joint Surg Br.* 1989;71:209–212.
26. Lehtimäki MY, Lehto MU, Kautiainen H, Savolainen HA, Hämäläinen MM. Survivorship of Charnley total hip arthroplasty in juvenile chronic arthritis: a follow-up of 186 cases for 22 years. *J Bone Joint Surg Br.* 1997;79:792–795.
27. Lybäck CC, Lybäck CO, Kyrö A, Kautiainen HJ, Belt EA. Survival of Bi-Metric femoral stems in 77 total hip arthroplasties for juvenile chronic arthritis. *Int Orthop.* 2004;28:357–361.
28. Maric Z, Haynes RJ. Total hip arthroplasty in juvenile rheumatoid arthritis. *Clin Orthop Relat Res.* 1993;290:197–199.
29. Massin P, Schmidt L, Engh CA. Evaluation of cementless acetabular component migration: an experimental study. *J Arthroplasty.* 1989; 4:245–251.
30. Merle D'Aubigné R, Postel M. Functional results of the hip arthroplasty with acrylic prostheses. *J Bone Joint Surg Am.* 1954; 36:451–475.
31. Moore MS, McAuley JP, Young AM, Engh CA Sr. Radiographic signs of osseointegration in porous-coated acetabular components. *Clin Orthop Relat Res.* 2006;444:176–183.
32. Nizard R, Pourreyron A, Raoult A, Hannouche D, Sedel L. Alumina on alumina hip arthroplasty in patients younger than 30 years old. *Clin Orthop Relat Res.* 2008;446:317–323.
33. Odent T, Journeau P, Prieur A, Touzet P, Pouliquen JC, Glorion C. Cementless hip arthroplasty in juvenile idiopathic arthritis. *J Pediatr Orthop.* 2005;25:465–470.
34. Pagnano MW, Hanssen AD, Lewallen DG, Shaughnessy WJ. The effect of superior placement of the acetabular component on the rate of loosening after total hip arthroplasty: long-term results in patients who have Crowe type-II congenital dysplasia of the hip. *J Bone Joint Surg Am.* 1996;78:1004–1014.
35. Ranawat CS, Dorr LD, Inglis AE. Total hip arthroplasty in protrusion acetabuli of rheumatoid arthritis. *J Bone Joint Surg Am.* 1980;62:1059–1065.
36. Ruddlesdin C, Ansell BM, Arden GP, Swann M. Total hip replacement in children with juvenile chronic arthritis. *J Bone Joint Surg Br.* 1986;68:218–222.
37. Sherry DD. What's new in the diagnosis and treatment of juvenile rheumatoid arthritis. *J Pediatr Orthop.* 2000;20:419–420.
38. Slooff TJ, Huiskes R, van Horn J, Lemmens AJ. Bone grafting in total hip replacement for acetabular protrusion. *Acta Orthop Scand.* 1984;55:593–596.
39. Sotelo-Garza A, Charnley J. The results of Charnley arthroplasty of hip performed for protrusio acetabuli. *Clin Orthop Relat Res.* 1978;132:12–18.
40. Williams WW, McCollough CJ. Results of cemented total hip arthroplasty in juvenile chronic arthritis: a radiological review. *J Bone Joint Surg Br.* 1993;75:872–874.
41. Witt JD, Swann M, Ansell BM. Total hip replacement for juvenile chronic arthritis. *J Bone Joint Surg Br.* 1991;73:770–773.
42. Wroblewski BM, Purbach B, Siney PD, Fleming PA. Charnley low-friction arthroplasty in teenage patients: the ultimate challenge. *J Bone Joint Surg Br.* 2010;92:486–488.
43. Wroblewski BM, Siney PD, Fleming PA. Charnley low-frictional torque arthroplasty in young rheumatoid and juvenile rheumatoid arthritis: 292 hips followed for an average of 15 years. *Acta Orthop Scand.* 2007;78:206–210.
44. Yoder SA, Brand RA, Pedersen DR, O'Gorman TW. Total hip acetabular component position affects component loosening rates. *Clin Orthop Relat Res.* 1988;228:79–87.
45. Yun AG, Martin S, Zurakowski D, Scott D. Bipolar hemiarthroplasty in juvenile rheumatoid arthritis: long-term survivorship and outcomes. *J Arthroplasty.* 2002;17:978–986.