Downloaded from UvA-DARE, the institutional repository of the University of Amsterdam (UvA) http://dare.uva.nl/document/124248

File ID124248FilenameChapter 9 Cemented hip revision surgery in severe acetabular defects
using a semirigid acetabular reinforcement ring

SOURCE (OF	R PART OF THE FOLLOWING SOURCE):
Туре	Dissertation
Title	Clinical and experimental aspects of fixation, loosening, and revision of
	total hip replacement
Authors	P.T. de Jong, F.H.R. de Man
Faculty	Faculty of Medicine
Year	2009
Pages	319

FULL BIBLIOGRAPHIC DETAILS: http://dare.uva.nl/record/293608

Copyright

It is not permitted to download or to forward/distribute the text or part of it without the consent of the author(s) and/or copyright holder(s), other than for strictly personal, individual use.

UvA-DARE is a service provided by the library of the University of Amsterdam (http://dare.uva.nl)



Chapter 9

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

A 5 TO 25 YEAR FOLLOW-UP STUDY

D. Haverkamp, MD, PhD F.H.R. de Man, MD R. Slegt, MD P.P. Besselaar, MD, PhD R.K. Marti, MD, PhD

Academic Medical Center, Department of Orthopaedic Surgery, Amsterdam, The Netherlands.

ACCEPTED FOR PUBLICATION IN JOURNAL OF ARTHROPLASTY, FEBRUARY 2009

216 | Cemented hip revision surgery in severe acetabular defects using a semirigid acetabular reinforcement ring | De Man

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 component¹. 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^{2; 3} or by creating bony support by means of bone grafting⁴⁻⁶ and/or reinforcement rings⁷. 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 on⁸⁻¹⁸. They differ with respect to having no medial wall^{8-10, 17}, in having peripheral flanges¹¹⁻¹⁵ or a caudal hook^{15, 16}. Because initial stability is imperative in preventing early loosening,¹⁹ 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)^{20, 21}. 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 resorption²² allowing bone grafts to remodel under the existing pressure⁴⁻⁶. 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.al²³ and Gross and Goodman²⁴. 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).

218 | Cemented hip revision surgery in severe acetabular defects using a semirigid acetabular

reinforcement ring | De Man





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 bonegrafting is necessary. Craniolateral defects are grafted with autologenous (bicortical) cortico-cancellous bone blocks^{4, 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).

reinforcement ring | De Man

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.





222 | Cemented hip revision surgery in severe acetabular defects using a semirigid acetabular reinforcement ring | De Man

А

Cemented hip revision surgery in severe acetabular defects using a semirigid acetabular reinforcement ring | De Man | 223







Fig. 5. *A*, Loosening and migration of a THA in a 53-year-old woman. *B*, X-rays 2 years postoperatively; the autologenous 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.

224 | Cemented hip revision surgery in severe acetabular defects using a semirigid acetabular reinforcement ring | De Man

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)²⁶. Trochanter refixation was performed with 2 lag screws with additional tension-band cerclage

Survival analysis was performed using a life table method²⁷ 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 Charnley²⁸. 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.

wiring.

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 then 1 mm were detected in the zones according to DeLee and Charnley²⁹ and classified as lateral radiolucency (type I), as middle radiolucency (type II), and as medial radiolucency (type III). Horizontal and vertical component migration was measured by using the center of the prosthetic femoral head and the bottom of the teardrop as reference points as described by Nunn et al.³⁰ Loosening of the cup and ring was classified according to the system by Gill et al.¹⁷ The cup was considered to be definitely loose (type III) if screws used for ring fixation were broken or if a complete, progressive radiolucent line medial or superior to the ring or around the screws was present or if there was evidence of migration of the cup or a fracture of cement was present. Probable loosening (type II) was considered if an

incomplete progressive radiolucent line medial or superior to the ring was present. The acetabular component showed possible loosening (type I) if a nonprogressive radiolucency was present that did not involve the screws. Heterotopic ossification was graded according to Brooker et al.³¹. Remodeling of autografts was classified as no remodeling (class 0), incomplete remodeling (class 1), or complete remodeling (class 2). Resorption of the autografts was classified as no resorption (class 0), partial resorption (class 1), or complete resorption (class 2).

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 (33%) as class C. The (average) HHS for each Charnley category is shown in Table 2. Five patients (28%) had a positive Trendelenburg sign.

226 Cemented hip revision surgery in severe acetabular defects using a semirigid acetabular	•
einforcement ring De Man	

Post operative years	No. of hips at start	No. of with- drawals	No. of patients who died	No. at risk	No. of failures	Cumula- tive survival
0-1	38.0	0.0	0.0	38.0	1.0	0.97
1-2	37.0	1.0	0.0	36.5	0.0	0.97
2-3	36.0	3.0	2.0	34.5	0.0	0.97
3-4	33.0	1.0	1.0	32.5	0.0	0.97
4-5	32.0	1.0	1.0	31.5	0.0	0.97
5-6	31.0	4.0	2.0	29.0	0.0	0.97
6-7	27.0	5.0	0.0	24.5	0.0	0.97
7-8	22.0	2.0	0.0	21.0	0.0	0.97
8-9	20.0	1.0	1.0	19.5	0.0	0.97
9-10	19.0	4.0	2.0	17.0	0.0	0.97
10-11	15.0	1.0	0.0	14.5	0.0	0.97
11-12	14.0	1.0	0.0	13.5	0.0	0.97
12-13	13.0	1.0	0.0	12.5	0.0	0.97
13-14	12.0	3.0	1.0	10.5	0.0	0.97
14-15	9.0	3.0	3.0	7.5	0.0	0.97
15+	6.0	1.0	1.0	5.5	0.0	0.97

 Table 1. Survival rates with revision for any reason (life table method) as end point.

	No. of patients	Average HHS	Range	Average follow-up time
All patients	18	72.5	31-100	11.2
Charnley A	8	89.7	73-100	9.7
Charnley B	4	61.5	34-79	13.3
Charnley C	6	57.0	31-90	12.2

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

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 nonunions, 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

Sex	Age at opera- tion	Follow-up (y)	Zone with radiolucency ¹ /max. width	Loosening ²	HO ³	Remodeling/ Resorption bone graft ⁴
Ŷ	70.8	8.2	no radiolucence	I	0	2/1
Ŷ	50.3	6.4	2+3/2mm	I	0	2/1
Ŷ	62.4	11.5	2+3/2mm	1	0	2/1
Ŷ	83.7	0.8	*	III	0	2/0
්	56.1	9.4	no radiolucence	no loosening	0	1/0
Ŷ	75.9	6.7	1+3/1mm	1	0	1/0
Ŷ	30.2	21.3	3/1mm	II	1	1/0
Ŷ	60.7	9.8	3/2mm	II	2	1/0
්	66.1	6.3	3/1mm	II	2	2/0
ď	55.4	19.8	no radiolucence	no loosening	1	1/1
්	67.3	7.8	1/1mm	II	1	1/0
Ŷ	52.3	11.7	no radiolucence	no loosening	0	2/1
Ŷ	53.5	13.7	no radiolucence	1	1	2/0
Ŷ	69.6	6.7	no radiolucence	no loosening	1	1/0
Ŷ	64.8	5.8	no radiolucence	no loosening	0	2/0
Ŷ	70	6.7	no radiolucence	no loosening	0	2/0
Ŷ	60.6	6.3	3/2mm	I	1	2/0
Ŷ	67.2	17.8	1+2+3/17mm	III	0	2/0
Ŷ	42.0	6.2	no radiolucence	no loosening	1	1/0
ď	39.9	6.2	3/12mm	111	0	2/1

Table 3. Radiological follow-up.

¹ Zones with radiolucence/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.

* Radiolucency was not measurable because of complete loosening of the acetabular component.

Discussion

In hip revision surgery, acetabular bone defects can be large (segmental), which makes sufficient restoration of defects by using a larg(er) cup and solid bone grafting alone not possible. For such cases, various types of rigid rings^{8-14,18, 32} providing the requested stability¹⁹ 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 reference³³. 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 ring³⁴. 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 these² 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 studygroup 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 migration³⁵. 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^{18, 30, 36-39}. However, we believe that the method we used has proven to be simple and reliable.

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^{7, 8, 11, 36, 40, 41}, the Eichler ring³³ 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 grafts⁵ as was also shown in a finite element study⁴² and in ywo previous clinical studies from our institution^{4, 6}.

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^{21, 43, 44}. 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^{45, 46}, the use of allografts is associated with early failure due to lack of bony ingrowth⁴⁷. 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.⁴⁰ 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-up¹¹ as well as in primary THA for dysplasia after long-term follow-up⁴⁸. 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^{2, 3}, 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 defects⁸⁻¹⁰. In a meta-analysis performed by Starker et al.⁴¹ 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 defects⁴¹. Midterm and longterm reports show a 9% to 10% rate of aseptic - including radiologic - loosening^{15, 16}. 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 defects¹¹. 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-up⁴¹.

Starker, in his own patient population (174 hips), found better results; after an average 5-year follow-up, 3.4% rings had radiologic loosening and 2.3% had had a revision. After an average 8.5 years follow-up of 63 BS rings, Gill et al.¹¹ reported a 6% revision rate of aseptic loosening of the whole acetabular construct and an additional 2.5% rate of definitive radiologic loosening.

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

- van der Vis, HM, Aspenberg, P, Marti, RK, Tigchelaar, W, and Van Noorden,
 CJ. Fluid pressure causes bone resorption in a rabbit model of prosthetic loosening. *Clin.Orthop.Relat Res. 201-208, 1998.*
- 2. Chen, WM, Engh, CA, Jr., Hopper, RH, Jr., McAuley, JP, and Engh, CA. Acetabular revision with use of a bilobed component inserted without cement in patients who have acetabular bone-stock deficiency. *J.Bone Joint Surg.Am.* 82:197-206, 2000.
- 3. **Koster, G, Willert, HG, Kohler, HP, and Dopkens, K.** An oblong revision cup for large acetabular defects: design rationale and two- to seven-year follow-up. *J.Arthroplasty* 13:559-569, 1998.
- 4. **de Jong, PT, Haverkamp, D, van der Vis, HM, and Marti, RK.** Total hip replacement with a superolateral bone graft for osteoarthritis secondary to dysplasia: a long-term follow-up. *J.Bone Joint Surg.Br.* 88:173-178, 2006.
- 5. **Marti, RK and Besselaar, PP.** Bone grafts in primary and secondary total hip replacement. In Marti,RK, (ed.). Progress in cemented total hip surgery and revision, proceedings of a symposium. *Excerpta Medica, 107, 1982*.
- Marti, RK, Schuller, HM, and van Steijn, MJ. Superolateral bone grafting for acetabular deficiency in primary total hip replacement and revision. *J.Bone Joint Surg.Br.* 76:728-734, 1994.
- 7. Schatzker, J and Wong, MK. Acetabular revision. The role of rings and cages. *Clin.Orthop. 187-197, 1999*.
- 8. Haentjens, P, Handelberg, F, Casteleyn, PP, and Opdecam, P. The Muller acetabular support ring. A preliminary review of indications and clinical results. *Int.Orthop.* 10:223-230, 1986.
- 9. Korovessis, P, Stamatakis, M, Baikousis, A, Katonis, P, and Petsinis, G. Mueller roof reinforcement rings. Medium-term results. *Clin.Orthop.Relat Res.* 125-137, 1999.
- 10. Schlegel, UJ, Bitsch, RG, Pritsch, M, et al. Mueller reinforcement rings in acetabular revision: outcome in 164 hips followed for 2-17 years. Acta Orthop. 77:234-241, 2006.
- 11. **Gill, TJ, Sledge, JB, and Muller, ME.** The Burch-Schneider anti-protrusio cage in revision total hip arthroplasty: indications, principles and long-term results. *J.Bone Joint Surg.Br.* 80:946-953, 1998.
- 12. Wachtl, SW, Jung, M, Jakob, RP, and Gautier, E. The Burch-Schneider antiprotrusio cage in acetabular revision surgery: a mean follow-up of 12 years. J.Arthroplasty 15:959-963, 2000.

- 13. Winter, E, Piert, M, Volkmann, R, et al. Allogeneic cancellous bone graft and a Burch-Schneider ring for acetabular reconstruction in revision hip arthroplasty. J.Bone Joint Surg.Am. 83-A:862-867, 2001.
- Berry, DJ and Muller, ME. Revision arthroplasty using an anti-protrusio cage for massive acetabular bone deficiency. *J.Bone Joint Surg.* Br. 74:711-715, 1992.
- Gerber, A, Pisan, M, Zurakowski, D, and Isler, B. Ganz reinforcement ring for reconstruction of acetabular defects in revision total hip arthroplasty. *J.Bone Joint Surg.Am. 85-A:2358-2364, 2003.*
- 16. **Siebenrock, KA, Trochsler, M, Sadri, H, and Ganz, R.** Hooked roof cup in revision of difficult loose hip prosthesis cups. Results after a minimum of 10 years. *Orthopade* 30:273-279, 2001.
- Gill, TJ, Sledge, JB, and Muller, ME. Total hip arthroplasty with use of an acetabular reinforcement ring in patients who have congenital dysplasia of the hip. Results at five to fifteen years. J.Bone Joint Surg.Am. 80:969-979, 1998.
- Gill, TJ, Siebenrock, K, Oberholzer, R, and Ganz, R. Acetabular reconstruction in developmental dysplasia of the hip: results of the acetabular reinforcement ring with hook. *J.Arthroplasty* 14:131-137, 1999.
- 19. **Mjoberg, B.** The theory of early loosening of hip prostheses. *Orthopedics* 20:1169-1175, 1997.
- 20. Wright, JM, Pellicci, PM, Salvati, EA, et al. Bone density adjacent to press-fit acetabular components. A prospective analysis with quantitative computed tomography. J.Bone Joint Surg.Am. 83-A:529-536, 2001.
- 21. **Mueller, LA, Voelk, M, Kress, A, Pitto, RP, and Schmidt, R.** An ABJS Best Paper: Progressive cancellous and cortical bone remodeling after press-fit cup fixation: a 3-year followup. *Clin.Orthop.Relat Res.* 463:213-220, 2007.
- 22. **Digas, G, Karrholm, J, and Thanner, J.** Different loss of BMD using uncemented press-fit and whole polyethylene cups fixed with cement: repeated DXA studies in 96 hips randomized to 3 types of fixation. *Acta Orthop. 77:218-226, 2006.*
- 23. Saleh, KJ, Holtzman, J, Gafni, A, et al. Reliability and intraoperative validity of preoperative assessment of standardized plain radiographs in predicting bone loss at revision hip surgery. *J.Bone Joint Surg.Am.* 83-A:1040-1046, 2001.
- 24. **Gross, AE and Goodman, S.** The current role of structural grafts and cages in revision arthroplasty of the hip. *Clin.Orthop.Relat Res. 193-200, 2004*.

25. **D'Antonio, JA, Capello, WN, Borden, LS, et al.** Classification and management of acetabular abnormalities in total hip arthroplasty.

Clin.Orthop. 126-137, 1989.

- 26. **de Jong, PT, van der Vis, HM, de Man, FH, and Marti, RK.** Weber rotation total hip replacement: a prospective 5- to 20-year followup study. *Clin. Orthop. 107-114, 2004.*
- 27. **Dobbs, HS: Survivorship of total hip replacements.** *J.Bone Joint Surg.Br.* 62-B:168-173, 1980.
- 28. Charnley, J: The long-term results of low-friction arthroplasty of the hip performed as a primary intervention. J.Bone Joint Surg.Br. 54:61-76, 1972.
- 29. **DeLee, JG and Charnley, J.** Radiological demarcation of cemented sockets in total hip replacement. *Clin.Orthop. 20-32, 1976*.
- Nunn, D, Freeman, MA, Hill, PF, and Evans, SJ. The measurement of migration of the acetabular component of hip prostheses. *J.Bone Joint Surg. Br.* 71:629-631, 1989.
- 31. **Brooker, AF, Bowerman, JW, Robinson, RA, and Riley, LH, Jr.** Ectopic ossification following total hip replacement. Incidence and a method of classification. *J.Bone Joint Surg.Am.* 55:1629-1632, 1973.
- 32. **Schneider, R.** Total hip prosthesis. A biomechanical concept and its consequences. *Aktuelle Probl.Chir Orthop.* 24:1-336, 1987.
- 33. **Eichler, J.** Protusio Acetabuli, a new Method of Operative Treatment. Preliminary Report. *Arch.orthop.Unfall-Chir* 75:76-80, 1973.
- 34. **Weber, U and Brunnemann, S**. Acetabular reconstruction with Eichler-Ring and cemented cup. *Chir Organi Mov 79:405-411, 1994*.
- *35.* **Harris,WH.** Traumatic arthritis of the hip after dislocation and acetabular fractures: treatment by mold arthroplasty. An end-result study using a new method of result evaluation. *J.Bone Joint Surg.Am. 51*:737-755, *1969*.
- 36. **Peters, CL, Curtain, M, and Samuelson, KM.** Acetabular revision with the Burch-Schnieder antiprotrusio cage and cancellous allograft bone. *J.Arthroplasty 10:307-312, 1995.*
- 37. **Phillips, NJ, Stockley, I, and Wilkinson, JM.** Direct plain radiographic methods versus EBRA-Digital for measuring implant migration after total hip arthroplasty. *J.Arthroplasty 17:917-925, 2002.*
- 38. **Sutherland, CJ, Wilde, AH, Borden, LS, and Marks, KE.** A ten-year followup of one hundred consecutive Muller curved-stem total hip-replacement arthroplasties. *J.Bone Joint Surg.Am.* 64:970-982, 1982.

reinforcement ring | De Man | 237

- 39. Wetherell, RG, Amis, AA, and Heatley, FW. Measurement of acetabular erosion. The effect of pelvic rotation on common landmarks. *J.Bone Joint Surg.Br.* 71:447-451, 1989.
- 40. Schatzker, J, Hastings, DE, and McBroom RJ. Acetabular reinforcement in total hip replacement. *Arch.Orthop.Trauma Surg* 94:135-141, 1979.
- 41. **Starker, M, Kandziora, F, Jager, A, and Kerschbaumer, F.** Acetabular reconstruction using acetabular reinforcement rings. *Orthopade* 27:366-374, 1998.
- 42. Schuller, HM, Dalstra, M, Huiskes, R, and Marti, RK. Total hip reconstruction in acetabular dysplasia. A finite element study. *J.Bone Joint Surg.Br.* 75:468-474, 1993.
- 43. Vasu, R, Carter, DR, and Harris, WH. Stress distributions in the acetabular region--I. Before and after total joint replacement. *J.Biomech. 15:155-164, 1982.*
- 44. **Mueller, LA, Kress, A, Nowak, T, et al.** Periacetabular bone changes after uncemented total hip arthroplasty evaluated by quantitative computed tomography. *Acta Orthop.* 77:380-385, 2006.
- 45. **Hooten, JP, Jr., Engh, CA, Jr., and Engh,CA.** Failure of structural acetabular allografts in cementless revision hip arthroplasty. *J.Bone Joint Surg.Br.* 76:419-422, 1994.
- 46. **Kwong, LM, Jasty, M, and Harris, WH.** High failure rate of bulk femoral head allografts in total hip acetabular reconstructions at 10 years. *J.Arthroplasty 8:341-346, 1993.*
- 47. **Hooten, JP, Jr., Engh, CA, Heekin, RD, and Vinh, TN.** Structural bulk allografts in acetabular reconstruction. Analysis of two grafts retrieved at post-mortem. *J.Bone Joint Surg.Br.* 78:270-275, 1996.
- 48. **MacKenzie, JR, Kelley, SS, and Johnston, RC.** Total hip replacement for coxarthrosis secondary to congenital dysplasia and dislocation of the hip. Long-term results. *J.Bone Joint Surg.Am.* 78:55-61, 1996.