Acetabular Reconstruction in Revision Hip Surgery Using Femoral Head Block Allograft

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**Abstract**

This prospective study analyzed the clinical and radiological results of 140 consecutive cases of acetabular revision using large frozen femoral head allografts and cemented all-polyethylene acetabular components. Mean follow-up was 10 years (range: 5-16 years). Thirty patients died, seven were lost to follow-up, and 26 had failed and undergone further surgery. Nineteen failures were due to aseptic failure and collapse of the graft. Kaplan-Meier survival analysis calculated a mean survival at 10 years of 88.5% for revision for any reason. We compared all reported techniques of acetabular reconstruction for similar defects and recommend a surgical strategy based on the available evidence, but weighted towards a preference to reconstitute bone stock rather than removing further bone in the revision situation.

Numerous techniques have been described to deal with the wide variety of problems facing the surgeon reconstructing the acetabulum with deficient acetabular bone stock. Unfortunately, many published series are difficult to interpret as they combine results of more than one surgical technique, results in primary and revision cases, and use numerous different classification systems to describe the acetabular defect. Many of the techniques currently being advocated have a short follow-up period of small numbers of cases.

We report the results of 140 consecutive acetabular reconstructions using a single surgical technique. This is the largest reported series to date of acetabular reconstruction during revision using frozen femoral head allograft in combination with a cemented all-polyethylene acetabular component without the use of reinforcement rings. This reconstruction technique was used in the treatment of large acetabular defects in which femoral head allograft was used to lateralize and lower the center of acetabular rotation, thereby attempting to restore its anatomical position. During the same period, massive acetabular defects with loss of columns or massive superior bone loss were treated with hemipelvic allografts, while smaller acetabular bone defects were managed with re-cementing of an acetabular component.

This study analyzes the clinical and radiological results in this group of patients followed for a mean of 10 years (range: 5-16 years), and compares our results with other series using a similar technique, and with the results of the currently advocated possible alternative.

**Materials and Methods**

One hundred and forty consecutive acetabular revisions were performed on 135 patients (5 bilateral) from 1984 to 1995 using this technique. Mean patient age was 61 years (range: 22-87 years). On average, the patients had undergone two previous surgical interventions (range: 1-10 operations) on the affected hip before the index intervention. Femoral revision was performed in 62 (44%) cases.

Acetabular defects were analyzed preoperatively with plain anteroposterior, lateral, and oblique Judet acetabular radiographs. The defect classification was confirmed intraoperatively according to the system of Paprosky et al.

Clinical scoring was performed us-
ing the Postel Merle d'Aubigne scoring system.²

All living patients were reviewed clinically and radiologically every two years from the date of the index procedure at the senior authors' institution.

Radiographs were digitized using a Vidar X-Ray Scanning System (Vidar Systems Co, Herndon, Va) and analyzed using the Imagika 1.40E digital analysis software program (CMC Corp, Upper Saddle River, NJ).

Migration of the acetabular component, and therefore indirectly, allograft collapse, was measured digitally using the method described by Nunn et al.³

**Figure 1**: Depiction of graft positioning within the acetabular defect. **Figure 2**: Postoperative AP radiographs illustrating bulk allograft stable without screw fixation (A), and illustrating no collapse of bulk allograft at 10 years (B).

Statistical analysis was performed using the SPSS 11.0 statistical package (SPSS Inc, Chicago, Ill). Kaplan-Meier survival analysis was performed, with failure defined as deterioration of the acetabular/graft component to the point of requiring revision surgery for any reason.⁴

**SURGICAL TECHNIQUE**

The surgical approach was dictated by the presence of associated pathology. A posterior approach was used in five cases in which femoral component revision was predicted to be complicated. A direct lateral transtrochanteric approach was used in 15 patients in which previous trochanteric osteotomy had been performed with a resultant non-union or malunion. In the majority of patients (120), an extended anterior Smith-Petersen approach was used with the patient positioned on the Judet traction table in the supine position. Using this technique, the lateral aspect of the ileum and the entire acetabulum could be clearly exposed.

The acetabulum was thoroughly debrided and gently reamed to attempt to achieve a geometrically shaped defect. The largest available fresh frozen (non-irradiated) femoral head allograft without cystic change was retrieved from the bone bank. The surfaces of the femoral head were denuded to subchondral bone and shaped to fit as close as possible within the acetabular defect.

The graft was positioned within the acetabulum to assess the best position of the graft. A neo-acetabular shape was created by a reamer in the graft while the graft was held in a vice grip. The graft was replaced into the acetabular defect and its stability assessed and recorded. The surgical intent in each case was to achieve a near perfect fit of the graft into the host defect with spontaneous stability of the graft in compression (Figure 1).

Furthermore, the intention was to achieve the largest possible graft-to-host contact and the largest possible circumferential coverage of the new acetabular component by allograft. The latter two factors were unable to be accurately analyzed in this study. The graft was not merely used as a shelf, but was deliberately used within the acetabulum to attempt to return the center of the acetabulum to its lower and more lateral anatomical position. A further aim was to preferentially load the graft rather than the host, thereby hoping to avoid stress shielding of the graft (Figure 2).

If any movement of the graft occurred when compressed in the direction of the usual acetabular forces, further stabilization using screws or a buttress plate was performed. Screws were used in a specific configuration to stabilize the graft. Tangential screws were used from the lateral wall of the ileum through the roof of the existing acetabulum into the allograft. Further screws were used from within the neo-acetabulum into the ileum. An average of 3.7 screws (range: 0-7 screws) were
used to stabilize the graft. Buttress plating was used in six patients with major segmental defects that may have been an indication for the use of hemipelvic allograft.

The aim in each case was to achieve absolute stability of allograft to host. Any gaps between host and graft were packed either with allograft reamings or, in most cases, with autologous cancellous bone from the readily available iliac crest.

Cementing of the acetabular component was then performed using standard cementing techniques. In all patients, >50% of the cemented acetabular component was supported by allograft bone. In the majority of patients, a small acetabular component was deliberately used to allow greater replacement of bone stock. An acetabular component >48 mm diameter was used in 10 patients.

Postoperatively, patients were mobilized at five to six days with partial weight bearing. Weight bearing was increased at six weeks but crutches were prescribed until three months.

RESULTS

Of the 140 hips, 32 patients died, 7 (5%) patients were lost to follow-up prior to five-year review, 26 had failed and undergone further surgery, and 75 remained functioning in living patients. Aseptic graft failure accounted for 19 of the failures.

Kaplan-Meier survival analysis gives a mean survival at 10 years of 88.5% (95% confidence interval [CI]=88.4; 88.6) and at 12 years of 77.8% (95% CI=77.7; 77.9) (Figure 3) with failure defined as revision surgery of the acetabulum for any reason.

Thirty-two patients died without requiring attention to the acetabular component. The average follow-up time in those who had died was 4.2 years (range: 1.6-10.5 years).

Seven patients were lost to follow-up prior to 5-year review. In most cases, this was because the patient either lived abroad or had moved abroad following surgery. The mean follow-up time in this group was 3.1 years (range: 0.8-4.8 years).

There were 26 acetabular failures. These occurred at an average of 10.4 years (range: 2.4-16.7 years) from the index surgery. Average patient age was 53 years (range: 33-75 years) at the time of the index procedure. Three (11.5%) patients had previous infections and 11 (42%) patients had infections associated with revision of the femoral component at the index procedure. There was a bimodal distribution of failures, with the first peak occurring around the two-year mark and the second peak occurring at approximately nine years. Aseptic graft lysis accounted for 19 (13.6%) failures. In 10, complete graft lysis was present (Figure 4) and in 9, partial lysis occurred. Eleven of these 19 patients displayed obvious loosening at the graft cement interface.

Graft lysis was not the cause of failure in 7 patients. These failures were due to: 4 (2.8%) cases of recurrent dislocation, 2 fatigue fractures of weak host bone acetabulum (both at 6 months from the index procedure), and 1 late deep infection at 6 years from the index procedure.

Seventy-five acetabular components remained functioning in living patients at the time of last review. Average patient age at the time of surgery was 58 years (range: 22-87 years). Average follow-up time was 10 years (range: 5-14.6 years).

Postel Merle D’Aubigne hip scores measured 39.3 (11) preoperatively and at most recent review measured 53.5, 64.3 (15.2) in this group.

The majority of patients (63.6%) had either moderate or significant superior acetabular migration, with 20% having moderate or severe medial wall and posterior column deficiencies in association with the superior bone loss (Table 1).

Survival analysis of each grade of acetabular defect is provided for comparison with other studies and techniques (Table 2). Survival analysis was not possible in the Paprosky 1 category as there were no failures, nor in Paprosky 3B category, as there were only two cases.

Five (3.6%) hip dislocations did not require revision surgery. Four (2.8%) hips had developed heterotopic ossification (1 Brooker II, 3 Brooker III). There were three (2.1%) cases of documented non-fatal pulmonary embolism. There were two (1.4%) cases of partial femoral nerve injury that recovered spontaneously. Five (3.6%) hips had undergone revision surgery for femoral loosening but did not require attention to the acetabular compo-
Table 1

<table>
<thead>
<tr>
<th>Paprosky Grade</th>
<th>Deceased</th>
<th>Lost to Follow-Up</th>
<th>Failed</th>
<th>Surviving</th>
<th>Total (%)</th>
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<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>6</td>
<td>8 (5.7)</td>
</tr>
<tr>
<td>2A</td>
<td>4</td>
<td>0</td>
<td>9</td>
<td>14</td>
<td>27 (19.3)</td>
</tr>
<tr>
<td>2B</td>
<td>19</td>
<td>4</td>
<td>6</td>
<td>32</td>
<td>61 (43.6)</td>
</tr>
<tr>
<td>2C</td>
<td>2</td>
<td>0</td>
<td>5</td>
<td>9</td>
<td>16 (11.4)</td>
</tr>
<tr>
<td>3A</td>
<td>7</td>
<td>1</td>
<td>5</td>
<td>13</td>
<td>26 (18.6)</td>
</tr>
<tr>
<td>3B</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>2 (1.4)</td>
</tr>
<tr>
<td>Total</td>
<td>32</td>
<td>7</td>
<td>26</td>
<td>75</td>
<td>140</td>
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</tbody>
</table>

Table 2

<table>
<thead>
<tr>
<th>Paprosky Grade</th>
<th>No. of Cases</th>
<th>10-Year Cumulative Survival (%)</th>
<th>Standard Error (%)</th>
<th>Mean Survival (y)</th>
<th>Standard Error</th>
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<td>71.9</td>
<td>11.2</td>
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<tr>
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<td>4.6</td>
<td>14.3</td>
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<tr>
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<td>80.7</td>
<td>12.6</td>
<td>12.9</td>
<td>0.9</td>
</tr>
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<td>3A</td>
<td>26</td>
<td>71</td>
<td>13.1</td>
<td>11.8</td>
<td>0.6</td>
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</tbody>
</table>

There have been no known cases of human immunodeficiency virus or other organism transmission from graft to host.

The immediate postoperative radiograph demonstrated no significant differences in the acetabular angle or height when comparing those hips which had failed to those that survived. Of interest, however, was the significant difference in acetabular offset between those hips that failed (36 mm), and those hips that survived (31 mm; P = .001) using an analysis of variance test (ANOVA).

There was no significant movement or signs of aseptic loosening of the acetabular component over the course of time in the 75 hips of surviving patients, or in the last available radiographs in the 32 hips of patients who are deceased.

The inherent stability of the allograft was assessed intraoperatively and augmented with screw fixation if slightly unstable (Figure 1) or a buttress plate if significantly unstable. There was no statistical correlation between the use of screws and graft failure.

Buttress plates were used to stabilize the allograft in 6 hips. Five of these hips had failed at a mean of 10.1 years (range: 6.5-12.4 years). The sixth hip remained functioning at 14 years. There was a statistical correlation between the use of a plate and graft failure (Khi² P = .001).

DISCUSSION

The technique of using frozen femoral head allograft to restore bone in acetabular reconstruction in revision surgery has been well described and remains a commonly used technique. It has fallen into disrepute due to poor long-term results reported in the literature. Some factors in our series lead to higher failure rates when using this technique.

We have demonstrated no significantly higher failure rate among those bone grafts judged to be unstable at the time of implantation, however, we have shown a significantly higher failure rate in those hips in which a plate was deemed necessary to stabilize the graft. The implication is that acetabular defects requiring a buttress plate to stabilize the graft were probably outside the limits of this technique. In retrospect, a hemipelvic allograft may have been preferential.

In contrast, those grafts able to be absolutely stabilized using screw fixation performed similarly to grafts that were well contained and automatically stable without further fixation. The implication is that when a graft could be absolutely stabilized by screw fixation alone, it performed as well as one that was perfectly coapted to the host bone.

We consider a large graft-to-host contact and a near perfect coaptation of the graft host surfaces to be beneficial; we were unable to accurately analyze these factors in our study.

There was a significantly increased lateral position of the acetabular center in those hips that failed as opposed to those that survived. This increased lateral offset may have altered the biomechanics of the hip, preferentially loading the allograft lateral to the coverage area by host bone, thereby leading to progressive collapse of the graft with time.

There were no statistically significant differences in survival at 10 years when comparing the different Paprosky grades. The best results were achieved in the 2B group, where there was moderate, superior, and medial bone loss with mild posterior column deficiency. Worse results were found in the 2A (mild bone loss), 2C (mild to severe medial wall defects), and 3A groups (significant superior, medial, and posterior column bone loss), with the latter perhaps better managed by acetabular allograft rather than femoral head.

The factor that most complicates direct comparison between series is the variety of classification systems used for acetabular defects in the revision situation. It is therefore not possible to draw direct comparisons, but it is possible to assess in each series whether
the acetabular defects were predominantly severe or not, and whether the defects were predominantly contained.

The initial report of the use of frozen femoral head allograft in acetabular revision was published in 1982, and reported excellent results on the initial eight cases. This series was gradually expanded and at nearly four years, a 17% failure rate was reported in 24 cases. At almost 6 years, there were 29% failures in 29 cases progressing to 50% failures in 22 cases at a mean of 10 years.

By 16.5 years, this group reported a 60% failure rate in 10 revision hips. A 60% failure rate among the 60 primary hips reconstructed with structural graft was also reported, and the authors found no difference in failure rates between the 15 allografts and the 55 autografts. These results prompted the authors to suggest the use of alternative methods of acetabular reconstruction.

These results compare poorly to the 88.5% 10-year survival in our series. There are few other series with a 10-year review available. Woodgate et al. reported on the use of structural segmental allograft with cemented cups in 13 cases. This constituted a subgroup of 51 cases with a 78% 10-year survival in which structural segmental allograft was used. The results of femoral head and acetabular allograft (irradiated) were amalgamated and there was no breakdown of the results of cemented as compared to cementless (including bipolar) implants.

Earlier reports from this group on a mixed series of 62 cases of structural allografts included 22 cases with a cemented cup and structural allograft without a reinforcement ring. The authors reported a 6.8% failure rate in the Gross 2A defects (uncontaminated with host bone supporting at least 50% of acetabular component), but a 45% failure rate in the Gross 2B defects (uncontaminated with host bone supporting <50% of acetabular component) at a mean 7.1 years follow-up. It appears that femoral head allografts were used in 21 Gross 2A defects, with partial acetabular structural grafts used in three Gross 2A and all of the Gross 2B defects. The results of the different types of acetabular components used (uncemented, bipolar, cement with reinforcement ring, cemented) are not differentiated, thereby making comparison with other series difficult. No aseptic failures occurred in the 12 cases in which a reinforcement ring and a cemented cup were used in conjunction with acetabular allografting. The 45% failure rate in cases with >50% of the acetabular component supported by the graft (as in all of our cases) compares poorly with the results in our series.

Lee et al. report on 54 revision cases with a mean follow-up of 10.2 years. The results of this group are amalgamated with 48 primary hip replacements. Seventy-four percent of cases received bulk femoral head graft, 35% of cases received allograft, and 11% of cases were supported with a reinforcement ring. We are unable to discern the results of revision cases that received bulk femoral head allograft and a cemented acetabular component without a reinforcement device. The authors reported a 30% probability of requiring an acetabular revision at 10 years in this mixed series.

Chandler and Tigges reported on 20 revision cases in which structural grafting of the acetabulum was performed and reviewed at 10 years. The authors did not specify the numbers of cemented versus cementless implants, nor the numbers of allograft versus autograft and type of structural allograft used, but reported a 31% aseptic failure rate in this series.

Morand et al. reported on 28 revision cases in which bulk and/or morcellized allograft was used without a reconstruction ring. The results are included with those of 10 cases in which a reinforcement ring was used. A failure rate of 13% was reported at a mean of 7.3 years.

Stiehl et al. report a mixed series of 17 cases. One aseptic failure occurred out of seven cases in which a cemented acetabular component was used in either femoral head or acetabular allograft, without a reinforcement device. The authors used a triradiate approach in 12 cases and reported a 50% dislocation rate using this approach.

Other series have far shorter follow-up:
• Tranckl et al. report 6% failure in 17 cases at 3.5 years.
• Knight et al. report 21% failures in a mixed series of 74 cases reviewed at a mean of 3.5 years. In 13 cases, an acetabular component was cemented with femoral head allograft. These results are not differentiated from other modes of treatment.
• Young et al. report an 18% failure rate at 3.7-year review in 40 patients with femoral head grafting during acetabular reconstruction. The results of allograft (11 cases) are not differentiated from autograft, nor are cemented and cementless component results differentiated.

By comparison, the overall results in our series of 140 cases at 10-year mean review display a satisfactory survival rate of 88.5% using the Kaplan-Meier survival analysis method. These contrast strongly with the 50% failure rate at 10 years reported by Kwong et al. They are similar to but better than most of the previously discussed series, with failures ranging from 13%–31% at 7 to 10-year mean follow-up.

Concern has been raised regarding the fate of bulk allograft. Histological analysis of two post-mortem cases demonstrated little evidence of graft-to-host healing, revascularization, or remodeling, while morcellized allograft appears to be capable of being remodeled virtually completely over an extended period of time. Fourteen percent of the failures in our series are related to radiological collapse of the graft, with 1.5% related to stress fracture of the weak host acetabular bone. In each of the failures, histological analysis of biopsy specimens of the collapsed graft has revealed dead bone. Why the graft should collapse in some cases, is a question we are unable to answer at this stage.

Alternative techniques for reconstructing acetabular defects during revision include the use of structural or morcellized allograft and bone graft substitutes,
reinforcement armatures, and cemented and cementless acetabular components including bipolar head prostheses.

The results of structural allografting with an uncemented acetabular component seem disappointing, with an 86% failure rate reported at 12.5 years. Others have had similarly disappointing results ranging from 20% to 72% failure rates at far shorter follow-up. This is most marked in the more severe defects, with one group reporting a 64% failure rate at 2.7 years in severe cases but only a 6% failure rate in less severe defects at 6.1 years. In the most severe defects, this group has subsequently reported a 12% aseptic failure rate using whole acetabular allografts at 2.6-year mean follow-up.

Others using whole acetabular allograft and an uncemented cup report a 50% failure rate in eight cases reported at a mean of 4 years. There are two reports of satisfactory results at short-term follow-up using this technique.

Excellent intermediate and long-term results have been reported with survival rates as high as 95% at 10 years. These results are at least as good as those in our series, however, one series reported 52% failures at 8.75 years.

Histological analysis of a single specimen of block allograft protected by a Muller ring showed minimal remodeling at 20 months. The limited series advocating this technique report excellent results, with the only long-term study reporting a 94% survival rate at 11.5 years in 60 hips and one short-term study reporting similar good results.

Of particular interest are the histological studies of biopsy specimens from 21 hips that demonstrate virtually complete remodeling of the bone graft using this technique.

Those using this technique report excellent results in the medium term with no aseptic failures at follow-up times ranging from 2.6 to 7.3 years.

Others report failure rates ranging from 3.6% to 20% at follow-up ranging from 4.6 to 8.5 years. In most series, this technique has been used in the management of moderate to severe acetabular defects similar to those in our series. These reported results seem as good as those in our series in most cases. No series, however, have a mean follow-up time of 10 years; we await the longer-term results of these series with interest.

The histological analysis of morsellized graft protected by a Muller ring in two cases demonstrated almost complete remodeling with time. Whether the environment for remodeling is identical when other forms of armature are used is unclear.

The use of bone graft substitute in association with reinforcement devices and a cemented cup has resulted in 66% aseptic loosening at 3 years. The authors suggest that the failures were due to incorrect choice of implant rather than a problem with the bone graft substitute. We will await the longer-term results of this technique before assessing its usefulness.

The use of a bipolar component during revision has produced poor results, with medium-term failure rates of 50%-70% when using bulk or morsellized allograft.

Excellent results (with as low as 1.8% failure at 10.5 years) have been reported with very low medium and long-term aseptic failure rates using the cementless revision (press fit porous ingrowth with supplemental screw fixation) with or without a high hip center technique. Similar excellent results have been reported using the so-called jumbo cups for the more severe defects.

These results are impressive and surpass those in our series. We have concerns, however, regarding the reconstructive options available should any of these cases fail in the future. The large amount of bone stock loss inherent in this procedure is of concern, and we prefer a more biological solution in which bone stock is restored rather than removed. The two series dealing with more significant bone loss have a mean follow-up time limited to seven years, and we await the longer-term results and the salvage solutions to any possible failures with interest.

The bilobed cup has resulted in a 26% failure rate at 3.5 years and as such does not appear to be an appealing option.

The long-term results of cemented revision of the acetabulum have been reported as having an almost 50% aseptic loosening rate in the long term, and it seems apparent that these results can be improved without the further loss of bone stock associated with this procedure.

CONCLUSION
While the results of frozen femoral head allografting with a cemented acetabular component in our series surpass results of series using a similar technique, they seem to have been surpassed by some other techniques, at least in the medium term. Our current approach, in view of the results of this study and literature review, is as follows.

Cementless revision seems to produce excellent results, but we prefer to not remove further bone stock to achieve stability, and prefer not to use a high hip center. This technique seems well suited to the acetabulum with small, contained defects that can be packed with morsellized allograft and allow at least 50% host contact with a stable implant; and we therefore choose this technique in these situations.

For larger contained lesions, the technique of impaction grafting of allograft bone prior to cementing an acetabular implant seems to yield exceptional midterm results, rivaling those of primary hip replacement. Whether these results can be replicated when a segmental lesion is converted to a contained lesion by using a reconstruction rim mesh prior to impaction grafting remains to be seen, but this remains an attractive option particularly if the segmental lesion is superiority positioned.

In large segmental defects particularly affecting the anterior or posterior columns or both and in pelvic dissociation, the use of impaction allografting and an anti-pro-
trusio cage may offer all the remodeling benefits of morsellized impaction grafting, while providing primary stability to the cemented acetabular component and pelvis.

In such massive bone loss as to prevent an anti-protrusio cage bridging the defect, the only available alternatives to resection arthroplasty are the use of hemipelvic grafts or the saddle prosthesis. Again, we prefer to attempt to restore bone stock if possible in case further surgery becomes necessary, and note that the results of cemented arthroplasty into acetabular allograft are good when the bulk allograft is protected with an anti-protrusio cage.

The evidence in the literature suggests that this approach should yield results better than a 10-year survival of 88.5%, but the longer-term results and possible late complications of some of the newer techniques will be awaited with interest.

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