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Acetabular and Femoral Reconstruction With Impacted Graft and Cement

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Loosening of primary cemented and noncemented components of total hip arthroplasties always is accompanied by a loss of bone stock. There are several options for reconstruction of the acetabular and femoral defects. The authors' treatment of choice is a standardized cemented revision procedure with tight impaction of morsellized cancellous autograft or allograft chips in acetabular and femoral reconstructions. In this study, the clinical and radiographic evaluation of acetabular defects reconstructed with impacted morsellized allograft femoral heads was described. A cemented cup supplemented with morsellized cancellous grafts and wire meshes in cases of segmental defects was sufficiently stable to allow for complete graft consolidation. After a mean followup of 70 months of 88 hips, 4 cases of clinical failures (including 1 infection) and 6 cases of radiologic failure of the reconstructions were observed, resulting in a failure percentage of 11.4% after 5 years. Autografts and allografts were equally effective. Because the clinical success of the technique also was supported by the results of histo-

logic and biomechanic studies in animals, the authors were encouraged to continue this technique, not only in the acetabulum, but also in the femur.

It is generally accepted that aseptic loosening is the most common long-term complication of total hip arthroplasty. The migration of implants during loosening and procedures to remove the prosthesis and cement during revision induce significant bone destruction, resulting in enlargement of the acetabulum and widening of the femoral medullary cavity. Choices have to be made regarding the reconstruction of the bone stock loss, how to repair the anatomy of the acetabulum and femur, and how to achieve direct postoperative functional stability of the revised total hip.

The use of bone grafts in orthopaedic surgery is described extensively in the literature and is generally accepted as a reconstructive technique.^{1,3,10,13,14,25,27} Regardless of the type of graft used, essential factors that influence the incorporation process are the stability of fixation, the amount of contact between host and graft, the strain pattern within the graft, and the degree of antigen matching. However, the size of the graft has also been found to play an important role in the graft incorporation process.

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The revascularization of graft bone is essential for successful bone incorporation. In cases of allograft bone, the host contributes all vascular and cellular elements required for incorporation of the graft. However, revascularization may differ among different types of graft. In theory, a cancellous graft allows rapid vascular invasion and should therefore enable a more rapid, complete, and uniform incorporation without mechanical weakening, as compared with the incorporation of solid cortical graft. Clinical studies of massive structural trabecular allografts¹⁵ used in revision or tumor surgery⁸ showed that the incorporation of these structural cancellous autografts and allografts is in many cases confined to the outer few millimeters, leaving a more centrally located permanent necrotic core, which in time may cause failure of the graft.

The authors have found that grafting with impacted allograft chips does not have the drawbacks of structural allografts. Since the late 1970s, impaction grafting combined with cement fixation of the prosthetic components has been their treatment of choice for restoring bone stock on the pelvic side and since the 1980s also on the femoral side. In 1984, their clinical experience was published²³ with a modification of the techniques developed by Hastings and Parker¹⁶ and McCollum et al.¹⁷ Morsellized allografts were used, and these chips were impacted tightly in the enlarged acetabulum. In cases of segmental medial and peripheral defects, containment was effected by reconstructing these defects with metal meshes, which resulted in direct initial stability of the reconstruction.

This reconstruction method was modified in close cooperation with Prof. Ling and Dr. Gie from Exeter (United Kingdom) and with representatives from Howmedica International for the clinical application in the femur to restore the femoral bone stock deficiencies after loosening of femoral components of total hip arthroplasty.^{11,12} The initial clinical experience with the reconstruction method in the femur was reported in 1991 by Simon et al.²² In the same year, Schreurs et al.^{20,21}

showed experimentally the increased stability of the femoral component obtained by combining the use of impacted graft and cement.

In the current study, the authors presented their 5-year followup of acetabular revisions of reconstructions with morsellized chips, wire meshes, and cement as well as a short-term followup of a few femoral revisions.

MATERIALS AND METHODS

Between January 1979 and January 1988, 91 cemented revision hip arthroplasties in 83 patients were done at the authors institution with the acetabular reconstruction technique with impaction grafting, wire meshes, and cement. The indications for surgical intervention were clinical and radiographic loosening. All patients reported pain and functional disability. Patients were excluded from the followup study if the revision procedure was done without bone grafts or if solid bone grafts or a metal acetabular reinforcement ring had been used.

Acetabulum

In the first half of 1990, all patients eligible to participate in the study were invited for a clinical and radiographic examination by 2 of the authors (T.J.J.H.S. and J.W.S.). Seven patients (7 hips) had died of causes unrelated to the revision procedure. One patient (1 hip) was lost to followup. Most patients were followed yearly, thus their records and radiograph results from previous visits could be evaluated. Finally, 80 patients (88 hips) entered the study with an average followup of 70 months (range, 24–132 months). The average age at the time of revision was 62 years (range, 33–89 years).

Femur

Between March 1991 and November 1992, 10 cemented revision arthroplasties were done with reconstruction of the femoral canal by means of impacted morsellized allografts and cement. In 9 of these cases, the acetabulum and impacted allografts were reconstructed simultaneously. All of the patients' records were reviewed. The mean followup time was 24 months (range, 14–34 months) (see Table 1). Seven of the patients were women and 3 were men, and the mean age at the time of revision was 64 years (range, 35–76 years).

TABLE 1. Summary of Results of Femoral Revision with X-Change Revision System

Case No.	Age (years)	Gender	Length (cm)	Weight (kg)	Side	Original diagnosis	No. of Earlier Revisions	Implant Removed (type)	Followup After Revision (months)	Endo-Klinik Classification	Preoperative Harris Hip Score		Postoperative Harris Hip Score		Complications
											Score	Score	Score	Score	
1	76	F	162	60	R	Osteoarthritis	1	Lubinus SP2	34	3	56	76	76	76	Fracture 23 months postoperative
2	35	F	165	78	R	Osteoarthritis	1	Müller curved stem	29	2-3	59	101	101	101	
3	67	M	190	84	R	Osteoarthritis	0	Unknown	27	3	47	96	96	96	
4	66	F	162	60	R	Rheumatoid arthritis	1	Müller straight stem	27	2-3	—	—	—	—	Fracture 4 months postoperatively
5	69	M	178	67	L	Osteoarthritis	2	Müller straight stem	26	2-3	34	97	97	97	
6	70	F	158	62	R	Osteoarthritis	2	Wagner long stem	22	4	24	97	97	97	
7	65	F	167	79	R	Osteoarthritis	0	Charney	22	3	36	90	90	90	Femoral fissure operation
8	69	M	180	80	L	Osteoarthritis	1	Lubinus SP2	18	4	59	97	97	97	
9	71	F	165	58	R	Rheumatoid arthritis	0	Müller curved stem	18	2-3	37	95	95	95	
10	52	F	158	73	R	Osteoarthritis	0	Müller curved stem	14	1	58	100	100	100	Perforation shaft at operation

The acetabular defects were classified on the basis of the preoperative and immediate postoperative radiographs and the operation charts. The American Academy of Orthopaedic Surgeons' classification for acetabular defects according to D'Antonio et al⁵ was used. In the femoral reconstruction group, the defects were assessed according to the Endo-Klinik classification.⁷ The data of the acetabular defects in this group were not included in the current study. Early in the series, bone grafts were taken from the iliac crest as autografts and sometimes combined with allografts. Most of the grafts were deep-frozen femoral head allografts from the hospital bone bank. Allografts were used in 65 hips. The grafts were prepared with a rongeur during surgery. The chip size was substantial (1 cm³), compared with the smaller-milled chips used for femoral reconstructions. The amount of the graft used varied from 1 to 3 femoral heads per patient depending on the severity of the acetabular defect. For all patients, the hip joint was approached by a posterolateral incision, and the exposure was combined with a trochanteric osteotomy in only 3 cases. The proximal part of the femur was exposed and mobilized carefully and extensively before the hip was dislocated. The entire socket of the acetabulum was exposed, from the transverse ligament to the superior margin and from the posterior wall to the anterior wall. After being tested for loosening, both components were extracted from the cement mantle. After removal of the socket and all of the cement, the fibrous interface was separated from the thin, irregular acetabular wall by means of sharp spoons. Removal of this layer led to abundant bleeding of the often sclerotic bone. At least 3 specimens were taken from the interfacial fibrous membrane for frozen sections and bacterial cultures. After these tests were performed, a perioperative prophylactic antibiotic regimen was started. The wall and floor of the cavity were examined to establish their integrity and bone quality and to detect any hidden defects. Reconstruction was directed to the closing of the medial and peripheral segmental acetabular rim defects with a metal-wire mesh. In this way, the segmental defects became a cavitary defect. This defect was filled with firmly impacted morsellized cancellous allografts, and the graft surface was covered by a second metal mesh. A polyethylene cup was cemented directly onto this reconstruction (Figs 1, 2). Care was taken to re-

Fig 1A-D. (A) Schematic drawing of a medial defect, a perforation of the acetabular medial wall (P). (B) Radiograph of a loose acetabular cup that migrated upward, leaving a gap at the site of the teardrop (lower arrows). The loosening process also has created bone loss in the acetabular roof (upper arrows), which is called a medial segmental and cavitary defect. (C) Schematic drawing of the reconstruction technique showing the closure of the medial defect with a metal mesh (M) and the impacted morselized chips (dotted area) filling the defect. The layer of chips was covered by a second mesh (M), and a cup was cemented in place. A new acetabulum of a desired size is created in the anatomic position near the teardrop. (D) The 5-year followup radiograph of the same patient after the acetabular reconstruction (Modified with permission from Slooff TJJH, Schimmel JW, Buma P: Cemented fixation with bone grafts. *Orthop Clin North Am* 24:667-677, 1993).²⁴

pair the hip by packing as much graft material as necessary until the socket was brought down to the level of the transverse ligament, which is the anatomic location of the acetabulum, but with a graft thickness of at least 5 mm.

On the femoral side, all of the bone cement and debris was removed with chisels and curettes. The canal was irrigated by means of pulsatile lavage. Segmental defects of the femoral tube were repaired with wire mesh to contain the graft (Fig 3). For facilitation of accurate and vigorous packing of the graft, special instruments were developed jointly at the Universities of Exeter (United Kingdom) and Nijmegen (the Netherlands) and in close collaboration with Howmedica International (United Kingdom). This technique was described extensively by Gie et al^{11,12} and by Schreurs et al.¹⁹⁻²¹

Postoperative treatment included anticoagulation therapy for 3 months and systemic antibiotic therapy for 24 hours. Indomethacin was administered for 7 days to prevent heterotopic ossification. Passive motion exercises were started 24 hours after the operation, partial weightbearing after 6 weeks, and full weightbearing after 3 months.

All patients were seen in the authors' outpatient department 6 weeks, 4 months, 1 year, and 2 years after the operation. Harris Hip Scores were estimated before and after surgery by interview and examination. All preoperative and postoperative radiographs were examined and graded consensually by 2 surgeons and a radiologist. Preoperative radiographs were graded according to the Endo-Klinik classification in case of femoral bone stock loss.⁷ Acetabular defects were classified as segmental or cavitary according to D'Antonio et al.⁵ Radiographs were used to evaluate consolidation and incorporation of the graft, migration measurement, and the occurrence of radiolucencies. Consolidation was defined as the presence of clearly delineated trabecula crossing the graft-host junction. Graft incorporation was assessed according to the criteria of Conn et al⁴ and was considered to be incorporated when an identical radiodensity of the graft and host bone, with a continuous trabecular pattern throughout, existed. Migration of the cup was established with digitization of the serial radiographs. Reliable, reproducible measurements were done on the monitor (Fig 4). The position of the socket was determined by the metal wire, and

Fig 2A–D. (A) Schematic drawing showing the acetabular rim defect anteroposteriorly and cross-sectionally. A combined segmental and cavitary defect exists. (B) Radiograph of a failed acetabular rim reconstruction with a solid structural graft and screw fixation. The result is visible: a segmental defect in the acetabular wall, a broken prosthetic cup, and a luxated femoral component. (C) Schematic drawing of the reconstruction. The acetabular rim is reinforced with a metal mesh (M) and the defects are filled with impacted morsellized grafts (dotted area). (D) Direct post-operative radiograph showing the reconstruction with the acetabular component at the anatomic site near the teardrop (Modified with permission from Slooff TJJH, Schimmel JW, Bursa P: Cemented fixation with bone grafts. *Orthop Clin North Am* 24:667–677, 1993.²⁴

the cup was measured relative to Köhler's line and the teardrop line. Radiographs were digitized (TEA Image Manager System, DIFA Measuring Systems Ltd, Breda, the Netherlands), and a computer program was developed. This program allowed for reproducible measurements to be made according to a coordinate system applied in each radiograph. In each radiograph, the magnification factor was determined based on the prosthetic head of 32 mm, which was used for all patients. The Köhler line was chosen as the Y axis, and K was the line along the medial aspect of ilium and ischium. The line T, running perpendicular to the line K and tangential to the inferior aspect of the teardrop, was chosen as the X axis. As a reference point on the acetabular cup, the center of the projected elliptical image of the metallic ring at the periphery of the cup was chosen. This point, c, which was considered to be the center of the cup, was determined through bisection of the long axis a–b of the projected ellipse. The angle between the long axis of the ellipse and the line T was defined as the inclination angle and was measured in each radiograph.

Subsidence of the stem within the bone cement was estimated as described by Fowler et al.⁹ Subsidence of the stem-cement mantle relative to the cortical bone was also estimated. Radiolucency at the graft-cement interface was assessed according to the criteria of DeLee and Charnley.⁶ Cups with continuous radiolucent lines thicker than 2 mm in all 3 segments were considered to be loose.

RESULTS

The results of the femoral revisions were preliminary and are described in the Discussion section.

At the time of the study, 4 acetabular components had been revised because of recurrent infection in 2 cases and aseptic loosening with migration in 2 cases. The postoperative Harris Hip Score averaged 87 points and, compared with the average preoperative score of 44 points, showed that the clinical results improved after the reconstruction. Consolidation

Fig 3A–D. Revision of an acetabular and femoral loosening of a straight-stem Muller prosthesis. (A) The preoperative situation. Moderate migration of the cup with radiolucent lines in all 3 segments. Around the stem a clear radiolucent lining is visible around the cement mantle. (B) Radiograph done immediately after the revision with the impacted morsellized chips in the acetabulum and femur. The X-Change Revision System and the Exeter Hip System were used. (C) Radiograph 1 year after surgery. Neither migration nor radiolucency is visible. (D) Radiograph 2 years after surgery. The position of the cup is the same as it was immediately after surgery. No migration has occurred. Signs of remodeling of the impacted graft are visible at the femoral side.

of the graft, which involves union of the graft to the host bone, was complete in all 88 hips. Signs of incorporation were difficult to assess

Fig 4. Radiograph with coordinate system for measurement of subsidence. See text for explanation of the lines and symbols.

because of the irregularities at the graft-cement interface. Eight acetabuli showed incomplete graft incorporation: 2 cups had remained stable during the followup period; 5 cups had migrated with partial graft resorption but were clinically asymptomatic; and 1 cup had been rerevised because of progressive loosening. Migration occurred in the 5 cups with incomplete graft incorporation. These cups were considered to be radiographically loose. One cup showed progressive continuous lucency with evident signs of incomplete graft incorporation, although migration had not occurred in this case. Clinical failures were seen in 4 cases and radiographic failures in 5 cases because of migration of >5 mm (4 cases) and continuous lucency thicker than 2 mm (1 case). The overall success rate was therefore 78 of 88 hips (88.6%).

DISCUSSION

The literature offers several options for reconstruction of the acetabulum in a patient with implant failure combined with loss of bone stock.^{15-17,26} In the authors' opinion, the reconstruction method must be directed to replace the loss of bone, to repair the hip mechanics to normal, and to obtain stability. All of these goals can be achieved with the use of impacted morsellized grafts, the establishment of containment of the graft, and the use of polymethylmethacrylate cement. Harris¹⁵ introduced a reconstruction method that involved autogenous solid and structural grafts that were fixed with screws and bolts to the iliac wall. Five years later, he reported an increasing number of graft resorptions. The authors of the current study believe that the quality of these degenerative femoral heads may be inadequate, and during the revascularization phase of the incorporation process, this structure will partly resorb and collapse. Resorption and collapse was not seen radiographically in the authors' patients nor in the animal models.^{2,20,21} For example, a study of goats was designed to support the clinical use of morsellized cancellous allograft chips with cemented total hip arthroplasties. The purpose of this experiment was evaluate histologically the processes involved in graft incorporation. The surgical technique was comparable with the technique used for the human situation. This method resulted in a rapid union of graft and host bone. Beginning at 24 weeks, very little of the original graft bone remained, and a new trabecular bony structure of lamellar bone was formed. Over time, no signs of local lysis in the graft or resorption or collapse of the reconstruction were seen. The results of this study encouraged the authors to apply this biologic reconstruction method more extensively in clinical practice.

Serious acetabular defects, even when combined with compromised acetabular columns, were restored successfully with this reconstructive method. Reconstruction was stabilized by containment of the graft, firm im-

paction, and the use of cement. Adequate containment is a prerequisite that can be achieved by screwing metal meshes to the iliac bone.

However, the main advantage of morsellized chips lies in the close adaptation of the graft to the irregularities of the host bed without any gap formation. This is in contrast with the use of structural femoral allografts in which cystic lesions as part of the degenerative process may be present. Structural grafts also contain a high amount of fatty marrow tissue that may decrease the incorporation process.²⁷ The fatty marrow is squeezed out of the graft, which may be advantageous to the incorporation process with use of impaction grafting.

After impaction, the surface of the graft shows many irregularities, which improve the cement-bone-interlock and primary stability. Studies from Roffmann et al¹⁸ showed that new bone formation is possible in direct contact with cement. This confirms the results of histologic studies in animals.^{2,20,21} The tight impaction of the graft and the cement protrusions into the graft also provided an increase of the initial stability of the entire reconstruction. Differences between the radiologic evaluation of autogenous grafts and allografts were not observed.

The reconstruction of the deficient acetabulum must be directed to the repair of normal hip mechanics. This restoration of the anatomic center of rotation included improvement of normal hip-joint motion and the repair of leg-length discrepancy. The authors of the current study do not agree with Harris¹⁵ regarding a high center of hip rotation. In all of the authors' cases, the cup could be placed at the anatomic location by varying the thickness of the graft. With all of the advantages of this biologic reconstruction method, questions such as the following remain: What is the optimal size of the chips? Are there limitations to the thickness of the graft layer? What are the differences between the incorporation process of a solid cancellous graft and of impacted cancellous chips, and what is the

exact clinical time course of incorporation of the chip graft?

Although the answers to these questions are not known, the authors continue to use this method, with caution, for deficient acetabulum and femur. The preliminary results of the femoral reconstructions are encouraging (Table 1). The results of longer followup studies, as reported by Gie et al^{11,12} justify, its further use.

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