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CLINICAL RESEARCH

Revisions of Extensive Acetabular Defects with Impaction Grafting and a Cement Cup

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Abstract
Background Loosening of acetabular components often leads to bony defects. Management of extensive acetabular bone loss in hip revision arthroplasty can be a tremendous challenge.
Questions/purposes We asked whether a reconstruction with impacted bone grafts will provide a durable and pain-free function in extensive acetabular defects. We specifically determined the (1) survival rates with the end point of revision for any reason, aseptic revision, and radiographic loosening; (2) visual analog scale (VAS) pain score, Harris hip score (HHS), and the Oxford Hip Questionnaire score (OHQS); (3) number of repeat revisions; (4) complications; and (5) radiographic loosening, wear, and radiolucencies.
Patients and Methods We retrospectively followed 25 patients (27 hips) with extensive acetabular defects. No patient was lost to followup. Two patients died during followup. Minimum followup was 3 years (mean, 8.8 years; range, 3–14.1 years).
Results Three patients (three hips) underwent repeat revision surgery and another two patients (two hips) had radiographically loose hips. The 10-year survival rate was 88% (95% confidence interval, 74.2%–100%) with the end point acetabular revision for any reason and 95% (95% confidence interval, 86.0%–100%) with the end point acetabular revision for aseptic loosening. The mean HHSs were 55 points before surgery and 72 points postoperatively.
Conclusions Acetabular reconstruction with impaction bone grafting and a cemented cup is a reliable technique with a 10-year survival rate of 88% in patients with extensive acetabular deficiencies.
Level of Evidence Level IV, case series. See the Guidelines for Authors for a complete description of levels of evidence.

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 has approved the human protocol for this investigation, that all investigations were conducted in conformity with ethical principles of research.

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Introduction

The most challenging aspect of acetabular revision is managing the bone stock loss and creating a stable reconstruction with long-term durability. Reports show that restoring the normal biomechanical anatomy enhances survival and function [19, 42]. Several techniques are described to reconstruct extensive acetabular defects, including structural grafts [20, 21, 26, 36, 46], reinforcement rings and cages [2, 28, 37, 38, 51, 52], placement of the acetabular component in a high hip center [12, 29, 45], jumbo cups [13, 24, 25, 35, 50], bilobed cups [1, 3, 8, 14, 30], use of trabecular metal acetabular augments [4, 32], and the triflange cup [9, 17]. Results vary among these techniques (Table 1).

We believe that restoring acetabular bone stock loss is essential for better survival rates, clinical function and pain, and radiographic appearances in revision hip arthroplasty. Also, restoring bone stock loss provides a better starting point for any subsequent revision. For almost

Table 1. Results after acetabular revision surgery using different methods

Study	Reconstruction method	Number of patients (hips)	Followup (years)*	Defect	Survivorship cup removal for any reason (95% CI)	Clinical outcome*		Number of revisions	Number of complications	Radiographic appearances	
						HHS*	Other			Number of radiolucent lines	Other
Berry et al. [3]	Bilobed cup	38 (38)	3 (2–5)	AAOS Types I–IV		90 (79–100)		1 (2.6%)	5 (13%)	2 (5.2%) complete; 24 (63%) incomplete	2 (5.2%) migration
Chen et al. [8]	Bilobed cup	38 (41)	3.4 (2–5.5)	Paprosky Types 2A–3C			Pain less severe in 82%	2 (5%)	10 (26%)	6 (16%) complete; 35 (85%) incomplete	6 (16%) migration
DeBoer and Christie [14]	Bilobed cup	18 (18)	4.5 (3.4–6.9)	AAOS Type III		91 (80–100)		0	1 (5.6%)	6 (33%) incomplete	
Abeyta et al. [1]	Bilobed cup	25 (25)	11	AAOS Type III	88% at 11 years	76.5 (25–91)		3 (12%)	3 (12%)	4 (16%)	
Moskal et al. [30]	Bilobed cup	11 (11)	6 (5–6.8)	AAOS Type III		85 (81–90)		0	0	0	
Shinar and Harris [46]	Structural graft	62 (70)	16.5 (14.1–21.4)	Crowe Types I–IV dysplasia	65% (55%–75%) at 16.5 years	75 (29–97)		25 (36%)			18 (26%) radiographic loose
Pollock and Whiteside [36]	Structural graft	20 (20)	Minimum 2	Noncontained superior weightbearing with anterior column defects				7 (35%)			6 (30%) radiographic loose; 6 (30%) migration
Jasty and Harris [26]	Structural graft	36 (38)	5.9 (4–9.1)	Large defect		82		8 (32%)	22 (50%)	7 (16%) incomplete	12 (32%) radiographic loose
Ito et al. [25]	Structural graft, jumbo cup, and/or high hip center	74 (83)	9.3 (5–13)	AAOS Types I–III	94.6% (87%–100%) at 10 years	81 (46–100)		4 (5%)	12 (14%) dislocations; 1 (1.2%) deep infection	12 (15%) complete; 19 (23%) incomplete	
Garbuz et al. [20]	Structural graft and some cases reinforcement ring	116 (54 Type 1; 29 Type 2A; 33 Type 2B)	7.1 (5–11)	Paprosky Types 1–2B		2A: 79.5 (19–73); 2B: 71.2 (52–88)**	Success rate: 2A – 90%; 2B – 76%	– 2A 4 (14%) – 2B 15 (45%)	2A 4 (14%); 2B 4 (12%)	6 (21%) incomplete 2A	
Garbuz et al. [21]	Structural graft and some cases reinforcement ring	32 (33)	7 (5–11)	AAOS Types III–IV		71 (52–88) Group 1**	Success rate: 55%	15 (45%)	4 (12%)		

Table 1. continued

Study	Reconstruction method	Number of patients (hips)	Followup (years)*	Defect	Survivorship cup removal for any reason (95% CI)	Clinical outcome*		Number of revisions	Number of complications	Radiographic appearances	
						HHS*	Other			Number of radiolucent lines	Other
Kawanabe et al. [28]	Reinforcement ring and morselized or bulk grafts	38 (42)	8.7 (4.3–12)	AAOS Types II–IV	Morselized: 53% (42.5%–63.5%); bulk: 85% (72.4%–91.6%) (radiographic failure) at 10 years		JOA hip score: 77.3 (65–95)	2 (5%)		6 (14%) complete	4 (9.5%) radiographic loose
Rosson and Schatzker [37]	Reinforcement ring and some cases bone grafts	81 (81)	5 (2–10)	AAOS Types I–IV		Muller: 87 (61–100); Burch-Schneider: 81 (56–99)		5 (6%)		5 (6.2%) complete; 15 (19%) incomplete	
Saleh et al. [38]	Reinforcement ring and structural graft	19 (20)	10.5 (5–16)	Gross Type IV > 50% segmental bone loss anterior and posterior column	77% at 10.5 years		WOMAC: Function 62 (31–93); Pain 18 (8.1–27.9); Stiffness 4.7 (3.6–5.8)	3 (15%)	3 (15%)	0	1 (5%) ring migration
Winter et al. [51]	Reinforcement ring and morselized bone graft	38 (38)	7.3 (4.2–9.4)	AAOS Types III–IV		82.6 (58.2–94.9)		1 (2.6%)	20 (53%)		
Zehntner and Ganz [52]	Reinforcement ring and allograft	27 (27)	7.2 (5.5–10)	AAOS Types I–III	79.6% at 10 years			9 (33%)			12 (44%) migration
Dearborn and Harris [12]	High hip center	44 (46)	10.4 (8.5–12.7)	Stages I–IV		81 (56–100)		4 (8.7%)	18 (39%)	10 (22%) complete	wear 0.17 mm/year (0.03–0.47 mm/year)
Kelley [29]	High hip center	22 (23)	2.9 (2–5)	Substantial superior defects		78 (45–98)		0	6 (27%)	1 (4.3%) complete; 7 (30%) incomplete	
Schutzer and Harris [45]	High hip center	51 (56)	3.3 (2–5.3)	Stages I–IV		86 (36–100)		0	5 (10%)	4 (7.1%) complete; 33 (59%) incomplete	
Dearborn and Harris [13]	Jumbo cup	24 (24)	7 (5–10.3)	AAOS Types I–III		86 (45–100)		3 (12.5%)	5 (21%) recurrent dislocations; 5 (21%) septic failure; 4 (19%) trochanteric nonunion; 4 (19%) remaining	5 (21%) complete	wear 0.2 mm/year (0.03–0.36 mm/year)

Table 1. continued

Study	Reconstruction method	Number of patients (hips)	Followup (years)*	Defect	Survivorship cup removal for any reason (95% CI)	Clinical outcome*		Number of revisions	Number of complications	Radiographic appearances	
						HHS*	Other			Number of radiolucent lines	Other
Hendricks and Harris [24]	Jumbo cup	24 (24)	13.9 (12.3–16.2)	AAOS Types I–III		79 (46–98)	UCLA activity scores: 5 (1–6)	3 (12.5%)	5 (21%) recurrent dislocations; 5 (21%) septic failure; 4 (19%) trochanteric nonunion; 4 (19%) remaining	5 (21%) complete	
Patel et al. [35]	Jumbo cup	42 (43)	10 (6–14)	AAOS Types I–III; Paprosky Types 2A–3A	83% (SE 0.07) at 13 years	81 (63–99)		5 (12%)	2 (4.7%)	4 (9.3%) incomplete 2 (4.7%)	2 (4.7%) radiographic loose
Whaley et al. [50]	Jumbo cup	89 (89)	7.2 (5–11.3)	AAOS Types I–III; Paprosky Types 1–3B	93% (85%–100%) at 8 years	83		4 (4.4%)	18 (20%)	5 (7%) complete	2 (3%) radiographic failure
Christie et al. [9]	Triflange cup	76 (78)	4.4 (2–8.9)	AAOS Types III–IV		82.1 (59–100)		0	19 (24%)	3 (12%) incomplete	
Dennis [17]	Triflange cup	24 (24)	4 (2–6.5)	Paprosky Type 3B		79 (68–89)		3 (13%)	3 (13%)		3 (13%) radiographic loose
Nehme et al. [32]	Trabecular metal	16 (16)	2.7 (2–3.25)	Paprosky Types 2A–3B		70 (52–92)		1 (6%)		4 (25%) incomplete	
Boscainos et al. [4]	Trabecular metal	14 (14)	2.7 (0.5–3.8)	AAOS Types I–IV			WOMAC: 33 (18–52)	0	3 (21%)	4 (29%) incomplete	
van Haaren et al. [48]	BIG, cemented cup	68 (71)	7.2 (1.6–9.7)	AAOS Types I–IV	72% (54.4%–80.5%) (aseptic loosening) at 7.2 years			25 (35%)			Graft incorporation: success group – 34 (66%); failed group – 4 (20%)
Palm et al. [33]	BIG, uncemented cup	79 (87)	9 (7–11)	Gustilo and Pasternak Types II, III, IV	90.5% (83.4%–97.6%) at 9 years	85 (34–100)	WOMAC: 70 (22–100)	7 (8%)	20 (23%)	5 (5.7%) complete; 16 (18%) incomplete	5 (7.2%) radiographic loose
Buttaro et al. [7]	BIG, mesh, cemented cup	23 (23)	3 (1–4.7)	AAOS Type III	90.8% (68.1%–97.6%) at 3 years		Merle D'Aubigné and Postel: 16.2	2 (8.7%)	2 (8.7%)	5 (22%)	migration 5.1 mm (2–25)
Schreurs et al. [41]	BIG, cemented cup	37 (42)	12 (3–21)	AAOS Types I–III	80% (67%–94%) at 20 years	89 (60–100)		8 (19%)	6 (14%)	6 (14%) complete; 14 (33%) incomplete	7 (17%) radiographic loose
Schreurs et al. [42]	BIG, cemented cup	56 (60)	11.8 (10–15)	AAOS Types II–III	90% at 11.8 years	85 (83–100)		5 (8.3%)	9 (15%)	15 (25%)	4 (6.7%) radiographic loose

Table 1. continued

Study	Reconstruction method	Number of patients (hips)	Followup (years)*	Defect	Survivorship cup removal for any reason (95% CI)	Clinical outcome*		Number of revisions	Number of complications	Radiographic appearances	
						HHS*	Other			Number of radiolucent lines	Other
Schreurs et al. [44]	BIG, cemented cup	28 (35)	7.5 (3–14)	AAOS Types II–III	85.1% (73%–97.1%) at 8 years	82 (52–97)		6 (17%)	4 (11%)	5 (14%)	5 (14%) radiographic loose
Current study	BIG, mesh, cemented cup	25 (27)	8.8 (3–14.1)	AAOS Types III, IV; Paprosky Types 2B–3B	88% (74.2%–100%) at 10 years	71.6 (33–95)	OHQS: 24.9 (12–49)	3 (11%)	13 (48%)	2 (7.4%)	5 (18.5%) radiographic loose; wear 0.05 mm/year (0–0.15 mm/year)

* Values are expressed as means, with ranges in parentheses; **Modified Harris hip score; AAOS = American Academy of Orthopaedic Surgeons; BIG = bone impaction grafting; HHS = Harris hip score; JOA = Japanese Orthopaedic Association; SE = standard error; UCLA = University of California at Los Angeles; WOMAC = Western Ontario and McMaster Universities Arthritis Index.

30 years, we have used bone impaction grafting in combination with a cemented cup to reconstruct the acetabulum during primary and revision procedures in patients with acetabular defects [40–44, 49]. Survival rates of 90.8% have been reported at short-term followup (24–56 months) [7], 72% to 90% at midterm (7.2–7.5 years) [43, 48], and 80% to 94% at long term (11.8–20 years) [40, 41, 44, 49]. With more extensive defects, there is controversy whether bone impaction grafting can be used. One study reported a survival rate of 72%; 70% of the reconstructed cups had an American Academy of Orthopaedic Surgery (AAOS) Type III or IV bone defect [48].

We studied a group of patients with acetabular reconstructions with bone impaction grafting for extensive bone deficiency. All had a reconstruction with a large-rim mesh. We determined the (1) survival rates with the end point revision for any reason, aseptic revision, and radiographic loosening; (2) VAS pain score, HHS [22], and the OHQS [11]; (3) number of repeat revisions; (4) complications; and (5) radiographic loosening, wear, and radiolucencies.

Patients and Methods

Between January 1993 and December 2003, we performed 27 acetabular revisions in 25 patients with large acetabular defects using impacted bone grafts and a cemented cup. During this period, we performed 358 acetabular revisions in total. We did not use any other technique for severe deficiency reconstruction. The indication for the revision was aseptic loosening of the acetabular component in 22 hips, septic loosening in four hips, and one with resection arthroplasty greater than 6 months. For this study, we included patients only with an X-Change large-rim mesh (Stryker-Howmedica, Newbury, UK). We had not classified the severity of the defects at the time of surgery and therefore included only patients who had 6 weeks of postoperative bed rest or 3 weeks of bed rest together with 3 weeks of nonweightbearing mobilization; these were all patients who were judged to have the most severe defects. All ages and all indications for revision THA were included. The number of previous revisions was not an exclusion criterion. Five men (five hips) and 20 women (22 hips) were included, with a mean age of 63 years (range, 42–82 years) at the time of the index revision procedure. Fifteen revisions were on the right side and 12 on the left side. The minimum followup for all patients was 3 years (mean, 8.8 years; range, 3–14.1 years). No patient was lost to followup. During followup, two patients (two hips) died from causes not related to the revision procedure at 1 year and 7.5 years postoperatively. One patient died from hepatic failure; however, she had aseptic loosening of her acetabular reconstruction but did not undergo reoperation because of her poor medical condition. The second patient had a well-functioning arthroplasty. The minimum followup of the surviving patients (not deceased, hips not revised) was 4 years (mean, 9.7 years; range, 4–14.1 years).

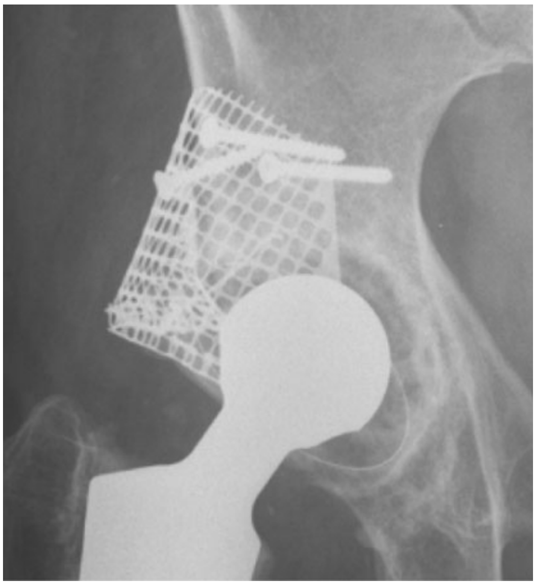

Fig. 1 An example of an X-Change large-rim mesh is shown.

We retrospectively classified all defects using the AAOS system [10]: 25 had a Type III defect and two had a Type IV defect. According to the classification of Paprosky et al. [34], four hips had Type 2B, 14 hips had Type 3A, and nine hips had Type 3B defects. One metal mesh was used in nine hips, two meshes were used in 16 hips, and three meshes were used in two hips. Three to nine screws were used for fixation of the meshes.

All revisions were performed by two surgeons (BWS, JWMG). The acetabular revision was combined with a femoral revision in 22 cases. The average surgical time was 240 minutes (range, 120–425 minutes). A posterolateral approach was used in all patients. The bone bed was rinsed with pulse lavage after removal of the cup, cement, and interface. Interface tissue was sent for cultures and frozen sections. Segmental bone defects of the acetabulum were contained with one or more metal meshes fixated with screws. In all cases, the superolateral wall defect was reconstructed with a large-rim X-Change metal mesh (Fig. 1). If needed, medial wall meshes were used (Fig. 2A). Next, sclerotic areas were perforated by multiple 2-mm drill holes, and impaction bone grafting was performed. Bone chips with a diameter of 0.7 to 1.0 cm were made by morselizing femoral head allografts from the local bone bank with a rongeur or a bone mill (Fig. 2B). The chips were impacted with metal impactors (X-Change system;

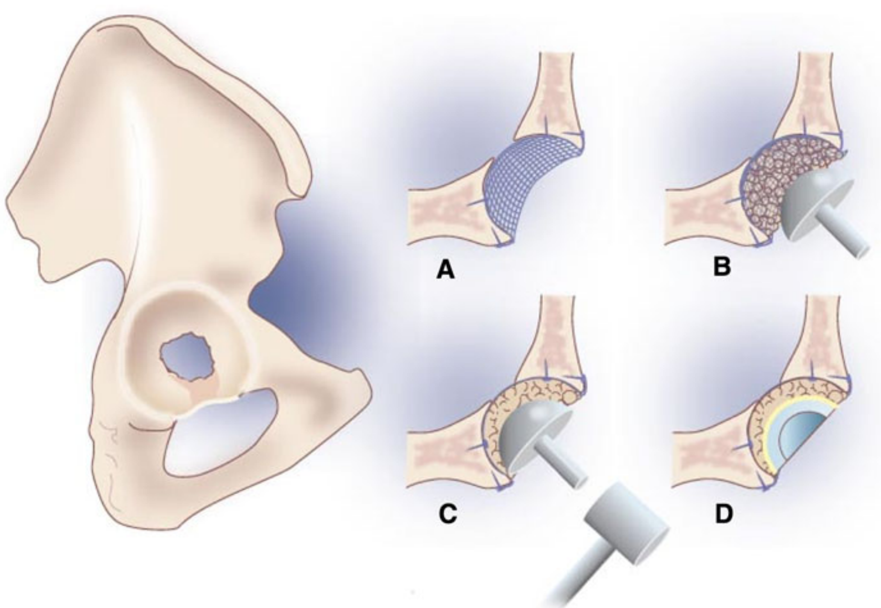

Fig. 2A–D (**A**) A flexible stainless steel mesh is used to close the segmental defects. (**B**) For acetabular reconstruction, 7- to 10-mm diameter fresh-frozen morselized bone chips are impacted using end metal impactors in several diameters. (**C**) With a hammer, the bone chips, layer by layer, are compressed tightly. (**D**) Bone cement is introduced in a relatively viscous state and is pressurized to force bone cement into the graft. Reconstruction of the cup after cup placement at the anatomic level is shown [6]. (Reproduced with permission from Busch VJ, Gardeniers JW, Slooff TJ, Veth RP, Schreurs BW. [Favourable long-term results from cemented total hip arthroplasty combined with acetabular bone impaction grafting in patients under the age of 50] [in Dutch]. *Ned Tijdschr Geneeskd.* 2007;151:1935–1940.).

Stryker Howmedica) and a mallet (Fig. 2C). The original center of rotation of the hip was reconstructed with the transverse acetabular ligament as a reference mark. We used one to five femoral heads for the reconstruction. Five patients needed an additional structural graft for proper fixation of the wire meshes. The structural grafts were placed behind the meshes. All cups were implanted with antibiotic-loaded bone cement (Surgical Simplex®; Stryker Howmedica) with third-generation cementing techniques and with a conventional full high molecular weight polyethylene (HMWPE) cup (Fig. 2D). Eleven Muller 32-mm cups (Sulzer, Winterthur, Switzerland), eight Exeter/Contemporary 28-mm cups (Stryker Howmedica), and eight Charnley/Elite 28-mm cups (DePuy, Leeds, UK) were used. The choice of the definitive cup size was made by the last trial cup and reamer used. The inner diameter was standard 28 mm, but occasionally a 32-mm cup was used to create a more stable situation or when there was a high risk of dislocation. We used only the planned operation technique; no alteration of surgical plans was necessary [6, 42] (Fig. 3).

All patients received antibiotics (cefazolin) after results of intraoperative cultures were obtained. On indication and guided by these cultures, prolonged antibiotics were prescribed. NSAIDs were given for 7 days to prevent heterotopic ossification. All patients received thrombosis prophylaxis with low-molecular-weight heparin for 6 weeks or, before 1999, with oral anticoagulation for 3 months. Twenty patients (21 hips) had bed rest for 6 weeks. In five patients (six hips), an initial 6-week period of bed rest was planned, but nonweightbearing mobilization was used for the last 3 weeks. Under the supervision of a physical therapist, mobilization with partial (10%) weightbearing was begun at 6 weeks and 50% weightbearing with crutches at 12 weeks. Full weightbearing was allowed after 18 weeks after surgery.

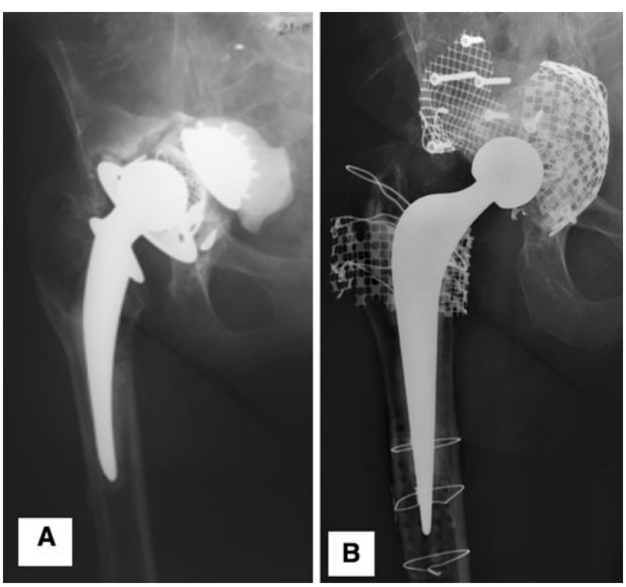

Fig. 3A–B (**A**) An AP radiograph shows the right acetabulum of a patient who had aseptic loosening of two cups in the pelvis with an AAOS Type III and Paprosky Type 3B defect. (**B**) Twelve years after revision, no radiolucent lines, no migration, and incorporation of the graft can be seen.

All patients were followed on a regular basis or until death; data of the two patients who died were included. Routine followups were scheduled at 6 weeks; 3, 6, and 12 months; and yearly or biannually thereafter. At our outpatient clinic, independent student researchers not participating in the treatment performed clinical analyses using the HHS [22], the OHQS (since 1998) [11], and a VAS for pain. The radiographic examination consisted of AP and lateral radiographs of the hip or pelvis. Preoperative and postoperative radiographs were available for all patients. At last review, three patients (three hips) were unable to return for the clinical review owing to their advanced age and general health limitations. By telephone interview, none had complaints of the reconstructed hip and none have had additional surgery on the hip. The last radiographs for these three patients (4.0, 4.4, and 7.8 years postoperatively) were included in the radiographic review. The preoperative HHSs were available for 15 patients and postoperative HHSs were available for 20 patients [22]. The preoperative OHQSs were available for two patients and postoperative scores were available for 19 [11]. Postoperative VAS scores for pain (0 = best score, 100 = worst score) were available for 18 patients.

Three investigators (NvE, DCJK, BWS) independently evaluated the radiographs for signs of incorporation, radiolucent lines, cup position, heterotopic ossification, and polyethylene wear. Whenever we differed regarding evaluation of a radiograph, we reviewed it again together without knowing our previous scores for that radiograph. We then reached agreement on the score, which, in all instances, was one of the scores from the previous evaluation; we did not determine interobserver variability of any measures. Radiographic evidence of incorporation was defined as equal radiodensity of the graft and host bone with a continuous trabecular pattern throughout, as described by Slooff et al. [47]. Radiolucent lines greater than 2 mm in width were identified in the three zones of DeLee and Charnley [16]. Radiolucent lines were defined as stable or progressive in width and extent. Position of the cup was defined as neutral in 45° (± 10°), vertical in 56° or greater, and horizontal in 34° or less, according to Salvati et al. [39]. Heterotopic ossification was classified according to Brooker et al. [5]. Polyethylene wear was calculated using the Dorr method as described by Ebramzadeh et al. [18].

Failure was defined as the need for repeat revision of the acetabular component for any reason, and radiographic failure was defined as radiolucent lines in all three zones or tilting of the cup 8° or greater and migration of 5 mm or greater relative to the interteardrop line, in any direction on the AP radiographs of the pelvis.

Survivorship analysis was performed using the Kaplan-Meier method [27] with the end points of revision for any reason, aseptic revision, and radiographic loosening. SPSS v 16.0 (SPSS Benelux BV, IBM Company Nieuwegein, The Netherlands) was used for statistical analysis.

Results

The probability of survival of the acetabular component at 10 years, with removal of the cup for any reason as the end point is 87.6% (95% confidence interval [CI], 74.2%–100%) (Fig. 4). With revision for aseptic loosening as the end point, the survival rate is 95.2% (95% CI, 86.0%–100%) at 10 years (Fig. 5). The survival rate with radiographic loosening as the end point is 77.2% (95% CI, 59.0%–95.4%) at 10 years (Fig. 6).

The surviving patients had improved clinical scores after acetabular revision with bone impaction grafting and a cemented cup, even after a mean followup of 9.7 years (Table 2).

Three hips (11%) had failed results and underwent rerevision or removal of the implant. The use of a structural graft did not influence the survival rate. One hip failed 1.1 years after surgery. This patient had two previous revision surgeries. There was a massive posterosuperior defect (AAOS Type III and Paprosky Type 3B). Against our protocol and advice, the patient started full weight-bearing 4 weeks postoperatively. The graft did not incorporate and the cup subluxated. At 1.1 years, conversion to a resection arthroplasty was done. One hip failed 4.7 years after surgery owing to culture-proven septic loosening. The index revision was the fourth revision.

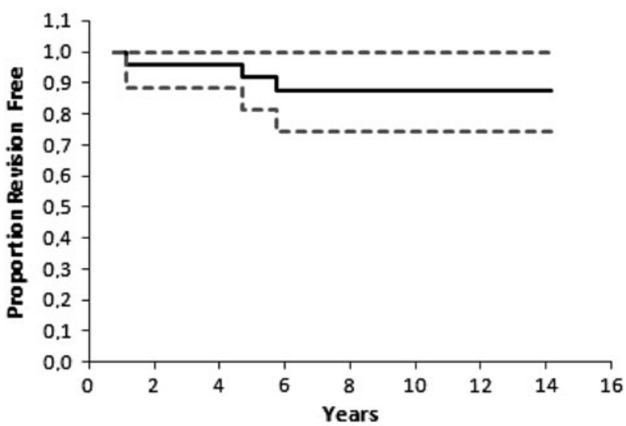

Fig. 4 A Kaplan-Meier curve shows survival with an end point of revision of the cup for any reason. Dotted lines = 95% CI. At 10 years, the survival rate was 87.6% (95% CI, 74.2%–100%).

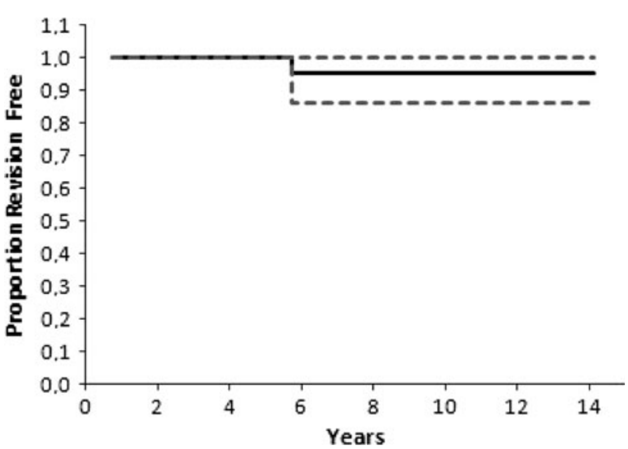

Fig. 5 A Kaplan-Meier curve shows survival with an end point of revision of the cup for aseptic loosening. Dotted lines = 95% CI. The survival rate was 95.2% (95% CI, 86.0%–100%) at 10 years.

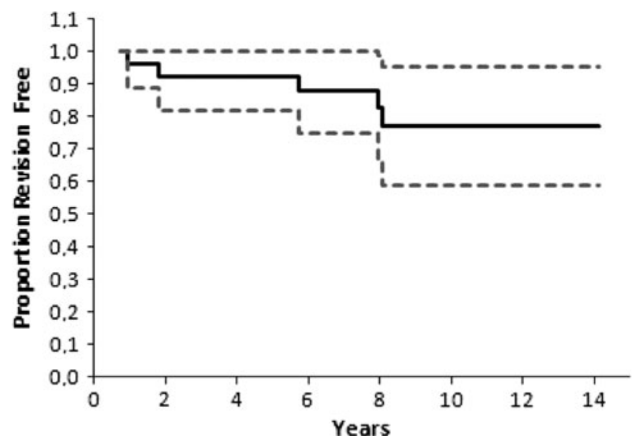

Fig. 6 A Kaplan-Meier curve shows survival with an end point of radiographic loosening of the cup. Dotted lines = 95% CI. The survival rate was 77.2% (95% CI, 59.0%–95.4%) at 10 years.

Table 2. Clinical outcomes

Score	Number of patients (hips) available	Median	Mean	Range
Preoperative HHS	15 (15)	51	55.3	30–95
Postoperative HHS*	18 (20)	73.5	71.6	33–95
Preoperative OHQS	2 (2)	26	26	17–35
Postoperative OHQS*	17 (19)	23	24.9	12–49
Postoperative VAS pain score at rest*	17 (18)	0	11.7	0–80
Postoperative VAS pain score on movement*	17 (18)	0	14.7	0–70

* Surviving hips in living patients who did not have a repeat revision; HHS = Harris hip score; OHQS = Oxford Hip Questionnaire Score; VAS = visual analog scale.

Table 3. Complications

Complications	Number	Treatment	Outcome
Cup failures			
Unstable cup	1	Resection arthroplasty	Resection arthroplasty
Septic loosening	1	Resection arthroplasty	Resection arthroplasty
Aseptic loosening	1	Cup rerevision	No additional problems
Revision femoral component			
Recurrent dislocation	1	Femoral stem rerevision	No additional problems
Perioperative unnoticed distal stem perforation of the femoral shaft	1	Femoral stem rerevision	No additional problems
Perioperative complication			
Periprosthetic fracture	3	Open reduction and internal fixation	Stable reconstruction
Postoperative complication			
Neurapraxia of peroneal nerve	1	Observation	Permanent partial motor paralysis
Dislocation hip	2	Newport brace	No additional problems
Delayed wound healing with effusion	1	Observation	No additional problems
Early septic loosening	1	Observation (owing to patient's poor medical condition)	

The patient had one previous revision because of septic loosening and three revisions because of aseptic loosening. He was treated with a resection arthroplasty. The third acetabular component was revised owing to aseptic loosening after the patient fell on the floor 5.8 years postoperatively and a cup revision was performed.

There were no major intraoperative complications during acetabular reconstruction. There were 13 complications in total (Table 3).

Five hips had radiographic signs of loosening based on migration; three of these were described above and had repeat revision surgeries. The revised hips were considered radiographically loose after 1.0, 1.9, and 5.8 years. Two hips in two patients, radiographically loose after 8.0 and 8.1 years postoperatively, were not revised. These two patients had complaints, but no repeat revision surgery was planned because of their old age and poor medical conditions. We observed no failures attributable to progressive radiolucent lines. All grafts (including structural grafts) incorporated. Fourteen hips had polyethylene wear however, the wear was excessive (> 0.1 mm/year) in only three. The mean wear was 0.05 mm/year (range, 0–0.15 mm/year). Heterotopic ossifications were seen in nine hips. Five hips had Class I ossifications, three had Class II, and one had Class III ossifications.

Discussion

Managing severe acetabular bone loss in revision arthroplasty can be challenging. Various techniques have been described to manage these deficiencies, with varying results (Table 1). Bone impaction grafting is one of the few reconstruction techniques that restores the loss of bone stock and allows creation of an anatomic and biomechanical natural center of rotation. It has reported survival rates between 72% and 94% [40, 41, 43, 44, 48, 49]. In the more extensive defects there is controversy whether bone impaction grafting can be used. One study found a survival rate of 72% [48]. Of the 20 acetabular components revised in patients in that study [48], 70% had an AAOS Type III or IV bone defect. In our current study, in a group of patients with acetabular revision with bone impaction grafting for extensive bone deficiency, we determined the (1) survivor rates, (2) pain relief and function, (3) number of rerevisions, (4) complications, and (5) radiographic appearances.

Our study has some limitations. First, we had a limited number of patients. However, no patients were lost to followup and the worst-case scenario survival rate [31] was 88% at 8.8 years. Also, we believe the group is representative because all ages and all revision and primary indications for the revision and primary arthroplasties are included. Second, we retrospectively classified the severity of the defects and therefore the indications for surgery were not strictly based on a given level of severity. However, for this study, we included only patients who had 6 weeks of bed rest and the use of the X-Change large-rim mesh, both of which we used only for patients needing more extensive reconstructions. Bed rest was prescribed only for patients with severe defects in whom we believed, at the time, early mobilization would jeopardize the stability of the reconstruction. Obviously, a 6-week period of bed rest is a disadvantage of this technique. Third, with a mean followup of 8.8 years our followup is midterm. For final proof long-term data are needed. Fourth, we unfortunately had some missing clinical data, but available data show a trend that the clinical function and pain are improving after acetabular reconstruction with bone impaction grafting. We have used the OHQS [11] only the past few years and therefore do not have previous data.

The 10-year survival rates of the reconstructions in this study were 88% with removal of the cup for any reason as the end point, 95% with revision for aseptic loosening as the end point, and 77% with radiographic loosening as the end point at a mean followup of 8.8 years (range, 3–14.1 years). Survival rates vary among the different techniques used in large acetabular defects (Table 1). Abeyta et al. [1], who investigated the bilobed cup in large reconstructions, reported a survival rate of 88% for 25 patients with an AAOS Type III defect after a followup of 11 years. The study was limited by a high number of lost and deceased patients. In the worst-case scenario, the overall survival rate would decrease to 48%. Reconstruction with a structural graft has good short-term survival rates (zero revisions at a mean of 17.3 months) [23], but middle and long-term (2–16.5 years) failure rates of 32% to 45% are reported for these grafts [21, 26, 36, 46]. Trabecular metal acetabular augments are now commonly used in the United States for reconstruction of large acetabular defects. Several studies show low failure rates of 0% to 6% [4, 32], but the followup is short (mean, 2.7 years) and the number of patients is small [4, 32]. Among 71 revisions with AAOS Types I to IV defects using bone impaction grafting and a cemented cup, van Haaren et al. found 25 hips (35%) needed repeat revision [48]. The survival rate after 7.2 years with repeat revision with aseptic loosening as the end point was 72% (95% CI, 54.4%–80.5%). However, greater than 50% of their aseptic revisions were based on cup loosening out of the cement mantle, which is an unusual failure mechanism.

In line with the literature, patients had better postoperative clinical scores after acetabular reconstruction with bone impaction grafting and a cemented cup (Table 1) [33, 40, 41, 43, 44, 49].

Three cups (11%) needed repeat revision. Jasty and Harris [26] reported eight (32%) of their patients needed repeat revision by a mean followup of 5.9 years using structural femoral head allografts to reconstruct large acetabular bone defects. The repeat revision rate of Abeyta et al. [1] was 12%, similar to ours, using a bilobed cup in the reconstruction of acetabular deficiencies.

There were 13 (48%) complications. Different complication rates are described using bone impaction grafting techniques (Table 1). Buttaro et al. [7] described only two (8.7%) reoperations and two (8.7%) other complications (infection and dislocation). Palm et al. [33] reported 20 (23%) complications. However, this report was based on bone impaction grafting with noncemented cups. Also, high complications rates are reported using structural grafts (50%) [26], jumbo cups (21%) [13, 24, 50], and the triflange cup (24%) [9].

In addition to the three hips needing repeat revision, another two cups were considered radiographically loose. In the other cases, no radiolucent lines were seen, which is remarkable. This could be attributed to the unique cup, graft, cement, and bone interface. De Kam et al. [15] reported fewer radiolucent lines were seen in patients with impacted bone grafts in primary THA. In a study of revision arthroplasty using impaction grafting, Buttaro et al. [7] also reported no additional radiolucent lucencies except in patients with hips needing repeat revision.

We believe the proper function and the survival of an acetabular reconstruction in revision surgery depend on achieving adequate fixation of the new component, restoring the anatomic center of rotation of the hip, and restoring bone stock loss. We believe that for extensive reconstructions with bone impaction grafting, an after-treatment protocol of 6 weeks of bed rest, or 3 weeks of bed rest and 3 weeks nonweightbearing mobilization, is crucial for acceptable survival rates and improving clinical function and pain. In the study by Buttaro et al. [7] regarding the outcome of larger defects and bone impaction grafting, 6 weeks of unloading with crutches was used and at 3 years, the survival rate was 90.8%. However, one of their failed results involved a patient who decided to fully load the reconstruction and this resulted in failure, as occurred with one patient with failed results in our study.

Acetabular reconstruction using impaction bone grafting together with a cemented cup is a reliable technique with favorable midterm survival rates and clinical function in patients with massive acetabular defects. Impacted bone grafting is an acetabular revision technique that restores bone stock loss and allows reconstruction of the normal anatomic biomechanics of the hip.

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