Acetabular reconstruction using morselized allograft and a reinforcement ring for revision arthroplasty with Paprosky type II and III bone loss: Survival analysis of 95 hips after 5 to 13 years


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KEYWORDS
Acetabular reconstruction;
Morselized allograft;
Acetabular reconstruction cages;
Hip arthroplasty;
Loosening;
Hip center of rotation

Summary
Introduction: Treatment of acetabular loosening and accompanying bone defects requires that the bone stock be rebuilt, the primary stability ensured, and the hip center of rotation restored to its anatomical location.

Hypothesis: Acetabular reconstruction using morselized allograft and a reinforcement ring will meet these requirements and ensure medium-term survival.

Patients and methods: A retrospective study was performed on 95 acetabular revision cases (95 patients) performed between 1987 and 1995. The average age at revision was 69.5 years (42 to 86 years). Among these acetabular loosening cases, 12 cases had a type II Paprosky acetabular bone defect and 83 cases had a type III defect.

Results: The average follow-up was 8 years (5 to 13 years). There were seven post-operative dislocations, three deep infections, and two cases of repeated acetabular loosening. The cumulative survival rate at 14 years was 77.9% (95% CI: 61.96% to 93.84%). The average Postel Merle d’Aubigné (PMA) score improved from 8 (range 6–11) preoperatively to 14.8 (range 8–18) at follow-up; the Harris score improved from 35.3 (range 11–52) to 71.1 (range 40–94) (P < 0.001). Based on the parameters outlined by Ranawat, the optimal centre of rotation was restored in 45% of cases. Graft integration was found to be good in 60% of cases. The reinforcement ring had migrated in five cases, including two cases of acetabular loosening that required an additional revision. The functional result was better when the hip center of rotation was restored (P < 0.05). Conversely, the position of the hip center of rotation had no effect on graft integration or acetabular fixation.

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Introduction

As early as 1979, Charnley [1] suggested that revision surgery, because of loosening, would be the “primary concern in total hip arthroplasty over the medium and long term” and this prediction came to fruition during the rapid development of hip replacement surgery. In 1989, Herbergs et al. [2] estimated that the number of total hip arthroplasty (THA) revisions would double every 10 years. Many surgical techniques can be used to revise a loosened THA, but there is no consensus as to the best approach. When the patient presents with severe bone loss (Paprosky [3] type II and III; Sofcot [4] stage 3 and 4), we chose to perform the acetabular reconstruction using frozen morselized allograft and a metal reinforcement ring. We hypothesized that by rebuilding the acetabular bone stock and restoring the hip centre of rotation, satisfactory functional results and good stability could be obtained over the medium and long-term. The goal of this study was to evaluate this hypothesis in the medium term, through an evaluation of the functional and radiological results of the reconstruction.

Patients and methods

Patients

This single-centre, retrospective study comprised a continuous series of 135 THA cases that were revised because of acetabular loosening and also had a significant bone loss. This procedure was indicated preoperatively based on an evaluation of clinical and radiological records, with potential intra-operative adjustment. Cases meeting the following criteria were included: aseptic acetabular loosening with significant bone loss (Paprosky [3] type II or type III determined preoperatively, with intra-operative adjustment), reconstruction using morselized allograft with reinforcement ring and cemented cup, annual monitoring and minimum follow-up of 5 years.

From 1987 to 1995, there were 135 cases of acetabular revision that met the above criteria. Forty cases were eliminated (patients lost-to-follow or data not useable), leaving 95 cases for analysis. The series included 66 women and 29 men, with an average age at revision of 69.5 years (42–86 years) (Fig. 1). In 50 cases (54%), primary hip arthroplasty was indicated because of hip osteoarthritis (Fig. 2). Patient physical status was classified using the American Society of Anesthesiologists (ASA) system: two patients were at ASA 1, 59 patients at ASA 2, and 34 patients at ASA 3. The Charnley [5] functional score was also determined: six patients were Class A, 44 patients were Class B and 45 patients were Class C.

Discussion: This series confirmed that acetabular reconstruction using morselized allograft and a reinforcement ring is effective in the medium term as a treatment for acetabular loosening with severe bone deficiency. It also revealed that restoring the hip center of rotation can improve functional results.

Level of evidence: Level IV, retrospective study.

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Cemented primary acetabular components had been used in 59 cases and cementless components in 36 cases. The cups had been implanted for 13.2 years on average (cemented cups: 0.42–13 years, cementless cups: 0.42–23 years). Fifty-eight patients had been subjected to one procedure before being seen by us and 37 had had at least two procedures (range two to seven procedures). The femoral component was changed in all cases. An analysis of the femoral component was performed, but it is not reported here.

Surgical technique

A postero-lateral approach was used in 80 cases (84.2%), a Hardinge transgluteal approach in 14 cases (14.7%) and a Smith-Petersen anterior approach in one case (1.1%). The hip joint was exposed and the acetabular component and cement were removed. Once the acetabulum had been cleaned, the severity of the acetabular defect was graded using the Paprosky [3], Sofcot [4], and AAOS (D’Antonio) [6] classification systems (Table 1).

Bone defects were filled with a frozen morselized allograft, which was then compacted; one tissue bank femoral head was used on average (range one to three heads). An acetabular reinforcement ring was used in every case (54...
Acetabular reconstruction using morselized allograft and a reinforcement ring

Table 1  Distribution of acetabular defects.

<table>
<thead>
<tr>
<th></th>
<th>Sofcot</th>
<th></th>
<th>AAOS (D’Antonio)</th>
<th></th>
<th>Paprosky</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Type II</td>
<td>Type III</td>
<td>Type IV</td>
<td>Type II</td>
<td>Type III</td>
<td>Type IV</td>
</tr>
<tr>
<td>Number</td>
<td>5</td>
<td>75</td>
<td>15</td>
<td>5</td>
<td>84</td>
<td>6</td>
</tr>
<tr>
<td>%</td>
<td>5.2</td>
<td>79</td>
<td>15.8</td>
<td>5.2</td>
<td>88.5</td>
<td>6.3</td>
</tr>
</tbody>
</table>


Eichler\textsuperscript{TM} rings, 24 Ganz\textsuperscript{TM} rings, 16 Müller\textsuperscript{TM} rings, one Burch-Schneider\textsuperscript{TM} ring (Zimmer, Etupes, France). On average, four screws (range 3–6) were used to improve the primary stability of the ring.

Clinical and radiological assessments

The Postel Merle d’Aubigné (PMA) [7] and Harris [8] scores were used to assess patient function. The average preoperative PMA score was 8/18 (range 6 to 11) and the average Harris score was 35.3/100 (range 11 to 52). We also noted any medical and surgical complications.

The radiological assessment was performed on an A/P view of the pelvis and A/P and lateral views of the hip. We also wanted to evaluate the outcome of the grafting procedure, but the challenge was that biopsies would have to be taken from the bone for a histological analysis to truly assess the degree of graft integration, which was not possible in practice. Some published studies [9, 10] have used the radiological appearance of trabecular remodelling in the graft to distinguish between partial or completely lysis of the graft, no change in the graft, or integration of the graft (when bone trabeculae appear in the graft) instead of resorting to a histological study. At the same time, the presence of radiolucent lines at the bone/graft interface was also evaluated [11, 12].

Implant position was evaluated with X-rays using the method described by Sutherland et al. [13] to define the position of the hip centre of rotation based on its transverse (x) and longitudinal (y) position, and the inclination of the cup (α). The position of the centre of rotation was compared to the “optimal” centre of rotation defined by Ranawat et al. [14].

Migration was defined as a change of more than 5° in the inclination of the reinforcement ring, migration of more than 4 mm in the centre of rotation, or breakage of the material [12]. The bone/graft interface was evaluated using the three-zone classification proposed by De Lee and Charnley [15] to locate radiolucent lines. Radiolucent lines were defined as either a simple (less than 1 mm thick, stable, less than 50% of area), complete (less than 1 mm thick, stable, covering the entire surface area), or complex (2 mm or more in thickness, with or without progression, independent of thickness, location and extent). The presence of ossifications around the prosthesis was also evaluated using the classification by Brooker et al. [16].

Statistical methods

Data were collected in a spreadsheet (Excel\textsuperscript{TM}, Microsoft, Redmond, Washington, USA) and then analysed with statistical software (Statview\textsuperscript{TM}, Berkeley, California, USA). The Chi\textsuperscript{2} test was used to compare quantitative variables; simple regression tests were used to compare quantitative and qualitative variable; Kruskall-Wallis non-parametric tests were used when the data were not normally distributed or the homogeneity of variance assumption was violated. An actuarial analysis of the cumulative survival rate (with all 135 records) was performed using surgical revision and/or clinical or radiological evidence of loosening as failure criteria; 95% confidence intervals were reported. The type I risk was set at 5%.

Results

Complications

During their hospital stay, 59 patients (62.1%) did not suffer from any complications. Thirty-three patients (34.7%) had medical complications: 20 with a urinary tract infection, 9 with deep venous thrombosis, two with acute pulmonary oedema, and two with pneumonia. Two patients died because of a massive pulmonary embolism. One patient had a dislocation 7 days after the surgery and two patients required a surgical revision (hematoma secondary to vitamin K antagonist overdose, superficial infection).

Later on, after the index procedure, we observed seven dislocations (rate of 7.4%) with three requiring another surgical revision, three deep infections less than 2 years after the index procedure (two were resolved after changing the implant over two procedures and the other one after prosthesis removal), two cases of repeated acetabular loosening that required revision and three cases of femoral loosening that also required revision.

Clinical results

The average follow-up was 8 years (range 60 to 157 months). The PMA [7] and Harris [8] functional scores improved significantly (P < 0.001), with the overall PMA score at 14.8 (8–18) and the Harris score at 71.1 (40–94), thus an increase of 6.9 and 36 points, respectively. The PMA pain score went from 1.9 to 5.0, the mobility score went from 3.4 to 5.0 and the walking score went from 2.6 to 4.8, on average (Fig. 3). Every component of the PMA and Harris score changed significantly (P < 0.001). Overall according to PMA grading, there were three excellent (3.2%), 24 very good (25.3%), 31 good (32.6%), 21 fair (22.1%), 12 mediocre (12.6%) and four poor results (4.2%).
Radiographic results

The polyethylene cup had an average inclination of 45° ± 7° (range 21° to 65°). In eight cases, the cup had an inclination angle between 21° and 35°; in 41 cases, the inclination was between 35° and 45°; in 46 cases, the inclination was greater than 46° (maximum of 65°). After the revision, a theoretically ‘optimal’ centre of rotation was found in 41 cases (45%) (Table 2, Fig. 4). The graft was considered to be integrated in 58 cases (60%), unchanged in 20 cases (21%), partially lysed in 14 cases (15%) and completely lysed in three cases (4%).

At the graft/acetabulum interface, 78 cups did not have any radiolucent lines (84.9%), 11 had a simple radiolucent line (12%), one had a complete radiolucent line (1%) and two had progressive radiolucent lines (2.1%). Two implants had to be revised due to loosening; one had a complete radiolucent line with complete graft lysis and one had a progressive radiolucent line. Ninety of the reinforcement rings were stable and five had migrated. Of the five migration cases, two required surgical revision as mentioned above. There were 21 cases of grade I and II peri-prosthetic ossification and 15 cases of grade III and IV according to Brooker et al. [16]; none required revision.

Table 2 Analysis of the centre of rotation relative to the optimal centre of rotation defined by Ranawat et al. [14].

<table>
<thead>
<tr>
<th></th>
<th>Too high/too lateral</th>
<th>Too high</th>
<th>Too high/too medial</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 case</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Too lateral</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7 cases (7.7%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Too low/too lateral</td>
<td></td>
<td></td>
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<tr>
<td>6 cases (6.6%)</td>
<td></td>
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</tbody>
</table>

Figure 3 Change in Postel Merle d’Aubigné from preoperative to follow-up.

Statistical analysis and implant survival

There was no significant effect of gender or severity of pre-operative bone loss on the functional results. Patients less than 65 years old had an average Harris score of 76.9 (48–91), while patients above 65 years of age had a Harris score of 69.3 (40–94) (P < 0.05).

There was a statistically significant effect of the position of the hip centre of rotation on the functional results (P < 0.001). Patients in whom the centre of rotation was restored to the ‘optimal’ position [14] had better functional results (P < 0.05). Conversely, patients in whom the hip centre of rotation was lateralized and/or lowered had less good functional results (Table 3) (P < 0.05). There was no significant effect of the centre of rotation and horizontal position of the cup on integration of the allograft (Fig. 4).

With failure criteria of surgical revision and/or radiological loosening, the cumulative survival at 13 years was 77.9% (95% confidence interval: 61.96% to 93.84%). Analysis of the survival curve showed two periods with increased risk of failure: the first occurred between year 2 and 3, and the second between year 9 and 11.

Figure 4 Patient, 65 years old, total hip arthroplasty performed in 1987 on the left side. Isolated acetabular loosening classified as type IIc according to Paprosky. Reconstruction with Eichler ring and morselized allograft in 1985. A. A/P view of pelvis with type IIc bone loss according to Paprosky. B. A/P view of pelvis after 5 years. Measurement of centre of rotation [14]. C. A/P view of pelvis after 14 years. No signs of graft lysis or loosening.
Table 3. Effect of the centre of rotation (CoR) defined by Ranawat et al. [14] on the functional results.

<table>
<thead>
<tr>
<th>CoR Type</th>
<th>No. patients</th>
<th>PMA score</th>
<th>Harris score</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Pain</td>
<td>Mobility</td>
</tr>
<tr>
<td>Optimal CoR</td>
<td>41</td>
<td>5.49</td>
<td>5.46</td>
</tr>
<tr>
<td>Low CoR</td>
<td>10</td>
<td>4.8</td>
<td>5.3</td>
</tr>
<tr>
<td>Lateral CoR</td>
<td>7</td>
<td>4.71</td>
<td>4.71</td>
</tr>
<tr>
<td>Medial CoR</td>
<td>11</td>
<td>4.82</td>
<td>4.82</td>
</tr>
<tr>
<td>Low/medial CoR</td>
<td>9</td>
<td>4.11</td>
<td>4.11</td>
</tr>
<tr>
<td>High/medial CoR</td>
<td>4</td>
<td>4.5</td>
<td>4.75</td>
</tr>
</tbody>
</table>

Unpaired t-test: comparison of functional result in optimal CoR group to the other types of CoR.

* P < 0.05.

Table 4. Outcome of the graft as a function of the position of the centre of rotation according to Ranawat et al. [14] and cup inclination (P > 0.05).

<table>
<thead>
<tr>
<th>Centre of rotation</th>
<th>Cup orientation/horizontal plane</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Optimal</td>
</tr>
<tr>
<td>Number</td>
<td>41</td>
</tr>
<tr>
<td>Graft outcome</td>
<td></td>
</tr>
<tr>
<td>Incorporated</td>
<td>29</td>
</tr>
<tr>
<td>Unchanged/Lysis</td>
<td>12</td>
</tr>
</tbody>
</table>
Table 5  Comparison of various published studies.

<table>
<thead>
<tr>
<th>Series</th>
<th>Nº. patients</th>
<th>Average age</th>
<th>Average follow-up</th>
<th>Acetabular defect Classification of bone loss</th>
<th>Type of reinforcement hardware</th>
<th>Type of graft</th>
<th>Survival rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pascarel et al. [50]</td>
<td>211</td>
<td>63 (24–86)</td>
<td>6 (8–11)</td>
<td>Type I – 7</td>
<td>Müller</td>
<td>Autograft/allograft</td>
<td>98.6% at 5 years</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Type II – 44</td>
<td></td>
<td>Structural/morselized</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Type III – 72</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Type IV – 18 SOFCOT</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Massin et al. [11]</td>
<td>81</td>
<td>61 (24–85)</td>
<td>8 (5–14)</td>
<td>Type I – 7</td>
<td>Müller</td>
<td>Structural allograft</td>
<td>72% at 10 years</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Type II – 18</td>
<td></td>
<td>Morselized allograft</td>
<td>55% at 15 years</td>
</tr>
<tr>
<td>Kerboull et al. [45]</td>
<td>60</td>
<td>57.7</td>
<td>10 (0–16)</td>
<td>Type III – 48</td>
<td>Kerboull</td>
<td>Morselized allograft</td>
<td>92.1% (±5%) at 13 years</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Type IV – 12</td>
<td></td>
<td>Structural allograft</td>
<td></td>
</tr>
<tr>
<td>Bonnomet et al. [12]</td>
<td>56</td>
<td>68.5 (48–84)</td>
<td>8.2 (0.7–16.7)</td>
<td>Type III – 51</td>
<td>Müller</td>
<td>Autograft/allograft</td>
<td>64% at 5 years</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Type IV – 5 SOFCOT</td>
<td>Burch-Schneider</td>
<td>Structural/Morselized</td>
<td>43% at 10 years Müller: 44% at 10 years Burch: 78% at 10 years</td>
</tr>
<tr>
<td>Kawanabe et al. [55]</td>
<td>42</td>
<td>60 (37–85)</td>
<td>8.7 (4–12)</td>
<td>Type II – 13</td>
<td>Kerboull</td>
<td>Morselized allograft</td>
<td>53% at 10 years</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Type III – 28</td>
<td></td>
<td>Bone substitute</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Type IV – 1 AAOS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Current study</td>
<td>95</td>
<td>69.5 (42–86)</td>
<td>8 (5–13.1)</td>
<td>Type II – 5</td>
<td>Eichler</td>
<td>Morselized allograft</td>
<td>77.9% at 13 years</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Type III – 84</td>
<td>Müller</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Type IV – 6 AAOS</td>
<td>Ganz</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Burch-Schneider</td>
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</tbody>
</table>
Discussion

Data from the Swedish Hip Registry [17] revealed that loosening alone leads 70% of all THA surgical revisions. Morsch et al. [18] reviewed the time line of acetabular loosening and found that the risk to be lowest during the first 8 years, but increasing exponentially afterward. Kobayashi et al. [19] summarized the main risk factors for loosening: young patient, male, rheumatoid arthritis, incomplete cementation (mainly in zone 1 and 2) and elevated cup position.

When faced with loosening and significant bone loss, some surgeons [20–28] choose to use a cemented cup of the next larger size and to fill the defect with cement. This approach continues to be used despite the 1988 Sofcot report [20] that highlighted a repeated loosening rate of 33.3% with this technique and a potential loosening rate of 25% at 5 years. These data support the need to rebuild and restore the acetabular bone stock during revision arthroplasty.

Graft incorporation occurs in two phases: the initial phase with partial resorption of the graft and the re-population phase where new host bone is formed in the graft [29,30]. Since the assembly is fragile during these phases, the use of hardware to protect the graft is recommended. The incorporation of frozen morselized allografts has been verified in animals [31–34] and confirmed in vivo [35–40]. Harris et al. [41] performed an acetabular reconstruction with a massive structural allograft in combination with a cemented cup, without using a reinforcement ring. After initially promising results [41], failures were reported after 5 years [42] (20% loosening rate), 10 years [43] (47% loosening rate) and then at 16 years [44] (66% loosening rate). Only using a bone graft when faced with significant bone loss does not resolve the problems associated with mechanical support and graft integration. Thus, it seems appropriate to use a protective metal ring to stabilize these allografts and improve integration.

Two types of metal reinforcement rings exist: one type provides proximal fixation only (Müller type ring) and the other type provides dual fixation through a hook (Ganz ring, Kerboull cross) or screw (Burch-Schneider) system. Kerboull et al. [45] believe that using proximal fixation only is not sufficient and that many of the failures can be attributed to lack of primary stability. Gerber et al. [46] added that most of their failures occurred because of lack of primary stability of the ring, which led to graft lysis then loosening. Starting in 1988, Goosens et al. [47] and Dumont et al. [48] reported very promising results with the Müller ring, results which were subsequently confirmed [14,49,50]. There are many advantages of combining a reinforcement ring with a graft. First, the hip centre of rotation is more likely to be restored [12,51,52], which avoids the "elevated" hip centre of rotation advocated by some surgeons. However, elevation of the centre of rotation is an acceptable alternative if multiple conditions are met: limited bone defects, no combined effect of centre of rotation lateralization, need to compensate at the femur for the resulting "shortening" [53,54]. Second, the graft is protected and stabilized, which is essential for graft integration [45,46,52]. Few studies have compared the use of different reinforcement rings. Bonnomet et al. [12] found the Burch-Schneider ring to be better than the Muller ring in cases of loosening with severe bone loss.

Our series with an average follow-up of 8 years confirmed the good long-term results described in other published studies [53,54] (Table 5). Gender, loosening stage or type of ring used did not significantly affect the functional results. The position of the hip centre of rotation had a statistically significant effect on the functional results (P < 0.001). Thus, patients with a centre of rotation in the optimal position [14] or in an identical position to healthy contralateral side had better functional results. Our series also confirmed the benefits of protecting and stabilizing the graft with a reinforcement ring, as only 4% of grafts underwent complete lysis. But we must be cautious, as results deteriorate beyond 10 years. Allografts have been known to resorb later on (after 10 years), thus we must continue to monitor this type of reconstruction over the long-term [11].

Our study had significant limitations. It was a retrospective study without a control group. Forty records could not be reviewed because of lack of data or because the patient had died or was lost to follow-up. Conversely, the study was performed with a single observer, which limits bias in how the results are interpreted. Using patient self-evaluation scores would have avoided bias related to the data collection. This study supports our surgical approach and highlights the benefit of correctly positioning the centre of rotation, which led us to use the Kerboull cross in most cases and use the Burch-Schneider ring only in cases of significant bone loss with severe protrusion.

Conclusion

Our series confirmed the effectiveness of using an allograft and metal ring during acetabular reconstruction and emphasized the need to restore the hip centre of rotation in its anatomical location for good long-term results. In cases of massive loosening, the anatomical centre of rotation can only be restored by rebuilding the bone stock using a graft protected with a reinforcement ring that improves hip centering.

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

References


