Hip Int 2014; 24 (2): 109-122 DOI: 10.5301/hipint.5000101

REVIEW

Options for managing severe acetabular bone loss in revision hip arthroplasty. A systematic review

Sameer Jain [1], Richard J. Grogan [1], Peter V. Giannoudis [2]

[1] Department of Trauma and Orthopaedic Surgery, Bradford Royal Infirmary, Bradford, Yorkshire - UK
[2] Academic Department of Orthopaedic Surgery, Leeds General Infirmary, Leeds, Yorkshire - UK

Revision hip arthroplasty in the presence of severe acetabular bone loss is challenging and requires a solid understanding of current techniques. A literature search of multiple databases applying specific criteria revealed a total of 50 articles of level IV scientific evidence comprising 2415 patients (2480 hips) managed with reinforcement devices (roof-reinforcement rings and anti-protrusio cages), custom-made triflanged acetabular components (CTACs), jumbo cups and tantalum metal (TM) systems. Overall, patients had improved postoperative hip scores for each technique. The use of reinforcement devices resulted in a mean revision rate of 8.2% and a mean complication rate of 29.21%. CTACs were associated with a revision rate of 15.9% and had a complication rate of 24.5%. Jumbo cups were revised in 8.8% of patients and had a complication rate of 18.4%. TM systems had an overall revision rate of 8.5% with complications seen in 18.5% of patients. CTACs had considerably higher revision rates compared to the other techniques. Jumbo cups and TM systems had lower complication rates compared to the use of reinforcement devices and CTACs. The most frequently occurring complications seen throughout the series were aseptic loosening, dislocation and infection.

Keywords: *Revision, Arthroplasty, Severe bone loss, Jumbo cup, Tantalum, Triflanged*

Accepted: August 8, 2013

INTRODUCTION

The management of severe acetabular bone loss in revision total hip arthroplasty (THA) is complex and there are many available surgical options. The UK National Joint Registry reported that 71,672 primary total hip replacements were performed in 2011 (1) In the same year, a total of 8,641 revision hip procedures were performed. Most commonly these were performed for aseptic loosening (42%) followed by pain (24%), instability (13%) and infection (12%). Acetabular component (AC) revision was performed in 75% of all revision procedures either alone (28%) or in combination with femoral stem revision (47%).

The aims of acetabular revision surgery are to achieve a stable fixation, restore the anatomic centre of rotation of the hip and to provide a well-contained component in the correct orientation. However, severe bone loss often occurs due to osteolysis and stress-shielding reducing the potential contact between host bone and a conventional uncemented AC. Excessive micromotion at this interface has been shown to cause bone resorption, fibrous tissue infiltration and early component loosening (2). Various classification systems have been proposed in order to help define the extent or location of bone loss and guide reconstructive surgery (3-5). In situations where there is at least 50% contact between the revision implant and host bone an uncemented hemispherical AC secured with screw fixation is widely regarded as the method of choice (6, 7). Impaction grafting is a well established technique and provides a successful adjunct in the presence of

contained defects (8). The use of a structural allograft provides further mechanical support but is associated with an unacceptably high rate of failure with larger areas of bone loss (9, 10).

In the presence of severe defects, i.e. more than 50% of the acetabulum, additional methods are required in order to improve contact between the AC and host bone. These include the use of reinforcement devices (roof-reinforcement rings and anti-protrusio cages) which span ilium to ischium and can be fixed to the pelvis. They can be used to support bone graft onto which an AC can be cemented in the correct orientation. These devices are non-porous and do not osseointegrate into host bone. More recently, porous-coated custom-made triflanged acetabular components (CTACs) have been introduced (10). These are patient-specific cages created from computed tomography (CT) scans which provide a rigid, modular and biologic fixation construct. Another option is the use of extra-large ACs or jumbo cups which provide a greater surface area for bony ingrowth whilst maintaining the centre of rotation (11). Most recently, the use of highly porous tantalum metal (TM) systems including ACs and augments has expanded (12). These systems provide a biologic fixation method, allow extensive bony ingrowth and have a high initial frictional resistance to mechanical loosening.

This systematic review was performed in order to evaluate the outcome of revision acetabular surgery in the presence of severe bone loss using reinforcement devices, CTACs, jumbo cups and TM systems.

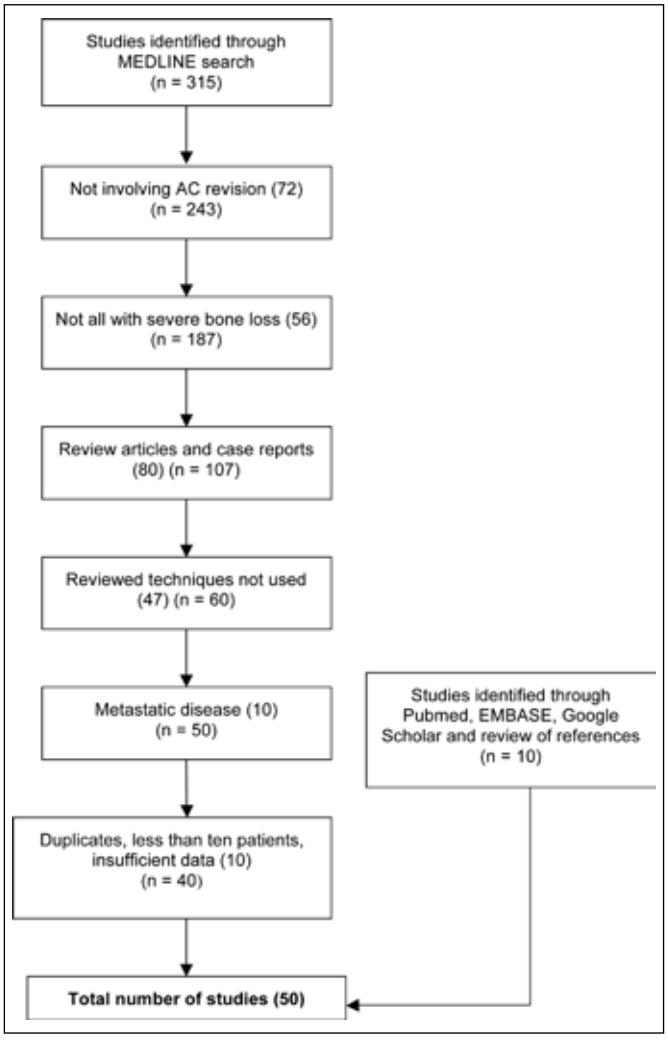

Fig. 1 - *Results of literature search and application of eligibility criteria.*

MATERIALS AND METHODS

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines were consulted in order to produce this systematic review (13). A comprehensive literature search was performed on 1st April 2013 using Ovid at MEDLINE (1946 to 2013). The search terms used were 'acetabulum or acetabular revision' and 'bone loss' or 'rings or cages' or 'triflange or triflanged' or 'jumbo' or 'trabecular or tantalum and component or cup' limited to the English language and human studies published in the last twenty years. In combination, these search terms resulted in a total of 315 articles. A review of abstracts was then performed based on the following inclusion criteria: adult patients undergoing acetabular revision surgery in the presence of severe bone loss (defined as more than 50%) with one of the above implants, indications and surgical techniques were described and quantative data presented. Exclusion criteria included studies involving metastatic disease, duplicate results, studies involving less than ten patients after accounting for those lost to follow-up, insufficient data provided, review articles and case reports. If the abstracts did not reveal the desired information, the complete articles were studied and filtered appropriately. Where duplicate studies from the same centre reporting on the same patient group were found, only the most recent article was included. After the application of these criteria, a total of 40 studies were deemed suitable for review (1-13, 17, 19-30, 33, 34, 36-44, 46-51, 53-63). A flow diagram outlining this process is given in Figure 1.

A further search was repeated on the Pubmed, EMBASE and Google Scholar search engines using the same search terms. Also, references were studied in each of the previous papers in order to find further relevant studies. This process revealed a further ten studies suitable for review (14-16, 18, 31, 32, 35, 45, 52, 57). These searches were repeated by each author to avoid the omission of any relevant articles. The outcome parameters were age, number of patients/hips after accounting for those lost to follow-up, length of follow-up, indications, implants, type of bone graft, hip scores, Kaplan-Meier survivorship analysis with revision for any reason as the endpoint for failure, revision rates (defined as reoperation due to problems with the AC) and complications. In total, 50 studies met the eligibility criteria and were reviewed with regards to these parameters (14-63).

RESULTS

Reinforcement devices

Overall, 24 articles of level IV scientific evidence reporting on 1,198 patients (1,230 hips) met the inclusion criteria (14-37). All studies reported age at revision (mean, 66.3 years; range, 52.4-75.6 years) and length of follow-up (mean, 5.9 years; range, 2.5-11.7 years). The main indications for revision surgery were aseptic loosening (954 cases), infection (43 cases), metalwork breakage (eight cases), instability (nine cases), trauma (seven cases), protrusion of metalwork (six cases), conversion from previous resection arthroplasty (two cases) and unspecified (three cases) (14, 16, 18-21, 23, 25-27, 29-37). Five studies did not clearly present their indications for primary revision surgery (15, 17, 22, 24, 28).

A variety of reconstruction devices were used including the Muller ring (Protek AG, Bern, Switzerland) in 448 cases, the Burch-Schneider Antiprotrusio cage (Sulzer Orthopaedic, Winterthur, Switzerland) in 357 cases, the Eichler ring (Sulzer, Protek, Baar, Switzerland) in 92 cases, a Contour device (Smith and Nephew Richards, Memphis, USA) in 77 cases, a modular porous-coated antiprotrusio component (Biomet, Indiana, USA) in 63 cases, the Ganz ring (Zimmer, Indiana, USA) in 54 cases, the Harris Galante cup (Zimmer, Indiana, USA) in 38 cases, the Acetabular reinforcement ring with hook (Protek AG, Baar, Switzerland) in 37 cases, a Kerboull device (Kobe Steel, Kobe, Japan) in 31 cases, the Graft Augmentation Prosthesis II reinforcement ring (Stryker Orthopaedics, Mahwah, NJ, USA) in 24 cases, the LINK cage (LINK, Germany) in six cases, the PROTEK reinforcement ring (Sulzer, Switzerland) in three cases, the Oh and Harris ring (Zimmer, Swindon, UK) in three cases and the ZCA ring (Zimmer, Swindon, UK) in two cases (14-37). Morcelised or structural allograft was used in all studies except five in which a combination of either allograft or autograft was used (24-26, 28, 31). One study did not specify the type of bone graft used (35).

Clinical results were assessed using either the Harris hip score (HHS) or Postel-Merle d'Aubigne (PMA) score in 13 studies (14, 17, 19, 23-25, 27, 28, 30, 32, 35-37). These all showed improved post-operative scores and specifically, the mean improvement in the HHS was 40.3 points (range 35-47.71 points) and the mean improvement in the PMA score was 6.4 points (range 2.9-12.5 points). Kaplan-Meier estimates of survivorship with further revision surgery as the end-point were presented in 11 studies (79.6-100% at a range of 2.6-13 years) (14, 16-19, 22, 25, 28, 29, 31, 33). Revision rates were presented in most of the studies (mean, 8.2%; range, 0-25%) (15-31, 35-37). In four studies, the revision rates were not presented or could not be calculated accurately from their data (14, 32-34). Complications were reported in all studies with the mean complication rate calculated as 29.1% (range, 6.3-58.3%) (14-37). The most common local complications were aseptic loosening of the revision AC (72 cases, 5.9%), dislocation (56 cases, 4.6%) and infection (47 cases, 3.8%) (14-37). Other local complications included metalwork breakage (28 cases), nerve palsy (22 cases), wound healing problems (seven cases), haematoma (eight cases), donor site morbidity (three cases), fracture (two cases), non-union of a trochanteric osteotomy (two cases), arterial injury (two cases), bursitis (one case), and heterotopic ossification (one case) (14-37). Systemic complications included urinary tract infection (UTI, 20 cases), deep vein thrombosis (DVT, 16 cases), death relating to the surgery or anaesthetic (13 cases), adult respiratory distress syndrome (ARDS, four cases), chest infection (four cases), non-fatal myocardial infarction (MI, two cases), stroke (one case), gastrointestinal (GI) bleed (one case) and iatrogenic bladder injury (one case) (14-37). The results regarding the use of reinforcement devices are presented in Table I.

Custom-made triflanged acetabular components

Five studies of level IV scientific evidence reporting on 193 patients (197 hips) were identified (38-42). All stud-

TABLE I - OUTCOME OF REINFORCEMENT DEVICES

Study	Year	Patients (hips)	Age (mean, yrs)	Follow-up (mean, yrs)	Indications	Implant	Improvement in Hip Score (mean)†	Survivorship (Kaplan-Meier)	Revision Rate	Local Complications	Systemic Complications/ Overall Complication Rate
Zehntner and Ganz (14)	1994	27 (27)	72.5	7.2	Aseptic loosening 55 Protrusion 1	Muller Ring 27 Allograft	PMA 3.6	79.6% at 10 yrs	NR*	Migration 7 Loosening 8 Bursitis 1	Nil Overall 33%
Panski and Tauber (15)	1997	14 (14)	61.3	3.3	NR	Muller Ring 14 Allograft	NR	NR	14%	Dislocation 1 Loosening 1	Nil Overall 14%
Stockl et al (16)	1997	47 (49)	67.8	6.4	Aseptic loosening 36 Protrusion 5 Instability 4 Stem breakage 3	Muller Ring 49 Allograft	NR	92.9% at 6 yrs	8%	Loosening 4 Infection 8	Death 3 Overall 30%
Haddad et al (17)	1999	45 (45)	61	5.3	NR	Muller Ring 27 Oh and Harris Ring 3 Burch-Schneider Cage 18 Allograft	HHS 36	100% at 5.3 yrs	0%	Haematoma 1	DVT 3 MI 1 Overall 11%
Bohm and Banzhaf (18)	1999	91 (101)	61	4.5	Aseptic loosening 94 Infection 9	Muller Ring 39 Burch-Schneider Cage 26 Harris-Galante Cup 38 Allograft	NR	82% at 13 years	10.6%	Nerve palsy 7 Dislocation 1 Infection 4	Nil Overall 11.8%
Schatzker and Wong (19)	1999	95 (95)	64.9	7.5	Aseptic loosening 86 Infection 2 Stem breakage 5 Girdlestone's 2	Muller Ring 57 Burch-Schneider Cage 38 Allograft	HHS 39.5	92% at 10 years	9.7%	Nerve palsy 4 Infection 1 Dislocation 1	Nil Overall 6.3%
Jain et al (20)	2000	24 (24)	72.7	2.8	Aseptic loosening 21 Dislocation 2 Trauma 1	Muller Ring 22 Burch-Schneider Cage 2 Allograft	Pre-op scores NR	NR	12.5%	Dislocation 4 Hematoma 3 HO 1 Loosening 1	DVT 2 Overall 46%
Gill et al (21)	2000	35 (37)	63	7.1	Aseptic loosening 37	Burch-Schneider Cage 30 Muller Ring 7 Allograft	NR	NR	2.7%	Dislocation 1 Sepsis 1 Nerve palsy 1 Fracture 1 HO 1 GT nonunion 1 Arterial injury 1	ARDS 1 MI 1 Overall 24.3%

To be continued

TABLE I - CONTINUED

Study	Year	Patients (hips)	Age (mean, yrs)	Follow-up (mean, yrs)	Indications	Implant	Improvement in Hip Score (mean)†	Survivorship (Kaplan-Meier)	Revision Rate	Local Complications	Systemic Complications/ Overall Complication Rate
Perka and Ludwig (22)	2001	62 (63)	67.4	5.45	NR	Burch-Schneider Cage 63 Allograft	Pre-op scores NR	85% at 10 yrs	4.7%	Nerve palsy 1 Infection 2 Dislocation 4 Loosening 1 Wound problem 2	Chest infection 1 GI bleed 1 Bladder injury 1 DVT 2 Death 2 Overall 27%
Van der Linde and Tonino (23)	2001	40 (42)	68	10	Aseptic loosening 42	Muller Ring 26 Burch-Schneider Cage 16 Allograft	PMS 6	NR	9.5%	Infection 3 Loosening 1	Nil Overall 10%
Yoon et al (24)	2003	37 (37)	52.4	4.5	NR	Acetabular Reinforcement Ring with Hook 37 Allograft/autograft	HHS 38	NR	2.7%	Dislocation 3 GT nonunion 1 Graftsite problem 3 Hook breakage 2	NR Overall 24%
Peters et al (25)	2004	60 (63)	65	2.5	Aseptic loosening 58 Infection 4 Instability 1	Modular Antiprotrusio Cage 63 Allograft/ autograft	HHS 40.5	87% at 2.6 yrs	19%	Infection 4 Loosening 8 Dislocation 8 Nerve palsy 2	DVT 2 Overall 38%
Ilchmann et al (26)	2006	40 (40)	70	4.7	Aseptic loosening 40	Burch-Schneider Cage 40 Allograft/ autograft	Pre-op scores NR	NR	5%	Broken screws 14	Death 1 Overall 37.5%
Bostrom et al (27)	2006	29 (31)	68.1	2.5	Aseptic loosening 29 Infection 2	Contour Antiprotrusio Cage 31 Allograft	HHS 35	NR	13%	Arterial injury 1 Infection 2 Dislocation 5 Broken plate 4 Loosening 5	Nil Overall 55%
Pieringer et al (28)	2006	64 (67)	70.4	4.2	NR	Burch-Schneider Cage Allograft/autograft	HHS 45.3	93.4% at 11 yrs	4.5%	Loosening 8 Haematoma 3 Nerve palsy 5 Wound problems 2 Dislocation 11	Death 1 Overall 45%
Schlegel et al (29)	2006	164 (164)	69	6	Aseptic loosening 143 Infection 13 Instability 2 Trauma 6	Muller Ring 164 Allograft	Pre-op scores NR	90% at 8 yrs	8%	Loosening 6 Infection 7 Screw breakage 1	Nil Overall 8.5%

To be continued

TABLE I - CONTINUED

Study	Year	Patients (hips)	Age (mean, yrs)	Follow-up (mean, yrs)	Indications	Implant	Improvement in Hip Score (mean)†	Survivorship (Kaplan-Meier)	Revision Rate	Local Complications	Systemic Complications/ Overall Complication Rate
Regis et al (30)	2008	54 (56)	65	11.7	Aseptic loosening 56	Burch-Schneider Cage 56 Allograft	HHS 45	NR	7.1%	Infection 2 Dislocation 6 Nerve palsy 1 Loosening 5 Screw breakage 2	Nil Overall 28.5%
Haverkamp et al (31)	2009	38 (38)	67	11.2	Aseptic loosening 31 Infection 7	Eichler Ring 38 Allograft/autograft	Pre-op scores NR	97% at 10 yrs	2.6%	Loosening 1 Dislocation 1 Nerve palsy 1 Fracture 1	Stroke 1 Overall 13%
Okano et al (32)	2010	31 (31)	67.9	6.3	Aseptic loosening 31	Kerboull type device 31 Allograft	PMA 2.9	NR	NR	Loosening 7 Infection 1 Implant breakage 6 Dislocation 2 Nerve palsy 1	DVT 1 Overall 58%
Uchiyama et al (33)	2010	28 (30)	60.8	8	Aseptic loosening 25 Infection 5	Ganz Ring 30 Allograft	NR	80.2% at 10 yrs	NR	Loosening 5	Nil Overall 17%
Krishnan et al (34)	2011	42 (45)	75.6	7	Aseptic loosening 42 Unspecified 3	Contour Ring 45 Allograft	NR	NR	NR	Dislocation 2 Infection 4	Death 1 Overall 15%
Zhai et al (35)	2011	12 (12)	63	3	Aseptic loosening 12	Link Cage 6 Contour Ring 1 ZCA Ring 2 Protek Ring 3 Unspecified bone graft	HHS 47.7	NR	0%	Dislocation 1 Wound problems 3	Nil Overall 33%
Buttaro et al (36)	2012	24 (24)	69	2.8	Aseptic loosening 21 Infection 3	Graft Augmentation Prosthesis II Ring 24 Allograft	PMA 12.5	NR	25%	Loosening 6 Implant fracture 5 Infection 3	Nil Overall 58.3%
Phillipe et al (37)	2012	95 (95)	69.5	8	Aseptic loosening 95	Eichler Ring 54 Ganz Ring 24 Muller Ring 16 Burch-Schneider Cage 1 Allograft	PMA 6.8 HHS 35.8	NR	5.2%	Dislocation 7 Loosening 5 Infection 4 Haematoma 1	Death 2 DVT 9 UTI 20 Chest infection 2 ARDS 2 Overall 54.7%

*NR = not reported, †PMA = Postel-Merle d'Aubigne score, HHS = Harris hip score, HO = heterotopic ossification, DVT = deep vein thrombosis, MI = myocardial infarction, GT = greater trochanter, ARDS = adult respiratory distress syndrome, UTI = urinary tract infection.

ies reported age (mean 65.8 years; range 55.8-75 years) and length of follow-up (mean 6 years; range 4.5-10 years) (38-42). None of the studies adequately reported the specific indications for revision surgery but all specified their indications for use of the CTAC i.e. Type III or IV bone loss as per the AAOS classification of acetabular bone defects. All CTACs were manufactured by either Techmedica (Camarillo, California, USA) and then by either Biomet or Depuy (both Warsaw, Indiana, USA). Apart from one study that did not evaluate clinical results through a hip scoring system (42), all studies reported a mean post-operative improvement using the HHS or the PMA score. Whilst the mean improvement in the HHS was 42.3 points (range 39-48.8 points), the PMA score was reported in only one study and this improved by 3.0 points (38-41). The mean revision rate was 15.9% (range 3.8-30.3%) and all studies either reported or presented enough data to calculate their overall complication rate (mean 24.5%; range 18-35%) (38-42). Local complications were dislocation (26 cases, 13.2%), nerve palsy (11 cases, 5.6%), infection (five cases, 2.5%), aseptic loosening (five cases, 2.5%) and seroma formation (two cases, 1%) whilst there were no systemic complications reported (38-42). A summary of these results is presented in Table II.

Jumbo cups

Eight articles of level IV scientific evidence were identified (43-50). These studies reported on a total of 552 patients (567 hips) and all reported age (mean 62.3 years; range 58-71.6 years) and length of follow-up (mean 7 years; range 5.4-10 years) except one (47). The indications for revision surgery were presented in all but three studies (43, 45, 47) and were aseptic loosening (257 cases), infection (14 cases), periprosthetic fracture (nine cases), osteolysis (seven cases), insert wear (six cases), failed hip resurfacing (five cases), dislocation (two cases) and unspecified causes (four cases) (44, 46, 48-50).

All reported the use of uncemented fixation with a jumbo cup defined as at being least 62 mm in diameter except in one study involving an Asian population where the definition involved a cup greater than 60 mm in diameter (48). Implants used were the Harris-Galante cup (Zimmer, Warsaw, Indiana) in 168 cases, the Mathys isoelastic cup (Robert Mathys, Bettlach, Switzerland) in 52 cases, the Duraloc cup (DePuy, Warsaw, Indiana) in 41 cases, the Secure-fit cup (Osteonic, Allendale, NJ) in 39 cases, the Trilogy cup (Zimmer, Warsaw, Indiana) in 36 cases, the Ringloc cup in (Biomet, Warsaw, Indiana) 22 cases, a jumbo Trabecular metal cup (Zimmer, Warsaw, Indiana) in 22 cases and the Sulzer APR cup and InterOp hemispherical cup (both Zimmer, Warsaw, Indiana) in an unspecified number of cases (43-50). Both allograft and autograft were used to supplement the fixation (43, 44, 46-50) except in one series where bone graft was not used (45).

Four studies used the HHS to assess clinical outcome and reported a mean postoperative improvement of 28.3 points (range 21-33 points) (43, 44, 46, 49). Kaplan-Mei-

TABLE II - OUTCOME OF CUSTOM-MADE TRIFLANGED ACETABULAR COMPONENTS

Study	Year	Patients (hips)	Age (mean, yrs)	Follow-up (mean, yrs)	Improvement in Hip Score (mean)*	Revision Rate	Local Complications	Systemic Complications/ Overall Complication Rate
Christie et al (38)	2001	65 (67)	75	4.5	HHS 48.8	7.8%	Dislocation 6 Infection 1 Nerve palsy 5	Nil Overall 18%
Joshi et al (39)	2002	27 (27)	68	4.8	PMA 3.0	7.4%	Dislocation 1 Infection 2 Nerve palsy 3	Nil Overall 22%
Holt and Dennis (40)	2004	26 (26)	69.3	4.5	HHS 39	3.8%	Dislocation 2 Loosening 3	Nil Overall 19.2%
DeBoer et al (41)	2007	18 (20)	55.8	10	HHS 39	30%	Dislocation 5 Nerve palsy 1 Loose screws 1	Nil Overall 35%
Taunton et al (42)	2012	57 (57)	61	6.3	NR	30.3%	Dislocation 12 Infection 2 Loosening 1 Nerve palsy 2 Seroma 2	Nil Overall 33.3%

* PMA = Postel-Merle d'Aubigne score, HHS = Harris hip score.

er estimates of survivorship with further revision surgery as the end-point were presented in five studies (range 79.8-94.5% at a range of 5-15 years) (44, 46-48, 50). Overall, revision rates were presented in all the studies or were easily calculated from the data provided (mean 8.8%; range 1.1-23.5%) (43-50). Complications were adequately reported in all but one study (47). The most common local complications were dislocation (36 cases, 6.3%), infection (15 cases, 2.6%), nerve palsy (seven cases, 1.2%) and aseptic loosening (five cases, 0.9%) (43-46, 48-50). Others included fracture (two cases) and haematoma (one case) (43-46, 48-50). Only one systemic complication was reported throughout all eight articles (gastrointestinal ileus with spontaneous resolution) (44). The mean complication rate was 18.4% (range 3.8-50%) (43-46, 48-50). A summary of these results is presented in Table III.

Tantalum metal systems

Thirteen articles of level IV scientific evidence reporting on 472 patients (486 hips) met the inclusion criteria (51-63). All studies reported age (mean 64 years; range 58.2-69.3 years) and length of follow-up (mean 3.9 years; range 2.6-6 years) (51-63). The indications for revision surgery were presented in all but two studies (53, 58) and were recorded as aseptic loosening (348 cases), infection (40 cases), mechanical failure of reconstruction devices (10 cases), osteolysis (nine cases), dislocation (four cases), periprosthetic fracture (three cases), insert wear (two cases), pain after hemiarthroplasty (two cases) and tumour (one case) (51, 52, 54-57, 59-63).

All the studies used the Trabecular Metal System (Zimmer, Warsaw, Indiana) utilising tantalum ACs either with or without tantalum augments (51-63). Morcelised autograft or allograft was used throughout the series. Only one study did not use a hip scoring system to evaluate clinical outcome (60) All mean hip scores improved from their preoperative values and specifically, the mean improvement in the HHS was 37 points (range 21-52 points), the mean improvement in the PMA score was five points (range 3.8-6.6 points) and the mean improvement in the Oxford hip score (OHS) was 34 points (range 22.3-45.7 points) (51-59, 61-63). All studies presented their revision rates or these could be calculated from the data provided (mean, 8.5%; range, 0-19%) (51-63). Only one study presented Kaplan-Maier survivorship analysis of the AC (63). With clinical or radiological failure due to any cause as the endpoint, the five-year Kaplan-Meier survival rate was 87.7%. At the same interval, with aseptic loosening as the endpoint, the survival rate was 91.1%. Complications were generally well reported throughout the articles. The most common local complications reported were dislocation (27 cases, 5.6%), infection (24 cases, 4.9%) and aseptic loosening (16 cases, 3.3%) and others included heterotopic ossification (nine cases), nerve palsy (four cases), haematoma (four cases) and fracture (two cases) (51-63). Systemic complications reported were vascular injury requiring repair (two cases), bowel injury (one case) and deep vein thrombosis (one case) (51-63). The mean complication rate was 18.5% (range 4.2-32.3%) (51-63). A summary of these results is presented in Table IV.

DISCUSSION

Most of the revision procedures that took place in the reviewed articles were performed on patients aged 50-70 years (14-63), although in future the age at first revision surgery can be expected to fall as more primary THAs are being performed in increasingly younger patients. The indications for revision surgery in the presence of severe acetabular bone loss are varied with aseptic loosening and infection predominating (14-63).

Both roof-reinforcement rings and anti-protrusio cages are designed to protect morcelised and structural grafts from excess force and to transfer load to peripheral host bone (30). With the advent of more biologic fixation methods, these devices are slowly falling out of favour. In particular, rings are less commonly used due to improved designs of hemispherical porous coated ACs which allow even stress distribution on the acetabular rim (64). Cages may still be useful as they span the acetabular defect whilst allowing a near anatomic centre of rotation. Variable success rates have been seen with reconstruction devices with most patients having improved post-operative hip scores, revision rates of up to 25% by 2.8 years and 10 year implant survivorship at 79.6-100% (14-37). Complications rates are also varied and are seen in up to 55% of patients (27). The most common complications include aseptic loosening (5.9%), dislocation (4.6%) and infection (3.8%) (14-37). Aseptic loosening more commonly occurred when rings are placed in a high lateral position (16). Haddad et al recommended that cages should be used where there is poor bony contact inferiorly as they provide a more stable fixation (17). Schatzker and Wong experienced a high failure rate of rings when used in patients with medial wall deficiency and protrusio

TABLE III - OUTCOME OF JUMBO CUPS

Study	Year	Patients (hips)	Age (mean, yrs)	Follow-up (mean, yrs)	Indications	Implant/Bone graft	Improvement in Hip Score (mean)*	Survivorship (Kaplan-Meier)	Revision Rate	Local Complications	Systemic Complications/ Overall Complication Rate
Dearborn & Harris (43)	2000	24 (24)	58	7	NR	Harris-Galante Morcelised graft 22	HHS 32	NR	12.5%	Dislocation 5 Nerve Palsy 2 Infection 5	NR Overall 50%
Whaley et al (44)	2001	89 (89)	59	7.2	Aseptic loosening 80 Fracture 5 Unspecified 4	Harris-Galante Morcelised bone graft 54 Bulk graft 9	HHS 27	93% at 8 years	1.1%	Dislocation 11 Nerve palsy 5 Infection 1	Ileus 1 Overall 20%
Khaleel et al (45)	2002	48 (52)	71.6	6	NR	Mathys Isoelastic No graft used	NR	NR	5.7%	Fracture 2	Nil Overall 3.8%
Patel et al (46)	2003	42 (43)	63	10	Aseptic loosening 29 Osteolysis 7 Infection 2 Failed resurfacing 5	Ringloc 22 & Duraloc 21 Morcelised bone graft 27 Bulk graft 8	HHS 33	92% at 14 years	11.6%	Dislocation 2	Nil Overall 4.6%
Gustke (47)	2004	166 (166)	NR	6.1	NR	Sulzer APR & Interop Cup Use of graft NR	NR	87% at 10 years	3%	Incompletely reported	NR
Fan et al (48)	2007	46 (47)	61.4	5.4	Aseptic loosening 42 Insert wear 3 Infection 2	Secure-fit 39, Trilogy 5, Duraloc 3 Allograft (unspecified) 25	NR	94.5% at 5 years	6.4%	Dislocation 5 Infection 2	Nil Overall 14.9%
Wedermeyer et al (49)	2008	17 (17)	60	6.8	Aseptic loosening 17	Duraloc Morcelised graft 15	HHS 21	NR	23.5%	Dislocation 1 Infection 3 Loosening 1 Haematoma 1	Nil Overall 35%
Lachiewicz & Soileau (50)	2013	120 (129)	63	8.1	Aseptic loosening 89 Infection 10 Dislocation 2 Insert wear 3 Fracture 4	Harris-Galante 55, Tribology 31, Trabecular Metal 22 Allograft 98, autograft 4, combined 5	NR	93.8% at 10 years 79.8% at 15 years	6.2%	Dislocation 12 Infection 4 Loosening 4	Nil Overall 15.5%

*PMA = Postel-Merle d'Aubigne score, HHS = Harris hip score.

(19). Along with pelvic discontinuity, these are contraindications for the use of rings and therefore, cages are preferred as they provide more structural support (30). Furthermore, two studies concluded that cages had improved mid-term survivorship outcomes when compared to rings (18, 19).

CTACs were introduced due to the variability in size and shape of the acetabular defects (38). Whilst improved postoperative clinical outcomes can be expected, revision rates of up 7.8% and complications rates of up to 22% are seen by five years (38-40). However, these values increase

TABLE IV - OUTCOME OF TANTALUM METAL SYSTEMS

Study	Year	Patients (hips)	Age (mean, yrs)	Follow-up (mean, yrs)	Indications	Implant	Improvement in Hip Score (mean)*	Revision Rate	Local Complications	Systemic Complications/ Overall Complication Rate
Sporer & Paprosksy (51)	2006	13 (13)	63	2.6	Aseptic loosening 13	Tantalum metal cup +/- augments Zimmer Trabecular Metal System	PMA 4.2	0%	Aseptic loosening 1	Nil Overall 7.7%
Weeden & Schmidt (52)	2007	43 (43)	65.4	2.8	Aseptic loosening 37 Infection 4 Pain after hemi 2	Tantalum metal cup +/- augments Zimmer Trabecular Metal System	PMA 4.9 HHS 52	2.3%	Dislocation 2 Infection 1	Nil Overall 7%
Flecher et al (53)	2008	22 (23)	58.2	2.9	Incompletely reported	Tantalum metal cup +/- augments Zimmer Trabecular Metal System	PMA 3.8	0%	Dislocation 1	Nil Overall 4.3%
Kosashvilli et al (54)	2009	24 (26)	64.9	3.7	Aseptic loosening 19 Mechanical failure 5 Infection 2	Tantalum metal cup + Antiprotrusio Cage No augments used Zimmer Trabecular Metal System	HHS 30	15.3%	Dislocation 2 Infection 1 Nerve palsy 1 Aseptic loosening 3	NR Overall 26.9%
Van Kleunen et al (55)	2009	90 (97)	59	3.75	Aseptic loosening 73 Infection 17 Fracture 2 Mechanical failure 2 Insert wear 2 Tumour 1	Tantalum metal cup +/- augments Zimmer Trabecular Metal System	HHS 21	9.3%	Dislocation 7 Infection 10 Haematoma 4	Nil Overall 21.6%
Lingaraj et al (56)	2009	23 (24)	67	3.4	Aseptic loosening 21 Infection 1 Fracture 1	Tantalum metal cup +/- augments Zimmer Trabecular Metal System	PMA 5.5 HHS 32.7	8.3%	Dislocation 2 Infection 1 Nerve palsy 3	DVT 1 Overall 29.2%
Siegmeth et al (57)	2009	34 (34)	64	2.8	Aseptic loosening 28 Infection 2 Dislocation 1 Mechanical failure 2	Tantalum metal cup + augments Zimmer Trabecular Metal System	OHS 45.7	8.8%	Dislocation 2 Aseptic loosening 2	Nil Overall 11.7%
Lachiewicz & Soileau (58)	2010	37 (39)	65.1	3.3	NR	Tantalum metal cup +/- augments Zimmer Trabecular Metal System	HHS 38	12.8%	Dislocation 5 Infection 2 Aseptic loosening 1 Fracture 1	Nil Overall 23%
Del Gaizo et al (59)	2012	36 (37)	60	5	Aseptic loosening 31 Infection 5 Dislocation 1	Tantalum metal cup +/- augments Zimmer Trabecular Metal System	HHS 48.5	19%	Dislocation 2 Aseptic loosening 1 Infection 3	Nil Overall 16.2%
Davies et al (60)	2012	43 (43)	66.7	4.2	Aseptic loosening 27 Osteolysis 9 Infection 4	Tantalum metal cup +/- augments Zimmer Trabecular Metal System	NR	2.3%	Dislocation 2 Infection 1 Heterotopic ossification 3	Vascular injury 1 Overall 16.3%

To be continued

TABLE IV - CONTINUED

Study	Year	Patients (hips)	Age (mean, yrs)	Follow-up (mean, yrs)	Indications	Implant	Improvement in Hip Score (mean)*	Revision Rate	Local Complications	Systemic Complications/ Overall Complication Rate
Sporer et al (61)	2012	20 (20)	67.5	4.5	Aseptic loosening 20	Tantalum metal cup +/- augments Zimmer Trabecular Metal System	PMA 6.6	5%	Aseptic loosening 1 Infection 1 Fracture 1	Bowel injury 1 Vascular injury 1 Overall 25%
Sternheim et al (62)	2012	53 (53)	62.4	6	Aseptic loosening 50 Dislocation 2 Infection 1	Tantalum metal cup Zimmer Trabecular Metal System	HHS 37.1	18.8%	Aseptic loosening 4 Dislocation 3 Infection 3	Nil Overall 18.8%
Abolghasemian et al (63)	2013	34 (34)	69.3	5.4	Aseptic loosening 29 Mechanical failure 1 Infection 4	Tantalum metal cup +/- augments Zimmer Trabecular Metal System	OHS 22.3	8.8%	Aseptic loosening 3 Infection 2 Heterotopic ossification 6	Nil Overall 32.3%

*PMA = Postel-Merle d'Aubigne score, HHS = Harris hip score, OHS = Oxford hip score.
*RD = Reconstruction devices, CTAC = Custom triflanged acetabular components, JC = Jumbo cups, TM = Tantalum metal systems.

to 30% and 35% respectively in studies with longer ten year follow-up (41, 52). Common complications include dislocation (13.1%), nerve palsy (5.5%), aseptic loosening (2.5%) and infection (2.5%) (38-42). They are also expensive as they are created from anatomic data derived from a CT scan of the pelvis. The total cost of the CT scan, model and implant is likely to cost more than other techniques with an estimated total cost of approximately £8,000 per case *(*41, 32*).* From the data collated in this review, this extra cost does not appear to be substantiated by clinical results although comparative studies would be needed to fully determine a true cost-benefit analysis.

Jumbo cups are extra-large cementless porous-coated titanium hemispherical ACs usually fixed with supplementary screws. Contraindications include previously irradiated bone and large defects in the superior-lateral rim or posterior column in which primary stability with any size porous AC may not possible (47). Improved post-operative clinical outcomes have been consistently seen with implant survivorship of up to 94% at 10 years but with reported revision rates of up to 23.5% by 6.8 years (49, 50). Complication rates are extremely varied ranging from 3.7-50% and most commonly include dislocation (6.3%), infection (2.6%), nerve palsy (1.2%) and aseptic loosening (0.8%) (43-50). The highest overall complication rate of 50% was experienced by Dearborn and Harris (43). They attributed this to the complexity of their cases but may also be due to their early experiences with a newly reported technique as the general tend was a fall in complication rates with more recent studies and implants. The exception was the report by Wedermeyer et al in which an unusually high infection rate in a small series adversely influenced their outcome (49). Of note, Whaley et al experienced a high dislocation rate of 12.4% and urged caution that the use of extra-large sockets may result in impingement or prevent reattachment of the abductor mechanism (44).

TM systems are the most recent advancement in complex revision hip surgery and are designed to maximize the degree of biologic fixation. They are made from a highly porous metal which allows a greater degree of ingrowth and shear strength when compared with conventional implants (65). Tantalum metal has an elastic modulus more similar to subchondral bone than other materials which improves bone remodelling and helps to minimize stress shielding (66). The high coefficient of friction of tantalum improves AC stability and unlike allograft it does not resorb over time. The honeycomb structure also allows the surgeon to drill through the AC to allow additional screw fixation.

TM acetabular components can also be supplemented with tantalum augments. These were initially developed for standard uncemented ACs to promote biologic fixation in the presence of bony defects (67). Weeden and Schmidt reported the indications for the use of augments as the presence of less than 50% host bone, when extra support was required for the AC and to stabilise the pelvis in the presence of pelvic discontinuity (52). Furthermore, Flecher et al described the use of bone cement between the AC and augments for further stability (53).

Overall, improved post-operative clinical outcomes can be expected with revision rates of up to 19% and complications rates of up to 32.3% seen by five years (51-63). Common complications include dislocation (5.6%), infection (4.9%) and aseptic loosening (3.3%) (51-63). As a relatively new technology, only short-term results are available but these are promising. Weeden and Schmidt found that 98% of the cups and augments were radiographically stable at a mean of 2.8 years follow-up whilst in a case series of patients with pelvic discontinuity, Sporer and Paprosky performed no re-revisions for aseptic loosening (51, 52). Most recently, Abolghasmesian et al demonstrated a five-year survival rate of 91.1% with aseptic loosening as an endpoint (63). Their high complication rate of 32.3% is mainly attributed to their reporting of heterotopic ossification which was not reported in other studies.

Limitations of this review include an inability to pool data for accurate meta-analysis due to the heterogeneity of patient demographics, surgical techniques, implants and methods used to collect data in the individual studies. Also, all of the reviewed articles were case series' of level IV evidence that are prone to both selection and experimental bias potentially limiting their external validity to the general population. Strengths of this review include the clarity and reproducibility of our search strategy using multiple evidence-based databases. In addition, validated hip scoring systems were used to assess clinical outcomes rather than subjective patient satisfaction scores.

Financial Support: None declared.

Conflict of Interest: No conflicts of interest.

Address for correspondence:
Sameer Jain
Bradford Royal Infirmary
Duckworth Lane
Bradford, BD9 6RJ
Yorkshire, UK
samjain@hotmail.co.uk

REFERENCES

1. National Joint Registry of England and Wales. Available at: http://www.njrcentre.org.uk. Accessed April 1, 2013.
2. Cook SD, Barrack RL, Thomas KA, Haddad RJ Jr. Quantitative analysis of tissue growth into human porous total hip components. J Arthroplasty. 1988;3(3):249-62.
3. D'Antonio JA, Capello WN, Borden LS, et al. Classification and management of acetabular abnormalities in total hip arthroplasty. Clin Orthop Relat Res. 1989;(243):126-37.
4. Saleh KJ, Holtzman J, Gafni A, et al. Development, test reliability and validation of a classification for revision hip arthroplasty. J Orthop Res. 2001;19(1):50-6.
5. Paprosky WG, Perona PG, Lawrence JM. Acetabular defect classification and surgical reconstruction in revision arthroplasty. A 6-year follow-up evaluation. J Arthroplasty. 1994;9(1):33-44.
6. Della Valle CJ, Berger RA, Rosenberg AG, et al. Cementless acetabular reconstruction in revision total hip arthroplasty. Clin Orthop Relat Res. 2004;(420):96-100.
7. Garcia-Cimbrelo E. Porous-coated cementless acetabular cups in revision surgery. J Arthroplasty. 1999;14(4):397-406.
8. Palm L, Jacobsson SA, Kvist J, Lindholm A, Ojersjö A, Ivarsson I. Acetabular revision with extensive allograft impaction and uncemented hydroxyapatite-coated implants. Results after 9 (7-11) years follow-up. J Arthroplasty. 2007;22(8):1083-91.
9. Morsi E, Garbuz D, Gross AE. Revision total hip arthroplasty with shelf bulk allografts. A long-term follow-up study. J Arthroplasty. 1996;11(1):86-90.
10. Issack PS, Nousiainen M, Beksac B, et al. Acetabular component revision in total hip arthroplasty. Part II: management of major bone loss and pelvic discontinuity. Am J Orthop. 2009;38(11):550-6.
11. Jasty M. Jumbo cups and morselised graft. Orthop Clin North Am. 1998;29(2):249-54.
12. Sporer SM, Paprosky WG, O'Rourke MR. Managing bone loss in acetabular revision. Instr Course Lect. 2006;55:287-97.
13. PRISMA statement. Available at http://www.prisma-statement.org/. Accessed April 1, 2013.
14. 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):469-79.

15. Panski A, Tauber C. Acetabular supporting ring in total hip replacement. Arch Orthop Trauma Surg. 1997;116(4):233-5.
16. Stöckl B, Beerkotte J, Krismer M, Fischer M, Bauer R. Results of the Müller acetabular reinforcement ring in revision arthroplasty. Arch Orthop Trauma Surg. 1997;116(1-2):55-9.
17. Haddad FS, Shergill N, Muirhead-Allwood SK. Acetabular reconstruction with morcellized allograft and ring support: a medium-term review. J Arthroplasty. 1999;14(7):788-95.
18. Böhm P, Banzhaf S. Acetabular revision with allograft bone. 103 revisions with 3 reconstruction alternatives, followed for 0.3-13 years. Acta Orthop Scand. 1999;70(3):240-9.
19. Schatzker J, Wong MK. Acetabular revision. The role of rings and cages. Clin Orthop Relat Res. 1999;(369):187-97.
20. Jain R, Schemitsch EH, Waddell JP. Functional outcome after acetabular revision with roof reinforcement rings. Can J Surg. 2000;43(4):276-82.
21. Gill TJ, Sledge JB, Müller ME. The management of severe acetabular bone loss using structural allograft and acetabular reinforcement devices. J Arthroplasty. 2000;15(1):1-7.
22. Perka C, Ludwig R. Reconstruction of segmental defects during revision procedures of the acetabulum with the Burch-Schneider anti-protrusio cage. J Arthroplasty. 2001;16(5): 568-74.
23. van der Linde M, Tonino A. Acetabular revision with impacted grafting and a reinforcement ring: 42 patients followed for a mean of 10 years. Acta Orthop Scand. 2001;72(3):221-7.
24. Yoon TR, Rowe SM, Chung JY, Song EK, Lee KB, Jung ST, Mulyadi D. Acetabular revision using acetabular roof reinforcement ring with a hook. J Arthroplasty. 2003;18(6):746-50.
25. Peters CL, Miller M, Erickson J, Hall P, Samuelson K. Acetabular revision with a modular anti-protrusio acetabular component. J Arthroplasty. 2004;19(7 Suppl 2):67-72.
26. Ilchmann T, Gelzer JP, Winter E, Weise K. Acetabular reconstruction with the Burch-Schneider ring: an EBRA analysis of 40 cup revisions. Acta Orthop. 2006;77(1):79-86.
27. Bostrom MP, Lehman AP, Buly RL, Lyman S, Nestor BJ. Acetabular revision with the Contour antiprotrusio cage: 2- to 5-year follow-up. Clin Orthop Relat Res. 2006;(453):188-94.
28. Pieringer H, Auersperg V, Böhler N. Reconstruction of severe acetabular bone-deficiency: the Burch-Schneider antiprotrusio cage in primary and revision total hip arthroplasty. J Arthroplasty. 2006;21(4):489-96.
29. Schlegel UJ, Bitsch RG, Pritsch M, Clauss M, Mau H, Breusch SJ. Mueller reinforcement rings in acetabular revision: outcome in 164 hips followed for 2-17 years. Acta Orthop. 2006;77(2):234-41.
30. Regis D, Magnan B, Sandri A, Bartolozzi P. Long-term results of anti-protrusio cage and massive allografts for the management of periprosthetic acetabular bone loss. J Arthroplasty. 2008;23(6):826-32.
31. Haverkamp D, De Man FH, Slegt R, Besselaar PP, Marti RK. Cemented hip revision surgery in severe acetabular defects using a semirigid acetabular reinforcement ring-a 5- to 25-year follow-up study. J Arthroplasty. 2009;24(2):246-55.
32. Okano K, Miyata N, Enomoto H, Osaki M, Shindo H. Revision with impacted bone allografts and the Kerboull cross plate for massive bone defect of the acetabulum. J Arthroplasty. 2010;25(4):594-9.
33. Uchiyama K, Takahira N, Fukushima K, Yamamoto T, Moriya M, Itoman M. Radiological evaluation of allograft reconstruction in acetabulum with Ganz reinforcement ring in revision total hip replacement. J Orthop Sci. 2010;15(6):764-71.
34. Krishnan KM, Longstaff L, Partington P. Acetabular reconstruction using morcellised bone with ring support-medium-term results at three to nine years. Acta Orthop Belg. 2011;77(1):61-7.
35. Zhai JL, Lin J, Jin J, Qian WW, Weng XS. Treatment of severe bone deficiency in acetabular revision surgery using a reinforcement device and bone grafting. Chin Med J (Engl). 2011;124(9):1381-5.
36. Buttaro MA, de la Rosa DM, Comba F, Piccaluga F. High failure rate with the GAP II ring and impacted allograft bone in severe acetabular defects. Clin Orthop Relat Res. 2012;470(11):3148-55.
37. Philippe R, Gosselin O, Sedaghatian J, et al. Acetabular reconstruction using morselized allograft and a reinforcement ring for revision arthroplasty with Paprosky type II and III bone loss: survival analysis of 95 hips after 5 to 13 years. Orthop Traumatol Surg Res. 2012;98(2):129-37.
38. Christie MJ, Barrington SA, Brinson MF, Ruhling ME, DeBoer DK. Bridging massive acetabular defects with the triflange cup: 2- to 9-year results. Clin Orthop Relat Res. 2001;(393):216-27.
39. Joshi AB, Lee J, Christensen C. Results for a custom acetabular component for acetabular deficiency. J Arthroplasty. 2002;17(5):643-8.
40. Holt GE, Dennis DA. Use of custom triflanged acetabular components in revision total hip arthroplasty. Clin Orthop Relat Res. 2004;(429):209-14.
41. DeBoer DK. Christie MJ. Brinson MF. Morrison JC. Revision total hip arthroplasty for pelvic discontinuity. J Bone Joint Surg Am. 2007;89(4):835-40.
42. Taunton MJ, Fehring TK, Edwards P, Bernasek T, Holt GE, Christie MJ. Pelvic discontinuity treated with custom triflange component: a reliable option. Clin Orthop Relat Res. 2012;470(2):428-34.
43. Dearborn JT, Harris WH. Acetabular revision arthroplasty using so-called jumbo cementless components: an average 7-year follow-up study. J Arthroplasty. 2000;15(1):8-15.
44. Whaley AL, Berry DJ, Harmsen WS. Extra-large uncemented hemispherical acetabular components for revision total hip arthroplasty. J Bone Joint Surg Am. 2001;83(9):1352-7.
45. Khaleel A, Dutta A, Scott WA, Crabtree S. Jumbo cups in acetabular revision. J Bone Joint Surg Br. 2002;84 (Suppl 2):155.
46. Patel JV, Masonis JL, Bourne RB, Rorabeck CH. The fate of cementless jumbo cups in revision hip arthroplasty. J Arthroplasty. 2003;18(2):129-33.

47. Gustke KA. Jumbo cup or high hip center: is bigger better? J Arthroplasty. 2004;19(4 Suppl 1):120-3.
48. Fan CY, Chen WM, Lee OK, Huang CK, Chiang CC, Chen TH. Acetabular revision arthroplasty using jumbo cups: an experience in Asia. Arch Orthop Trauma Surg. 2008;128(8):809-13.
49. Wedemeyer C, Neuerburg C, Heep H, von Knoch F, von Knoch M, Löer F, Saxler G. Jumbo cups for revision of acetabular defects after total hip arthroplasty: a retrospective review of a case series. Arch Orthop Trauma Surg. 2008;128(6): 545-50.
50. Lachiewicz PF, Soileau ES. Fixation, survival, and dislocation of jumbo acetabular components in revision hip arthroplasty. J Bone Joint Surg Am. 2013;95(6):543-8.
51. Sporer SM, Paprosky WG. Acetabular revision using a trabecular metal acetabular component for severe acetabular bone loss associated with a pelvic discontinuity. J Arthroplasty. 2006;21(6 Suppl 2):87-90.
52. Weeden SH, Schmidt RH. The use of tantalum porous metal implants for Paprosky 3A and 3B defects. J Arthroplasty. 2007;22(6 Suppl 2):151-5.
53. Flecher X, Sporer S, Paprosky W. Management of severe bone loss in acetabular revision using a trabecular metal shell. J Arthroplasty. 2008;23(7):949-55.
54. 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):870-6.
55. Van Kleunen JP, Lee GC, Lementowski PW, Nelson CL, Garino JP. Acetabular revisions using trabecular metal cups and augments. J Arthroplasty. 2009;24(6 Suppl):64-8.
56. Lingaraj K, Teo YH, Bergman N. The management of severe acetabular bone defects in revision hip arthroplasty using modular porous metal components. J Bone Joint Surg Br. 2009;91(12):1555-60.
57. Siegmeth A, Duncan CP, Masri BA, Kim WY, Garbuz DS. Modular tantalum augments for acetabular defects in revision hip arthroplasty. Clin Orthop Relat Res. 2009;467(1):199-205.
58. Lachiewicz PF, Soileau ES. Tantalum components in difficult acetabular revisions Clin Orthop Relat Res. 2010;468(2): 454-8.
59. Del Gaizo DJ, Kancherla V, Sporer SM, Paprosky WG. Tantalum augments for Paprosky IIIA defects remain stable at midterm follow-up. Clin Orthop Relat Res. 2012;470(2): 395-401.
60. Davies JH, Laflamme GY, Delisle J, Fernandes J. Trabecular metal used for major bone loss in acetabular hip revision. J Arthroplasty. 2011;26(8):1245-50.
61. Sporer SM, Bottros JJ, Hulst JB, Kancherla VK, Moric M, Paprosky WG. Acetabular distraction: an alternative for severe defects with chronic pelvic discontinuity? Clin Orthop Relat Res. 2012;470(11):3156-63.
62. Sternheim A, Backstein D, Kuzyk PR, et al. Porous metal revision shells for management of contained acetabular bone defects at a mean follow-up of six years: a comparison between up to 50% bleeding host bone contact and more than 50% contact. J Bone Joint Surg Br. 2012;94(2):158-62.
63. Abolghasemian M, Tangsataporn S, Sternheim A, Backstein D, Safir O, Gross AE. Combined trabecular metal acetabular shell and augment for acetabular revision with substantial bone loss: a mid-term review. Bone Joint J. 2013;95(2): 166-72.
64. Paprosky WG, Sporer SS, Murphy BP. Addressing severe bone deficiency: what a cage will not do. J Arthroplasty. 2007;22(4 Suppl 1):111-5.
65. Bobyn JD, Stackpool GJ, Hacking SA, Tanzer M, Krygier JJ. Characteristics of bone ingrowth an interface mechanics of a new porous tantalum biomaterial. J Bone Joint Surg Br. 1999;81(5):907-14.
66. Bobyn JD. Fixation and bearing surfaces for the next millennium. Orthopedics. 1999;22(9):810-2.
67. 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;(429):201-8.