Clinical and experimental aspects of fixation, loosening, and revision of total hip replacement

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Chapter 9

Cemented hip revision surgery in severe acetabular defects using a semirigid acetabular reinforcement ring

A 5 TO 25 YEAR FOLLOW-UP STUDY

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Abstract
Between 1978 and 1998, a total of 38 consecutive acetabular component revisions were performed in 38 patients. Average age was 67 years, and 87% of patients had severe uncontained segmental acetabular defects of more than 50%. We describe the operative technique of acetabular component revisions performed with bone grafting and a steel, semirigid acetabular reinforcement ring (Eichler), and long-term results are presented. After an average of 11.2 years follow up, one cup was revised after 0.8 years for mechanical loosening, but the ring remained stably fixed. Remodeling (partial) of autografts occurred in all cases. The average Harris hip score was 72.5. The Eichler reinforcement ring is a viable option for segmental acetabular defects in revision hip surgery, allows for restoration of pelvic bone, and makes future revisions feasible.

Introduction
The presence of large segmental acetabular defects caused by cup migration or migration of a hemi-prosthesis is a great challenge in hip revision surgery. During the loosening process of an acetabular component, bony defects can develop by (micro-) motion, by debris reaction and through bone resorption caused by fluid pressure waves induced by a loose prosthetic component. In small cavitary defects, when sufficient bony support is still present, a large(r) polyethylene cup can be placed in the anatomical position sometimes with additional bone grafting. When bone defects are larger and segmental, revision of the acetabular component is difficult: the structures required for the fixation of the cup are no longer intact, and it is impossible to place the cup in the anatomical position. This bone loss can be addressed with mega-implants or by creating bony support by means of bone grafting and/or reinforcement rings. The advantage of bone grafting and pelvic reconstruction is that future revisions are facilitated. Several types of reinforcement rings have been developed and have been reported on, in having peripheral flanges or a caudal hook. Because initial stability is imperative in preventing early loosening, rings are usually made of a more rigid material (eg, commercially pure [CP] titanium). Rigidity of components may cause stress shielding as is seen in press-fit metal-backed cups in primary total hip arthroplasty (THA). Since 1978, we have been using a reinforcement ring for revisions with large segmental acetabular defects, which is essentially different from other rings because it is made of steel and is semirigid. It has no medial wall and no peripheral but central flanges. This Eichler ring should give sufficient initial stability and theoretically should cause less stress shielding with less periprosthetic bone resorption allowing bone grafts to remodel under the existing pressure. This bone grafting can be used additionally to support the ring and fill defects to reconstruct the pelvic bone and make future revisions feasible. Our research question is whether the long-term and clinical results of acetabular revision surgery with the Eichler acetabular reinforcement ring is superior compared to the reported results of other (more rigid) reinforcement rings.

Material and Methods
Between 1978 and 1998, from a total of 240 hip revisions, 38 consecutive hip revisions (38 patients) were performed with the Eichler ring by the two senior orthopaedic surgeons (RKM, PPB). In 27 procedures, both acetabular and femoral components were exchanged, and in 11 procedures, only the acetabular component was revised. For 6 hips (16%), this was the second revision, and for 3 hips (8%), the third revision was on the acetabular side. Seven (16%) revisions were performed for septic loosening as a second-stage procedure. Patients were operated on at an average age of 67.3 years (range, 30.2-86.5 years). Twenty-nine patients (81%) were female. Indications for the primary THA were idiopathic osteoarthritis in 15 hips, developmental dysplasia in 11 hips, posttraumatic osteoarthritis in 11 hips, and rheumatoid arthritis in 1 hip.

The acetabular defects were scored according to the classification as described by Saleh et al and Gross and Goodman. In 3 hips, a type II defect was present in which the defect was cavitary and contained with an intact rim. In 2 hips, a type III defect was present, meaning an uncontained segmental defect with bone loss of less than 50% of the acetabulum. The remaining 33 hips had a type IV defect, indicating an uncontained segmental defect with bone loss of more than 50%. There were no type V defects (pelvic discontinuity).

All procedures were performed in a supine position, using an anterolateral approach combined with an osteotomy of the greater trochanter. The cup, cement mantle, granulation tissue, and non vital scar tissue are removed until the sclerotic bony surface is visible. After careful minimal reaming of the remaining acetabulum, the definitive classification of the defect is possible. At this point, it is decided whether a large(r) cup (with bone grafting) can be placed in the anatomical position or – usually in case of segmental defects - an Eichler ring is warranted (Fig. 1).
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Fig. 1. The surgical algorithm for cemented hip revision surgery we have used since 1978.

Loosening acetabular component

Revision surgery is planned

Small (cavitair) acetabular defect

Large (segmental) acetabular defect

Large cup can be inserted in correct position

No defects remain

Small defect remain

Large cup cannot be inserted in correct position

Insert Eichler ring

Superolateral defects remain

Provide stability with corticocancellous bone grafts from the iliac crest and fixate with screws

Central defects remain

Fill with autologous bone slices or donor grafts (prevent leakage of cement)

Intrinsic stability

Insufficient intrinsic stability

Add grafts

Add screws

Cup standard technique

Cement the Eichler ring and cup in two steps

Fig. 2. The smallest (diameter, 44 mm; 7 holes) Eichler acetabular reinforcement ring.

The Eichler ring (Fig. 2) is made of V 2 A steel (Sulzer, Protek, Baar, Switzerland) and comes in four sizes of 44, 50, 54, and 58 mm in diameter. The smallest size has 7 holes, and the largest size has 15 holes for screw fixation. At insertion, the central flanges can be (slightly) bent until intrinsic stability is reached. If the intrinsic stability is not optimal, screws are added to fix the ring (9 hips). Correct inclination and anteversion of the ring are not an absolute requirement because the position of the cup can be tilted approximately 20° in inclination and 15° in anteversion relatively to the position of the ring (Fig. 3). At this point, it is judged if and where additional bone grafting is necessary. Cranolateral defects are grafted with autologenous (bicortical) cortico-cancellous bone blocks4, 6 from the contralateral iliac crest because the largest forces act in this part of the acetabulum. These grafts are fixated with screws and washers (Fig. 4). Defects of the medial wall are filled with autologenous slices of the lamina interna of the iliac crest or donor grafts5 so that height and center of rotation of the hip are restored25, and in addition, leakage of cement is prevented (Fig. 5).
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Fig. 3. Correct inclination and anteversion of the Eichler ring are not an absolute requirement because the position of the cup is not related to that of the ring.

Fig. 4. A, Loosening with severe acetabular bone loss in a 30-year-old female patient. B, Postoperative radiograph after revision. The Eichler ring was inserted, restoring the height and center of rotation, but not in the correct amount of anteversion. Because initial intrinsic stability was judged as being insufficient, screws were added. Then, the remaining superolateral defects are filled with autogenous grafts from the contralateral iliac crest. The dotted line shows the border between the grafts and the supraacetabular bone. In this “new” acetabulum, the cup is cemented in the ideal amount of anteversion at the original height and center of rotation. C, Anteroposterior and lateral x-ray after 21.1 years of follow-up. There are no signs of component loosening. There is remodeling of the supraacetabular bone with complete restoration of bone stock.
Fig. 5. A. Loosening and migration of a THA in a 53-year-old woman. B. X-rays 2 years postoperatively; the autologous superolateral graft is completely restructured and incorporated. The slices of allograft used for the restoration of the central defect remain unchanged. C. X-rays 13.7 years postoperatively. No sign of loosening is visible. The central slices of allografts remained unchanged during follow-up.
Multiple anchorage holes with a diameter of 6 mm are made into the remaining acetabulum. If the stability of the Eichler ring and grafts is perfect, the Eichler ring and cup can be placed in a one-step cementing technique. However, we prefer a 2-step cementing technique to achieve an optimal fixation with a small amount of cement. The central flanges can be fixed with a small amount of cement inserted as a ball mass at high viscosity and then pressurized with the trialcup-pusher to create a new acetabulum. A good visualisation of the defects and anchorage holes remains with using this 2-step technique, ensuring the optimal filling with cement by filling it digitally under compression. As the cement has hardened, the surface is roughened and new anchorage holes are made. A second (small) portion of cement at less high viscosity is then inserted to fix the cup in the right position. The cup is pressurized until the cement is hardened. The same prosthetic implant was used in all patients, a cemented Weber Rotation THA System (Allopro, Baar, Switzerland).

Trochanter refixation was performed with 2 lag screws with additional tension-band cerclage wiring.

Survival analysis was performed using a life table method with revision for any reason of the acetabular component and/or ring as endpoint. All patients were invited to our outpatient clinic where a Harris hip score (HHS) was obtained. Because many patients had comorbidity that could influence the interpretation of the HHS, the patients were categorized according to Charnley. Class A means that only one hip is affected, in Class B the contralateral hip is also affected causing limited mobility, and comorbidity influencing mobility is present in Class C.

Weight-bearing anteroposterior pelvic and lateral hip x-rays were obtained at follow-up and compared with the available postoperative x-rays and radiographs made at annual or biannual follow-ups. Radiolucencies with a width of more than 1 mm were detected in the zones according to DeLee and Charnley and made at annual or biannual follow-ups. Radiolucencies with a width of more than 1 mm were detected in the zones according to DeLee and Charnley and made at annual or biannual follow-ups. Radiolucencies with a width of more than 1 mm were detected in the zones according to DeLee and Charnley and made at annual or biannual follow-ups. Radiolucencies with a width of more than 1 mm were detected in the zones according to DeLee and Charnley and made at annual or biannual follow-ups. Radiolucencies with a width of more than 1 mm were detected in the zones according to DeLee and Charnley and made at annual or biannual follow-ups. Radiolucencies with a width of more than 1 mm were detected in the zones according to DeLee and Charnley and made at annual or biannual follow-ups. Radiolucencies with a width of more than 1 mm were detected in the zones according to DeLee and Charnley and made at annual or biannual follow-ups. Radiolucencies with a width of more than 1 mm were detected in the zones according to DeLee and Charnley and made at annual or biannual follow-ups. Radiolucencies with a width of more than 1 mm were detected in the zones according to DeLee and Charnley and made at annual or biannual follow-ups. Radiolucencies with a width of more than 1 mm were detected in the zones according to DeLee and Charnley and made at annual or biannual follow-ups. Radiolucencies with a width of more than 1 mm were detected in the zones according to DeLee and Charnley and made at annual or biannual follow-ups. Radiolucencies with a width of more than 1 mm were detected in the zones according to DeLee and Charnley and made at annual or biannual follow-ups. Radiolucencies with a width of more than 1 mm were detected in the zones according to DeLee and Charnley and made at annual or biannual follow-ups. Radiolucencies with a width of more than 1 mm were detected in the zones according to DeLee and Charnley and made at annual or biannual follow-ups. Radiolucencies with a width of more than 1 mm were detected in the zones according to DeLee and Charnley and made at annual or biannual follow-ups. Radiolucencies with a width of more than 1 mm were detected in the zones according to DeLee and Charnley and made at annual or biannual follow-ups. Radiolucencies with a width of more than 1 mm were detected in the zones according to DeLee and Charnley and made at annual or biannual follow-ups. Radiolucencies with a width of more than 1 mm were detected in the zones according to DeLee and Charnley and made at annual or biannual follow-ups. Radiolucencies with a width of more than 1 mm were detected in the zones according to DeLee and Charnley and made at annual or biannual follow-ups. Radiolucencies with a width of more than 1 mm were detected in the zones according to DeLee and Charnley and made at annual or biannual follow-ups.

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Results

Both 10-year and 15-year survival with revision for any reason as an endpoint was 97% (95% confidence interval, 92-100) (Table I); and with grade III definitive radiologic loosening as endpoint, this was 94% (95% confidence interval, 85-100). There was one revision of the acetabular component in one patient (2.6%) because of mechanical loosening, 0.8 years after the index operation. In this patient, 2 portions of cement had been used, and only the cup with the second portion of cement loosened and was revised, whereas the Eichler ring (and grafts) remained well fixed.

At the latest follow-up, 16 patients (42%) had died of causes unrelated to the procedure at an average age of 84 years (range, 64-93 years), reaching a mean follow-up of 8.1 years (range, 2.0-16.3 years). None of these patients had a revision of the acetabular component.

Clinical evaluation was possible in 14 patients (37%). Four patients (11%) were unable to visit our outpatient department because of logistic reasons, but a HHS could be obtained by phone interview. One patient (3%) was unable to visit our outpatient department and no reliable HHS could be obtained because of severe dementia, but the prosthetic implant was still functioning well. Two patients (5%) were lost to follow-up. Thus, hip scores could be calculated for 18 patients after an average follow-up of 11.2 years (range 5.8-21.1 years). The average HHS was 72.5 (range, 31-100). Three patients had poor hip scores of 31, 34 and 35, respectively: this was caused by recurrent dislocations of the prosthesis in one patient and by comorbidity in the other 2 patients (Charnley C category). Eight patients (44%) were classified as Charnley class A, 4 patients (22%) as class B and 6 patients (33%) as class C. The (average) HHS for each Charnley category is shown in Table 2. Five patients (28%) had a positive Trendelenburg sign.
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Radiological evaluation including the one revised hip was possible for 20 hips after an average follow-up of 9.9 years (range 5.8-21.3). When the cups were scored for loosening, 7 hips (37%) were classified as no loosening, 6 hips (31%) as possible loosening (type I), and 4 hips (21%) as probable loosening (type II). The remaining 3 cups (10%) were scored as definitive loosening (type III), which occurred after 0.8, 6.2 and 17.8 years (Table 3). The case with early loosening was revised because of severe migration with complaints. The other 2 hips had very few complaints with hip scores of 78 and 90, respectively, and obviously a revision was not indicated. Remodeling of superolateral bone grafts was complete in 12 hips (including the one revised case) and partial in the remaining 8 hips. Areas of partial resorption of bone grafts were seen in 5 hips; in the remaining 15 hips, there was no resorption of grafts at all.

Surgery-related complications occurred in 4 patients (10%): one patient had recurrent dislocations of the hip, requiring additional surgery without component revisions; one hip dislocated once and responded well to conservative treatment; in one patient a sciatic nerve lesion occurred, which resolved partially; and in one patient, an intraoperative femoral fissure occurred requiring fixation with cerclage wiring only which lead to uneventful healing. No deep infections, trochanteric non-unions, or problems related to the harvest of iliac autologous bone grafting occurred. One patient had a period of hypotension during surgery; this occurred while the cement was inserted. Postoperatively, she presented with a hemiplegia due to an ischemic stroke.

<p>| No. of | No. of | Average | Average |</p>
<table>
<thead>
<tr>
<th>patients</th>
<th>patients</th>
<th>HHS</th>
<th>Range</th>
<th>follow-up</th>
</tr>
</thead>
<tbody>
<tr>
<td>All patients</td>
<td>18</td>
<td>72.5</td>
<td>31-100</td>
<td>11.2</td>
</tr>
<tr>
<td>Charnley A</td>
<td>8</td>
<td>89.7</td>
<td>73-100</td>
<td>9.7</td>
</tr>
<tr>
<td>Charnley B</td>
<td>4</td>
<td>61.5</td>
<td>34-79</td>
<td>13.3</td>
</tr>
<tr>
<td>Charnley C</td>
<td>6</td>
<td>57.0</td>
<td>31-90</td>
<td>12.2</td>
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</tbody>
</table>

Table 2. Number of patients, HHS, and follow-up time for each Charnley category.
Discussion

In hip revision surgery, acetabular bone defects can be large (segmental), which makes sufficient restoration of defects by using a larger(ger) cup and solid bone grafting alone not possible. For such cases, various types of rigid rings\(^8-14,18,32\) providing the requested stability\(^19\) are in use. Eichler, in 1972, reported on the operative technique of a semirigid steel reinforcement ring, which was developed for protrusion coxarthrosis and used in the presence of a primary THA: the number of patients was small (17) and (clinical) results were not reported on reference\(^33\). Later, it was noted that in the case of revisions with pathological acetabula and bony deficiencies, the Eichler ring could be a valuable solution. In 1994, Weber and Brunnemann reported their results of 38 hip revisions from a total of 304 hip revisions performed with the Eichler ring\(^34\). There were no re-revisions, but mean follow-up was 5 years and the number of patients who had died and/or were lost to follow-up was substantial. From these\(^2\) studies, a lack of information on surgical technique and (long-term) results of this specific augmentation ring remains. In this retrospective study, we asked whether the long term and clinical results of this “Eichler” reinforcement ring that we have been using since 1978 for revision hip surgery are superior compared to the reported results of other reinforcement rings with a different design and made of a more rigid material. In addition, we describe the surgical technique we used.

A possible limitation of this study is that a substantial number of patients (47\%) had withdrawn. Because the study group contained several elderly patients, the main reason for this was that many had died during follow-up, whereas only two patients (5\%) were actually lost to follow-up. For those patients who had died, we know from our records (standard annual or biannual follow-up) and from additional information from the general practitioner that they did not seek medical attention for a hip problem and no revisions occurred. Because the aim of revision surgery is to improve the quality of life and to prevent any further revision of the prosthetic implant, we do believe that the outcome for these patients can be considered successful. Also, when evaluating radiologic stability of components, it is important to have reliable methods of measurement of component migration\(^35\). The precise measurement of migration is difficult because of overprojection of the ring on x-rays and the obscured anatomical landmarks in these multiple operated hips. This difficulty is also established by the great number of methods for measurement of migration described in the literature\(^16, 10, 36-39\). However, we believe that the method we used has proven to be simple and reliable.

Table 3. Radiological follow-up.

<table>
<thead>
<tr>
<th>Sex</th>
<th>Age at operation (y)</th>
<th>Follow-up (y)</th>
<th>Zone with radiolucency(^1)/max. width</th>
<th>Loosening(^2)</th>
<th>HO(^3)</th>
<th>Remodeling/Resorption bone graft(^4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>♀</td>
<td>70.8</td>
<td>8.2</td>
<td>no radiolucence</td>
<td>I</td>
<td>0</td>
<td>2/1</td>
</tr>
<tr>
<td>♀</td>
<td>50.3</td>
<td>6.4</td>
<td>2+3/2mm</td>
<td>I</td>
<td>0</td>
<td>2/1</td>
</tr>
<tr>
<td>♀</td>
<td>62.4</td>
<td>11.5</td>
<td>2+3/2mm</td>
<td>I</td>
<td>0</td>
<td>2/1</td>
</tr>
<tr>
<td>♀</td>
<td>83.7</td>
<td>0.8</td>
<td>*</td>
<td>III</td>
<td>0</td>
<td>2/0</td>
</tr>
<tr>
<td>♀</td>
<td>56.1</td>
<td>9.4</td>
<td>no radiolucence</td>
<td>no loosening</td>
<td>0</td>
<td>1/0</td>
</tr>
<tr>
<td>♀</td>
<td>75.9</td>
<td>6.7</td>
<td>1+3/1mm</td>
<td>I</td>
<td>0</td>
<td>1/0</td>
</tr>
<tr>
<td>♀</td>
<td>30.2</td>
<td>21.3</td>
<td>3/1mm</td>
<td>I</td>
<td>0</td>
<td>1/0</td>
</tr>
<tr>
<td>♀</td>
<td>60.7</td>
<td>9.8</td>
<td>3/2mm</td>
<td>II</td>
<td>2</td>
<td>1/0</td>
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<td>66.1</td>
<td>6.3</td>
<td>3/1mm</td>
<td>II</td>
<td>2</td>
<td>2/0</td>
</tr>
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<td>55.4</td>
<td>19.8</td>
<td>no radiolucence</td>
<td>no loosening</td>
<td>1</td>
<td>1/1</td>
</tr>
<tr>
<td>♀</td>
<td>67.3</td>
<td>7.8</td>
<td>1/1mm</td>
<td>II</td>
<td>1</td>
<td>1/0</td>
</tr>
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<td>♀</td>
<td>52.3</td>
<td>11.7</td>
<td>no radiolucence</td>
<td>no loosening</td>
<td>0</td>
<td>2/1</td>
</tr>
<tr>
<td>♀</td>
<td>53.5</td>
<td>13.7</td>
<td>no radiolucence</td>
<td>I</td>
<td>2</td>
<td>0/0</td>
</tr>
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<td>♀</td>
<td>69.6</td>
<td>6.7</td>
<td>no radiolucence</td>
<td>no loosening</td>
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<td>64.8</td>
<td>5.8</td>
<td>no radiolucence</td>
<td>no loosening</td>
<td>0</td>
<td>2/0</td>
</tr>
<tr>
<td>♀</td>
<td>70</td>
<td>6.7</td>
<td>no radiolucence</td>
<td>no loosening</td>
<td>0</td>
<td>2/0</td>
</tr>
<tr>
<td>♀</td>
<td>60.6</td>
<td>6.3</td>
<td>3/2mm</td>
<td>I</td>
<td>1</td>
<td>2/0</td>
</tr>
<tr>
<td>♀</td>
<td>67.2</td>
<td>17.8</td>
<td>1+2+3/17mm</td>
<td>III</td>
<td>0</td>
<td>2/0</td>
</tr>
<tr>
<td>♀</td>
<td>42.0</td>
<td>6.2</td>
<td>no radiolucence</td>
<td>no loosening</td>
<td>1</td>
<td>1/0</td>
</tr>
<tr>
<td>♀</td>
<td>39.9</td>
<td>6.2</td>
<td>3/12mm</td>
<td>III</td>
<td>0</td>
<td>2/1</td>
</tr>
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</table>

1 Zones with radiolucency/max. width according to DeLee and Charnley: type I = lateral radiolucency, type II = middle radiolucency, type III = medial radiolucency
2 Loosening according to Gill et al.: type I = possible loosening, type II = probable loosening, type III = definite loosening.
3 HO = Heterotopic ossification according to Brooker et al.: class I = small islands of bone in the soft tissue; class IV = bone ankylosis of the hip.
4 Remodeling of the autograft: class 0 = no remodeling, class 1 = incomplete remodeling, class 2 = complete remodeling. Resorption of the autograft: class 0 = no resorption, class 1 = partial resorption, class 2 = complete resorption.
5 Radiolucency was not measurable because of complete loosening of the acetabular component.
In this study, we had only one (2.6%) re-revision, two cases (5.2%) of definitive radiological loosening, a 15-year survival of 97% for revision for any reason as endpoint and 94% for definitive radiologic loosening as endpoint, and a relatively low surgery-related complication rate of 10%. These results may be due to the mechanical properties of the ring. Although most other types of acetabular reinforcement rings are made of titanium, the Eichler ring is made of steel. The elasticity (Young elastic modulus) of steel is twice as high as titanium and therefore the Eichler ring can be denoted as semirigid. Furthermore, it has no medial wall, making it more elastic compared to rings that do have a medial wall. This allows for load transfer to the acetabular bone with subsequently remodeling and structural integration (according to Wolff Law) of the (superolateral) autologenous grafts as was also shown in a finite element study and in ywo previous clinical studies from our institution.

In this study, in the presence of a semirigid reinforcement ring, all superolateral autografts demonstrated partial or complete remodeling with no resorption of the grafts in the weight-bearing zone. This finding is in concordance with the occurrence of less retroacetabular stress shielding in primary THA when a cemented polyethylene cup is used compared to when a more stiffer press-fit uncemented cup is used. In our opinion, the fact that autografts incorporated was highly responsible for the low rate of failure of the ring and acetabular component and additionally can facilitate a future revision, should this be necessary. We did not use (bulk) allograft for superolateral bone reconstruction. As was seen in clinical studies, the use of allografts is associated with early failure due to lack of bony ingrowth. Similarly, we did not see the same remodeling of the central allografts as compared to the superolateral autografts. Nevertheless, no protrusion of the rings and/or cups occurred and, obviously, the Eichler ring together with the first small portion of cement is able to withstand forces acting in a central direction. In a biomechanical study, Schatzker et al. compared the Eichler ring with wire mesh reinforcement of the medial wall alone and with the ring combined with wire mesh wall reinforcement: the latter situation showed the strongest resistance against a medially directed force. An important difference between Schatzker’s experiment and our approach is that he used morselized bone grafts, whereas we used solid slices of bone graft to support the medial wall. In our opinion, the combination of solid grafts with the Eichler ring makes it a strong construction.

The advantage of the Eichler ring combined with bone grafting seems to be that initial stability with pelvic reconstruction can be sufficiently achieved and long-term stability is not hampered by possible stress shielding. The central bone (allo-)grafting seems less important for long-term stability, but its volume is mainly needed to restore the center of rotation and to prevent leakage of cement into the pelvis.

In all hips, we used cement to fixate the Eichler ring and the cup; however, we did not use cement to fill bony defects. Filling of bone defects with cement has been associated with increased signs of (radiologic) cup loosening both in revision hip surgery with use of a Burch-Schneider (BS) augmentation ring after medium-term follow-up as well as in primary THA for dysplasia after long-term follow-up. Donor site morbidity is often mentioned when using autologenous grafts. To lower this incidence, we always leave the outer layer of the iliac crest intact and we harvest from the contralateral iliac crest to avoid weakening of the ipsilateral crest. In our opinion, the possibility of donor site morbidity with our technique is outweighed by the advantages of autologenous bone grafts, but in case of limited availability, the use of allograft can be considered. Bone defects can also be addressed with the use of mega-implants, but bone stock is not restored, which might compromise future revisions.

Other types of rings include the Muller acetabular reinforcement ring, which is made of titanium, has no medial wall and no peripheral flanges, and is recommended for smaller, contained, cavitary defects. In a meta-analysis performed by Starker et al. of a total of 535 hips, the acetabular reinforcement ring showed definitive radiologic loosening in 10.5%, whereas an additional 5.6% was revised for aseptic loosening after an average of 6 years. The titanium Ganz-ring has a medial wall and a distal hook that embraces the teardrop adding further stability and is recommended for intermediated-sized segmental defects. Midterm and longterm reports show a 9% to 10% rate of aseptic - including radiologic - loosening. The BS-ring has a medial wall and has two peripheral flanges and is indicated for larger segmental defects. The flanges are fixed to vital iliac and ischial bone, respectively, so that the underlying bone defects are bridged. Usually, homologous bone grafts instead of autologous grafts are used to fill these defects. The forces generated by loading of the hip are almost solely absorbed by the stiff titanium BS ring and remodeling of bone is theoretically decreased. In the same meta-analysis by Starker et al., 203 BS-rings showed radiologic loosening in 9.4% cases and an additional 6.9% revision rate for aseptic loosening after an average of 5.1 years follow-up.
Based on our experience, the satisfactory long term result (especially in relation to results of other augmentation rings), and the low incidence of complications in these difficult acetabular cup revisions with large defects, it is our opinion that the Eichler ring should be considered for use in such cases, in combination with superolateral autografting and central allografting. It is possible that the semirigid properties of the Eichler ring enables the superolateral graft reconstruction to become incorporated. The eventual restoration of pelvic bone is beneficial in case of future revisions. In the authors' opinion, this technique is preferable to those using mega-implants without osseous reconstruction of the acetabulum.

**References**


