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Tantalum Augments Combined with Antiprotrusio Cages for Massive Acetabular Defects in Revision Arthroplasty

Hinnerk Baecker, MD [a, b, *], Sebastian Hardt, MD [a], Matthew P. Abdel, MD [c], Carsten Perka, MD [a]

[a] Center for Musculoskeletal Surgery, Charité − Universitätsmedizin Berlin, Berlin, Germany
[b] Department of Trauma and Orthopedic Surgery, BG University Hospital Bergmannsheil, Ruhr-University Bochum, RUB, Bochum, Germany
[c] Department of Orthopedic Surgery, Mayo Clinic, Rochester, MN, USA

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ABSTRACT

Background: Tantalum components have gained popularity for the management of Paprosky type IIIA and IIIB defects during revision total hip arthroplasty. Although the use of antiprotrusio cages solely shows suboptimal results, there are certain defects that still require their use. We hypothesized that combining tantalum augments and an antiprotrusio cage would (1) improve radiographic stability, (2) enhance survivorship, (3) decrease complications, and (4) improve clinical outcomes.
Methods: We retrospectively reviewed 20 patients with Paprosky type IIIA or IIIB defects who underwent revision of the acetabular component with a highly porous tantalum augment and an antiprotrusio cage combination. Preoperative and postoperative radiographs, survivorship free from aseptic component revision, and the Harris Hip Score, Western Ontario and McMaster Universities Osteoarthritis Index, and Short Form-36 scores were analyzed. The mean follow-up was 2.8 years.
Results: At the most recent follow-up, no antiprotrusio cages had migrated and all tantalum augments had radiographic evidence of osseointegration. In addition, only 2 components were revised for aseptic etiologies and only 1 was loose. Both were revised secondary to failures of the inferior flange of the antiprotrusio cage. All clinical outcome scores significantly improved postoperatively. Finally, the risk of major postoperative complications was noted to be 10%.
Conclusions: In summary, a tantalum augment combined with an antiprotrusio cage in Paprosky IIIA and IIIB defects with divergent anatomy not amenable to a hemispherical socket provides a reliable technique to restore the anatomic hip center and prevent superior migration and provides a bony ingrowth surface. Longer term follow-up is required before the technique is widely adapted.
Level of Evidence: Level IV, therapeutic studies.
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Introduction

The latest updated projections on total joint replacement demand in the United States show a continuing growth trend for the incidence of revision total hip replacement [1]. One of the main difficulties during revision procedures is managing large uncontained acetabular defects, particularly Paprosky type IIIA and IIIB defects [2]. Multiple solutions have been proposed, including structural allograft reconstruction, impaction bone grafting with wire meshes, antiprotrusio cages, custom triflange components, uncemented jumbo cups, and cup-cage constructs. However, variable results have been reported with these techniques [3-8].

For many years, antiprotrusio cages were used, but high failure rates (up to 15%) with implant loosening due to superior migration tempered the use [9-14]. In addition, most antiprotrusio cages do not allow for the possibility of long-term biologic fixation. For almost 2 decades now, surgeons have used porous hemispherical implants because of the desire to gain long-term biologic fixation.

The use of highly porous acetabular components combined with modular highly porous acetabular augments has gained recent attention during revision surgery, given not only the enhanced biologic fixation but also the improved mechanical stability [15-18]. Multiple midterm studies have supported the use of such a

* Corresponding author. Bürkle-de-la-Camp-Platz 1, 44789 Bochum, Germany. Tel.: +49 0 234 302 0.
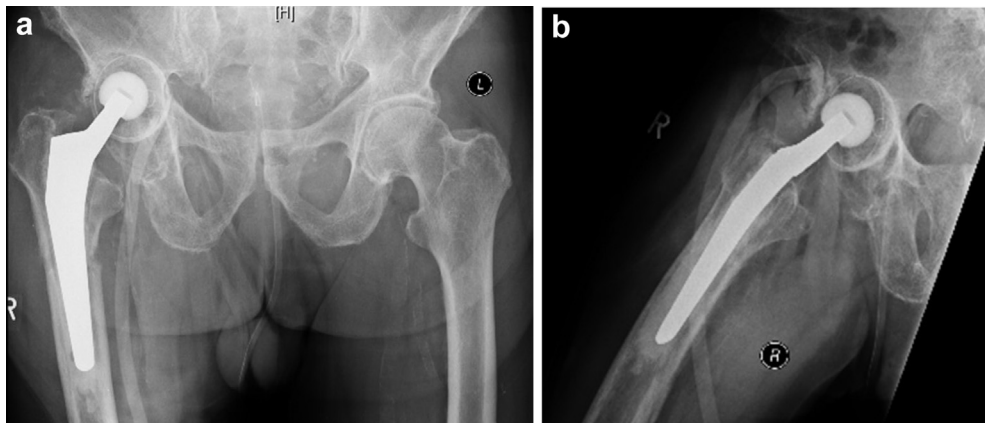*E-mail address:* hinnerk.baecker@bergmannsheil.de

Figure 1. Anteroposterior (AP) (a) and lateral (b) radiographs depicting a patient with a Paprosky type IIIA defect.

construct in Paprosky type II, IIIA, and IIIB defects [8,15-18]. This technique allows the surgeon to maximize the contact with the host bone, while also restoring the anatomic hip center.

However, there are rare cases of acetabular bone loss where the severity and geometry do not favor an uncemented highly porous socket for press fit, even when combined with highly porous acetabular augments. This occurs when there is massive global bone loss (including the ischium) or severe bone loss with a divergent geometry that precludes gaining stable rim fixation of a hemispherical component [14]. In these rare circumstances, an antiprotrusio cage may be needed. However, given the aforementioned limitations, antiprotrusio cages are rarely used independently. We hypothesized that the use of modular highly porous acetabular augments combined with an antiprotrusio cage would allow for initial rigid fixation, adequate host-bone contact for longer term bony ingrowth, and anatomic placement of the hip center in these severe cases with global bone loss and divergent anatomy. As such, the aims of this study were to determine the (1) radiographic stability, (2) survivorship, (3) complications, and (4) clinical outcomes associated with a highly porous acetabular augment-antiprotrusio cage combination in patients with Paprosky type IIIA and IIIB defects.

Material and methods

From January 2007 to December 2010, 20 patients with Paprosky type IIIA or IIIB defects (Fig. 1a and b) underwent revision of the acetabular component with a combination of a highly porous tantalum augment (Trabecular Metal®; Zimmer Biomet, Warsaw, IN) and an antiprotrusio cage (Fig. 2a and b). During the study period, 2 types of antiprotrusio cages were used: Burch-Schneider Ring® (Zimmer Biomet; Warsaw, IN) in 11 cases and Reko-Ring® (Smith and Nephew, Marl, Germany) in 9 cases. All cases were completed at a single academic, tertiary care institution by one of 2 highly experienced revision hip surgeons. After obtaining local ethics approval and informed consent, these cases were retrospectively reviewed. All patients had a minimal follow-up of 2 years, with a mean follow-up of 2.8 years (range, 2-5.8 years).

The acetabular bone defects were categorized preoperatively with the Paprosky classification [2]. Preoperative radiographs included an anteroposterior view of the pelvis and a cross-table lateral view of the hip. It is not our routine practice to obtain a computed tomography scan, given that the intraoperative defect varies based on the bone loss that occurs with removal of the prior implants. Based on the Paprosky classification, there were 12 (60%) type IIIA and 8 (40%) type IIIB defects. Four patients with type IIIB defects had pelvic discontinuities. The classification was confirmed intraoperatively.

Patients were seen at 3 months after surgery, 1 year after surgery, and then annually by a single orthopaedic surgeon who did not perform the procedures and was not involved in the study. At each visit, postoperative radiographs were obtained and included an anteroposterior radiograph of the pelvis, in addition to a cross-table lateral radiograph. Two blinded orthopaedic surgeons not
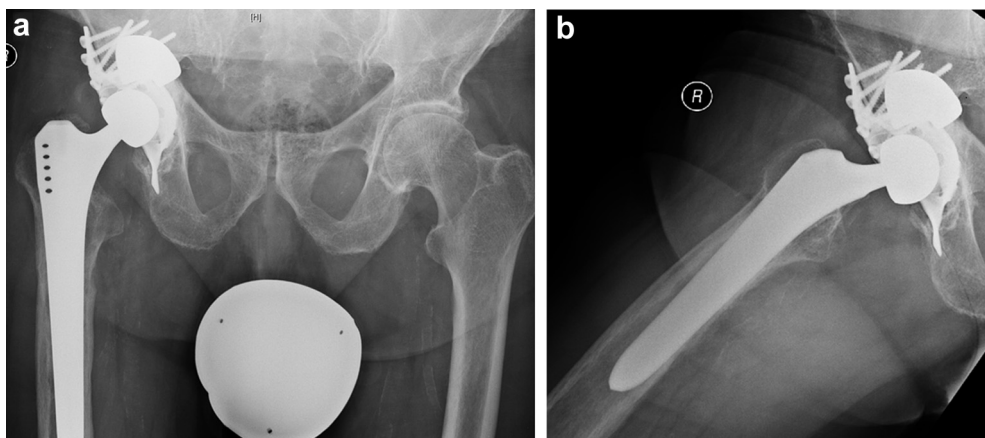

Figure 2. Postoperative anteroposterior (a) and lateral (b) radiographs after the same patient had a reconstruction with a tantalum augment and an antiprotrusio cage.

involved in the study evaluated all postoperative radiographs for evidence of loosening or migration. An analysis of radiolucent lines was carried out for each patient and measured within each of the 3 DeLee and Charnley zones [19,20]. Gap sizes were compared between the initial postoperative radiographs and the radiographs that were taken at each follow-up examination. Of note, preoperative and postoperative limb lengths were measured and documented on the radiographs.

Survivorship was evaluated free from aseptic acetabular revision for loosening and free from any aseptic acetabular reoperation. Complications were analyzed during 3 time points: intraoperatively, early postoperative period (within 3 months), and later postoperative period (>3 months after the revision procedure). The clinical outcomes were assessed by the Harris Hip Score [21], Short Form-36 [22], and Western Ontario and McMaster Universities Osteoarthritis Index [23] score.

The mean age of the cohort at the time of the revision surgery was 60.6 years (range, 33-83 years). There were 8 men and 12 women. The mean body mass index was 28.4 kg/m^2 (range, 22.1-33.1 kg/m^2). The mean number of operations before the tantalum augment-antiprotrusio cage combination was 3.7 arthroplasty procedures (range, 2-7 arthroplasty procedures). The initial indication for the primary total hip arthroplasty was primary coxarthrosis in 13 patients, secondary coxarthrosis after acetabular fracture in 3 patients, idiopathic osteonecrosis of the femoral head in 2 patients, and developmental dysplasia of the hip in 2 patients. The indications for revision with the tantalum augment-antiprotrusio cage combination were aseptic cup loosening in 14 (70%) cases and the second stage of a 2-stage revision procedure with a Girdlestone arthroplasty for the treatment of chronic periprosthetic joint infection in 6 (30%) patients. In 6 cases, the femoral component was also revised.

Surgical technique

General anesthesia with regional nerve blocks was used in all cases. All procedures were completed in the supine or lateral position with either a Hardinge approach (12 patients; 60%) or modified Watson-Jones approach (8 patients; 40%). For all cases in which a prior acetabular component was in place, this was extracted without difficulty or additional bone loss, given the preexisting loosening of the component. Multiple intraoperative cultures were obtained, and none showed any growth at final follow-up. All acetabular defects were classified intraoperatively and found to be consistent with our preoperative assessment. In addition, the fixation of the stem was assessed.

Next, the acetabular pseudomembrane was removed and any remaining bone was gently reamed to produce a bleeding surface. Of note, in all of these cases, there was severe bone loss with divergent anatomy that did not allow placement of a highly porous hemispherical socket. As such, modular porous augments were trialed in the superior weight-bearing dome followed by placement of a trial antiprotrusio cage. Combinations were attempted until the hip center was recreated, and the modular porous augment was placed on the host bone. At this point, the highly porous augments were fixed to the host bone with multiple screws through the augment (Fig. 3). Cancellous bone grafting material was then placed in any cavitary defects. Next, bone cement was placed on the lateral surface of the augment before placement of the antiprotrusio cage. This was essential because it rigidly joined the augment and antiprotrusio cage, minimizing micromotion and allowing for bony ingrowth. Finally, the antiprotrusio cage was placed based on previously described methods (Fig. 4) [14]. All cages were secured with multiple screws into the host bone (Fig. 5).

A key point in using antiprotrusio cages is the technical difficulty of the inferior flange insertion due to a risk of ischial fractures or cutout of the flange. A big emphasis is put on the technique:
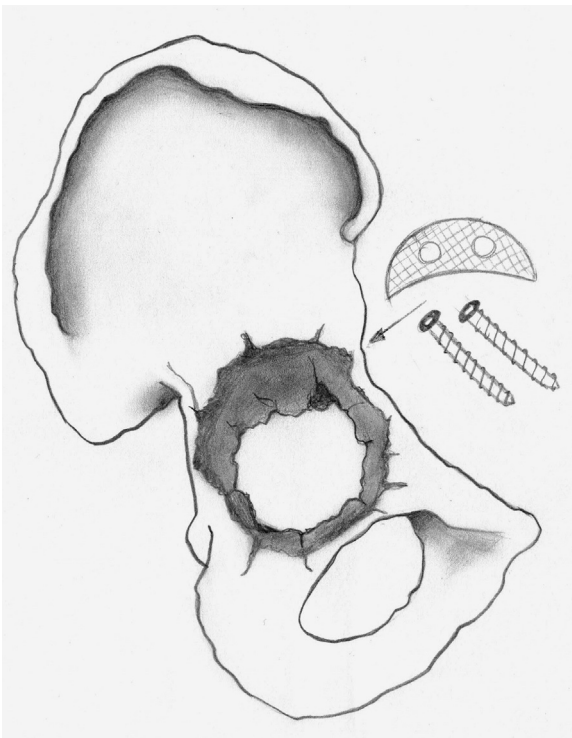

Figure 3. The schematic picture demonstrates placement of the tantalum augment in the superior weight-bearing dome, along with supplemental screw fixation. Placement of the augment allows for bony ingrowth, as well as recreation of the anatomic hip center.
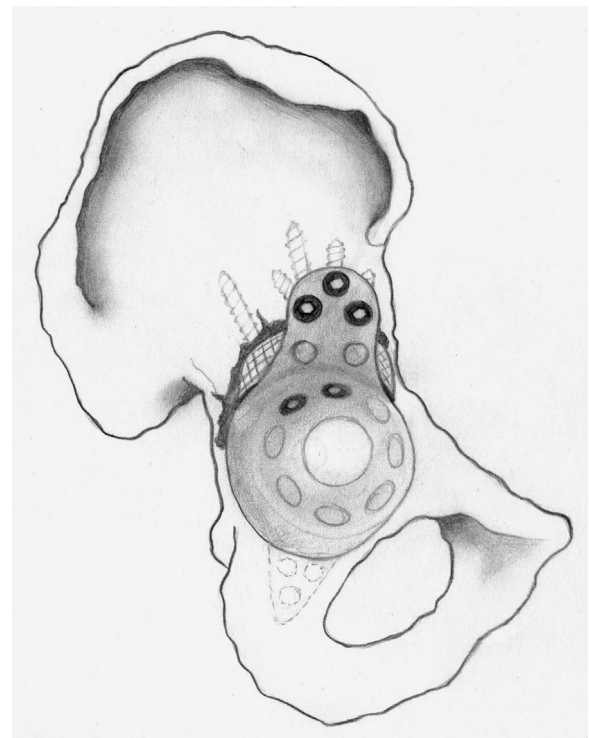

Figure 4. The schematic picture depicts placement of the antiprotrusio cage with the use of bone cement between the tantalum augment and cage.
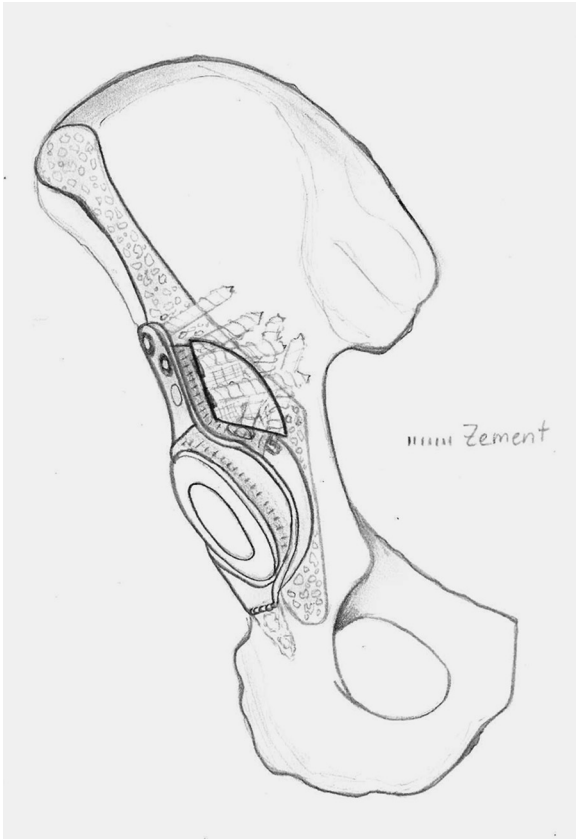
Figure 5. The schematic picture depicts the final tantalum augment—antiprotrusio cage augment with supplemental screw fixation into host bone.

identify the ischium, drill a hole in the ischium, put a depth gauge in, and hit the bone at 2-3 cm to be sure that you are in the ischium. Always create a slot, and never put the inferior flange on the top of the ischium. The use of trial flanges is optional. In acute pelvic discontinuity with good bone stock, additional osteosynthesis of the posterior column can be performed if the inferior flange is slotted in the ischium.

All patients had the same postoperative protocol, which included low-molecular-weight heparin for venous thromboembolic prophylaxis. Patients were toe-touch weight-bearing with the use of a walker for 6 weeks after surgery, followed by partial weight-bearing for 6 weeks. At 3 months, patients were allowed full weight-bearing.

Statistical analysis

Data analysis was performed using the Statistical Package for Social Sciences software (IBM SPSS Statistics, version 18.0, for Windows, Chicago, IL). Descriptive statistical results (the mean, standard deviation, range, percentage) were recorded to describe results, complications, and revisions. Statistical analysis was performed using the Kaplan-Meier estimates and survival curves. Subgroups were compared with the Mann-Whitney U test for nonparametric analysis. Ethical approval was obtained before the investigation from the local ethics committee (reference number EA1/086/14).

Results

Radiographic stability

We observed radiolucent lines around the antiprotrusio cage in 6 hips. There were 3 gaps in zone 1, 4 in zone 2, and 2 in zone 3. None of the radiolucent lines progressed, and in 2 cases, they completely resolved by the most recent follow-up. There was no component migration appreciated, and all tantalum augments appeared to be osseointegrated. The mean preoperative limb length inequality was 2.9 cm of shortening (range, 0.5-6.0 cm of shortening) in the operative extremity. Postoperatively, there was a shortening of 0.5 cm (range, 0-3 cm) in the operative extremity.

Survivorship

A total of 5 (25%) hips had to be revised at an average of 15.5 months (range, 6-21 months) postoperatively. However, this included both septic and aseptic etiologies. Two revision arthroplasties failed because of recurrent deep infections (6 and 14 months postoperatively) and were treated with a resection arthroplasty and 2-stage revision. In the remaining 3 aseptic revisions, 2 were due to failures of the inferior flange of the antiprotrusio cage and 1 was due to aseptic loosening of the femoral component. As such, only 2 components were revised for failure of the acetabular construct, resulting in a 90% survivorship at the most recent follow-up. In the hip with the breakage of the inferior flange of the Burch-Schneider ring (21 month postoperatively), the implant seemed to be stable intraoperatively (Fig. 6a and b). After
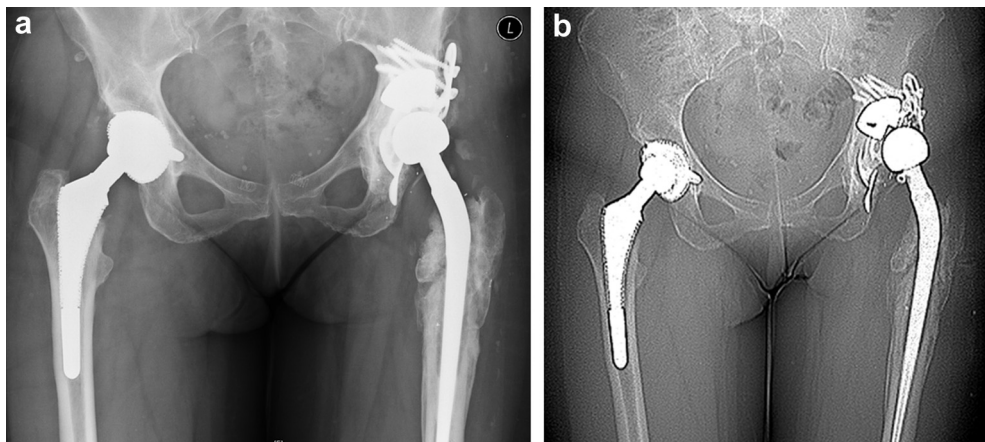

Figure 6. Premature implant failure of the antiprotrusio cage in anteroposterior radiograph (a) and computed tomography scan (b).

removing the antiprotrusio cage, the tantalum augment showed osseointegration and remained in situ. The cage was changed to cemented dual-mobility cup. The follow-up examinations showed good clinical results, without signs of implant failure on the radiographs. One hip was revised because of a dislocation of the inferior flange. Intraoperatively, the antiprotrusio cage was noted to be loose, but it had not migrated. In addition, the tantalum augment was stable. This Burch-Schneider ring was changed to a larger Reko-Ring. Finally, one hip underwent revision for aseptic loosening of the femoral component at 21 months postoperatively. The acetabular components proved to be stable intraoperatively and remained in situ.

Complications

There was one intraoperative complication, which consisted of injury to the femoral artery with placement of a Hohmann retractor on the deficient anterior acetabular wall. The patient underwent an immediate primary repair and did well without any subsequent issues.

There were 2 major and 2 minor complications. A temporary palsy of the peroneal nerve was observed in one case that had completely resolved at the most recent follow-up. Another patient had an isolated dislocation 2 weeks postoperatively while at physical therapy. He was treated with a closed reduction. A third patient had prolonged serous drainage for 1 week, but it did not require any additional intervention. Finally, there was one deep venous thrombosis that was treated conservatively.

There were no late complications besides the 2 failed inferior flanges of the antiprotrusio cages as noted previously.

Clinical outcomes

The mean Harris Hip Score improved from 35.3 (range, 13.8-67) preoperatively to 77.3 (range 38-99) postoperatively (Table 1). The Short Form-36 improved from a mean of 36 (range, 15-87) to 62.6 (range, 21-97) postoperatively. The Western Ontario and McMaster Universities Osteoarthritis Index score showed improvement from a mean of 38.1 (range, 10.3-87.8) preoperatively to 74.1 (35.2-98.4) postoperatively (Table 1). Patient satisfactory scores showed that 6 (30%) patients were very satisfied, 12 (60%) patients were satisfied, and 2 (10%) patients were unsatisfied because of a limited range of motion at the last follow-up.

Discussion

Reconstruction of complex uncontained acetabular defects is one of the major challenges in revision hip arthroplasty. Although multiple solutions have been proposed, variable results have been reported. The advent of highly porous hemispherical sockets combined with modular highly porous augments has revolutionized management of many of these complex defects. However, there are some circumstances in which an antiprotrusio cage is still required because of massive bone loss and divergent anatomy. To maintain the anatomic hip center, ensure bony ingrowth in the weight-bearing dome, and achieve rigid fixation, we hypothesized that such cases could be managed with a tantalum augment-antiprotrusio cage combination.

The combination of a tantalum augment with an antiprotrusio cage is essential, as antiprotrusio cages have shown high failure rates secondary to the lack of osseointegration [14,24,25]. The tantalum augment in the weight-bearing dome allows for a bony ingrowth surface, rigid fixation to the antiprotrusio cage, and the hip center to be brought down to a more anatomic location [26,27]. Moreover, in this investigation, it prevented superior migration that was previously noted in other series without the use of a tantalum augment [9,24,25,28]. In this study, all patients had rigid fixation, bony ingrowth, and no evidence of radiographic loosening or migration of the tantalum augment or antiprotrusio cage.

In regard to survivorship, we noted only 2 aseptic failures of the acetabular construct, resulting in a survival rate of 90%. In addition, only 1 of the constructs was loose at the time of revision surgery, indicating that 19 of 20 constructs (or 95%) were well fixed. Although the follow-up is short, the early findings are optimistic, given that these patients have the most difficult acetabular defects to revise, often having failed previous complex acetabular reconstructions. In addition, the results are more encouraging than those of antiprotrusio cages alone [14]. Indeed, it is concerning that one inferior flange in the Burch-Schneider group fractured. This may have occurred either because of excessive bending during intraoperative placement (leading to fatigue failure) or secondary to micromotion in the ilium.

Moreover, it is important to note that there was a 10% rate of major postoperative complications. This included one temporary nerve palsy that fully recovered at the most recent follow-up, in addition to an isolated postoperative dislocation. This rate is consistent with complication rates reported for major revision total hip arthroplasties.

There are limitations to the present study. Foremost, the patient numbers are small. However, it is a reasonable number of cases for a difficult situation encountered during revision hip arthroplasty. In addition, although the follow-up is only midterm in length, it is sufficient to establish the technique's ability to restore the anatomic hip center, achieve rigid initial fixation, and provide a bony ingrowth surface. It will be important to follow up these patients to determine longer term results. In our cohort, we observed a high rate of patients who were lost to follow-up; therefore, it was not possible to obtain long-term results.

In summary, a tantalum augment combined with an antiprotrusio cage in Paprosky type IIIA and IIIB defects with divergent anatomy not amenable to a hemispherical socket provides a reliable technique to restore the anatomic hip center, prevent superior migration, and provide a bony ingrowth surface for longer term durability. Long-term follow-up is required before the technique is widely adapted.

Conflict of interests

M.P. Abdel receives royalties, financial, or material support from Stryker, is a member of the *BJJ* editorial board, is a member of the MOS Board of Directors, is an AAHKS committee member, and the Chair of the ICJR committee; H. Baecker is a member of the speakers' bureau for Zimmer/Biomet, Aesculap, P. Brehm, and InfectoPharm; C. Perka receives royalties from DePuy/Synthes and Smith & Nephew, is a member of the speakers' bureau for Smith & Nephew, DePuy/Synthes, Link, Zimmer/Biomet, is a paid consultant for, Smith & Nephew, DePuy/Synthes, Link, and Zimmer/Biomet, is

Table 1
Preoperative and postoperative functional outcome scores.

	Preoperative N = 20 Mean (range)	Postoperative N = 20 Mean (range)	*P*-value
HHS	35.3 (13.8-67)	77.3 (38-99)	<.001
SF-36	35.9 (15-87)	62.6 (21-97)	<.001
WOMAC	38.1 (10.3-87.8)	74.1 (35.2-98.4)	<.001

WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index score; HHS, Harris Hip Score; SF-36, Short Form-36.

a member of the editorial/governing board of the *BJJ*, Der Orthopäde, and Zeitschrift für Orthopädie und Unfallchirurgie, and a member of the German Arthroplasty Society and Deutsche Gesellschaft für Orthopädie und Unfallchirurgie; S. Hardt declares no potential conflicts of interest.

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References

[1] Kurtz SM, Ong KL, Lau E, Bozic KJ. Impact of the economic downturn on total joint replacement demand in the United States: updated projections to 2021. J Bone Joint Surg Am 2014;96(8):624.

[2] Paprosky WG, Perona PG, Lawrence JM. Acetabular defect classification and surgical reconstruction in revision arthroplasty. J Arthroplasty 1994;9(1):33.

[3] Khan FA, Rose PS, Yanagisawa M, Lewallen DG, Sim FH. Surgical technique: porous tantalum reconstruction for destructive nonprimary periacatabular tumors. Clin Orthop Relat Res 2012;470(2):594.

[4] Patel JV, Masonis JL, Bourne RB, Rorbeck CH. The fate of cementless jumbo cups in revision hip arthroplasty. J Arthroplasty 2003;18(2):129.

[5] Garbuz D, Morsi E, Gross AE. Revision of the acetabular component of a total hip arthroplasty with a massive structural allograft. Study with a minimum five-year follow-up. J Bone Joint Surg Am 1996;78(5):693.

[6] Zehntner MK, Ganz R. Midterm results (5.5-10 years) of acetabular allograft reconstruction with the acetabular reinforcement ring during total hip revision. J Arthroplasty 1994;9(5):469.

[7] Kosashvili Y, Backstein D, Safir O, Lakstein D, Gross AE. Acetabular revision using an anti-protrusion (ilio-ischial) cage and trabecular metal acetabular component for severe acetabular bone loss associated with pelvic discontinuity. J Bone Joint Surg Br 2009;91(7):870.

[8] Jenkins DR, Odland AN, Sierra RJ, Hanssen AD, Lewallen DG. Minimum five-year outcomes with porous tantalum acetabular cup and augment construct in complex revision total hip arthroplasty. J Bone Joint Surg Am 2017;99(10):e49.

[9] Perka C, Ludwig R. Reconstruction of segmental defects during revision procedures of the acatabulum with the Burch-Schneider anti-protrusio cage. J Arthroplasty 2001;16(5):568.

[10] Regis D, Magnan B, Sandri A, Bartolozzi P. Long-term results of anti-protrusion cage and massive allografts for the management of periprosthetic acetabular bone loss. J Arthroplasty 2008;23(6):826.

[11] Regis D, Sandri A, Bonetti I, Bortolami O, Bartolozzi P. A minimum of 10-year follow-up of the Burch-Schneider cage and bulk allografts for the revision of pelvic discontinuity. J Arthroplasty 2012;27(6):1057.

[12] Saleh KJ, Jaroszynski G, Woodgate I, Saleh L, Gross AE. Revision total hip arthroplasty with the use of structural acetabular allograft and reconstruction ring: a case series with a 10-year average follow-up. J Arthroplasty 2000;15(8):951.

[13] Berry DJ, Müller ME. Revision arthroplasty using an anti-protrusio cage for massive acetabular bone deficiency. J Bone Joint Surg Br 1992;74(5):711.

[14] Berry DJ. Antiprotrusio cages for acetabular revision. Clin Orthop Relat Res 2004;(420):106.

[15] Nehme A, Lewallen DG, Hanssen AD. Modular porous metal augments for treatment of severe acetabular bone loss during revision hip arthroplasty. Clin Orthop Relat Res 2004:201.

[16] Del Gaizo DJ, Kancherla V, Sporer SM, Paprosky WG. Tantalum augments for Paprosky IIIA defects remain stable at midterm followup. Clin Orthop Relat Res 2012;470(2):395.

[17] Rose PS, Halasy M, Trousdale RT, et al. Preliminary results of tantalum acetabular components for THA after pelvic radiation. Clin Orthop Relat Res 2006;453:195.

[18] Noiseux NO, Long WJ, Mabry TM, Hanssen AD, Lewallen DG. Uncemented porous tantalum acetabular components: early follow-up and failures in 613 primary total hip arthroplasties. J Arthroplasty 2014;29(3):617.

[19] Gruen TA, Poggie RA, Lewallen DG, et al. Radiographic evaluation of a monoblock acetabular component: a multicenter study with 2-to 5-year results. J Arthroplasty 2005;20(3):369.

[20] DeLee JG, Charnley J. Radiological demarcation of cemented sockets in total hip replacement. Clin Orthop Relat Res 1976:20.

[21] 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 1969;51(4):737.

[22] Ware Jr JE. SF-36 health survey update. Spine (Phila Pa 1976) 2000;25(24):3130.

[23] Klassbo M, Larsson E, Mannevik E. Hip disability and osteoarthritis outcome score. An extension of the Western Ontario and McMaster Universities Osteoarthritis index. Scand J Rheumatol 2003;32(1):46.

[24] Udomkiat P, Dorr LD, Won YY, Longjohn D, Wan Z. Technical factors for success with metal ring acetabular reconstruction. J Arthroplasty 2001;16(8):961.

[25] Schatzker J, Wong MK. Acetabular revision. The Role of rings and cages. Clin Orthop Relat Res 1999:187.

[26] Mäkinen TJ, Abolghasemian M, Watts E, et al. Management of massive acetabular bone defects in revision arthroplasty of the hip using a reconstruction cage and porous metal augment. Bone Joint J 2017;99-B(5):607.

[27] Günther KP, Wegner T, Kirschner S, Hartmann A. Modular reconstruction in acetabular revision with antiprotrusio cages and metal augments: the cage-and-augment system. Oper Orthop Traumatol 2014;26(2):141.

[28] van Koeveringe AJ, Ochsner PE. Revision cup arthroplasty using Burch-Schneider anti-protrusio cage. Int Orthop 2002;26(5):291.