Patients who had a revision total hip arthroplasty using the Bürch-Schneider anti-protrusio cage (APC) by a single surgeon have been reviewed after a minimum of five years. There were 63 operations in 58 patients with an average age of 63 years (41 to 83) at the time of revision. At an average follow-up of 8.5 years (5 to 18), 15 patients (25.9%) rated their results as excellent, 38 (65.5%) as good, and five (8.6%) as fair. Five further revisions of the acetabular prosthesis were required, three due to aseptic loosening, one for recurrent dislocation and one due to sepsis. Of the remainder, one was definitely loose, two probably loose, and 12 possibly so.

Impressive augmentation of bone stock can be achieved with the anti-protrusio cage, while enabling the hip to be centred in its anatomical position.

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The anti-protrusio cage (APC) was originally designed by Bürch in 1974 and modified by Schneider in 1975 to address the problem of protrusio acetabuli. The aim was to bridge areas of bone loss, allow grafting and bone augmentation in areas of protected stress, and give support for the socket. The APC provides a large contact area between the implant and eroded pelvic bone, bringing resultant forces across the hip under the acetabular roof while providing metal backing for the polyethylene cup. Joint forces are distributed over a large area, theoretically decreasing the chance of implant migration. Of equal importance, the cage provides the basis for bone repair, not just a temporary solution for cup placement since bone graft placed deep to the APC is protected from excessive stress until its maturation, allowing considerable augmentation of the pelvic bone stock. Immediate stability is obtained by using multiple screws. The APC also allows restoration of the true centre of the hip.

As the indications for total hip arthroplasty (THA) expand, particularly in the younger age groups, the number of revision procedures carried out in the future will increase. Loss of acetabular bone stock will also increase due to the original disease process, removal of bone during the initial procedure, subsequent prosthetic failure and component migration, and osteolysis resulting from wear particles of cement and polyethylene.

A variety of techniques has been advocated for reconstruction after loss of acetabular and pelvic bone using prostheses, grafting or a combination of these techniques. Bipolar prostheses, eccentric prostheses, oversized cups and custom-designed components have been used. The last do not always match the defect found at surgery and are expensive. Uncemented prostheses may not span large defects, and the area of contact for ingrowth of host bone is questionable. Cavities or excavations can be filled with additional cement, or by the use of autograft or allograft bone with cemented or uncemented sockets. Unfortunately, the survival of bulk allograft is uncertain at best. Combinations of bone grafting and prosthetic augmentation have been reported using metallic mesh or a variety of reinforcement rings. Due to the poor results with many of these treatments, resection arthroplasty has been advocated by some authors.

Early studies using the APC have been encouraging. Peters, Curtain and Samuelson reported excellent restoration of the centre of the hip and an 8 mm increase in the thickness of the medial wall, using the APC. No revisions had been needed following acetabular reconstruction after three years. Rosson and Shatzker reported a revision rate of 7.5% for aseptic loosening in a mixed series using both
acutal reinforcement rings and the APC. Berry and the senior author (MEM) found a rate of aseptic loosening of 12%, with no cup failure or loosening in 76%, at 4.7 years.1

The current Bürch-Schneider APC has been used by the senior author (MEM) since 1977 for revision arthroplasties with massive acetabular bone loss. Our aim now was to report the long-term results with the APC, and offer recommendations on its use. Radiological criteria for loosening of an APC are described.

**Patients and Methods**

All patients who had a revision THA by the senior author (MEM) using the Bürch-Schneider APC were reviewed. The indication for its use in revision THA was massive pelvic bone loss. A minimum follow-up of five years was required. Since 1977, we have performed 84 acetabular reconstructions in 78 patients using the Bürch-Schneider APC. In this group, five patients have died, seven were excluded because the follow-up was less than five years, five could not be located, and four were not able to return for a clinical examination. The remaining 63 reconstructions in 58 patients were reviewed.

Of the 21 procedures in 20 patients which were excluded, four had been revised. One was removed for recurrent dislocation of the femoral prosthesis; both components were revised in an effort to improve stability. Sepsis was responsible for revisions in three patients of whom two had not received perioperative antibiotics, and one was a one-stage revision for septic loosening using antibiotic-impregnated cement. At their most recent follow-up (1 to 4 years), four of the remaining 17 revisions had evidence of radiolucency. One APC was definitely loose with screw breakage, one probably loose with a progressive radiolucency superior and medial to the cage, and two possibly loose with a non-progressive radiolucency line medial to the APC not involving the screws. Two patients rated their result as fair, three as good and 11 as excellent. The four revisions which had been revised and the one which was definitely loose were considered poor results.

Of the group studied there were 48 women and ten men with a mean age of 63 years (41 to 83) at the time of revision. Bone loss was classified according to the method of D’Antonio et al.44 There were 36 hips with cavitary deficits, 13 with segmental loss, and 14 with combined deficiencies. Superior and lateral defects were predominant in 22 hips. Of the 41 medial defects, 29 were greater than 2 cm deep. In 29 cases, superior migration was between 5 and 10 mm, and in two was greater than 10 mm; 20 cases were classified as protrusion acetabuli and the socket was intrapelvic in four. The mean number of previous arthroplasties was 2.4 per hip (2 to 4). The mean time since the last arthroplasty was 11.8 years (1 to 21). The mechanism of failure was combined aseptic loosening of the socket and stem in 16 cases, aseptic acetabular loosening in 38, and isolated femoral loosening in eight. One patient had malposition of components with repeated dislocations.

A support was needed for walking by 41 patients and four patients were able to walk for less than ten minutes without aid. Seven patients complained of mild pain, 37 moderate, and 11 severe. A leg-length discrepancy of between 1 and 2 cm was present in 40 patients, of 3 cm in nine, and of 4 cm in four.

All patients were reviewed by a single examiner. They were asked to answer a questionnaire regarding their ability to perform a variety of activities of daily living, the presence or absence of pain, their functional status compared with their previous visit, whether their expectations had been fulfilled, and how they would rate the outcome of their surgery. Clinical data were recorded using the International Documentation and Evaluation System (IDES-4).

Radiological analysis was carried out by a single examiner. We have defined criteria for loosening of the APC based on our experience with acetabular reinforcement devices (Table I). An acetabular component was considered definitely loose (type III) if the screws used to fix the APC were broken, if there was evidence of acetabular migration more than 5 mm, or if a complete, progressive radiolucent line was present both medial and superior to the cage, or around the screws. The analysis of acetabular migration was based on anteroposterior radiographs of the hip, using the distance from the bottom of the teardrop and the medial wall as reference points. Type-II loosening was defined as a progressive radiolucent medial or superior to the cage. Type-I radiolucencies were non-progressive and did not involve the screws.

The presence of grade-III or grade-IV heterotopic ossification was reported according to the system of Brooker et al.45 The presence and progression of any acetabular osteolysis were noted.

<table>
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<th>Table I. Radiological criteria for loosening of an acetabular reinforcement device, with type III being defined as having any or all of the indicated criteria</th>
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<td>Definitely loose (type III)</td>
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<td>Probably loose (type II)</td>
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**Operative technique.** We performed all the operations in a vertical laminar-flow operating room with greenhouse enclosure. A transtrochanteric approach was used in each case. Although trochanteric osteotomy is not always required, the use of the APC requires a more extensive exposure of the acetabulum and iliac wing, and it is therefore recommended. The failed acetabular component was removed and a thorough debridement of the remaining bone and soft-tissue membrane carried out. The residual defect was then assessed. The outer wall of the ilium was cleared for several centimetres above the defect and the residual bone roughened. Before 1982, cement was used to fill most bony defects. Since then, bony deficiencies have been reconstructed using allograft bone (Fig. 1). Morselised graft is used for all medial or contained defects. Solid allograft is reserved for segmental defects.
The implant comes in either large or small sizes, and is specific for left or right sides. The APC is placed by driving the inferior flange into a precut slot in the ischium from within the acetabulum. The flange can be bent to improve seating. The superior flange is fixed to the superior margin of the acetabulum using 6.5 mm titanium screws, preferably placed at right angles to each other to lock the implant against the proximal host bone. It is not as important to have a perfect fit with the APC as it is with a press-fit component or an acetabular reinforcement ring, provided that the inferior flange is firmly impacted into the ischium and good screw purchase is obtained in the ilium. After placement of the APC, the remaining medial defects can be packed with morsellised graft through the holes in the implant. A 50 mm outer-diameter polyethylene socket is cemented into place with the large APC, and a 44 mm socket for the smaller cage. Cement should not be used to fix the APC to bone.

Postoperatively, the patients are restricted to partial weight-bearing for six weeks if considerable grafting is required. Otherwise, they are allowed to progress as tolerated.

**Results**

A Bürch-Schneider APC and cemented polyethylene cup were used in all 63 hips. Allograft bone was used to fill bony deficiencies in 38 procedures (60.3%), in 15 with morsellised graft alone, in 13 with solid graft alone, and in 10 with both morsellised and solid graft. No graft was used in eight cases (12.7%), while 17 (27%) were augmented with cement.

**Clinical evaluation.** The average follow-up was 8.5 years (5 to 18). Of the 58 patients with unrevised hips, 15 (25.9%) rated their results as excellent, 38 (65.5%) as good, and five (8.6%) as fair. Walking capacity was restricted by hip pain in 17 patients (29.3%), while 15 were able to walk for longer than 60 minutes, and 24 for less than 30 minutes without support. Postoperatively, 17 (29.3%) were unable to walk without support compared with 41 (70.7%) preoperatively. A total of 28 patients (48.3%) generally used one cane or crutch for walking and 19 (32.8%) used two canes or crutches. Four patients (6.9%) had severe pain and four (6.9%) had moderate pain compared with 48 (82.8%) with moderate or severe pain preoperatively. Occasional medication for pain was used by 29 patients, and regular analgesics by two. The leg lengths were equal in 30 patients (51.7%), while 28 (48.3%) had an average discrepancy of 2.0 cm.

**Radiological examination.** Of the 58 unrevised hips, one was classified as definitely loose, two as probably, and 12 as possibly so. There was no superior acetabular migration greater than 2 mm. Medial migration was greater than 2 mm in two hips of which one had developed 3 mm of protrusio. Nine had non-progressive radioluencies medial to the cage; cement had been used to augment the medial wall in six of these. No augmentation had been used in two cases and morsellised allograft in one. Two hips had non-progressive radioluencies superiorly and three both medially and superiorly. There were no radioluencies around any screws, none of which was broken.

Of the 38 allografts, all but one had radiological evidence of full incorporation, defined as the absence of radioluencies at the graft-host bone interface. A radiolucent line measuring 1 mm in width between the allograft and host bone was observed in one hip medial to the APC without evidence of bony resorption. Heterotopic ossification of grade III was seen in two patients. There was no significant acetabular osteolysis in any hip.

**Revisions.** Five further revisions of the acetabular reconstruction were performed in four patients, three for aseptic loosening. One patient with a previous high subluxation of the hip had a large combined bony deficiency which was filled with cement before placement of the APC. In this patient the cage was placed too superiorly, the centre of the hip was not restored, and loosening occurred. A second patient had bilateral revisions for loosening. In one hip, cement was used to fill a large medial defect, but the inferior flange was not embedded into the ischium. This resulted in loosening and medial migration. In the opposite hip the APC had been placed in a position of protrusio without any medial grafting and without embedding the inferior flange in the ischium. This led to further protrusio and revision with a second APC using a medial bone graft and an embedded inferior flange. The patient is doing well 12 years later, with no evidence of further loosening.

The fourth revision was carried out for recurrent dislocation, which led to displacement of the polyethylene liner. The APC had been positioned vertically and 25% of the cup left uncovered.

The fifth revision was for sepsis. At the time of removal of the component, the allograft in the medial wall had reconstituted well and was fully incorporated. An uncremented acetabular component was used for the revision since an APC was no longer required.

**Complications.** The overall complication rate was 19%. Neurapraxia of the sciatic nerve was observed in two patients who recovered without incident. Two patients had postoperative dislocations, one of which required revision due to a dislocated polyethylene liner. There was an intra-operative vascular complication in one case, which was repaired without further problems. Myocardial ischaemia occurred in four patients, and two developed respiratory distress syndrome. One patient had a pulmonary embolus and one a deep-vein thrombosis. One developed a protracted postoperative paralytic ileus.

**Discussion**

A variety of techniques has been reported to reconstruct bony deficiencies of the acetabulum resulting from erosive arthritis or migrating replacement prostheses. Acet-
abular rings have been advocated to prevent socket migration and to help to reconstruct bony voids, with largely favourable short to mid-term results.\textsuperscript{2,12,33-42} These devices have limited indications for hips with loss of medial bone stock, and are not indicated for protrusio acetabuli. In such situations, a prosthesis must provide strong medial support for the socket, which is not possible using most ring designs.

Several anti-protrusio devices have been developed. To the best of our knowledge, our study is the only long-term report of such an implant. Unfortunately, direct comparison with other methods is not possible. Hedde

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Figure 2a – Radiographs showing considerable acetabular bone loss in a 65-year-old woman with a failed all-polyethylene cup and superior acetabular migration. Figure 2b – Preoperative plan showing desired placement of an APC in the anatomical centre of the hip and bone graft (hatched area). Without an acetabular reinforcement device, structural allograft is likely to be needed. Figure 2c – Radiograph of the large combined pelvic defect filled with morsellised allograft bone. The superior flange of the APC is anchored to host ilium while the inferior flange is embedded in the ischium. Figure 2d – Radiograph of restoration of bone stock, with no evidence of loosening and equalisation of leg lengths at eight years.
et al.\textsuperscript{46} reported a follow-up of 2.5 years of the anti-protrusio prosthesis designed by Kerboull, with generally good results. Oh and Harris\textsuperscript{13} described the use of a protrusio shell, while Jasty and Harris\textsuperscript{13} used wire mesh and cement. They found a rate of loosening of 75% at six years, and concluded that the technique was ineffective. Sloof, Schimmel and Buma\textsuperscript{47} have achieved good results using cement, wire mesh, and morsellised cancellous grafts. Zehntner and Ganz\textsuperscript{42} emphasised that morsellised medial grafts are not adequate without prosthetic support, with a failure rate of 11.4% at five years.

Reports have been mixed on bipolar reconstruction using bone graft, with some good results\textsuperscript{22-28} but others with high rates of failure due to migration.\textsuperscript{7,26} Wilson and Scott\textsuperscript{3} had good early results but 24% had migrated at four years.

Preliminary experience with eccentric components has been discouraging. Sutherland\textsuperscript{10} reported that instability was a major problem, leading to mechanical failure in 26%, clinical failure in 16%, and an 11% revision rate at less than four years. Oversized components have had limited long-term success, perhaps because of good peripheral contact but poor approximation in the polar area.\textsuperscript{11}

Reports of structural bone grafting have been mixed, with the results of incorporation using bulk allograft being variable at best. Some authors have described good short-term results,\textsuperscript{22,24,26-28} while others have reported early rates of failure as high as 65%.\textsuperscript{23,29,48} Although some have indicated satisfactory longer-term success rates,\textsuperscript{20,21,27} others have cautioned against the use of structural allografts, because of unacceptably high mid- to long-term failure rates.\textsuperscript{29-32} Our results in this period using bulk allograft together with the Bürch-Schneider APC have been promising.

Most surgeons agree that if significant complications and early aseptic loosening can be avoided, it is preferable to reconstruct pelvic and acetabular bone loss using bone graft rather than prosthetic devices. The restoration of bone stock is especially important if further revision surgery is to be expected in the future. It is our experience that impressive augmentation of bone stock can be achieved with the APC, while enabling the centre of rotation to be returned to its anatomical position.\textsuperscript{12} Bone grafts placed with the APC show no significant resorption.

Since 1988 the APC has been made of rough-blasted titanium. Medial support is provided by resting the superior flange against the ilium and sinking the inferior flange into the ischium. Security is obtained by multiple screws placed in the superior flange, preferably with at least two placed at right angles to each other in order to lock the implant proximally. In the early designs of the APC, the screws placed in the inferior flange tended to loosen and pull out. The flange should be embedded through the acetabulum into the ischium to enhance the inferior stability. Some surgeons prefer to bend the flange into the obturator foramen or leave it free, but this is not recommended in cases in which there is considerable loss of medial bone. All three revisions for aseptic loosening in our study were performed in hips in which the inferior flange was not embedded into the ischium. Of the unrevised hips, the only case of definite loosening occurred in a patient with progressive protrusio in which the inferior flange was left free.

Although the selection of bone graft for use with the APC must be individualised, solid graft is reserved for segmental defects in the weight-bearing dome. A great advantage of the APC is that it allows the use of morsellised graft in many situations in which bulk graft would normally be required (Fig. 2). Morsellised or wafer-type graft is used for reconstruction of deficient medial walls, rather than placing the APC directly against the quadrilateral plate, thereby giving considerable augmentation of existing bone. Even in the case of revision for sepsis, medial bone stock had been restored to such an extent that a reconstruction using a standard press-fit component was possible. Excessive lateralisation must be avoided when reconstructing medial defects with the APC since it interferes with abductor mechanics and may increase the risk of aseptic loosening.

Cement poses a significant risk for aseptic loosening of the APC and should not be used to fill medial or superior defects. Of the 14 cases with radiolucencies in our study, 11 had bony deficiencies reconstructed with cement. In two hips, the APC was placed directly against the quadrilateral plate without any graft material. A non-progressive radiolucent line was present in only one case in which bone graft was used.

A further advantage of the APC is the ability to restore the anatomical centre of rotation of the hip, while generally relying on host bone for support.\textsuperscript{43} This was possible in all but one of the 63 cases. This one hip in which the anatomical centre was not restored has a continuous progressive radiolucency and is classified as probably loose.

The significance of radiolucencies with the APC has been raised, with doubts about long-term survival. Rosson and Schatzker\textsuperscript{17} do not predict failure in reconstructions using the APC, with or without bone graft, unless there is radiological progression of the lines, an association with cup migration, radiolucencies around the screws, or screw breakage. This is similar to previous experience with the Müller acetabular reinforcement ring, in which a high incidence of non-progressive lucencies at five years did not correlate with functional results.\textsuperscript{34} During this series, it was noted that progressive radiolucencies tended to form at the graft-host bone interface when cement was used as graft material. Cement therefore has not been used to fill areas of bone loss since 1982. In addition, care should be taken to remove as
much cement debris and soft-tissue membrane as possible before inserting bone graft, particularly in areas of previously cemented, eburnated bone.

The Büch-Schneider APC is recommended for cases of major acetabular bone loss, particularly medial defects, large cavitary defects and combined deficiencies. Secondary indications include osteoporosis and metastatic disease in which the strength of the host bone for a standard reconstruction is questioned. By following the principles outlined above, long-term clinical success with restoration of bone stock can be expected.

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