

Acetabular Revision with Metal Mesh, Impaction Bone Grafting, and a Cemented Cup

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Abstract Impaction grafting is controversial in the presence of segmental and cavitory acetabular defects and requires the use of supplemental devices to close segmental defects. This approach, however, would allow treating combined deficiencies that could not be managed with impacted cancellous bone alone. We raised the following two questions: (1) What is the survival rate in patients with combined deficiencies reconstructed with metal mesh, impaction grafting and a cemented cup and (2) can metal mesh prevent cup migration? We evaluated 23 cavitory uncontained acetabular defects in revision hip arthroplasty. Preoperative diagnoses were aseptic loosening (19 hips) and second-stage reimplantations after resection for infection (four hips). The preoperative Merle D'Aubigné-Postel score averaged 7.4 points. Two patients had reoperations for mechanical failure at 6 and 24 months. The survival rate with further revision as an end point was 90.8% at an average of 36 months (range, 24–56 months; 95% confidence interval, 68.1–97.6). Metal mesh did not prevent cup migration: migration occurred in all patients, averaging 5.1 mm (range, 2–25 mm). Another three patients with severe combined defects had asymptomatic mesh rupture with 3- to 15-mm migration. Postoperative functional score

averaged 16.2 points. Metal mesh, impaction grafting, and a cemented cup should be considered for reconstruction of medium uncontained acetabular defects, but not for severe combined deficiencies.

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

Introduction

Substantial bone loss after THA creates a challenge in reconstruction. Many patients now have more than one failed revision or serious cavitory and segmental acetabular defects.

Impaction grafting techniques reportedly have excellent clinical and radiographic medium-term results in primary and revision hip surgery, in the acetabulum and in the femur [6, 8, 9, 16, 37, 42, 49]. A 96% overall survivorship rate at 51 months in 142 aseptic acetabular cases and 96% survivorship (excluding infected cases) in 30 patients younger than 55 years with acetabular bone loss were reported [9, 10]. Reconstruction of segmental acetabular defects using impacted allografts originally was described by Slooff et al. in 1993 [49]. They mentioned the occasional use of medial or peripheral metal mesh. van Haaren et al. reported a series of 71 patients with large acetabular defects including 44 patients with additional peripheral metal mesh augmentation; 15 of these 44 patients needed rerevision for aseptic failure from 1 to 7 years after index revision [54].

Nevertheless, impaction grafting in peripheral acetabular defects is controversial and often requires the use of supplemental devices such as metal mesh or reconstruction rings fixed to the iliac bone to transform noncontained into

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contained deficiencies [6, 8, 9, 16, 37, 42, 49]. This approach, however, would allow treating combined deficiencies that could not be managed with impacted cancellous bone alone.

We raised the following questions: (1) What is the survival rate in patients with combined acetabular deficiencies reconstructed with metal mesh, impaction grafting, and a cemented cup, and (2) can metal mesh prevent cup migration?

Materials and Methods

We prospectively followed 100 patients operated on between May 2002 and April 2005 for a failed acetabular cup and major bone stock deficiency. We defined major deficiency as one involving local quadrant wall defects and massive global collapse involving two or more acetabular walls [19]. Of these 100 patients, 23 with segmental acetabular bone defects were operated on using impacted morselized bone grafts contained by flexible peripheral metal mesh fixed to the iliac bone with screws. The right hip

was affected in eight patients and the left hip in 15 patients. During this same period, another 20 patients with severe combined defects had revision surgery using a reconstruction ring and impacted bone allografts; our indications for this approach are more severe bone deficiencies than those treated with the proposed method. Data were collected prospectively by two of the authors (MB, FC). We used our information sheet in which individual data are collected for every patient. No patient was lost to followup. The patients' average age was 62 years (range, 23–88 years); five were men and 18 were women. The average preoperative Merle D'Aubigné and Postel score [11] was 7.2 points. The minimum followup was 24 months (range, 24–56 months, mean, 35.8 months). We had prior approval of our local ethics review board.

We classified acetabular deficiencies radiographically before surgery and confirmed the class after removal of components during the procedure using the American Academy of Orthopaedic Surgeons (AAOS) classification [10] and the one described by Gustilo and Pasternak [19] (Table 1). All the defects were combined (AAOS Type 3), defined as cavitory and segmental. Thirteen patients had

Table 1. Epidemiology

Patient number	Age (years)	Diagnosis	AAOS	Gustilo	Femoral heads	MDA preoperatively	MDA postoperatively	Followup (months)
1	57	AL	3	IV	3	5	14	52
2	52	AL	3	III	2	7	14	51
3	40	AL	3	III	2	6	18	38
4	76	AL	3	IV	4	8	18	48
5	67	AL	3	III	2	9	15	56
6	55	AL	3	III	2	6	14	36
7	77	AL	3	IV	4	8	18	38
8	54	AL	3	III	2	7	18	48
9	49	AL	3	IV	2	9	18	43
10	63	AL	3	IV	2	9	15	26
11	78	AL	3	IV	2	4	12	32
12	64	AL	3	III	2	8	16	40
13	56	AL	3	III	2	8	18	25
14	76	AL	3	IV	4	9	18	25
15	88	AL	3	III	1	9	12	34
16	67	AL	3	III	2	6	14	24
17	72	AL	3	IV	2	9	18	28
18	78	SL	3	IV	3	6	15	44
19	70	AL	3	IV	2	7	18	24
20	25	SL	3	III	2	6	18	40
21	73	SL	3	III	2	6	16	24
22	68	AL	3	III	2	9	18	24
23	35	SL	3	III	2	9	18	25

AAOS = American Academy of Orthopaedic Surgeons; MDA = functional Merle D'Aubigné and Postel score; AL = aseptic loosening; SL = septic loosening.

acetabular bone loss with local quadrant wall defects: anterior, posterior or superior, and central (Gustilo and Pasternak Type III). Ten patients had massive global collapse involving two or more acetabular walls (Gustilo and Pasternak Type IV). The severity of the segmental bone defects was evaluated on postoperative anteroposterior radiographs with a magnified ruler measuring the height of the metal mesh needed to close the segmental bone deficiency.

Surgeries were performed by two of the authors (MB, FP) following general techniques described for this method [45]. The senior authors (RP, FP) have been using the original method since 1986 [8, 9]. Under epidural hypotensive anesthesia and through a posterolateral approach, the acetabulum and femur were widely exposed, obtaining complete visualization of the acetabular limits and its anterior, superior, and posterior segmental defects. We did not perform neurolysis of the sciatic nerve in any of the cases. The presence of active infection during one-stage surgeries or second-stage reimplantations was ruled out in all patients using intraoperative frozen section biopsy [34], bacteriologic testing, and histology.

All implants, polymethylmethacrylate (PMMA), granulation tissue, and interface were removed completely and the transverse ligament or the inferior teardrop was identified. These landmarks allowed reconstruction of the center of rotation in an anatomic position. We obtained an underlying bone devoid of soft tissue, thus avoiding early acetabular radiolucencies on postoperative radiographs caused by the lack of contact between both bones. The specific requirements for the metal mesh were determined by inserting a trial cup at the transverse ligament level. We used metal mesh when the segmental posterosuperior defects measured 20 mm or greater at the highest part. Segmental defects measuring less than 20 mm were treated with impaction grafting and without additional devices. Cages were used when the defects were 35 to 40 mm or greater. The acetabular metal mesh was 0.15 inches thick and had 2-mm [2] perforations. Fico[®] (Fico[®], Buenos Aires, Argentina) metal mesh was implanted in 15 cases, and X-Change metal mesh (Stryker Howmedica[®], Newbury, UK) was used in eight cases. That mesh was trimmed and shaped according to the segmental deficiency. Once placed in position, it was fixed to the iliac bone with at least three bicortical screws. Small medial wall defects were filled with impacted allografts. If there was an important medial wall defect (greater than 3 to 4 cm in diameter), the peripheral mesh was combined with molded oval metal mesh without screws (four cases).

Bone allografts were obtained from frozen femoral heads from our own bank following the protocol of the American Association of Tissue Banks for harvesting and processing grafts [15, 32]. An average of 2.3 femoral heads was used per case (range, 1–4) to reconstruct the acetabular

defects. We made the cancellous chips 7 to 10 mm with a grinder from the unwashed bone allografts and impacted according to the technique described by Slooff et al. [48] using specific instruments (Exchange Revision Instruments System; Stryker Howmedica Osteonics[®], Allendale, NJ; and Primary Impaction Grafting Instruments; DePuy Int[®], Leeds, UK). These instruments consist of increasing-diameter impactors placed in the desired acetabular position and impacted vigorously until stability of the impacted grafts was determined, defined as the presence of a solid wall of impacted bone grafts and without graft moving under manual pressure (Fig. 1A). The diameter of the last impactor was 4 mm greater than the definitive cup to allow a circumferential 2-mm cement mantle (Fig. 1A). The thickness of the graft layer was at least 5 mm. Once the noncontained defect was modified to appear hemispheric, a trial cup was inserted for positioning followed by cement mixing. Wet gauze soaked in epinephrine 1/500,000 was used to avoid accumulation of blood between the grafts. Next, the cement was pressurized and the definitive cup was positioned (Fig. 1B). The components were fixed with Simplex with tobramycin cement (Stryker Howmedica Osteonics[®], Rutherford, NJ) in eight patients and CMW1

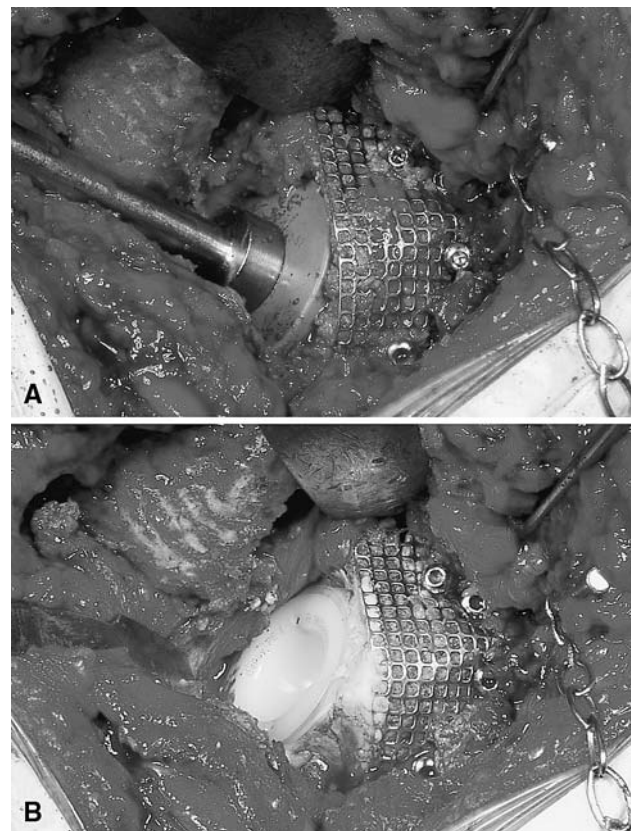


Fig. 1A–B Intraoperative photographs show (A) the last impactor, which is 4 mm greater than the definitive cup to allow a circumferential 2-mm cement mantle, and (B) the definitive implanted cup.

Fig. 2A–B (A) An anteroposterior radiograph shows the left acetabulum of Patient 20 who had septic loosening with cavitory and segmental defects and a dislocated antibiotic-loaded spacer. (B) Forty months postoperative, trabecular incorporation can be seen.



with gentamicin (DePuy[®], Warsaw, IN) in 15 patients. An Ogee (DePuy[®]) acetabular component was placed in 15 cases, an Osteonics Flanged (Stryker Howmedica Osteonics[®]) in seven cases, and a Contemporary cup (Stryker Howmedica Osteonics[®]) in one case. The internal acetabular diameters were 28 mm in 16 cases and 22 mm in seven cases (Fig. 2). The average height of the metal mesh needed to close the bone deficiency was 34 mm (range, 25–40 mm). The average inclination of the 23 cups was 46° (range, 38°–60°) with an average anteversion of 14° (range, 3°–22°). Center of rotation (COR) was determined according to the initial position of the cups using the marking wires relative to the Köhler line and the tear-shaped image with a magnified ruler. Preoperative COR was placed proximally an average of 12.4 mm (range, 0–30 mm), and immediate postoperative COR was placed an average 1.8 mm proximally (range, 0–10 mm).

The rehabilitation protocol included early mobilization and ambulation with a walker and toe-touch weightbearing on the operated side for 45 days. After that, patients were encouraged to progressively weightbear as tolerated until they were free of walking assists (range, 45–120 days).

We (MB, FC) evaluated patients clinically and radiographically at 15, 45, 90, and 180 days postoperatively and then yearly. The Merle D'Aubigné and Postel scoring system was used [11]. Preoperative, immediate postoperative, and last followup COR were measured in every case. Radiolucencies in the allograft-cement interface were classified according to DeLee and Charnley [14]. Acetabular orientation was calculated with the method described by Ackland et al. [1]. To determine allograft incorporation, we followed the radiographic criteria described by Slooff et al. [49] and evaluated graft consolidation and migration

of the acetabular component. Consolidation was defined by the presence of trabecular bone crossing the graft-host union. Owing to the presence of metal meshes and screws, it was not possible to evaluate consolidation of the graft in some DeLee and Charnley [14] zones. Migration of the acetabular components was determined according to the initial position of the cups using the marking wires relative to the Köhler line and the tear-shaped image with a magnified ruler. Cups with continuous radiolucent lines greater than 2 mm thick were considered loose.

Clinical failure was defined as the need for further acetabular revision regardless of the etiology. Radiographic failure was defined as progression of radiolucent lines in the three acetabular areas or migration greater than 5 mm. We determined survival using the Kaplan-Meier survival method using further revision as the end point [25].

Results

Reconstruction survival rate was 90.8% at an average of 35.8 months (range, 24–56 months; 95% confidence interval, 68.1–97.6).

Metal mesh did not prevent cup migration: an average of 5.1 mm (range, 2–25 mm) migration occurred all cases (Table 2). Asymptomatic 8-, 10-, and 12-mm proximal migrations with intact mesh were observed in three patients with bone deficiencies that required between 30- and 35-mm height meshes, respectively. Metal mesh rupture with proximal migration (3, 10, and 15 mm) and without clinical symptoms was present in another three patients who had 25-, 30-, and 35-mm height defects, respectively. One occurred after a fall during which the patient sustained

an iliopubic fracture. Because these patients were asymptomatic, we decided not to reoperate on them. In the 14 remaining patients, no acetabular radiolucencies, migration, graft resorption, loosening, or rupture of the components was observed. The average postoperative Merle D'Aubigné and Postel [11] score was 16.2 points. Of the 69 DeLee and Charnley areas radiographically evaluated in the 23 reconstructions, five had radiolucent lines at the cement-graft interface and all of them were related to radiographic failures.

Two patients had clinical acetabular failure for which they had reoperations. Radiographically, these patients had pulled screws (Patient 7) and bent mesh (Patient 21). The first patient originally had a cavitary and 35-mm height segmental defect (AAOS [10] Type 3, Gustilo and Pasternak [19] Type IV) (Fig. 3A), which was reconstructed with oval mesh on the medial wall and a second mesh on the posterosuperior acetabular region (Fig. 3B). The patient began full weightbearing 30 days postsurgery and had rupture of the acetabular mesh 6 months postoperatively

(Fig. 3C). She underwent revision surgery with an acetabular reconstruction ring. The second reoperation was in a patient with a 30-mm height segmental defect (AAOS [10] Type 3, Gustilo and Pasternak [19] Type III). At 24 months postoperatively, she had progressive superolateral 15-mm migration and bent mesh. This patient also had revision surgery using a reconstruction ring. Biopsy specimens obtained during revision surgery from the allografted acetabular zone revealed necrotic bone and fibrous tissue. We observed no intraoperative complications related to the use of the grafts or meshes. There were no postoperative peripheral neurologic complications. One patient experienced dislocation 6 weeks postoperatively and was treated nonoperatively. One patient had a hematogenous deep infection after an infection of the urinary tract and without radiographic signs of loosening or migration 30 months postoperatively. This patient was treated with surgical débridement, component retention, and antibiotic therapy suppression, and showed no signs of loosening 40 months after the initial reconstruction.

Table 2. Results

Patient number	Mesh height (mm)	COR preoperatively	COR postoperatively	Migration (mm)	RL lines	CF	RF	Observations
1	25	20	5	10	No	No	Yes	Mesh rupture
2	25	0	0	2	No	No	No	
3	35	5	0	2	No	No	No	
4	30	8	0	15	No	No	Yes	Mesh rupture
5	25	2	0	3	z3 3-mm prog	No	Yes	Mesh rupture
6	35	15	5	2	No	No	No	
7	40	30	0	25	z1, 2, 3	Yes	Yes	Failure, reoperation
8	35	20	5	2	No	No	No	
9	35	5	0	2	No	No	No	
10	40	5	0	2	No	No	No	
11	35	20	10	2	No	No	No	
12	30	0	0	3	No	No	No	Infection, débridement
13	35	15	3	3	No	No	No	
14	40	5	0	3	Unavailable	No	No	
15	25	10	0	2	No	No	No	
16	40	0	0	10	z2, 3 10-mm prog	No	Yes	
17	35	20	0	3	No	No	No	
18	40	30	0	3	No	No	No	
19	40	5	0	2	No	No	No	
20	35	25	0	3	No	No	No	
21	35	20	10	15	z2, 3 15- mm prog	Yes	Yes	Failure, reoperation
22	35	15	0	3	No	No	No	
23	30	10	5	2	No	No	No	

COR = preoperative center of rotation; RL Lines = radiolucent lines according to DeLee zones; CF = clinical failure; RF = radiographic failure; z = zone; prog = progressive.

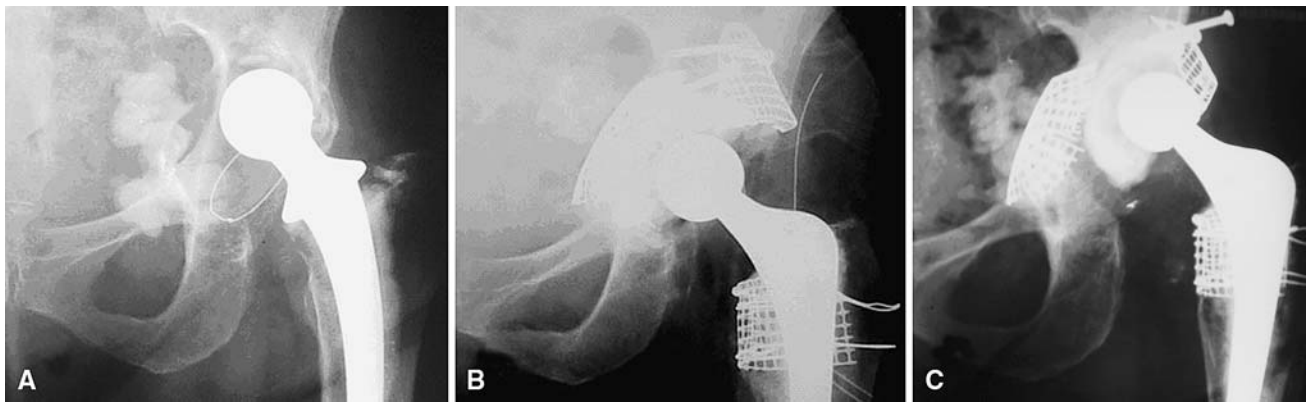


Fig. 3A–C (A) A combined segmental and cavitary bone defect is seen on the anteroposterior left acetabular preoperative radiograph for Patient 7. (B) An immediate postoperative anteroposterior radiograph

shows reconstruction with a medial wall mesh, a peripheral mesh, and impacted bone allografts. (C) Mechanical failure of the medial and segmental mesh is observed 6 months postoperatively.

Discussion

Segmental and cavitary acetabular defects require supplemental devices to close peripheral defects if the bone impaction grafting technique is used. We analyzed our survival rate in patients with combined deficiencies reconstructed with metal mesh, impaction grafting, and a cemented cup to determine if metal mesh could prevent cup migration.

Limitations of this study include a small patient cohort and lack of a control group of patients with similar age, weight, and acetabular defects. Migration was measured without radiostereometric analysis, which could have misdiagnosed sockets with less than 4 mm migration. Despite the substantial amount of migration, these patients had good pain relief, and on followup, we did not consider their bone stock jeopardized, therefore rerevision was not considered. Migration without revision has been described by others [35]. Longer followup is necessary to determine whether any of these reconstructions ultimately will require reoperations (Fig. 4).

Treatment options in segmental acetabular defects include the use of a high COR [12, 27, 45, 56], structural grafts [20, 24, 46, 52], impacted allografts [8, 9, 37, 42, 44, 54], PMMA filling [26], large cementless cups [13, 22, 36, 47, 51], bilobed cups [4, 29], and reconstruction rings [3, 17, 18, 28, 40]. Results vary among these techniques (Table 3).

Impacted bone allografts reportedly have satisfactory clinical and radiographic medium-term results in primary and revision surgery [2, 8, 9, 39, 44, 49, 55], with survival rates approaching 95% at 20 years [42, 44]. Comba et al. reported a 96% survivorship rate in 142 revisions followed up for an average of 51.7 months that increased to 98% when infection was excluded [8]. These findings prompted us to consider an initially stable reconstruction that

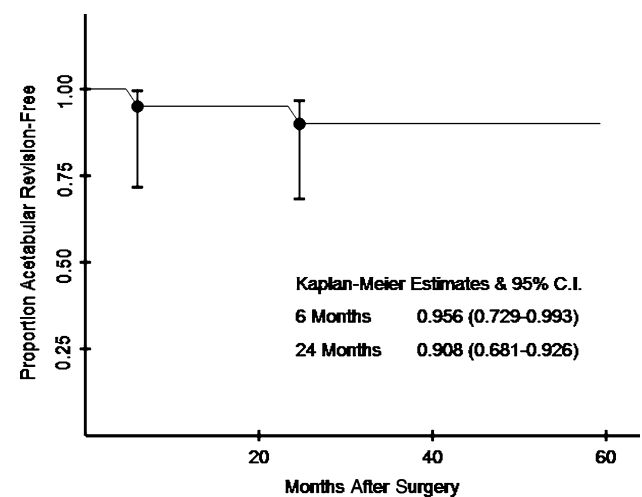


Fig. 4 The survivorship curve shows the Kaplan-Meier [25] analysis with the need for further revision as an end point.

surgically converts a noncontained defect to a hemispheric contained defect could reach our previous results.

Metal meshes have been used as surgical implants for a long time [30, 31]. Although it has been reported that the combination of metal mesh with PMMA increases the tension force of the cement [41, 50], the stresses in the PMMA are complex, and a difficult analysis of individual cases would be needed to ascertain whether the construct resistance increased.

A comparison with other series of patients treated with this method is difficult. Harris and Jones presented a series of 10 patients with acetabular medial wall defects reconstructed with metal mesh and no bone grafts without loosening or mechanical failure at 11 months average followup [21]. At an average of 6.8 years followup, the complication rate was 75% with 11% of the cups showing migration [23]. van Haaren et al. [54] recently published a series of 71 acetabular revisions with large defects

Table 3. Results of acetabular revision surgery using different methods

Authors	Year	Reconstructive method	Cases	Success rate	Followup (years)	Complications
Katz et al. [26]	1997	PMMA filling	81	35%	10	16% acetabular rerevision rate, 22% reoperation rate
Dearborn and Harris [12]	2000	Jumbo cups	15	100%	7	21% dislocation, 21% infection
Koster et al. [29]	1998	Oblong cups	102	98%	3.6	10% nerve lesion, 8% migration
Kelley [27]	1994	High hip center	20	95%	3	11% dislocation, 25% femoral loosening
Templeton et al. [51]	2001	Uncemented cups	28	97%	13	
Goodman et al. [18]	2004	Reconstruction rings	61	76%	15	10% nerve lesion, 10% dislocation, 5% infection
Shinar and Harris [46]	1997	Bulk allografts	15	40%	16	
Comba et al. [8]	2006	Impaction grafting	142	96%	4	
van Haaren et al. [54]	2007	Impaction grafting	71	72%	7	70% failure rate in large defects
Current		Impaction grafting and metal mesh	23	90%	3	

PMMA = polymethylmethacrylate.

reconstructed with impacted allografts, including 44 cases with metal rim mesh with an overall survival rate of 72% (95% confidence interval, 54.4–80.5) at a mean of 7.2 years. Fifteen cases (34%) with rim mesh failed. They emphasized failures were observed predominantly in AAOS Types 3 and 4 defects with insufficient support for the bone graft. Graft incorporation was present in only four of their 13 available histologic biopsies. These findings are similar to one of our clinical failures and to those observed by van der Donk et al. [53], indicating graft incorporation is essential for survival of the construct. Because incorporation depends on the quality of the host bone, this condition could be more important than the size or type of bone defect.

Roidis et al. described low active bone formation in tibial defects of rabbits contained by metal mesh and impacted allografts [38]. Although their data may cause concern, we consider the experimental model does not accurately reflect the clinical situation, because the animals were not bearing weight on the operated limb, a factor that influences incorporation of the grafts [43]. Furthermore, Bolder et al. recently recommended using open wire mesh instead of strut grafts for segmental femoral defect reconstruction in combination with impaction grafting to allow for optimal revascularization in an area with impaired vascularity [5]. Histologic observations of biopsy specimens obtained from impacted bone allografts contained by calcar femoralis metal mesh showed morselized bone incorporation under these devices was not affected [7].

We consider severe segmental defects combined with major medial wall defects a contraindication for the use of metal mesh. Although one of our patients in whom treatment failed did not follow the rehabilitation protocol, that reconstruction had this type of preoperative deficiency.

In patients with these deficiencies, we prefer to use an acetabular reconstruction ring with impacted allografts. However, some of the radiographic failures we observed in these patients were in AAOS Type 3 combined simple defects. Potential causes of failure may include graft resorption, micromovement, and mechanical instability. Stainless steel fatigue resulting in mesh rupture and migration could be explained by this mechanism. Metal trabecular augments [33] in combination with impacted bone allografts could offer a more stable construct initially while the impacted allografts are incorporated to the host bone. Other advantages of metal augments are the ability to use ingrowth acetabular components and the need for less volume of bone graft. The contact between the cup flange and the augment could prevent vertical migration. Vascularization of the native bone also could have played a major role in the failures we observed and could explain radiographic failures in relatively simple cases. Bone graft incorporation enhancers may accelerate the incorporation process to avoid such complications in the future.

Although long-term followup in patients is mandatory to assess ultimate survival of these reconstructions, we believe metal mesh fixed to the ilium combined with impacted allografts and a cemented cup should be considered among the implants used in revision surgery. We do not recommend its use for severe combined bone defects, although we observed clinical and radiographic failures in different kinds of bone deficiencies. In comparison with contained deficiencies, better underlying host bone quality seems an essential condition for the success of these constructs. Because this condition cannot be interpreted with preoperative diagnostic methods, we do not consider indications for use of this method to be completely elucidated. Metal mesh, impaction grafting, and a

cemented cup should be considered for reconstruction of medium uncontained acetabular defects, but not for severe combined deficiencies.

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