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THA Revisions Using Impaction Allografting With Mesh Is Durable for Medial but Not Lateral Acetabular Defects

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Abstract

Background Most acetabular revisions are managed with cementless hemispherical or elliptical metal implants relying on bone ingrowth. Nonetheless, loss of acetabular bone stock and inability to achieve secure component fixation represent challenges in the setting of revision total hip arthroplasty. Impaction bone grafting (IBG) using allograft represents one option for treatment of this problem. However, cup migration and bone graft resorption are limitations when IBG is used for large segmental defects, and the precise role of IBG as well as the use of mesh (and the kinds of defects for which mesh does not work well) in this setting remains unknown.

Questions/purposes We therefore evaluated patients undergoing acetabular revision surgery using IBG and a cemented cup in large bone defects to determine (1) the frequency with which the hip center could be restored in hips with Paprosky 3A and 3B defects and in hips with or without the use of metallic mesh during surgery; (2) survivorship of IBG acetabular-revision reconstructions in patients with severe Paprosky 3A and 3B defects; and (3) risk factors for failure of the reconstruction, including the use of mesh and defect severity (3A versus 3B).

Methods Between 1997 and 2009, we performed 226 acetabular revisions using IBG. During that time, indications for using IBG in this setting included Paprosky 3A and 3B defects without pelvic discontinuity. Of these, 204 (90.2%) were available for followup at a minimum of 5 years (mean, 10 years; range, 5–17 years). There were 100 hips with an intraoperative bone defect of Paprosky 3A and 104 with a 3B. Medial or rim acetabular uncontained defects were treated with medial and/or lateral metallic mesh in 142 hips. We determined the postoperative radiological cup position and acetabular reconstruction of the hip center according to Ranawat in both groups. We assessed the appearance of cup loosening and the possible risk factors with regression analysis.

Results Mean postoperative acetabular abduction angle and vertical, horizontal, and hip rotation center distances improved ($p < 0.001$ in all parameters). Nine hips showed radiological loosening in the group with bone defect 3A and 16 in Group 3B. The survival rate for loosening at 15 years was 83% (95% confidence interval [CI], 71%–95%) for Group 3A and 73% (95% CI, 60%–84%) for Group 3B ($p = 0.04$). The survivorship for loosening when using mesh or not at 15 years was: no mesh 89% (95% CI, 74%–99%), medial mesh 85% (95% CI, 72%–97%), lateral mesh 80% (95% CI, 67%–91%), and medial and lateral meshes

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54% (95% CI, 31%–76%) (p = 0.008). After controlling the most relevant confounding variables we found that the most important factor associated with loosening was lateral mesh use (p = 0.008; hazard ratio, 2.942; 95% CI, 1.328–6.516).

Conclusions IBG provides an improvement in reconstruction of the hip rotation center in acetabular revision surgery. Although results are good for contained or medial large defects, hips with a rim or lateral segmental defect may need other options for reconstruction of these challenging surgeries.

Level of Evidence Level III, therapeutic study.

Introduction

Cementless cups are a durable option in revision hip surgery, although they have shown some limitations when major acetabular bone loss is present [11]. The impaction bone grafting (IBG) technique was introduced for use in the acetabulum by Slooff et al. [35] and has proven to be effective in revision surgery. Different series have confirmed excellent results using this technique [10, 30, 32, 33] and bone graft incorporation has been reported in histologic and positron emission tomography studies [2, 4, 28, 31, 34, 37]. In a goat model of impacted allograft, Schimmel et al. [28] showed complete incorporation of the allograft by 48 weeks. Studying 24 human acetabular biopsies after reconstruction, Van der Donk et al. report similar findings [38].

However, cup migration and bone graft resorption are some of the limitations after IBG in revision surgery when used for large segmental defects despite the use of medial and lateral stainless steel meshes specifically designed to reconstruct segmental bone loss [12, 15, 27, 40]. Because of these concerns, the precise role of IBG as well as the use of mesh (and the kinds of defects for which mesh does not work well) in this setting remains unknown.

We therefore evaluated patients undergoing acetabular revision surgery using IBG and a cemented cup in large bone defects to determine (1) the frequency with which the hip center could be restored in hips with Paprosky 3A and 3B defects and in hips with or without the use of metallic mesh during surgery; (2) survivorship of IBG acetabular-revision reconstructions in patients with severe Paprosky 3A and 3B defects; and (3) risk factors for failure of the reconstruction, including use of mesh and defect severity (3A versus 3B).

Patients and Methods

Between January 1, 1997, and December 31, 2009, we performed 226 acetabular revision surgeries using IBG and a cemented cup in 217 patients. The indications were hips with Paprosky 3A and 3B defects [24]. During that time patients with milder bone defects were treated with a cementless porous-coated or tantalum cups and hips with a pelvic discontinuity with alternate techniques including stabilization of both columns. Two hundred and four hips (196 patients [90.2%]) were available for followup at a minimum of 5 years (mean, 10 years; range, 5–17 years). Twenty-one patients (22 hips) were excluded: nine patients had died for reasons unrelated to the revision surgery and 12 (13 hips) were lost to followup. Each revised cup was individually assessed; 76 (37%) only underwent acetabular revision, whereas 128 (63%) underwent revision of both components. There were 100 Grade 3A hips and 104 Grade 3B hips.

Mean age was 69 years (± 13.1) for the whole series and the most frequent diagnosis was primary osteoarthritis (Table 1). There was no difference in age between the Grade 3A patients and the Grade 3B patients. The groups were different in terms of sex; the Grade 3A group included 24 men and 76 women, whereas the 3B group included 37 men and 67 women (p = 0.49). Data on body mass index were not available. The average time between the initial THA and the revision acetabular surgery described here was 76 months (range, 38–194 months). First revision surgeries were more frequent in 3A than in 3B defects ($p < 0.001$). Medial and lateral stainless steel meshes specifically designed to reconstruct loss of bone (X-change; Stryker, Howmedica International, Staines, Middlesex, UK) were used for segmental uncontained defects with a size greater than 2 cm^3 on the medial side or the roof of the acetabulum. The use of metallic meshes was also more frequent in 3B defects (Table 1).

All surgeries were done by the same surgical team (three different surgeons) using a posterolateral approach. The acetabular cup and cement were removed and the membrane excised and sent for histologic and bacteriologic study. The acetabular margins were defined. When appropriate, segmental acetabular defects were reconstructed with metallic meshes screwed to the bone bed. We used medial and/or rim metallic meshes for uncontained defects in 142 hips in 134 patients, including medial mesh in 56, lateral mesh in 51, and both in 35. No mesh was used in 62 hips (Table 1). Fresh-frozen femoral heads allograft from the bone bank were used in all hips. Allograft bone chips were morselized with a bone mill (Lere Bone Mill; Johnson & Johnson, DePuy, Warsaw, IN, USA) or manually using a rongeur with a size of 0.7 to 1 cm^3 and impacted with a trial prosthesis socket from X-Change instruments (Stryker, Howmedica International) according to the Nijmegen technique [36, 39]. The acetabulum was cleaned and filled with bone graft to a thickness of at least 5 mm [38]. A standard low-profile all-polyethylene cup (Stryker,

Table 1. Preoperative patient data and bone defect

Paprosky bone defect [24]	3A defect (n = 100)	3B defect (n = 104)	Total (n = 204)	p value
Male/female	24/76	37/67	61/143	0.049†
Mean age (years; range)*	68 ± 13	69 ± 10	69 ± 13	0.720‡
Diagnosis				
Osteoarthrosis	58	62	120	
Rheumatoid arthritis	5	17	22	
Developmental arthritis‖	1	2	3	
Avascular necrosis	12	9	21	
Posttraumatic arthritis	13	7	20	
Congenital hip disease	10	5	15	
Others	1	2	3	
Number of revisions				
First	82	63	145	0.001§
Second	11	23	34	
Third	5	13	18	
Fourth	1	4	5	
Fifth	1	0	1	
Sixth	0	1	1	
Metallic meshes				
No mesh	43	19	62	< 0.001§
Medial wall	18	38	56	
Lateral mesh	35	16	51	
Both	4	31	35	

* Values are expressed as mean ± SD; the remaining values are expressed as number of hips; †Fisher's exact test; ‡Student's t-test; §Pearson chi square test; ‖arthritis secondary to Perthes' disease, septic arthritis in children, and slipped capital femoral epiphysis.

Howmedica International) was cemented using antibiotic-loaded PMMA (Palacos with gentamicin; Merck, Darmstadt, Germany) in 177 hips in 170 patients. In cases in which a well-fixed Charnley stem was associated with a loosened 22.25-mm Charnley cup, a Charnley cemented cup (Johnson & Johnson, DePuy) was used (27 hips in 26 patients).

Standard AP and lateral radiographs of the pelvis were made for all patients immediately after operation and at every followup examination. All postoperative and followup radiographs were made at our institution following the same protocol [18]. Measurements were made by a single author (EG-R). The locations of radiolucent lines around the cup were recorded using the DeLee and Charnley zones [9]. The preoperative and postoperative positions of the cup were assessed by determining the acetabular inclination of the cup. The center of rotation of the hip was defined using the center of the femoral head and the interteardrop line or obturator foramina. The true acetabular region was defined according to Ranawat et al. [26]. The approximate femoral head center was used as the reference point to measure distances between the center of rotation of the patient's normal hip and the center of the prosthetic femoral head. These distances were recorded for each hip. Radiographic cup loosening was difficult to evaluate because of the frequent use of metallic meshes. However, cup migration was defined as a change of more than of 5° in the acetabular abduction angle or of 5 mm in either the height or lateral position of the cup. Radiographic cup loosening was defined based on Schmalzried and Harris criteria [29] and classified as definite loosening, probable loosening, or possible loosening. Although bone graft density, appearance of the graft-host junction, and trabecular continuity between bone graft and acetabular bone could be assessed by radiographs, these parameters are of limited usefulness in evaluating bone graft remodeling [14, 33]. The anatomic center of the hip was considered as reconstructed when the distance between the femoral head and the desired center of rotation was less than 5 mm.

Qualitative data were expressed as counts and percentages and quantitative data by means ± SD. Qualitative data for hips with and bone defect 3A and 3B were compared using the chi-square test or Fisher's exact test, and quantitative data for these groups and for hips with or without mesh were compared using Student's t-test. Pearson's chi square test was used to compare the demographic qualitative data of patients between groups. Kaplan-Meier survivorship analysis [19] with 95% confidence intervals (CIs) was used to estimate the cumulative probabilities of not having cup loosening related to the bone defect or the use of metallic mesh. Differences in survival were determined using the log-rank test. Pre- and postoperative changes in the inclination angle, the height and location of the center of the hip, and/or the distance between the femoral head and the desired center of rotation for the two groups were compared using two-way analysis of variance of repeated-measures factoring for Grade 3A and 3B hips. To assess the possible risk factors for cup loosening, Cox proportional hazard regression analysis [8] was performed to determine whether bone defect (3A or 3B), the use of a lateral mesh, and the postoperative radiological cup position (vertical distance and hip rotation center distance) affected the loosening rate over time. Statistical analysis was performed using statistical package SAS 9.3 (SAS Institute Inc, Cary, NC, USA).

Results

There was an improvement in both groups in the postoperative cup position for all measurements, including acetabular abduction angle, horizontal and vertical distances, and distance from the femoral head to the desired center of rotation ($p < 0.001$ in all parameters) (Fig. 1). Preoperative radiological findings showed that cup position was worse in 3B hips than 3A hips; however, postoperative acetabular abduction angle and horizontal distance were similar ($p = 0.813$ and $p = 0.196$, respectively) (Table 2). Postoperative vertical and hip rotation distances were greater in 3B hips ($p < 0.001$ for both parameters). No differences were found in postoperative cup position regarding the use of different metallic mesh (Table 3).

Nine hips showed radiologically probable or definite loosening in the group with a 3A bone defect and 19 in Group 3B (Fig. 2). The cumulative probability of not having definite or probable loosening at 15 years by bone defect was 83% (95% CI, 71%–95%) for Group 3A and 73% (95% CI, 60%–84%) for Group 3B (Mantel-Cox, $p = 0.04$) (Fig. 3). The cumulative probability of not having probable or possible loosening with the use of a metallic mesh at 15 years was: no mesh 89% (95% CI, 74%–99%), medial wall mesh 85% (95% CI, 72%–97%), lateral mesh 80% (95% CI, 67%–91%), and medial and lateral meshes 54% (95% CI, 31%–76%) (Mantel Cox, $p = 0.008$) (Fig. 4). There were 14 hips rerevised: three resulting from recurrent dislocation, two for infection, eight attributable to cup loosening rerevised to a new reconstruction using IBG, and one hip with severe congenital hip disease and major bone graft resorption converted to permanent resection arthroplasty at last followup. Nineteen loosened hips were not revised because the patients reported only mild symptoms, their physical activity was not high, and they refused surgery (Table 4).

Finally, we analyzed the possible relationship among the preoperative bone defect, the use or not of meshes, surgical technique according to the radiographic reconstruction on the postoperative radiograph, and the appearance of cup

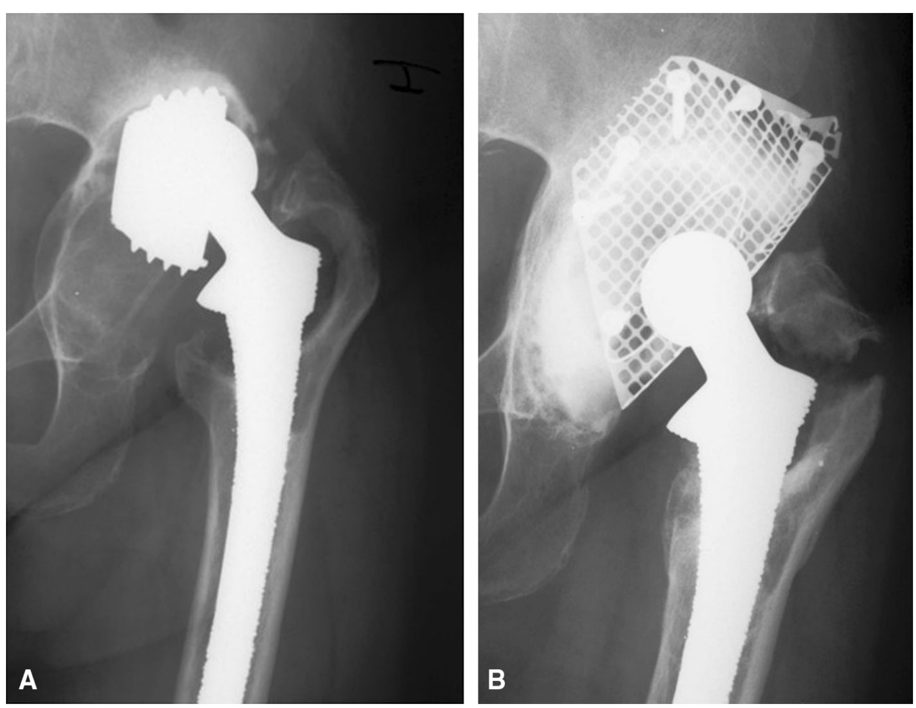

Fig. 1A–B (**A**) Preoperative radiograph of a 65-year-old woman showing a loosened threaded cup. (**B**) Postoperative radiograph of the same patient taken at the 14th year followup examination shows the segmental acetabular defect treated with IBG and cement. A metallic mesh with screws had been used to reconstruct the acetabulum. The cup is stable, the bone graft is incorporated, and the patient has a good clinical result.

Table 2. Preoperative and postoperative clinical results and radiological findings according to bone defect [24]

Results and finding	3A defect (n = 100)	3B defect (n = 104)	Total (n = 204)	p value
Radiological findings				
Acetabular abduction angle (°)				
Preoperative	54 ± 17	60 ± 23	57 ± 20	0.034
Postoperative	44 ± 3	44 ± 5	44 ± 4	0.813
Horizontal distance (mm)				
Preoperative	28 ± 11	21 ± 15	24 ± 13	< 0.001
Postoperative	30 ± 4	29 ± 7	30 ± 6	0.196
Vertical distance (mm)				
Preoperative	36 ± 9	47 ± 14	41 ± 13	< 0.001
Postoperative	23 ± 7	28 ± 9	26 ± 9	< 0.001
Mean distance from femoral head to desired center of rotation (mm) [26]				
Preoperative	18 ± 10	28 ± 13	23 ± 13	< 0.001
Postoperative	6 ± 5	10 ± 8	8 ± 7	< 0.001

Values are expressed as mean ± SD.

Table 3. Clinical results and radiological findings according to the use of metallic meshes

Results and finding	No mesh	Medial mesh	Lateral mesh	Both	Total	p value
Clinical results [21]						
Postoperative pain	5.8 ± 0.7	5.6 ± 1	5.8 ± 1	5.6 ± 1	5.7 ± 1	0.456
Postoperative function	5.5 ± 0.8	5.5 ± 1	5.6 ± 1	5.2 ± 1	5.5 ± 1	0.092
Postoperative ROM	5.3 ± 1	5.3 ± 1	5.4 ± 1	4.9 ± 1	5.3 ± 1	0.014
Radiological findings						
Acetabular abduction angle (°)	44 ± 4	45 ± 5	43 ± 4	43 ± 3	44 ± 4	0.202
Horizontal distance (mm)	30 ± 7	29 ± 6	30 ± 5	30 ± 4	30 ± 6	0.822
Vertical distance (mm)	26 ± 8	25 ± 7	26 ± 11	25 ± 7	26 ± 8	0.969
Mean CPFH to AFHC distance (mm) [26]	9 ± 8	7 ± 6	8 ± 8	8 ± 5	8.52 ± 7	0.407

Values are mean ± SD; CPFH = center of the prosthetic femoral head; AFCH = approximate center of the femoral head.

loosening. After controlling these relevant confounding variables, we found that the most important factor associated with loosening was lateral mesh use (p = 0.008; hazard ratio, 2.942; 95% CI, 1.328–6.516; Table 5).

Discussion

Most acetabular revisions can be managed with cementless hemispherical or elliptical metal implants relying on bone ingrowth. However, these provide poor results when acetabular bone defects are greater than 50%, particularly if the posterior column and the dome are not intact [11]. Other options are available, including extralarge components [41], antiprotrusio cages [1], and trabecular metal devices [20]. Nonetheless, loss of acetabular bone stock and inability to achieve secure component fixation represent challenges in the setting of revision THA. IBG combined with cemented fixation offers the opportunity for regeneration of bone stock and allows restoration of the anatomic and biomechanical natural center of rotation of the hip [12, 30]. Low rates of aseptic loosening at different followups have been reported using this technique (Table 6). However, other series also report cup migration and bone graft resorption after IBG in revision surgery when used for large segmental defects [27, 40]. We therefore evaluated patients undergoing IBG and a cemented cup to determine (1) the frequency with which the hip center could be restored in hips with Paprosky 3A and 3B defects and in hips with or without the use of metallic mesh during surgery; (2) survivorship of IBG acetabular revision reconstructions in patients with severe Paprosky 3A and 3B defects; and (3) risk factors for failure of the reconstruction, including the use of mesh and defect severity (3A versus 3B).

Some of the limitations in our study may be the case number because this might have influenced some statistical p values close to 0.05; a larger number may have powered

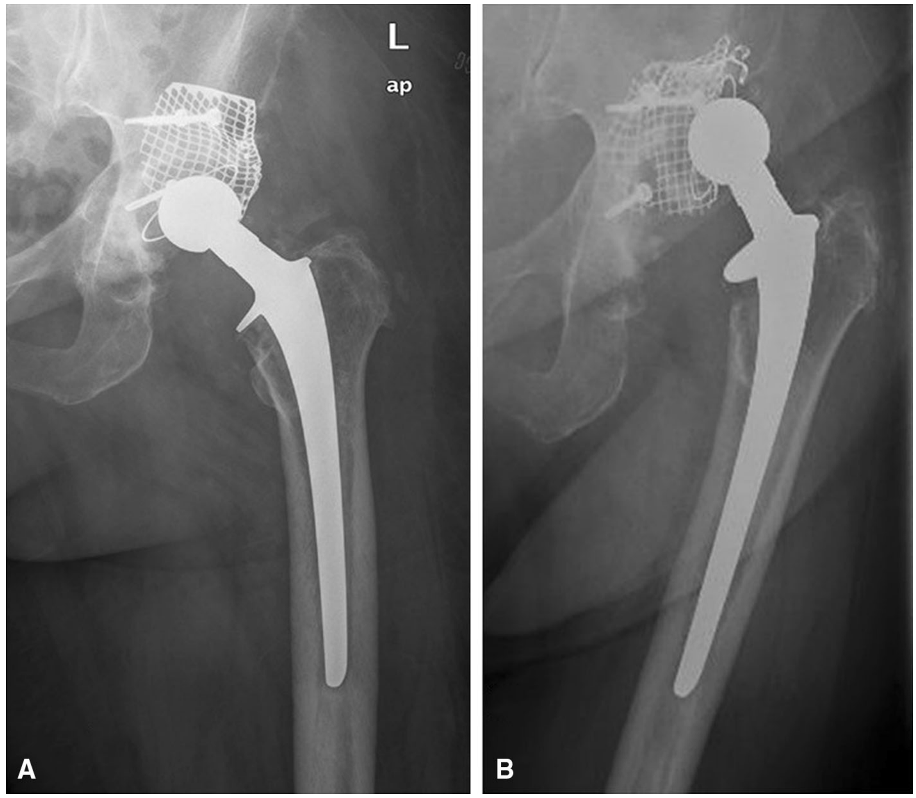

Fig. 2A–B (**A**) Postoperative radiograph of a 78-year-old woman showing a segmental acetabular defect treated with IBG and cement. A metallic mesh with screws was used to reconstruct the acetabulum. (**B**) Postoperative radiograph of the same patient taken at the 20-month followup examination showing definite loosening of the cup. The cup is migrated, the bone graft presents major resorption, the lateral mesh has failed, and the patient has a poor clinical result.

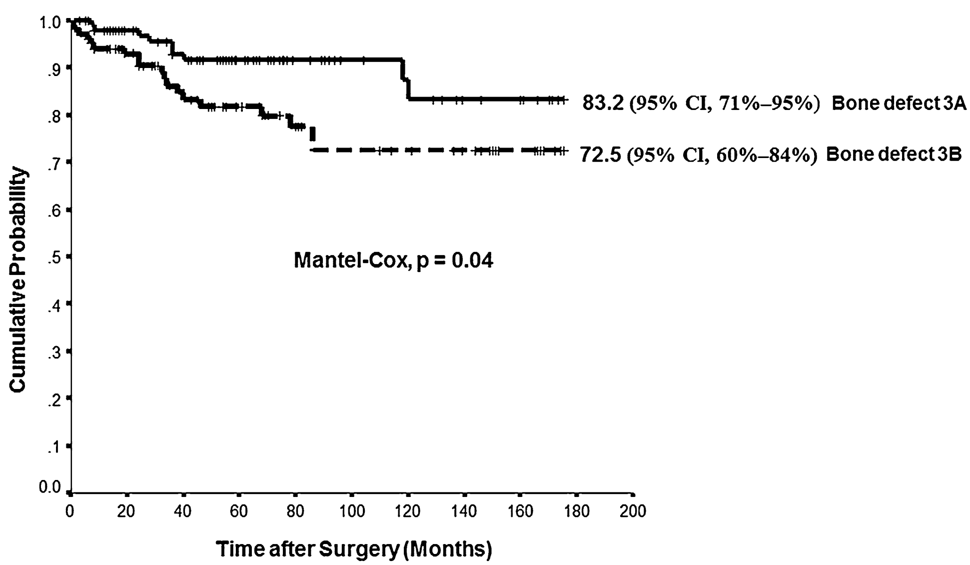

Fig. 3 Graph showing the Kaplan-Meier cumulative probability of not having definite or probable cup loosening at 15 years by bone defect. Crossed lines represent censored hips. Ranges represent the 95% CIs.

these findings. However, our series represents a large group with extended followup, and we doubt that a larger patient group would result in substantial changes in either our technique or our conclusions. Although we followed the surgical recommendations from Nijmegen, we are aware that differences between this and other institutions may also affect the results. We lacked a control group of patients with similar ages and acetabular defects who were operated on with other techniques with which to compare our observations. Different postoperative management regarding bone defect and acetabular and femoral sides could also influence results [22]. Cup migration and bone allograft resorption were difficult to evaluate when metallic mesh was used on conventional radiographs. This analysis could be inadequate for detecting migration of less than 4 to 6 mm, a less accurate method than radiostereometric analysis (RSA), which could have detected migration and rotation of the cup at an early stage and over time [19].

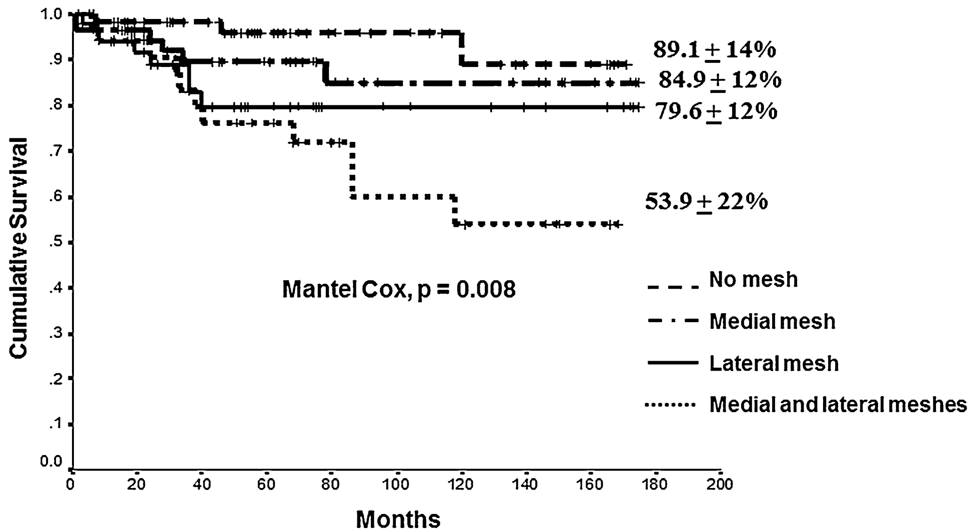

Fig. 4 Graph showing the Kaplan-Meier cumulative probability of not having definite or probable cup loosening at 15 years with the use of a metallic mesh. Crossed lines represent censored hips. Ranges represent the 95% CIs.

Table 4. Data on probably or definitely loosened (N = 28) and rerevised cups (N = 14)

Case number	Sex	Age (years)	Diagnosis	Cause of loosening	Bone defect [24]	Loosening (months)	Mesh	Rerevision (months)
1	Female	81	Fracture	Aseptic	3A	Definite (8)	Lateral	–
2	Female	70	Arthrosis	Aseptic	3A	Probable (40)	Lateral	–
3	Female	68	RA	Aseptic	3B	Definite (38)	Both	IBG (49)
4	Female	71	RA	Aseptic	3B	Definite (32)	Both	IBG (59)-
5	Female	74	Necrosis	Aseptic	3B	Probable (40)	Both	–
6	Male	40	Arthrosis	Aseptic	3B	Definite (86)	Both	–
7	Female	81	Arthosis	Aseptic	3B	Probable (68)	Both	–
8	Female	78	Arthrosis	Aseptic	3A	Definite (36)	Lateral	IBG (41)
9	Female	74	Dysplasia	Aseptic	3B	Definite (19)	Lateral	RArth (22)
10	Female	82	Arthrosis	Aseptic	3B	Definite (8)	Both	–
11	Female	79	Arthrosis	Aseptic	3B	Definite (3)	Lateral	–
12	Female	80	Arthrosis	Aseptic	3B	Probable (33)	Both	–
13	Male	65	RA	Infection	3B	Possible (1)	Medial	RArth (3)
14	Male	78	Arthrosis	Aseptic	3B	Definite (7)	No	IBG (8)
15	Female	72	RA	Aseptic	3B	Definite (34)	Medial	–
16	Female	71	Arthrosis	Aseptic	3B	Proable (78)	Medial	–
17	Male	36	RA	Aseptic	3B	Definite (24)	Medial	–
18	Female	80	Arthrosis	Aseptic	3B	Definite (46)	No	IBG (51)
19	Female	34	Dysplasia	Aseptic	3A	Definite (118)	Both	IBG (124)
20	Male	64	Arthrosis	Aseptic	3A	Definite (28)	Medial	IBG (29)
21	Female	66	Necrosis	Aseptic	3A	Definite (120)	No	IBG (126)
22	Female	81	Arthrosis	Aseptic	3A	Probable (42)	Lateral	–
23	Male	64	RA	Infection	3B	Definite (1)	Both	RArth (3)
24	Male	81	Arthrosis	Aseptic	3A	Probable (36)	Lateral	–
25	Female	42	Necrosis	Aseptic	3B	Definitie (14)	Medial	IBG (15)
26	Female	78	Arthrosis	Aseptic	3B	Definite (20)	Lateral	IBG (27)
27	Female	56	RA	Aseptic	3B	Definite (24)	Both	–
28	Female	47	Dysplasia	Aseptic	3B	Definite (6)	Btoh	IBG (19)

RA = rheumatoid Arthritis; IBG = impaction bone grafting; RArth = resection arthroplasty.

Table 5. Cox proportional hazards regression analysis and risk factors for cup loosening by bone defect, use of metallic mesh, and postoperative radiological cup position

Risk factor	Nonadjusted univariate			Adjusted multivariate		
	p value	HR	95% CI	p value	HR	95% CI
Bone defect [24]	0.05			0.076		
3A		1			1	
3B		2.211	0.999–4.894		2.053	0.926–4.551
Mesh	0.01			0.008		
No or medial mesh		1			1	
Lateral mesh		4.907	1.452–16.591		2.942	1.328–6.516
Vertical distance (mm)	0.306	1.022	0.981–1.065	–	–	–
Femoral head to desired center of rotation distance (mm) [26]	0.387	1.021	0.974–1.071	–	–	–

HR = hazard ratio; CI = confidence interval.

Table 6. Results of different series of revision acetabular reconstruction with impaction bone grafting using fresh-frozen allograft

Study (year)	Number of hips	Bone defect	Type of graft	Followup (range)	Survival rate for rerevision	Survival rate for aseptic loosening
Schreurs et al. [33] (1998)	60	Cavitary 37, combined 23	Fresh-frozen	11 years (10–15)	90% at 11.8 years	94% at 11% years
Schreurs et al. [30] (2004)	61	Cavitary 3, combined 23	Fresh-frozen	16 years	79% at 15 years	84% at 15 years
El-Kawy et al. [10] (2005)	28	Paprosky 3	Fresh-frozen and freeze-dried	72 months (48–91)	96.4%	92.8%
Ornstein et al. [22] (2003)	17	Different grades	Fresh-frozen	5 years	100% at 5 years	5/17
Comba et al. [6] (2006)	142	Different grades	Fresh-frozen	51 months	95.8%	98%
Van Haaren et al. [40] (2007)	71	All, including pelvic discontinuity	Fresh-frozen	7 years (1–9)	72%	20/71 (14 large defects and pelvic discontinuity)
Buttaro et al. [5] (2008)	23	Segmental	Fresh-frozen	35 months (24–59)	90.8% at 24 months	8 /23
Schreurs et al. [32] (2009)	62	No data	Fresh-frozen	22 years (20–25)	86%	96%
Comba et al. [7] (2009)	30	Different grades	Fresh-frozen	85 months	75% at 20 years	87% at 20 years
García-Cimbrelo et al. [12] (2010)	181	Paprosky 3	Fresh-frozen	7 years	83% (Grade 3A) 81% (Grade 3B)	91%
Rigby et al. [27] (2011)	339	Different grades	Fresh-frozen	6.1 years	89.1% at 5.8 years	95% at 10 years
Van Egmond et al. [39] (2011)	25	Paprosky 2B and 3	Fresh-frozen	8.8 years	88% at 10 years	85.8% at 13.5 years
Gilbody et al. [15] (2014)	304	Different grades	Fresh-frozen and irradiated	12.4 years	82.8% at 13.5 years	85.9% at 13.5 years

Last, we also lacked biopsies and autopsy retrieval of acetabula reconstructed with this technique to confirm the bone graft remodeling and new bone formation.

Like in other series [12, 32], we observed that the use of IBG and a cemented cup in acetabular revision surgery is a durable option for large defects. Postoperative cup position improved in this series, even for hips with 3B, findings that may promote low rates for rerevision, which depends on achieving adequate fixation of the new implant, restoring the anatomic center of rotation of the hip, and restoring bone stock loss [39]. This new cup position reflects the amount of filling, which is a combination of graft, which may be greater than 5 mm thickness in large defects, and cement [38]. The better radiological reconstruction in 3A patients, particularly for the vertical distance and reconstruction of the hip rotation center according to Ranawat et al. [26], may also have influenced differences observed between groups. Metallic mesh use was more frequent in 3B hips; however, postoperative clinical score was similar except for ROM and the postoperative cup position. This might be explained because adequate reconstruction with this technique can be obtained, but the different rates for loosening between medial and lateral mesh use can also be one of the reasons for these observations as described subsequently.

The rates of cup loosening were worse for hips with 3B defects and particularly when we used a large lateral mesh to repair a large segmental defect. We also observed that all loosened cups did not require rerevision because mild groin pain is well tolerated in some patients [12, 25]. Although there is a place for IBG, and the advantage of this method is that if a further operation is required, there is likely to be more living bone present; the poorer result when a large rim mesh was used has led surgeons to consider the use of acetabular tantalum augments combined with or without IBG [27]. Metal augments try to create peripheral acetabular containment to facilitate graft impaction [16]. Different series have been recently published reporting good preliminary results [3, 13, 15, 16].

After controlling for relevant confounding variables such as preoperative bone defect and postoperative radiological position, we found that the most important factor for loosening was the use of a lateral mesh, which suggests that this option for reconstruction may not be enough for a large segmental defect on the rim rather than bone defect and the postoperative radiological reconstruction. Rigby et al. [27] and Van Haaren et al. [40] also report poor results in patients with these large segmental defects. Rigby et al. explain that the mechanism of failure of these cups consisted of movement and rotation of the cup/cement composite within the graft. This was followed, eventually, by the mesh being pulled off the reconstructed rim. Another possible explanation for this failure rate in this series could be that in large segmental defects, the absence of superior bony support leads to a large amount of bone graft being placed at the most loaded area above the acetabular component. Owing to insufficient support for the bone graft, it is likely that micromovement of the prosthesis results in implant failure [40]. RSA studies have shown that almost all impacted sockets migrate in the postoperative period, although the rate of migration decreases with time. Ornstein et al. report that 41% of sockets were still found to be migrating 18 to 24 months after surgery [23]. Only fresh-frozen allograft has been used in this series and results and histology with untreated graft have been reported [17]. Although we used chips with a size of 0.7 to 1 cm^3 [39], larger chips and larger diameter cups make it possible to fill the cavity and could improve these poor results. Obviously, in challenging cases with large rim segmental defects, a substantial layer of bone graft to a thickness of at least 5 mm under the large rim mesh could not be obtained in all cases in this series [38].

These findings allow us to conclude that IBG combined with cemented fixation offers the opportunity for regeneration of bone stock and provides improvement of the reconstruction of the rotation of the hip center in most hips in acetabular revision surgery; however, although results are good for contained or medial large defects, hips with a large rim segmental defect may need other options for reconstruction of these challenging surgeries.

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