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Acetabular Reconstruction Using Bipolar Endoprosthesis and Bone Grafting in Patients With Severe Bone Deficiency

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Eighty-one patients who had hip reconstruction with bone grafting and bipolar endoprosthesis for severe acetabular deficiency were reviewed retrospectively at 3 to 8 years postoperatively. Failed total hip arthroplasty was the most common indication for operation. Bone grafts were fixed bone blocks, morselized cancellous bone, and wafer-type grafts used singly or in combination. The average Harris hip rating score was 49.9 points preoperatively, 81.4 points at 1 year, and 70.8 points at latest followup examination. The 35 unsuccessful procedures included 25 reoperations for implant removal (resection arthroplasty or revision) and 10 cases pending revision. At latest followup examination, 54.7% of patients considered themselves improved and 62.7% had no or mild pain. Eighty-five percent of cases had radiographic evidence of component migration that was superior and medial in direction. Overall probability of implant survival was 96% at 1 year, but only 47% at 6.5 years postoperatively. Because of the high failure rate, this procedure has a limited role in hip reconstruction, but may be a reasonable part of a staged reconstruction for patients with massive bone loss or in certain revision cases where instability is a concern.

Severe acetabular bone deficiency can be a major challenge at the time of total hip arthroplasty. Deficiencies may be caused by several different conditions, including rheumatoid arthritis, congenital or developmental dysplasia, and acetabular fractures.[4,17,27] This article is concerned especially with those deficiencies that arise from complications or failures (or both) of total hip replacements.[3,9,38,39,47,50]

The methods for managing particular defect patterns are similar regardless of the cause of the defect. Factors that have a major effect on reconstruction of a particular defect include the characteristics of the bone loss, the available bone graft resources, the implant and equipment options, and the preference and experience of individual surgeons.

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Whereas resection arthroplasty is a method of managing gross acetabular deficiencies, clinical outcomes after resection with regard to function and pain relief are frequently disappointing. Repair techniques using cement and various mechanical supplements such as protrusio rings and wire mesh have had poor long-term outcomes,[21,26] and longer-term failure rates of 9% to 60% have been reported.[1,3,31,32,40,47]

These high failure rates provided an incentive for the development of uncemented options, in which fixed, ingrowth acetabular components in conjunction with bone graft have been used for defects encountered during primary and revision total hip arthroplasty.[13,21,24,26] Bone grafts have been reported to be of value when used in several forms, including cancellous bony chips, corticocancellous wafers, and bone blocks used with or without internal fixation.[17,18,29,45] Recommendations have emerged regarding the use of autogeneic and allogeneic bone, cancellous and structural graft, anatomic source, fixation method, and trabecular orientation of block grafts.[9,28,39] Unfortunately, interpretation of these recommendations is hampered by a shortage of long-term clinical data regarding their effectiveness.

Techniques for adapting bipolar endoprostheses, such as the Bateman[2] and Gilliberty,[19] with extra-large outer-bearing diameters combined with allobone grafting for repair of acetabular deficiency, were described by Murray[37] and Wilson and Scott[54] in 1990; recently Wilson and Scott[55] described promising results.

Selected cases of failed total hip arthroplasty and gross acetabular bone deficiencies have been selected since 1983 at the authors' institution for the application of this type of reconstructive technique using bipolar endoprosthesis and bone grafting in lieu of resection. The possibility that later conversion to a conventional total hip arthroplasty after graft incorporation or deficiency repair (or both) might be required was not ignored and was frequently discussed with the patients; but shorter-term outcomes seemed satisfactory enough in 1991 to have encouraged the belief that the initial procedure might be definitive for many patients.[35]

The purpose of the present study was to review the longer-term experience with this same group of reconstructions to assess the durability of the reconstructive technique.

MATERIALS AND METHODS

From January 1983 to December 1985, 81 patients (45 women and 36 men) with severe acetabular deficiency were treated with bone grafting and insertion of a bipolar prosthesis. Their average age at the time of operation was 52.3 years (range, 22–89 years).

The most common indication for operation was aseptic loosening of a total hip prosthesis (60 patients [74%]). Other indications were failed resurfacing arthroplasty, 10 patients (12%); congenital dislocation or dysplasia of the hip with resulting destruction of bone stock in the acetabular dome, 6 patients (7%); Girdlestone procedure, 3 patients; and failed arthrodesis and degenerative disease with protrusio acetabuli in 1 patient each.

Of the patients, 77 (95%) had a previous operation: 34 had 1 operation; 19, 2 operations; and 24, >2 operations. The average number of previous operations was 2 (range, 0–8 operations). By diagnosis, among the 81 patients 6 had congenital dysplasia of the hip (3 had had a pelvic "shelf" osteotomy, and 3 had not had a previous operation); 1 had degenerative joint disease and protrusio acetabuli (no previous operation); 1 had an unsuccessful total hip arthroplasty and 2 degenerative joint disease (all 3 had had a Girdlestone procedure); 1 had a failed arthrodesis for congenital dysplasia of the hip; 60 had a failed total hip arthroplasty; and 10 had a failed surface arthroplasty. Therefore, only 4 patients had no previous operation.

Preoperative evaluation with radiographs (anteroposterior view of the pelvis and true lateral view of the hip) was performed in all patients. Aspiration and subtraction arthrograms or technetium bone scans (or both) and indium-labeled leukocyte scans were done if infection was suspected.

Classification of Acetabular Defects

By combination of radiographic analysis and observations recorded intraoperatively, the acetabular bony defects were characterized according to the classification scheme developed by the American Academy of Orthopaedic Surgeons Committee on the Hip.[11] There were 49 segmental Type I defects (31 peripheral, 18 medial), 14 cavitary Type II, 17 combined Type III, and 1 Type V arthrodesis. There were no cases of pelvic discontinuity, Type IV.

Surgical Technique

The surgical approach varied according to the preoperative indications. It was influenced by whether there had been a previous operation and by the extent of bone deficiency. In addition, surgeon preference was an important factor. The direct lateral approach as described by Hardinge[22] was used during most revision arthroplasty procedures. When very difficult acetabular exposure was anticipated, a transtrochanteric surgical approach was used. Also, individual surgeon preference influenced whether the anterolateral approach or posterior approach was used for uncomplicated primary-type surgical procedures. Overall, a transtrochanteric approach was used in 14 patients, a direct lateral approach in 43, an anterolateral approach in 16, and a posterior approach in 8. However, by preoperative diagnosis, significant variability was evident: 39 of 70 patients (56%) with failed prior arthroplasty underwent a direct lateral approach; 15 (21%), an anterolateral approach; 8 (11%), a transtrochanteric approach; and 8 (11%), a posterior approach. Of the 6 patients with congenital dysplasia of the hip as the preoperative diagnosis, 4 (66.8%) underwent a transtrochanteric approach; 1, a lateral approach; and 1, an anterolateral approach. The mean duration of the surgical procedures was 4.1 ± 1.5 hours (range, 2–7 hours).

Three types of bone graft were used for acetabulum reconstruction: cancellous bone, biconcave disks of cancellous bone, or blocks of bone fashioned from femoral heads. Cancellous bone graft consisted of morselized chips that were pressed into defects and contoured with reverse acetabular reaming. Concave disks of cancellous bone usually were used to cover medial wall defects. With medial defects, an attempt usually was made to achieve a rim fit of the bipolar head. This technique consisted of overreaming an outer rim wider than the central acetabular cavity to allow the bipolar head to be seated on stronger, intact bone and not entirely on the bone graft. Femoral heads were fashioned into block grafts to fit larger peripheral defects of the anterior or posterior walls or superior dome. Cancellous screws with washers were used for the fixation of these grafts, and by using the reamers, a concentric cavity was created to accept the bipolar prosthesis.

Graft types included solid femoral head blocks alone in 2 patients, cancellous grafts in 33, cancellous and solid concave discs in 12, cancellous and solid block femoral heads in 24, and all 3 types of grafts in combination in 10. Autologous bone grafting alone (obtained from the patient's femoral head or from the anterior or posterior iliac crest) was used in 11 patients, bone only from a bone bank in 57, and both autogenous and bone bank grafts in 13. Autogenous graft was used whenever the patient's own femoral head was available, as in primary cases or when the volume of graft was small enough to make use of iliac crest graft feasible. For most patients undergoing revision operation, the volume of graft required made the use of autogenous bone impractical, forcing the use of allograft bone. Decision-making regarding solid or cancellous grafts occurred intraoperatively and was guided by the location, size, and configuration of the bone defect encountered. In general, solid block grafts were used when major defects were present in the weight-bearing portion of the acetabulum superiorly, or for containment of graft when medial wall defects were present. However, simple cavitary-type defects were filled with cancellous graft; thus, solid block-type grafts were used for more severe bone defects, generally of a segmental type, and were frequently subjected to significant loads during the postoperative period (Table 1).

Of the 60 patients with a previous failed total hip arthroplasty, 29 had only the acetabulum revised and 31 had acetabulum and femoral components revised (Table 2). Of the 31 femoral revisions performed for failed previous total hip arthroplasties, femoral loosening was the cause of revision in 30 patients; for only 1 patient was revision necessary because the femoral head

TABLE 1. Type of Bone Graft Used According to Preoperative Diagnosis

Preoperative Diagnosis	Bone Graft						Total No. of Patients
	Autologous		*Homologous*		*Combined*		
	No.	*%*	*No.*	*%*	*No.*	*%*	
Failed THA	3	5	51	85	6	10	60
Failed resurfacing THA	1	10	4	40	5	50	10
Congenital dysplasia of hip	5	83	—	—	1	17	6
Other	2	40	2	40	1	20	5
Total no.	11		57		13		81

THA = total hip arthroplasty.

TABLE 2. New Acetabular and Femoral Components Implanted According to Preoperative Diagnosis

Preoperative Diagnosis	No. of New Acetabular and Femoral Components Implanted	No. of New Acetabular Component Implanted	Total No. of Patients
Failed THA	31	29	60
Failed resurfacing THA	10	—	10
Congenital dysplasia of hip	6	—	6
Other	5	—	5
Total	52	29	81

THA = total hip arthroplasty.

TABLE 3. Type of Femoral Component Used According to Preoperative Diagnosis

Preoperative Diagnosis	No. of New Femoral Component		No. of Old Femoral Component		Total No. of Patients
	Cementless	*Cemented*	*Cementless*	*Cemented*	
Failed THA	21	10	2	27	60
Failed resurfacing THA	9	1	—	—	10
Congenital dysplasia of hip	6	—	—	—	6
Other	4	1	—	—	5
Total	40	12	2	27	81

THA = total hip arthroplasty.

could not be accommodated to a bipolar component, because of a nonstandard head size.

In the 52 patients in whom femoral components were inserted, 12 components were cemented, and 40 uncemented (Table 3). Bone grafting was required for 24 patients with uncemented revised femoral components.

The following types of implants were used: Universal Head System UHR (Osteonics, Allendale, NJ) in 33 patients; Bi-Articular II (Zimmer, Warsaw, IN) in 24; Bicentric Head (Howmedica, Rutherford, NJ) in 17; Bateman Universal Proximal Femoral II (3M, St Paul, MN) in 5; and Bipolar Prosthesis (DePuy, Warsaw, IN) in 2.

The patients were allowed to sit in a chair by the third postoperative day. They then were allowed to walk with crutches or a walker, bearing no weight on the involved extremity. An abduction hip guide brace was used in some patients for periods varying from 6 to 12 weeks postoperatively. Decisions about using an abduction brace were made by the treating surgeon on the basis of the type and extent of the surgical approach needed, the quality of the abductor muscles and the surgical repair achieved, and the relative stability of the arthroplasty with reference to subluxation or dislocation as judged intraoperatively. The length of time of non-weight-bearing varied among patients and surgeons, and ranged from 3 months to 1 year. The time to partial and full-weight bearing also varied according to the patient, the surgeon, and the results of the radiographic evaluation.

Followup Examination

The patients were evaluated through physical and radiographic examinations at 3 months and yearly thereafter. Some patients had 1 or more followup examinations by a local or referring physician.

Although the study dates allowed for a minimum of 7 years of followup observation for all patients, the actual periods of observation varied because of death, loss of contact, or early reoperation. Of the 81 patients, 3 died within the first postoperative year and 3 were lost to followup observation, leaving 75 patients for study. The average followup time for patients who were alive and had not had reoperation because of failure (implant removal, resection arthroplasty, or revision) was 5.5 years (range, 3–8 years). The patients who had unsuccessful operations were evaluated clinically and radiographically to the time of reoperation.

The clinical data of these 75 patients were obtained from personal physical examination for 61 patients and from a written questionnaire supplemented by examination by a local consulting physician for 14, so that a modified Harris hip rating score could be calculated. For every patient, the presence of pain and limp, the use of support devices, and the walking distance and ability to climb stairs, tie his or her shoes, sit in a chair, and get in and out of a motor car were assessed. Also, at the clinical examination, hip motion, presence of deformity, leg-length discrepancy, and presence of Trendelenburg's sign were assessed. The Harris hip rating clinical scores were used for the clinical evaluation.[23] Results were rated as excellent (90–100 points), good (80–89 points), fair (70–79 points) and poor (<70 points).

Standard radiographs were made of all patients before dismissal and at subsequent followup examinations. The radiographs were examined for component position or migration, bone graft migration, incorporation or dissolution, screw breakage or motion, and presence of heterotopic ossification. The cemented femoral components were evaluated in accordance with the categories of definite, probable, and possible loosening described by Harris et al.[25] For uncemented femoral components, the radiographic criteria described by Engh et al[14] were used. Because the landmarks (including the teardrop) were destroyed by bone loss in many of the patients, the standard reference lines proposed by other investigators could not be used.[20,43,52] Superior migration of the prosthesis was determined on supine anteroposterior radiographs of the pelvis by measuring along a line perpendicular to the transischial line.[35] The thickness of the medial wall was measured at the thinnest section between the component head and the inner wall of the acetabulum at the same point on all radiographs. The underlying pathologic condition and subsequent surgical procedure frequently resulted in the obliteration of the teardrop as a useful landmark in these often multiply operated on hips. The outer diameter of the component head was measured on all radiographs to allow correction for magnification.

Survivorship free of reoperation was estimated as a function of time because operation by using Kaplan–Meier survivorship analysis.[30] Survivorship of the prosthesis was assessed from the time of operation to the time of failure, or to the latest followup evaluation if the prosthesis was not removed. Failures were defined as those patients who had reoperation performed (implant removal, resection arthroplasty, or revision) or were advised to have a revision. Any other type of reoperation that did not need removal or reimplantation of the prosthesis was not considered as failure of prosthetic survival. The effects on implant survivorship[41] of age, gender, surgical diagnosis, previous surgical procedures, type of implant, type of acetabular defect,[11] and type of bone graft were evaluated also. The log-rank test was used to assess any association of discrete risk factors on survivorship. The association of continuous or ordinal variables with survivorship was estimated and tested with the Cox[10] proportional hazards model. For comparisons at different time points, paired t-test, sign test, and sign-rank test were used. Probability values <0.05 were considered significant.

RESULTS

Complications

Intraoperative complications included femoral perforations in 12 patients (14.8%) and fracture of the greater trochanter as a result of revisions of failed total hip arthroplasty in 3. Recognized contusion of the sciatic nerve occurred in 1 patient. Breakage of a screw during insertion was the only complication directly related to the acetabulum per se (2.8% of the 36 patients in which screws were used to fix bone grafts).

Major postoperative complications included 2 early deaths: 1 caused by fatal pulmonary embolism and the other by pneumonia. Five patients (6%) had partial sciatic nerve palsies that subsequently resolved. Two patients had a true dislocation of the bipolar endoprosthesis from the reconstructed acetabular cavity: 1, 5 days postoperatively; the other, 1 year postoperatively after a fall. The bipolar endoprosthesis dislocated in 2 patients (2.5%) after component disassembly and required reoperation (Fig 1). In 1 patient, necrosis of the edge of the incision required debridement and primary closure. There was also 1 deep venous thrombosis and 1 nonfatal pulmonary embolus.

Deep infection occurred in 2 patients and was treated successfully with resection arthroplasty, antibiotics, and delayed reimplantation of hip components. Before reconstruction, heterotopic bone was present in 15 patients (20%): Grade I in 12 patients and Grade II in 3. Heterotopic bone formation was present at final followup evaluation after reconstruction in 28 (37.3%) of the 75 patients. On the basis of the classification of Brooker et al,[6] there were 11 patients with Grade I heterotopic bone, 2 with Grade II, 4 with Grade III, and 11 with Grade IV. Thus, clinically significant ectopic bone (Grade III or IV) was seen in 15 patients (20%), only 1 of whom required reoperation for excision. Breakage of screws used to fix bone grafts occurred in 13 patients (36%). In all 13 patients with breakage of the screws used to fix bone grafts, there was bone graft resorption. Superolateral subluxation of the bipolar cup was present in 9 of these patients. Other radiologic findings included block bone graft nonunion in 2 patients and dissolution of the outer third of the block in 3. In 1 patient, avulsion of the abductor muscles and their surgical reattachment was performed. One patient had a femoral fracture distal to the femoral component and was treated elsewhere with open reduction and plate fixation.

Clinical Results

Preoperatively, the patients had an average Harris hip rating score of 49.9 points. This score significantly improved to 81.40 points ($p < 0.0001$) at 1 year postoperatively, but had decreased to 70.83 points at latest followup for the entire group, although this score still was significantly improved from that preoperatively ($p < 0.0001$). In the subset of patients who did not have failure, Harris hip rating score was improved from a preoperative score of 50.23 points to 83.16 points at the latest followup ($p < 0.0001$). The clinical results are summarized in Table 4.

For the entire series, these differences in hip scores were largely attributable to pain relief as a result of operation, but also reflected changes in limp, walking distance, and dependence on gait aids (Table 5). At

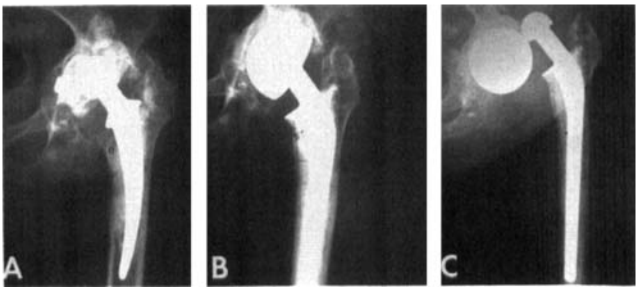

Fig 1. A 67-year-old woman. (A) Aseptic loosening of acetabular and femoral components, left total hip arthroplasty. (B) Immediate postoperative radiograph after bipolar revision and acetabular bone grafting. (C) Disassembly of bipolar head 10 days postoperatively because of implant defect. The patient ultimately had a good result, but the initial technique was considered a failure.

latest followup evaluation, the postoperative level of pain was significantly less than that preoperatively ($p < 0.0001$) but was not as satisfactory as that at 1 year, with the deterioration at latest followup significant compared with the 1-year result ($p < 0.0001$).

Patient satisfaction was assessed at the most recent followup evaluation (or just before revision). Of the 75 patients in this study, 34.7% considered their condition much improved, 22.7% improved, and 20% unchanged from that preoperatively; 22.7% were worse. This also represented a significant change from patient response at 1 year, with significantly fewer patients reporting much improved or improved at latest followup ($p < 0.01$) (Table 5). Ac-

TABLE 4. Harris Hip Rating Scores for Patients in the Study

Patient Groups	Score ± SD (points)	Range
Overall scores for 75 patients		
Preoperatively	49.90 ± 15.60	15 to 89
At 1 year	81.40 ± 14.89	23 to 100*
At latest followup examination	70.83 ± 20.55	23 to 100**
25 patients with reoperation for implant failure		
Preoperatively	49.56 ± 13.43	25 to 87
At 1 year	79.69 ± 18.96	23 to 100†
At last followup examination before reoperation	56.61 ± 17.84	23 to 89‡
50 patients with no reoperation for implant failure§		
Preoperatively at 1 year	50.23 ± 17.29	15 to 89
At 1 year	82.83 ± 10.47	54 to 100‖
At latest followup examination	83.16 ± 13.71	51 to 100¶

* Significant improvement as compared with preoperative scores ($p < 0.0001$).

** Significant improvement as compared with preoperative scores ($p < 0.0001$), and worsening as compared with 1-year postoperative scores ($p < 0.001$).

† Significant improvement as compared with preoperative scores ($p < 0.0001$).

‡Significant worsening as compared with 1-year postoperative scores ($p < 0.0001$), but no significant difference as compared with preoperative scores.

§ Includes 10 patients with revision pending at latest followup examination.

‖ Significant improvement as compared with preoperative scores ($p < 0.0001$).

¶ Significant improvement as compared with preoperative scores ($p < 0.0001$), but no significant difference as compared with 1-year postoperative scores.

TABLE 5. Clinical Results of 75 Patients Who Had Acetabular Reconstruction With Bipolar Endoprosthesis and Bone Grafting*

Clinical Criteria	Preoperatively		At 1 Year		At Latest Followup Examination	
	No. Patients	*%*	*No. Patients*	*%*	*No. Patients*	*%*
Pain						
No pain	2	2.7	39	52	24	32
Mild	8	10.7	30	40	23	30.7
Moderate	32	42.7	4	5.3	20	26.7
Severe	33	44	2	2.7	8	10.7
			$p < 0.0001$		$p < 0.0001$	
Limp						
None	3	4	16	21.3	9	12
Slight	18	24	43	57.3	41	54.7
Moderate	49	65.3	14	18.7	24	32
Marked	5	6.7	2	2.7	1	1.3
			$p < 0.0001$		$p < 0.0001$	
Support						
None	16	21.3	29	38.7	26	34.7
One cane long walks	11	14.7	8	10.7	15	20
One cane full time	19	25.3	23	30.7	18	24
One crutch	5	6.7	1	1.3	1	1.3
Two crutches	24	32	14	18.7	15	20
			$p < 0.05$		$p < 0.05$	
Walking distance						
Unlimited	12	16	34	45.3	22	29.3
4 to 6 blocks	18	24	21	28	17	22.7
1 to 3 blocks	29	38.7	18	24	26	34.7
Indoors	11	14.7	0	0	7	9.3
Bed to chair	1	1.3	0	0	2	2.7
Unable to bear weight	4	5.3	2	2.7	1	1.3
			$p < 0.001$		$p < 0.05$	
Patient response						
Much improved			45	60	26	34.7
Improved			19	25.3	17	22.7
Same			6	8	15	20
Worse			4	5.3	17	22.7
					$p < 0.01$	

* The 25 patients who had reoperation were evaluated at the examination before reoperation.

cording to the Harris hip score, 38 patients (50.6%) were rated as good or excellent, 8 (10.7%) fair, and 29 (38.7%) poor.

Radiographic Results

Average superior migration measured from the transischial line to the top of the bipolar prosthesis was 4.7 mm (range, 0–37.2 mm) at 1 year and had increased to 10.1 mm (range, 0–40.4 mm) at latest followup examination. In 13 cases of superior migration, this was caused by solid bone block failure or collapse (or both) with breakage of the screws used for graft fixation (Fig. 2). In all, 36% of patients (13 of 36) showed screw breakage when these had been used for graft fixation and 25% (9 of 36) had

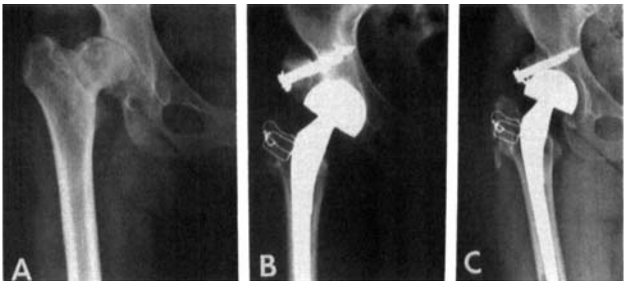

Fig 2A–C. A 43-year-old woman. (A) Painful congenital right hip dysplasia. (B) Three months after bipolar replacement and acetabular reconstruction using bone grafting and screw fixation. (C) Superolateral migration of bipolar prosthesis with bone graft collapse 7 years postoperatively. Note resorption of outer third of bone graft. Patient had revision operation.

associated superolateral subluxation of the bipolar cup after screw breakage occurred (Fig 3). The immediate postoperative medial wall thickness averaged 9.7 mm (range, 1–24 mm). Average medial migration of the bipolar endoprosthesis was 2.3 mm (range, 0–10.7 mm) at 1 year and had increased to 4.15 mm (range, 0–16.5 mm) at latest followup examination (Fig 4).

Radiographically, final success and time to union of bone grafting was difficult to assess. However, in 23 patients (31%) bone grafts were thought to be definitely, solidly united. Major resorption of the bone grafts was clearly present in 11 patients (15%). In 22% of patients (8 of 36) in whom solid bone block grafts had been screwed to the acetabular rim, graft dissolution was present, occurring mainly in the outer, unloaded ⅓ of the block graft.

Definite radiographic loosening of the femoral component was present in 18 patients (24%) at latest followup examination. Four were cemented, and 14 uncemented.

Reoperations

Twenty-seven patients underwent reoperation by the time of the latest followup evaluation, and 10 patients had been advised to have revision of their components, but surgical treatment was pending at latest followup evaluation.

Reoperation included revision in 23 patients, resection arthroplasty for a deep infection in 2, reattachment of avulsed hip abductors of the trochanter in 1, and open reduction and plate fixation of a femoral fracture distal to the femoral component in 1.

An attempt was made to correlate acetabular component performance and femoral component performance with failures. All

Fig 3A–C. A 33-year-old woman. (A) Failed left total hip arthroplasty. (B) Immediate postoperative radiograph after bipolar revision and acetabular bone grafting. (C) Superior migration with bone graft collapse and screw breakage. Patient had pain and revision operation 8 years postoperatively.

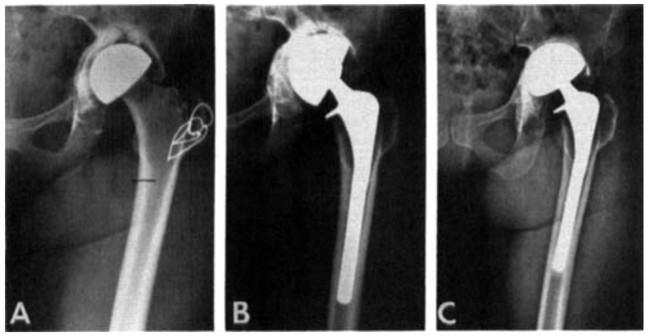

Fig 4A–C. A 32-year-old woman. (A) Failed left surface hip arthroplasty. (B) Four months after bipolar revision and acetabular bone grafting. (C) Seven years postoperatively with bone graft collapse and superomedial migration of prosthesis.

patients had pain before revision, or if revision was pending, also because of pain. Of the 23 patients who had revision surgery, 10 (43%) had revision only of the acetabular component and 13 (57%) had revision of the acetabular and the femoral components. Thirteen of these patients (35%) had femoral component loosening, but the main reason for revision surgery was superior subluxation of the component in 19 patients, dislocation after disassembly in 2, and femoral loosening alone in 2. Thus, 21 of 27 reoperations (78%) were attributable to failure of the acetabular component. Of the 10 patients pending revision, 4 (40%) had femoral loosening, although the main reason for operation was superior subluxation of the component in 9 patients and only femoral loosening in 1. Therefore, femoral loosening was the only indication for revision in only 3 of the 33 hips (9%).

Of the 23 patients in whom revision of an acetabular component was performed, 19 received a cementless porous acetabular component at revision and 4 had another bipolar cup placed. In only 7 of these patients was additional bone grafting necessary at the time of bipolar endoprosthesis removal, and frequently the previous bipolar endoprosthesis and grafting was thought to have facilitated significantly the subsequent revision through improvements in the bone stock available. In 13 patients in whom femoral component revision was performed, a cementless component was used.

Survivorship analysis showed that the overall probability of the hip components remaining in place was 96%, 84%, and 70% at 1, 3, and 5 years, respectively, and had declined to 47% at 6.5 years postoperatively (Fig 5).

Previous failed total hip arthroplasty was related significantly to poorer implant survival (Fig 6). Patients with previous failed total hip arthroplasty had a lower implant survival at 5 years (61.7%) as compared with patients with a surgical diagnosis other than failed total hip arthroplasty (94.73%) ($p < 0.05$). Also, in comparing the patients' results according to implant type for the 3 implants used most frequently (Universal Head System UHR, Bi-Articular II, and Bicentric Head), the UHR system had the best performance ($p < 0.03$) (Fig 7). In the present study, the authors were unable to corre-

Fig 5. Overall probability of survival of the bipolar prosthesis with 95% confidence interval (at 1, 3, 5, and 7 years).

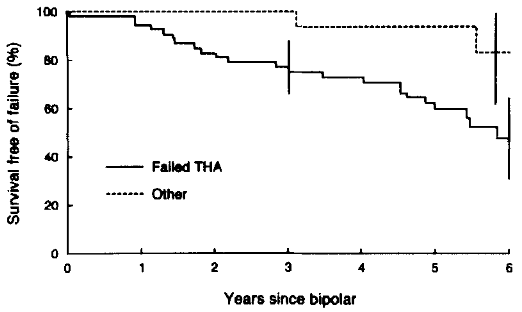

Fig 6. Probability of implant survival with 95% confidence interval (at 3 and 6 years) by diagnosis. (THA = total hip arthroplasty.)

late age, gender, acetabular defect type (by American Academy of Orthopaedic Surgeon criteria), or type of bone graft used with implant survival. Although use of screw-fixed block grafts yielded a lower probability of survival at 5 years (66% versus 75%), the fact that this was not statistically significant may relate to the size of the samples compared.

DISCUSSION

Currently, failed total hip arthroplasty accounts for the majority of patients with severe acetabular deficiency. Pelvic bone loss caused by progressive osteolysis after acetabular component loosening may vary from small contained defects requiring little or no alteration in standard technique to massive bone loss involving either the wall or anteroposterior columns that can affect technique and implant selection.[9]

Implant alternatives for management of conditions with severe acetabular deficiency include cemented acetabular components, fixed cementless cups, and bipolar components.

The concept of using a bipolar endoprosthesis for the reconstruction of the deficient acetabulum with molding of the bone graft while bone healing occurs was introduced by Scott.[48] Although initially introduced as a 2-stage procedure at the authors' institution to restore bone stock while providing a functional arthroplasty during graft incorporation, researchers soon showed that the procedure could provide satisfactory short-term results, possibly obviating second reconstruction with a fixed socket.[54] Satisfactory early clinical and radiographic results after the use of a bipolar prosthesis and bone grafting seemed to justify continued use of this technique for difficult revision total hip arthroplasty[46] and protrusio acetabuli.[55] However, subsequent reports raised concern about the fate of bone grafts when used with bipolar cups, and failures were reported.[53]

In the present series, there were 17 intraoperative complications (21%), which is comparable with that of other reported revision total hip arthroplasty series.[16,31,32]

A significant rate of postoperative complications also has been reported after revision hip operation.[7,31,32] In the present series, major postoperative complications included frank dislocation, disassembly of the bipolar component, and deep infection in 2 patients each.

True dislocation of the bipolar endoprosthesis from the reconstructed acetabulum in the series reported here occurred in only 2 patients (2.5%). This rate compares favorably with the postoperative dislocation rate of 3.2% at the authors' institution after

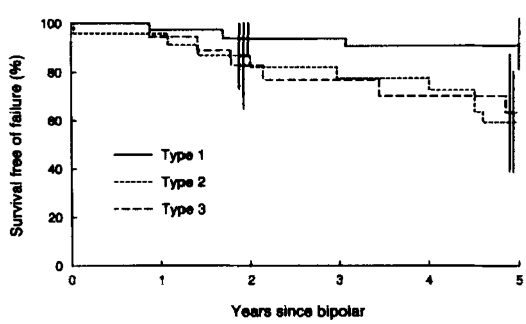

Fig 7. Probability of implant survival with 95% confidence interval (at 2 and 5 years) by type of implant. Type 1, Universal Head System UHR; Type 2, Bi-Articular II; Type 3, Bicentric Head.

primary total hip arthroplasty.[56] It also compares favorably with dislocation rates of 9% and higher for revisions reported from the same institution.[31,32] The increased stability provided by a bipolar cup has prompted its use for revision in patients with difficult recurrent dislocation problems.[36,57] This may be 1 of the main potential indications remaining for use of bipolar components during revision operations. Another 2 cases in the present series (2.5%) were associated with bipolar disassembly. One of these occurred on postoperative Day 10 and involved a Bi-Articular bipolar component believed to have a defective head implant connection. The second case occurred late in a Universal prosthesis with a 32-mm femoral head and was caused by marked polyethylene wear. Substantial deformation of the polyethylene liner under cyclic load has been reported for the Bateman bipolar prosthesis.[33] Bipolar disassembly was an uncommon complication in other series.[8,37,49] The authors believe that this rare complication can be decreased by proper manufacture and assembly of these components and use of small-diameter femoral heads to decrease polyethylene wear.

Heterotopic bone formation has been reported in 10% to 72% of cases of acetabular reconstruction using bone grafting (Brien et al,[5] 72%; Phillips and Rao,[42] 62%; Gerber and Harris,[18] 36%; Harris et al,[24] 10%). In the present series, Grade III or IV heterotopic ossification was seen in 20% of patients, but excision was required in only 1. Systemic use of nonsteroidal antiinflammatory agents or low dose of radiation has been documented to be effective in preventing heterotopic bone formation.[12,15,44] No form of prophylaxis for heterotopic ossification was used in patients in this series because of concern about adverse effects on graft healing. The authors' current practice is not to use any form of prophylaxis in patients requiring acetabular bone grafting unless other risk factors exist, such as significant previous symptomatic heterotopic ossification requiring excision at the time of revision. If prophylaxis is elected, the authors favor low-dose radiation with custom shielding of bone graft and any newly inserted ingrowth prosthetic components.

In previous series of acetabular reconstructions using bone grafting and bipolar sockets, progressive superomedial or superolateral acetabular migration has been a concern.[5,37,46,51,53,54] Superior migration and medial migration were seen in most of the patients in the present series, and superior subluxation with failure of the bony block grafts associated with screw breakage was common. Chandler and Penenberg[9] have emphasized the need to achieve normal trabecular orientation to facilitate load bearing and reduced graft compaction when structural grafts are used. Allograft size also may be important, because larger avascular grafts may be more durable when union occurs in the absence of revascularization in comparison with smaller grafts that are weakened by the peripheral revascularization process.[29] Rigid fixation of bone grafts with pelvic reconstruction plates and multiple screws may decrease the risk of graft displacement and nonunion.[13,34]

In the present series (using the methods described), an unacceptably high failure rate was found at a mean of 5.5 years of followup evaluation. Survivorship analysis showed that the probability of survival was only 47% at 6.5 years. Also, clinical results in the 50 patients who did not have implant removal were not encouraging. The present series included severely disabled patients with significant acetabular deficiency, for many of whom resection arthroplasty may have been the only alternative. The clinical and radiographic results of the study reported herein show that this technique should not be viewed as a definitive or durable reconstruction method. Two situations remain where this method may be reasonable. One is severe acetabular defects in which staged reconstruction is acceptable to the surgeon and the patient, although these instances will be extremely uncommon. The choice of a bipolar prosthesis in this setting must be weighed against recently published data[38,50] showing intermediate-term predictable outcomes for the treatment of acetabular deficiencies using cementless fixed sockets. The technique of cementless sockets fixed to maximize support on intact viable bone of the patient and supplemented with cancellous grafting as needed or defect filling, has emerged as the authors' preferred reconstructive method for patients with acetabular bone deficiency. The other situation where use of a bipolar prosthesis is a reasonable choice is the unstable hip with associated major acetabular defect in which stability with standard fixed components seems unlikely or is unachievable. Zelicof and Scott[57] have documented the efficacy of this method in managing recurrent instability problems that have failed standard revision methods. It is important to stress, however, that even in those patients in whom failure of the bipolar endoprosthesis occurs, subsequent revision is facilitated by frequent bone graft incorporation, especially in cavitary defects treated with cancellous bone. This allows subsequent insertion of a fixed component in an easier, technically less demanding, and hopefully more durable fashion than would have been possible before the bipolar procedure.

In conclusion, despite the early acceptable results of revision with bone grafting and bipolar prosthesis, longer-term results show an unacceptably high failure rate, with a probability of implant survival of only 47% at 6.5 years postoperatively. Bone grafts remain a useful adjunct for reconstruction of the acetabulum and supplementation of bone stock in cases of acetabular deficiency, especially in younger patients. However, bone resorption and collapse is common and is usually associated with superior migration when a bipolar prosthesis has been used next to the graft. If this procedure is used, patients should be warned that a second-stage reconstruction may be necessary, with exchange of the bipolar endoprosthesis to a fixed socket if bone graft incorporation is observed. In most instances, the authors believe that alternative reconstruction options that use fixed cups and maximized implant support on intact patient bone should be sought whenever possible.

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