



## Severe pelvic bone loss treated using a coned acetabular prosthesis with a stem extension inside the ilium

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We describe a modified surgical technique for the reconstruction of major acetabular defects using a coned acetabular component (the Stanmore 'ice-cream' cone prosthesis) and report its early clinical outcomes. A single surgeon performed 28 acetabular reconstructions using a stemmed-cone acetabular prosthesis (mean age 70.9 years ; 61% female) in 15 oncology patients with periacetabular metastases and 13 patients requiring complex arthroplasty procedures. Defects were graded using the Paprosky classification (10 = 3A ; 8 = 3B ; 10 = pelvic discontinuity). All procedures were performed without fluoroscopy using an extended posterior hip approach. Mean operative time (including anaesthesia) was 133 minutes ; there were no intraoperative complications. Postoperative complications had occurred in 14% (n = 4), at a mean follow-up of 12.5 months (range : 2-33 months). There were no failures in patients with pelvic discontinuity. The stemmed-cone acetabular prosthesis was found to provide a useful method for acetabular reconstruction (including pelvic discontinuity) in both complex oncological and hip arthroplasty cases.

**Keywords :** acetabular reconstruction ; ice-cream cone ; pelvic discontinuity ; posterior approach ; surgical technique.

### INTRODUCTION

Acetabular reconstruction is often a complex surgical procedure ; it may be required in patients with periacetabular metastases, failure of total hip

arthroplasty, and those sustaining traumatic acetabular fractures. Methods for reconstruction include hemispheric porous cups, plating with jumbo cups, antiprotrusion cages with or without bone allografts, in addition to custom made pelvic endoprostheses which remain an option in tumour patients (5,7,8,12,15,16). However, such major reconstruction is often associated with significant patient morbidity and the need for further surgery with deep infection and dislocation rates of 30% and 40% reported in the literature respectively (5,7,8,12,15,16).

The 'ice-cream' cone prosthesis (Coned Hemi-Pelvis ; Stanmore Implants, Elstree, U.K.) is a coned acetabular prosthesis initially developed in 2003 with outcomes reported in 27 oncology patients with primary and secondary pelvic bone tumours as well as in patients with failed pelvic

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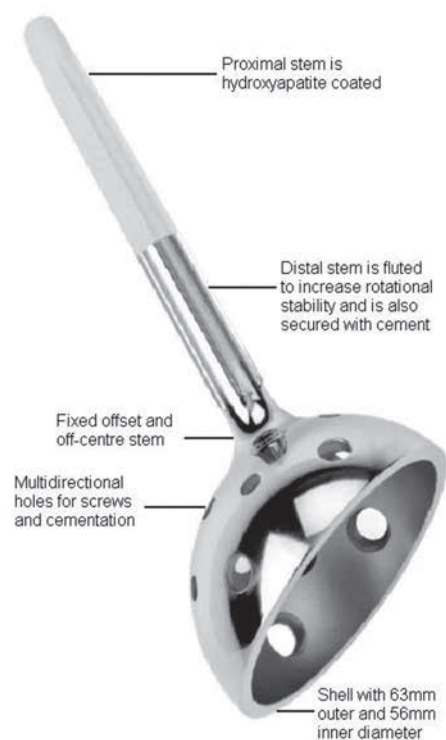
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reconstruction following previous primary tumour resection (11). Although the procedure was associated with a relatively high overall morbidity (37%) in the short-term, the early results with this implant were considered promising given the case complexity, with complications diminishing as surgeons developed increasing experience (11). In addition, all early cases were performed using extensive surgical dissections through an Ollier or ilioinguinal approach (11).

More recently the senior author (LJ) has been implanting the stemmed-cone acetabular prosthesis through an extended posterior hip approach in patients with periacetabular tumours and those requiring complex primary or revision hip arthroplasty with severe bone loss and/or pelvic discontinuity. In previous years devices similar to this acetabular prosthesis, such as the McMinn cup (1,9,20,31) and the Ring prosthesis (24), have been implanted through this same surgical approach (1,31) in patients requiring complex acetabular reconstruction. In general these devices were reported to have poor clinical outcomes with aseptic loosening a common mode of device failure (9,31), therefore these implants were withdrawn from clinical use. Although this newer stemmed-cone acetabular prosthesis (Fig. 1) is effectively a modified version of the McMinn stemmed acetabular component (20), its unique design features include: (1) a hydroxyapatite-coated proximal stem which can incorporate into existing cancellous acetabular bone, (2) the distal part of the stem is fluted with cutting teeth to provide rotational stability and can also be secured with cement, (3) the prosthesis has an offset stem which allows for better loading and positioning in the iliolumbar bar, and (4) the reaming for the stem is line-to-line with that of the implant thus providing a more secure fit of the stem in pelvic bone. It was hypothesised these design features would provide better fixation of the newer stemmed-cone acetabular prosthesis compared to the similar implants used previously (1,9,20,24,31) and may therefore improve implant survival in complex acetabular reconstructions.

The primary study objective was to describe in detail the surgical technique used for the reconstruction of major acetabular defects in oncology and hip arthroplasty patients using the stemmed-cone ace-



**Fig. 1.** — Design features of the stemmed-cone acetabular ('ice-cream' cone) prosthesis (reproduced with permission from Stanmore Implants, Elstree, U. K.).

tabular prosthesis through an extended posterior hip approach. The secondary objective was to assess the early clinical outcomes associated with this method of reconstruction.

## PATIENTS AND METHODS

This retrospective single-surgeon series consisted of all patients undergoing reconstruction of the acetabulum using a stemmed-cone acetabular prosthesis at a tertiary referral centre using an extended posterior hip approach. Whilst most patients were referred from external centres (70%), 30% were referred from revision hip surgeons at this institution who were unable to offer acetabular reconstruction using more traditional methods. Procedures were performed in patients with periacetabular metastases (2008-2012) and those requiring complex hip arthroplasty procedures (2010-2012). This study was approved by the institutional review board.

Acetabular reconstruction using the stemmed-cone acetabular prosthesis was indicated in all cases due to the presence of one or more of the following: (1) severe

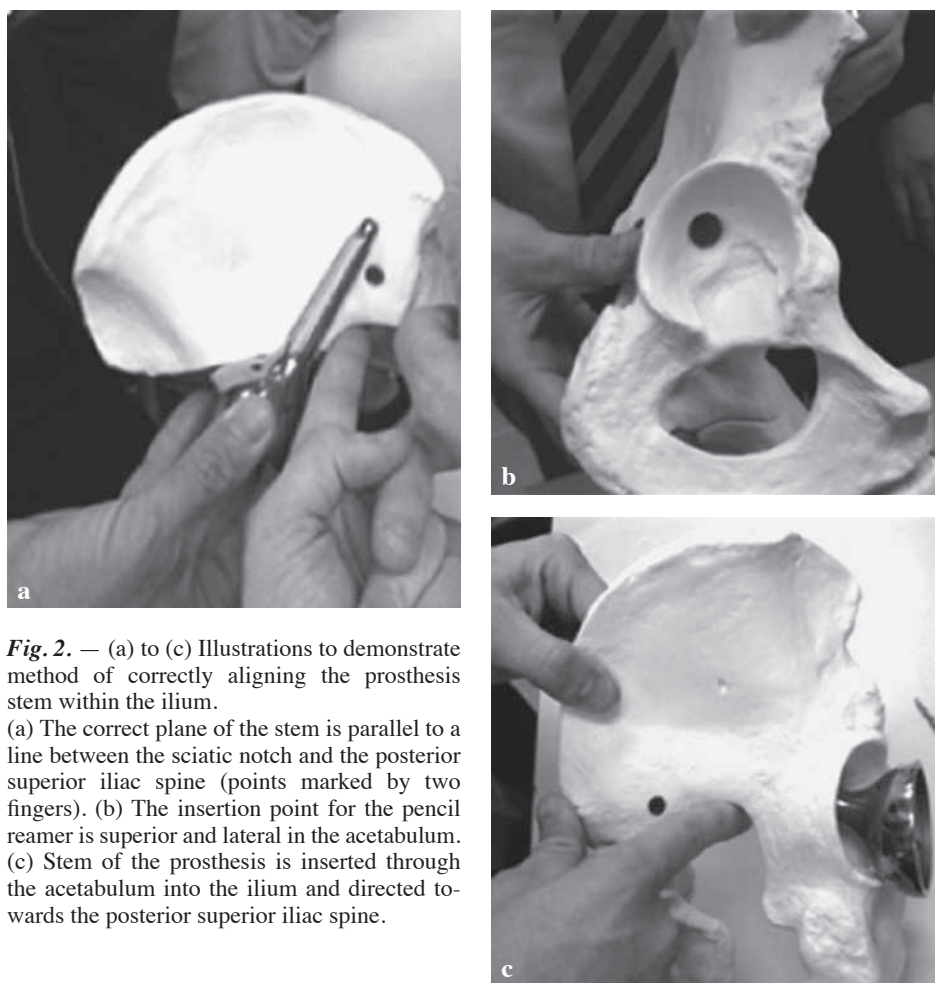
acetabular bone loss ; (2) central acetabular fracture with hip dislocation ; (3) pelvic discontinuity. Acetabular defects were also graded using the Paprosky classification (22). All oncology patients underwent CT scanning to determine the size and extent of the bone defects requiring resection and subsequent reconstruction, with the defects to be reconstructed subsequently classified using the Paprosky classification (22). There were 28 acetabular reconstructions performed in 28 patients during the study period. No patient in the present study was reported on in the initial series (11). All patients were appropriately consented for acetabular reconstruction with this implant and no patient refused to undergo surgery once the procedure and risks were explained.

### Surgical technique for acetabular reconstruction

After appropriate anaesthesia, patients were positioned in the lateral position on the operating table in a

standard manner for a total hip replacement. Before applying skin preparation the ipsilateral posterior superior iliac spine (PSIS) was palpated and a marker (electrocardiography dot) was placed on this bony landmark. All procedures were performed without fluoroscopic guidance. An extended posterior hip approach was used to expose the acetabulum, sciatic nerve and notch in all cases (14,19). In order to allow good exposure and easier anterior retraction of the femur, the femoral insertion of gluteus maximus was released routinely. In patients with periacetabular metastases, the tumour was subsequently curetted.

In order to align the stem of the stemmed-cone prosthesis into the correct position, a finger was placed into the sciatic notch (taking care not to damage the gluteal vessels) and another finger was placed on the PSIS marker which could be palpated through the sterile drapes intra-operatively. The orientation of the stem must be parallel to the line between these two points (Fig. 2), which is



**Fig. 2.** — (a) to (c) Illustrations to demonstrate method of correctly aligning the prosthesis stem within the ilium.

(a) The correct plane of the stem is parallel to a line between the sciatic notch and the posterior superior iliac spine (points marked by two fingers). (b) The insertion point for the pencil reamer is superior and lateral in the acetabulum. (c) Stem of the prosthesis is inserted through the acetabulum into the ilium and directed towards the posterior superior iliac spine.

often more posterior than appreciated. A pencil reamer was gently inserted in the plane of this line, and if the bone was sclerotic the superior part of the acetabulum was reamed to softer cancellous bone to make achieving the correct orientation easier. After hand reaming to an appropriate size, the integrity of the ilium was checked with a flexible probe. The stem of the prosthesis was then inserted into the ilium and guided towards the PSIS. The proximal portion of the stem is hydroxyapatite coated and must sit in the ilium and not pass into the sacroiliac joint. When the correct position of the stem had been achieved, the distal portion of the stem was secured using Palacos G cement (Biomet, Swindon, U.K.) containing added vancomycin. The prosthesis is made from titanium alloy and is available in four different stem diameters (9 mm, 10 mm, 12 mm, or 16 mm) with a fixed stem length (93 mm) and shell size (outer diameter 63 mm and inner diameter 56 mm). The minimum amount of pelvic bone recommended to anchor the stem is 40 mm. The coned acetabular prosthesis has a fixed offset stem which is off-centre to the cup therefore allowing variable cup inclination and anteversion depending on the orientation the stem is implanted in. Care must be exercised to obtain the best orientation of the cup as possible, however, the cone simply serves as a cage for the subsequent insertion of a cemented 51 mm bipolar cup (SERF, Orthodynamics Limited, Gloucestershire, U.K.) and the inclination and anteversion can thus be improved. The femoral component was implanted in the standard manner and a suction drain was routinely inserted prior to wound closure.

### Postoperative regimen and follow-up

Postoperatively all patients received five days of antibiotics (600 mg of intravenous Teicoplanin once daily and 600 mg of oral Rifampacin twice daily) and 28 days of mechanical (graduated compression stockings) and chemical (40 mg of subcutaneous enoxaparin) thromboprophylaxis. Patients were routinely mobilised full weight-bearing postoperatively. The suction drain was removed 24 to 48 hours following surgery. After hospital discharge patients were reviewed in the clinic at six-weeks postoperatively, then at three-monthly intervals for the first two-years, followed by six-monthly intervals thereafter. At each visit patients were examined and radiographs of the pelvis (anteroposterior view and lateral of the prosthesis) were performed. CT scans were not routinely performed during follow-up and only used if patients were considered to have ongoing problems related to the implant. No patient was lost to follow-up.

### Data collection and outcomes of interest

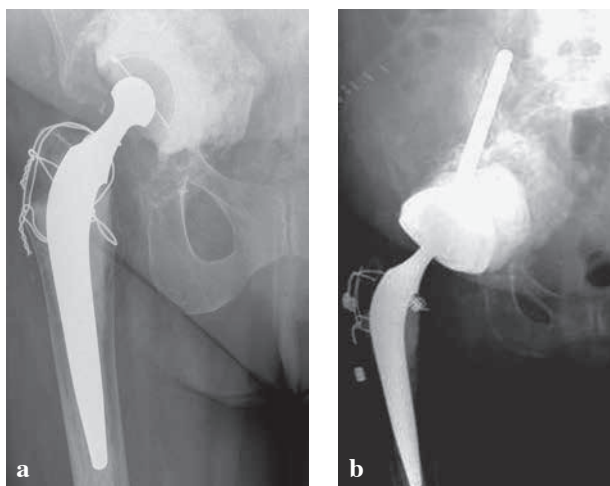
Relevant data were collected from the electronic hospital database and the patient case notes which included patient demographics, details regarding all investigations and operations performed on the ipsilateral hip, and any complications following acetabular reconstruction. Outcomes of interest were : (1) intraoperative and postoperative complication rate (including surgical re-intervention), (2) radiographic evidence of implant failure, and (3) mortality during follow-up.

## RESULTS

Patient demographics and outcomes of interest for the cohort are summarised in Table I. All 15 oncology patients had periacetabular metastases and the primary malignancies were : breast (5), colorectal (3), myeloma (2), renal (1), prostate (1), hepatocellular (1), endometrial (1) and lymphoma (1). Arthroplasty patients had between zero and five surgical procedures on the ipsilateral hip prior to undergoing acetabular reconstruction (Fig. 3). Of the 13 non-oncological cases, 12 were performed for failed primary or revision total hip arthroplasty with indications including deep infection, aseptic acetabular loosening or recurrent dislocation. In all cases both the acetabular and femoral components were revised. The final patient had a traumatic central acetabular fracture with dislocation of a native hip joint resulting in pelvic discontinuity. Preoperatively all patients were either immobile and wheelchair bound, or only able to transfer from bed to chair. There were no intraoperative complications during the 28 procedures and the mean length of hospital stay was 11.6 days (range : 7-20 days).

### Postoperative clinical outcomes

During follow-up 7 patients died due to progression of malignant disease at a mean time of 11.6 months from surgery (range : 4.1-22.5 months), with no early postoperative deaths occurring within 30-days of surgery. All patients who remained alive were mobilising independently or with walking aids at latest follow-up. Two patients had mild to moderate hip pain at latest follow-up with no cause

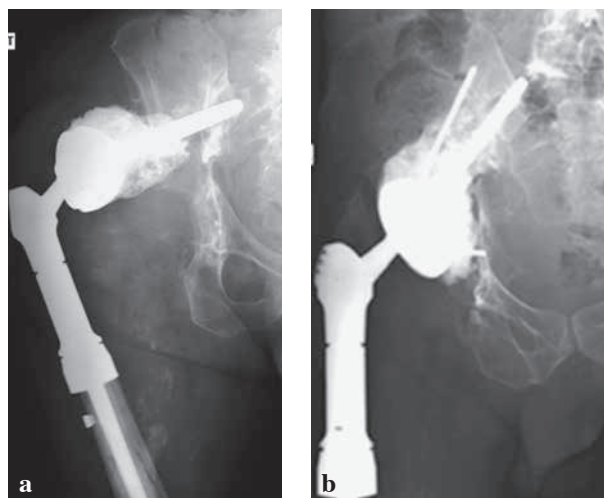


**Fig. 3.** — (a) Anteroposterior pelvic radiograph of a female patient having undergone failed revision hip arthroplasty which shows severe pelvic bone loss and major medial migration of the hip joint. (b) Anteroposterior pelvic radiograph demonstrating successful acetabular reconstruction with the coned acetabular prosthesis.

identified whilst the remainder of those alive were completely asymptomatic.

One patient in the oncology group sustained a single hip dislocation. The dislocation occurred 27 days after acetabular reconstruction and a successful closed reduction was performed in theatre with no subsequent dislocations during follow-up.

Three postoperative complications occurred in the arthroplasty group. This included a deep infection treated with debridement, implant retention and a prolonged course of intravenous antibiotics. The patient remains well at latest follow-up with normal blood inflammatory markers. One patient with a longstanding neuromuscular condition sustained a hip dislocation 62 days after acetabular reconstruction. A closed reduction of the hip was attempted but unsuccessful. Given the patient's neuromuscular problems it was elected not to perform any further surgery and the patient remains asymptomatic when mobilising at latest follow-up. The final patient required revision of the stemmed-cone prosthesis at three months postoperatively due to initial surgical error. The prosthesis was inserted with inadequate anteversion and the patient subsequently had a hip dislocation. This occurred early in the senior authors' series and the implant was revised to



**Fig. 4.** — (a) Anteroposterior hemipelvic radiograph demonstrating failure of the coned acetabular prosthesis which had initially been inserted with inadequate anteversion. (b) Anteroposterior pelvic radiograph demonstrating successful revision of the coned acetabular prosthesis which remains *in situ* 1.5 years after revision.

achieve better position and joint stability (Fig. 4). There were no intraoperative or postoperative complications following revision surgery and the patient remains mobile with walking aids 1.5 year after the revision procedure.

### Radiological outcomes

One patient developed proximal migration of the implant into the pelvis at five months postoperatively. At latest follow-up the implant position has remained stable and the patient remains independently mobile and asymptomatic, therefore revision surgery is not indicated. Apart from this early migration and the patient revised there was no evidence of radiological failure in the remaining 26 patients at latest follow-up. Specifically there was no evidence of implant migration, loosening, periprosthetic radiolucent lines, or osteolysis in these 26 patients.

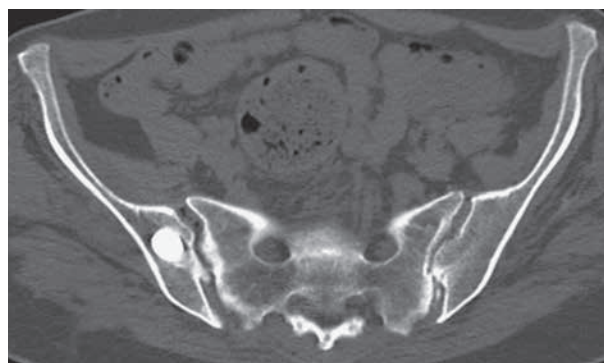
### DISCUSSION

A variety of methods have been described to reconstruct major acetabular defects, including custom made implants for pelvic discontinuity (30),

however these are often associated with significant patient morbidity with deep infection and hip dislocation reported as frequent complications (5,7,8,12,15,16). This study has used a modified technique for acetabular reconstruction using a stemmed-cone acetabular prosthesis. Although stemmed acetabular components with a similar design have been implanted previously through the same surgical approach (1,20,31) the results of these were largely unsuccessful (9,31). The newer coned acetabular prosthesis may be used in a range of complex clinical scenarios which have resulted in major acetabular defects, and it can be implanted through a less extensive surgical approach than first described (11). Given the case complexity the early clinical outcomes using this technique were considered promising, with no intraoperative complications and a relatively low incidence of postoperative complications (14%) and need for further surgical intervention (4%).

One of the key steps for successfully performing acetabular reconstruction with the coned prosthesis is correct positioning and alignment of the implant stem within the ilium. This relies on the surgeon's ability to orientate the implant in relation to important bony landmarks, namely the PSIS and the sciatic notch (Fig. 2). Although the latter landmark can be easily palpated during the procedure, to facilitate identification of the PSIS intraoperatively we used an electrocardiography dot marker which can be palpated through the sterile drapes. This allowed the surgeon to direct the implant stem and helped avoid placing the stem in an incorrect position, such as through the sacroiliac joint, which can be a source of postoperative pain (Fig. 5). Although fluoroscopic guidance was not used intraoperatively to assist correct placement of the coned acetabular prosthesis in this series, this may be useful when surgeons are familiarising themselves with this implant (11).

In addition to the role of the stemmed-cone acetabular prosthesis in treating patients with tumours of the pelvis (11) we feel this implant may have a role to play in the treatment of major acetabular defects in patients requiring complex primary and revision hip arthroplasty. In the arthroplasty group in which the prosthesis was implanted as a salvage option, the only surgical alternative in all cases would



**Fig. 5.** — Axial CT image of the pelvis following reconstruction of the acetabulum with the stemmed-cone prosthesis. Image demonstrates the correct position of the tip of the prosthesis stem which is directed towards the posterior superior iliac spine and must not penetrate the ipsilateral sacroiliac joint.

have been a Girdlestone procedure. With an increasingly ageing population the burden of revision arthroplasty is expected to increase and as such it is reasonable to assume that lack of bone stock will frequently be a problem in these elderly patients (3,18). Apart from traditional modes of arthroplasty failure, such as infection and aseptic loosening, one must also consider the emerging problems of adverse reactions to wear debris which are likely to require revision surgery in future years and have been shown to be associated with significant osteolysis (8). In addition, insufficiency fractures of the acetabulum in elderly and osteoporotic individuals can be complex if treated surgically and will only increase as the older population grows (26). As these complex clinical cases will often be referred to hip arthroplasty and reconstructive surgeons who most commonly use a posterior surgical approach to the hip joint (14,21), it is advantageous that the coned acetabular prosthesis can be implanted through a similar approach. The Kocher-Langenbeck approach was originally described for the fixation of posterior column acetabular fractures and traditionally involves a trochanteric osteotomy (14,19). The technique described in this study essentially uses the proximal part of the Kocher-Langenbeck approach without a trochanteric osteotomy, with the proximal portion of the skin incision curved from the greater trochanter towards the PSIS (14,19). In addition, we consider the total operative time (mean 133 minutes

including anaesthesia) acceptable ; this also included the time for careful patient positioning and pre-operative planning.

Pelvic discontinuity is recognised as a difficult problem to manage surgically. A number of different surgical techniques have been used to manage pelvic discontinuity with variable success and include reconstruction with trabecular metal, antiprotrusio cages, and plating (4,17,25,28,29). Essentially all techniques attempt to reconstruct the pelvic ring and provide structural support for the hip joint. However, the results of these various methods have generally been of limited success with aseptic loosening, hip dislocation, and deep infection responsible for most of the morbidity, and revision surgery required in up to 33% in the short-term and up to 47% in longer-term series (4,17,25,28,29).

The advantage of the stemmed-cone acetabular prosthesis is that it uses the bone stock from the ilio-lumbar bar and posterior ilium, which is often preserved even in severe cases. In pelvic tumour resections, patients are often left with pelvic discontinuity. In these cases the pelvic ring is not reconstructed, but instead the local defect is bypassed using hemipelvic endoprostheses or other reconstruction methods with good results in appropriately selected patients (10,11,13,15). The coned acetabular prosthesis bears resemblance to a previously used stemmed acetabular implant, the McMinn cup, which both the designing surgeons and other authors considered to be contraindicated in patients with pelvic discontinuity (2,20). However, there are some differences in prosthetic design which make the newer stemmed-cone prosthesis better suited for pelvic discontinuity. In addition to cementing the distal portion of the cone's stem which is also fluted and therefore provides good rotational stability, the proximal part of the implant is hydroxyapatite coated and therefore achieves good fixation in the cancellous bone. This more secure fixation will hopefully prevent longer-term failures from aseptic loosening which were reported with previous stemmed acetabular components, such as the McMinn prostheses (9). However it is recognised longer-term follow-up is required to assess this, with the present report only providing early clinical outcomes. Therefore we consider the coned acetabular

prosthesis to be a useful reconstructive option in the setting of pelvic discontinuity and feel it may provide a better solution to previous largely unsuccessful attempts of reconstructing the pelvic ring (4,17,25,28,29). In addition, there were no implant failures in cases with pelvic discontinuity in this series, with an earlier study confirming the prosthesis was not subject to mechanical failure when used following tumour resection in patients with 'effective' pelvic discontinuity in the short-term (mean follow-up of 39 months) (11).

The short-term clinical outcomes appear promising with this method of acetabular reconstruction and are comparable, if not slightly favourable to previous reports (5,7,8,12,15,16). Similar to the literature (5,7,8,11,12,15,16) the main complications in this study were infection and hip dislocation. The one case of deep infection (4%) was favourable compared with the deep infection rate (11%) in the initial report with this implant (11). Although this may be a reflection of a shorter follow-up period in the present series, it is likely the more limited extra-abdominal surgical approach, dissection and reduced operative time were responsible. In the initial study all coned acetabular prostheses were implanted using an extended Ollier approach with trochanteric osteotomy, or an anterior ilioinguinal approach combined with a Kocher-Langenbeck approach (11).

The lower dislocation rate (8% versus 15% in initial series) may also be partly attributable to the less extensive surgical dissection and/or tumour resections required (11). The bipolar cup may also serve to reduce the dislocation rate with studies demonstrating it reduces the long-term dislocation rates following primary total hip arthroplasty (6,23) with similar findings observed in the short-term following revision surgery (27) and unpublished work at this centre of one dislocation following implantation of 53 bipolar SERF cups used in complex arthroplasty and oncology reconstructions). The bipolar cup has the additional advantage of adjustable inclination and anteversion of the inner shell after cementation of the outer shell, thus contributing to hip stability. The disadvantages of bipolar cups are the lack of long-term results when used in revision surgery (27). In the one case re-revised in this series it was not possible to revise the bipolar

cup alone because it was cemented and well-fixed into the cone's shell, therefore a complete cone revision was required. Migration of the coned acetabular prosthesis did occur in one case, but this stabilised and the patient remains asymptomatic. The only revision performed was for suboptimal implant position. However this was early in the surgeon's learning curve and the patient had undergone five arthroplasty procedures on the ipsilateral hip before the cone was implanted with poor bone stock (Paprosky 3B). After revision of the prosthesis the patient made a full recovery and is mobilising pain free. Although only one revision has been performed it is recognised with the current follow-up period patients may require additional procedures in the future.

Although the numbers were small there were more complications in arthroplasty patients than oncology patients in this series (Table I). One explanation could be the longer follow-up in the arthroplasty group compared to the oncology patients in which seven deaths occurred during follow-up, hence there were less oncology patients at risk of complications for a similar time period. A further explanation is that arthroplasty patients may be at higher risk of deep infection compared to the oncology group giv-

en the multiple surgical procedures undertaken on the hip, and indeed one patient in the arthroplasty group did develop a deep infection. A further complication requiring re-revision in the arthroplasty group was due to surgical error which was early in the surgeons' learning curve with this implant, and given the small numbers of complications being compared between the two groups this may have contributed to the seemingly higher complication rate in arthroplasty patients.

The main study limitation is the short follow-up period. Although this was not the primary study objective any conclusions about clinical outcomes must be considered in light of this. However we feel the modified technique for inserting this implant is important and hopefully will allow other surgeons to consider using the stemmed-cone acetabular prosthesis when dealing with complex acetabular defects, including pelvic discontinuity. In addition, this series includes the surgeon's complete learning curve with this technique. A further limitation is that, as this was a retrospective study, patient-reported outcome measures were not available either before or after reconstruction, although improvement in patient mobility status has been recorded.

Table I. — Patient demographics and outcomes of interest following reconstruction using the Stanmore coned acetabular prosthesis

	Whole cohort (n = 28)	Oncology patients (n = 15)	Arthroplasty patients (n = 13)
Mean age (range) in years	70.9 (47.2 to 85.5)	68.6 (47.2 to 83.3)	73.5 (55.2 to 85.5)
Male : Female	11 (39%) : 17 (61%)	6 (40%) : 9 (60%)	5 (38%) : 8 (62%)
Paprosky classification			
3A	10 (36%)	6 (40%)	4 (31%)
3B	8 (28%)	4 (27%)	4 (31%)
Pelvic discontinuity	10 (36%)	5 (33%)	5 (38%)
Mean operative time including anaesthesia (range) in minutes	133 (87 to 288)	120 (87 to 288)	198 (118 to 267)
Intraoperative complications	0 (0%)	0 (0%)	0 (0%)
Postoperative complications	4 (14%)	1 (7%)	3 (23%)
Further surgery	1 (4%)	0 (0%)	1 (8%)
Deaths	7 (25%)	7 (47%)	0 (0%)
Mean follow-up time (range) in months	12.5 (2 to 33)	9.7 (2 to 23)	15.6 (4 to 33)



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