Revision Total Hip Arthroplasty: The Acetabular Component

Pasquale Petrera, MD, and Harry E. Rubash, MD

Abstract

Intermediate and long-term results of revision total hip arthroplasty performed with the use of a cemented acetabular component have been disappointing, with high rates of radiographic and clinical failure. Other methods of acetabular revision involving the use of threaded cups and bipolar implants have also met with high failure rates. Although the long-term results of revision arthroplasty with uncemented acetabular components, especially in terms of polyethylene wear and pelvic osteolysis, are not yet available, the intermediate results have been excellent.

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The need for revision total hip arthroplasty (THA) continues to grow yearly. Fixation of the acetabular component in this circumstance remains a challenge to the orthopaedic surgeon, and many methods have been tried with varying success. To understand fully the problems that can arise with acetabular revisions, the history and results of primary acetabular replacement must be partially reviewed.

Historical Review

John Charnley's initial attempt to find a bearing surface for his low-friction arthroplasty was a failure. Polytetrafluoroethylene (PTFE), despite its characteristic slipperiness, was ill suited to the demands of a human hip joint. Cemented PTFE cups wore quickly, and the wear particles were associated with large, amorphous periprosthetic granulomas. The resultant osteolysis resulted in catastrophic bone destruction and early implant loosening. Discouraged, but not defeated, Charnley discovered that high-molecular-weight polyethylene had better wear characteristics than PTFE. Acetabular components were fashioned from this material and first implanted in 1962.[1]

The technique for implanting polyethylene cups required reaming of the native acetabulum, with removal of all articular cartilage and subchondral bone. Later the technique evolved to include multiple 6-mm-deep anchor holes to improve cement fixation. Other investigators demonstrated the importance of the subchondral acetabular bone as a weight-bearing structure and recommended preservation of this bone in acetabular preparation.[2]

Within 6 months after implanting the polyethylene cup, Charnley noted some radiographic demarcation between acetabular bone and cement and described this as a radiolucency. Radiolucencies were not present around the femoral component, and Charnley worried that they might be indicative of early cup loosening or infection. Despite his concerns, the patients with radiolucencies did well clinically, and initially the radiolucent lines did not appear to be progressive.[3]

In 1976, DeLee and Charnley[4] reviewed the results in 141 patients with cemented cups after an average of 10 years. These patients were derived from Charnley's initial experience with the all-polyethylene cup from 1962 through 1965. Over 69% of the cups showed radiolucent demarcations of varying thickness between the cement and the bone of the acetabulum, and 13% of the implants had migrated. Overall, 9.2% of the cups in the total series had loosened at the 10-year surveillance. DeLee and Charnley attributed this often symptomless demarcation to technical causes during initial implantation and believed that improved surgical techniques could halt it.

Review of Recent Literature

In a retrieval study in 1992, Schmalzried et al[5] documented a cause for the radiolucencies around cemented

Dr. Petrera is in private practice with Peninsula Orthopaedic Associates, Salisbury, Md. Dr. Rubash is Associate Professor and Clinical Vice Chairman, Department of Orthopaedic Surgery, and Chief, Division of Adult Reconstructive Surgery, University of Pittsburgh Medical Center, Pittsburgh.

Reprint requests: Dr. Rubash, Kaufmann Building, Suite 1010, 3471 Fifth Avenue, Pittsburgh, PA 15213.

acetabular cups. They examined implants from 23 revisions, most of which were performed because of pain, and 11 autopsy specimens from patients who had been asymptomatic. All had some evidence of periprosthetic bone loss. Loosening appeared to be biologic in nature, and the investigators concluded that it was a result of a physiologic reaction to small particulate polyethylene debris. They observed a "cutting wedge" of bone resorption, beginning at the periphery of the cup and contiguous with the joint space. The areas that corresponded to radiographic radiolucencies were filled with a fibrous membrane. Histologic examination of the membranes revealed polyethylene wear debris within macrophages. Ultimately these membranes extended to the dome of the component associated with eventual component loosening. This study and others have substantiated Charnley's initial concern about acetabular radiolucencies.

In 1988, Hodgkinson et al[6] reported a definite correlation between radiographic demarcation and component loosening. They found that 94% of cups with a continuous radiolucent line were loose at subsequent revision and concluded that radiolucencies around a cemented socket were a sign of eventual failure. These findings, coupled with those of Schmalzried et al[5] and others,[7-13] changed opinions about radiolucencies and the eventual failure of cemented acetabular cups.

Despite the dire predictions, most total hip prostheses with cemented all-polyethylene cups that have not migrated have functioned well. At a minimum follow-up of 20 years, Schulte et al[7] examined 94 cemented Charnley hips. While 22% of the acetabula showed radiographic evidence of loosening, only 10% required revision for aseptic loosening. This finding points out the relative "forgiveness" of the acetabulum in THA and the fact that a loose cup does not necessarily indicate a need for revision (Table 1). However, longer follow-up has corresponded with higher failure rates for cemented all-polyethylene acetabular components, as documented by radiographic evidence of loosening (Fig. 1) and the need for revision surgery.[7,8,11-13]

Acetabular Revision With Cement

Soon after the popularization of THA, revision procedures became necessary. Initially, acetabular revisions relied on recementing a new polyethylene component into the pelvis with the use of the same technique employed for primary arthroplasty. Cemented acetabular revision was a less-than-optimal treatment for several reasons. The acetabular bed was frequently sclerotic without normal trabecular architecture for cement fixation. Osteolysis and motion of the loose component within the acetabular bed often had destroyed large amounts of the anterior and posterior column and dome of the acetabulum. Therefore, acetabular component fixation, which can be difficult to achieve under optimal conditions in a primary THA, was bound to have more frequent failures after revision procedures. Later investigations have confirmed this prediction (Table 2).

Fig. 1 Ten-year follow-up radiograph of a loosened cemented all-polyethylene acetabular component in a patient scheduled for revision THA. Note the continuous bone-cement radiolucency, the crack in the bone cement, and the evidence of superior cup migration (zone III).

Table 1
Results With Charnley Cemented All-Polyethylene Acetabular Components

Study	No. of Patients	Follow-up, yr	Rate of Loosening, %	Revision Rate, %
Eftekhar[9]	138	7-8	0	1.5
Griffith et al[10]	547	8.3	3.3	0.91
Stauffer[8]	231	10 (mean)	11.3	3.0
Hozack et al[11]	1,041	10 (mean)	25	1.65
Older[12]	153	10-12	15	2.0
Kavanagh et al[13]	166	15 (mean)	14	7.2
Schulte et al[7]	98	20 (minimum)	22	10

Table 2
Results of Cemented Acetabular Revision

Study	No. of Patients	Follow-up, yr*	Rate of Loosening, %	Revision Rate, %
Kavanagh et al[14]	166	4.5	53	2
Amstutz et al[15]	66	2.1	71	3
Pellicci et al[16]	110	3.4	. . .	1.8
Callaghan et al[17]	139	3.6	34.2	. . .
Snorrason and Kärrholm[18]	15	2	93	0
Engelbrecht et al[19]	138	7.4	54	. . .
Goodman and Schatzker[20]	32	3	7	0
Marti et al[21]	60	5-14 (range)	17	5

*Values are means except as noted.

Kavanagh et al[14] evaluated 166 cemented acetabular components with an average follow-up of 4.5 years after revision. Fewer than 2% required another revision, but 25% were characterized as probably loose at this early review. Using the stricter criterion of Hodgkinson et al,[6] which requires only a complete radiolucency independent of its thickness or location, 53% of these cups would be defined as loose.

In a review of 66 revisions for aseptically loosened total hip prostheses, Amstutz et al[15] noted a 3% rate of further revision after a mean of only 2 years. Even more alarming was the observation that 10% of patients had a complete radiolucency around the cup immediately after surgery. By 2 years, this rate had increased to 71%.

Similarly, Pellicci et al[16] reviewed 110 revisions at a mean of 3.4 years and found that 1.8% required further revision. However, radiographs taken immediately after the revision procedure revealed radiolucent lines in all but nine patients.

At a mean follow-up of 3.6 years, Callaghan et al[17] found that 34.2% of revised cemented acetabular components had circumferential radiolucencies; 9% of these cups had migrated. Similar findings were noted in the studies by Snorrason and Kärrholm,[18] Engelbrecht et al,[19] Goodman and Schatzker,[20] and Marti et al.[21] The findings of Kavanagh and Fitzgerald[22] in patients requiring multiple revisions were even more alarming: 69% of the cups they examined had radiographic signs of loosening after a second revision, and the loosening rate among patients requiring a third revision was 100%. Clearly, other methods were needed for acetabular component fixation in revision procedures.

Threaded Cups

Threaded metal cups that screwed into the acetabular bed gained popularity in the 1980s, but initial enthusiasm was soon tempered by early failures. Engh et al[23] found that 45% of such cups of various designs were loose an average of 4.4 years after implantation. Engelbrecht et al[19] noted that 83% of the titanium-threaded cups used in revision arthroplasty had migrated after an average of 7.4 years. Emerson et al[24] found that 61% of the threaded cups they had placed were loose at an average of 3.4 years; four required rerevision. Others[25,26] obtained equally poor results using threaded cups for revision.

Bipolar Implants

As a possible solution, Scott[27] and others proposed the use of bipolar implants with acetabular bone grafting. However, 61% of acetabular reconstructions performed with the use of bipolar prostheses at the Hospital for Special Surgery had failed by 3 years, and the technique was recommended for salvage procedures only.[28] Emerson et al[24] found a 49% rate of migration and a 68% incidence of loosening in bipolar components at a mean of only 28 months after revision; clinical results were also poor. Scott et al[29] noted that 10 of 19 components had migrated after 2 to 4 years.

Outstanding results recently were reported for cemented femoral components affixed with the use of new cementing techniques in both primary and revision arthroplasty.[30-32] Although these reports have increased enthusiasm for cemented femoral components, the results obtained with newer cement techniques and metal-backed sockets have not shown similar improvement.[33-35]

Acetabular Revision With Bone-Ingrowth Prostheses

Bone-ingrowth prostheses became popular in the United States for both primary and revision procedures in the early 1980s and were seen as the solution to the problem of the misnamed “cement disease.” The published results of revisions with uncemented components (Table 3)

Table 3
Results of Uncemented Acetabular Revision

Study	No. of Patients	Mean Follow-up mo	Rate of Loosening, %	Revision Rate, %
Hedley et al[36]	61	20.7	6.6	1.6
Emerson et al[24]	46	22	15.2	0
Engh et al[23]	34	52.8	2.9	0
Harris et al[37]	60	17	0	0
Tanzer et al[38]	140	41	1.4	0.7
Padgett et al[39]	124	44	0	0

favor the use of hemispheric components with some additional form of supplemental fixation, be it fins, spikes, or screws (Fig. 2).

Hedley et al[36] performed 61 acetabular revisions for infection and mechanical loosening using the porous-coated anatomic ingrowth cup (PCA Hip; Howmedica, Rutherford, NJ). Bone slurry was placed in the bed of each acetabulum before impaction of the component. Almost half of the procedures also required structural bone grafts. After 20 months, four cups (6.6%) were loose, but only one (1.6%) required further surgery. Clinical results were excellent or good in 56 patients despite the presence of radiolucencies at the bone-implant interface in 60.7% of cases.

Fig. 2 Anteroposterior radiograph of a titanium-mesh ingrowth-cup (HGP I) uncemented acetabular component used for acetabular revision. At 8-year follow-up, there is no evidence of migration, radiolucencies, or pelvic osteolysis. Note the asymmetric polyethylene wear of the cup liner with the 32-mm femoral head.

Emerson et al[24] reviewed the results of 46 acetabular revisions in which a hemispheric porous-coated, titanium plasma–spray cup with four fins had been used. After an average of 22 months, seven cups (15.2%) had migrated minimally; none of these was revised. Four of the seven had required structural allografting at the index procedure.

Engh et al[23] reported the results in 34 revision THAs in which a hemispheric porous-coated acetabular component with three spikes had been used. They found that only one acetabular component was loose after an average of 4.4 years.

Harris et al[37] identified a need for particulate bone grafting to the acetabular bed in more than 80% of 60 acetabular revisions in which a titanium-mesh ingrowth cup (HGP I; Zimmer, Warsaw, Ind) had been used. After follow-up averaging 17 months, only one cup had a complete radiolucent line.

Tanzer et al[38] reported the 41-month results for 140 acetabular revisions in which titanium-mesh ingrowth prostheses with supplemental acetabular screws had been used (HGP I and HGP II; Zimmer). Bone grafting was necessary in 127 revisions; in most of these cases, contained defects were filled with particulate graft material. None of these grafts was used for major structural support of the implant. Only two cups (1.4%) were loose, and in both cases the patients had major pelvic discontinuity at the time of the operation. Five components demonstrated a continuous radiolucency, but none had migrated; these were not considered loose.

Padgett et al[39] conducted a prospective study of 124 consecutive acetabular revisions in which a titanium-fiber metal cup with screws (HGP I) was used. At 44 months, no revisions for loosening had been performed, but 4% of arthroplasties had a continuous radiolucent line.

The use of cemented acetabula for primary THA still has its supporters. Long-term review (for more than 10 years) of the use of ingrowth cups for primary arthroplasty is awaited, but at intermediate follow-up of 5 to 7 years, ingrowth cups are producing results equal to or better than those obtained with cemented cups.[40] Although the short length of follow-up remains a point of contention in the comparison of cemented and ingrowth primary acetabular reconstruction, the same does not appear to be true for revisions. Although the short-term results with recemented acetabula have been disappointing, they still are used in rare circumstances (e.g., patients who require extensive allografts or who previously underwent irradiation of the acetabular bed). In comparable follow-up periods of 3 to 5 years, ingrowth cups are performing better in revision circumstances. Initial enthusiasm, however, must be tempered by the fact that these results are early. Early experience with cemented total joint implants and the nearly exponential failure of cemented all-polyethylene cups after 10 years indicate that low early failure rates cannot be extrapolated to 20 years.[7,8]

Modes of Failure

In addition to aseptic loosening and mechanical failure, other modes of failure are occurring with uncemented implants. A recent investigation by Maloney et al[41] documented the occurrence of severe pelvic osteolysis related to uncemented acetabular reconstruction performed with a variety of implants. The largely asymptomatic osteolysis was noted an average of 5.5 years after the initial arthroplasty, and particulate polyethylene was implicated as its cause. Radiographic evaluation revealed wear of the polyethylene liner in 80% of the hips. The liner was 8 mm thick or less in 80% of the hips, and the femoral head size was 32 mm in 11 of 15 patients. Pelvic osteolysis is becoming a more frequent indication for revision, and its incidence will most likely continue to increase with long-term studies.

Modular-cup polyethylene assemblies with thin (measuring less than 8 mm) press-fit liners and 32-mm femoral heads are all potential causes of increased polyethylene wear. In particular, holes in cups may provide access for particulate polyethylene to migrate to the pelvic area from the dome of the acetabulum. With uncemented cups, access to the implant-bone interface can also occur at the periphery of the acetabulum. This may be one of the reasons for the continued occurrence of peripheral radiolucencies in the reported studies on uncemented components and is partially responsible for the recent popularity of underreaming and press-fitting acetabular components into the slightly smaller acetabular bed.

Modular polyethylene assemblies are also available with augmented and extended-lip liners. These constructs have been advocated to improve femoral-head coverage and hip stability. In some instances, they may be a liability because they can decrease the effective range of motion and increase the chance of dislocation by impingement of the femoral neck on the buildup.

While the long-term results with ingrowth cups are pending, thus far their use has proved to be a successful and reproducible method of revision acetabular reconstruction.

Surgical Technique for Porous Ingrowth Revision

Our technique for acetabular revision using a hemispheric titanium-mesh cup is as follows: A modified lateral approach to the hip is used. Trochanteric osteotomy is not routine unless it is needed to facilitate exposure and dislocation. If the femoral component is unstable, it is removed; if it is stable, it is displaced posteriorly to allow access to the acetabulum. All fibrous capsular tissue surrounding the component is removed to provide access to the bone-cement-implant interface. Osteotomes are used to separate the polyethylene cup from the underlying cement. The contour of the cup is followed closely to prevent unnecessary bone loss or intrapelvic perforations. Osteotomes, chisels, and curettes are used to remove all cement from the acetabular side. Cement within anchor holes is also removed with great care. The acetabular membrane is totally removed. Every attempt is made to preserve the acetabular rim.

Power reamers are used to enlarge but not deepen the acetabulum. Once rim contact has been obtained, fitting of the component is tried with the size of the last reamer used. Depending on the bone quality and the size of reamer, a cup that is 2 to 4 mm larger than the reamed acetabulum is chosen. Before final cup placement, all acetabular defects are filled with particulate bone graft (autograft or allograft) and reverse-reamed for concentricity. A positioning device is used to impact the component into the acetabulum in 45 degrees of abduction and 15 to 20 degrees of anteversion. “Bottoming out” of the dome of the component into the acetabulum is recommended, along with the rim press-fit.

Stability is then assessed by manual manipulation. If the cup appears to be unstable, two screws are placed into the safe zones of Wasielewski et al.[42] A 28-mm-head polyethylene liner is then placed. A smaller head size may be needed for smaller cup diameters. Each system is different, and the surgeon must be familiar with the options available.

This technique, although not greatly different from our primary acetabular reconstruction technique, can have pitfalls in revisions. Overzealous reaming can result in loss of the anterior and/or posterior columns. Padgett et al[39] found that retention of the load-bearing posterior column was of the utmost importance for successful reconstruction. Anterior-column defects and contained cavitary defects, whether preexisting or reamer-induced, can be managed with a particulate bone graft. Structural defects of the posterior column or dome often require large (jumbo) acetabular components, bulk allograft, and ancillary internal fixation of the acetabular column and a graft. Pelvic discontinuity remains an unsolved problem in revision surgery.

At present, acetabular components for primary THA are being produced without screw holes. The rationale is to prevent polyethylene wear debris from gaining central access to the bone-implant interface through holes. Investigations are proceeding to assess the efficacy of these press-fit acetabula without screws in revision procedures.

Conclusion

We are entering a very exciting period for THA. The next 10 years will bring forth answers to questions asked by Charnley more than a generation ago.

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