Revision of the femoral prosthesis with impaction allografting and a Charnley stem

A 2- TO 12-YEAR FOLLOW-UP

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Impacted morcellised bone allograft and a Charnley stem was used to revise 59 loose femoral components in 57 consecutive patients. Femoral bone loss was rated as Endo-Klinik grade 2 in nine patients, grade 3 in 41, and grade 4 in nine. The immediate postoperative radiographs and those taken at the most recent follow-up were compared for radiolucencies, subsidence and incorporation of the graft. One patient was lost to follow-up and two were not available for radiological analysis.

The mean clinical follow-up in 58 procedures was 56.7 months (24 to 144) and the mean radiological review of 56 reconstructions was 54.4 months (24 to 144). An intraoperative femoral fracture occurred in one patient (1.7%) and was successfully treated by strut grafting and cerclage wiring. Extrusion of cement through perforations or incomplete hoop fractures was detected in the postoperative radiographs of ten procedures (17%); none of these patients sustained a complete fracture. Three patients had dislocations (5%) and two (3.5%) developed painful subsidence of the stem which required a further revision. The latest follow-up radiographs in 56 reconstructions showed a well fixed stem and radiological healing of the graft in 52 (93%), and definite loosening in four (7%). Of these four, two were revised again and two were asymptomatic after a follow-up of 120 months each. The mean subsidence in the 52 successful revisions was 0.38 mm (0 to 4). Impaction allografting with a Charnley stem restored bone stock and provided adequate fixation of the stem in 93% of the hips. There was a low rate of rerevision (3.5%) and a low incidence of intraoperative and postoperative complications.

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The incidence and severity of loss of bone stock associated with aseptic loosening of a total hip replacement continue to increase. Patients are living longer, and the indications for total hip replacement have been extended to younger, more active individuals. Additional factors include the implantation of poorly designed stems, faulty surgical technique, and the fact that early osteolysis may be asymptomatic. For a loose femoral component in the presence of deficient bone stock, revision with impacted, morcellised, bone allograft combined with a cemented stem has been advocated.1,2

The impaction technique combined with the use of a highly-polished, double-tapered stem was proposed by Gie et al.3 They reported a rerevision rate of 3.5% in 56 reconstructions at a mean follow-up of 30 months. The technique has been increasingly used with stems of varying surface finish.4-6 The Charnley stem (DePuy, Warsaw, Indiana) has shown excellent results in primary total hip arthroplasty. We were, however, unable to find any reports in the literature on the results of impaction allografting with this stem.

We describe the clinical and radiological results in a series of patients who underwent femoral revision using the impaction technique with a Charnley unpolished stem.

Patients and Methods

We reviewed retrospectively a consecutive series of 57 patients with aseptic loosening of the femoral component who were revised using the impaction allografting technique between August 1987 and February 1999. We used other revision techniques during the same period for patients with Endo-Klinik type-I defects, severe femoral deficiencies which were judged incapable of withstanding normal loads, cemented revisions of stems with an intact cement-bone interface and, before 1997, two-stage reimplantation after infection. Other indications for impaction grafting in the same period included periprosthetic fractures and, since 1997, two-stage reimplantation after infection. These were not included in this study.

There were 35 women and 22 men with a mean age at the time of revision of 65.2 years (32 to 88). The left side was affected in 35 patients and the right in 24 (two bilateral revisions). The preoperative diagnosis was osteoarthritis in...
38 hips, fracture in nine, congenital hip dysplasia in six, avascular necrosis in three, rheumatoid arthritis in two, and Perthes’ disease in one. There were 56 loose primary arthroplasties and three loose first-time revisions.

Before operation, anteroposterior (AP) and lateral radiographs of the pelvis and the affected hip were taken in all patients. The femoral deficiencies were classified retrospectively according to the Endo-Klinik classification as grade 2 in nine hips, grade 3 in 41 and grade 4 in nine. The operations were carried out by two hip specialists (FP, RP) and a trainee.

All but one patient were operated on in the dorsal decubitus position using a transtrochanteric approach. Intraoperative frozen sections of the loosened prosthetic interface were routinely obtained to exclude infection. The bone allograft used consisted of fresh-frozen femoral heads in 56 revisions (95%), lyophilised bone combined with autologous bone in two (3.3%) and autologous graft in one (1.7%). In the 27 patients operated on before October 1996, the graft was packed in the widened canal using custom-made, non-cannulated tamps and a Charnley femoral prosthesis as initially advocated by Gie et al. The Exeter stem. After November 1996, we used the Primary instrumentation (DePuy). We implanted a Charnley stem in all hips. It had an unpolished surface finish and proximal flanges to enhance cement pressurisation, to provide proximal centralisation and to prevent subsidence. The stems were cemented with CMW3 (DePuy) in 51 reconstructions and refrigerated Palacos (Smith and Nephew Richards, Memphis, Tennessee) in eight. The cement was delivered retrogradely using a cement gun. A total of 44 patients (74.5%) underwent revision of the acetabular component at the same time. Additional hardware was required in 15 reconstructions (25%), cerclage wires in 11 and metal mesh combined with wires to contain cortical defects in four.

After surgery, all patients received antibiotics for the first 24 hours. Patients were mobilised early with two crutches or a frame with touch weight-bearing on the operated side for 45 days. They then progressed to a stick until fully mobile. No routine prophylaxis for heterotopic ossification was used.

The patients were followed clinically and radiologically for a minimum of two years or until death or further revision. At their last follow-up, 39 patients (70%) were personally interviewed by the authors and rated according to the Merle d’Aubigné and Postel hip score. We interviewed 17 patients (30%) by telephone, who then completed a detailed survey and sent an updated radiograph.

Radiographs obtained in the recovery room after surgery were compared with those obtained at the annual follow-up. We recorded the presence and location of radiolucent lines, progressive or otherwise and over 1 mm in width, the presence of extruded cement from the femoral canal and the alignment of the stem. The filling of the bone defect was classified into one of two groups based on the AP radiographs; adequate, when the defect was uniformly graded, and inadequate, when areas of insufficient grafting and direct contact of the cement or stem with the thinned femoral cortices were observed. Heterotopic ossification was rated according to the classification of Brooker et al.

Radiological incorporation of the graft was assessed from the last follow-up radiograph by the presence of corticalisation and trabeculation. The implant was considered to be fixed when no progressive radiolucent lines were observed. Reconstructions showing progressive, incomplete, radiolucent lines of more than 1 mm were rated as probably loose. Those with progressive, circumferential radiolucencies, or subsidence greater than 5 mm were considered as definitely loose. Subsidence was calculated by comparing the immediate postoperative radiographs and those obtained at the latest visit using the method reported by Eldridge et al.

Results

The mean clinical follow-up was for 56.7 months (24 to 144). No patient died, but one (1.7%) was lost to follow-up before the second year. Two patients were unable to walk at their last review. The first was an 88-year-old man who had suffered a stroke two years after surgery. The second was a 58-year-old woman who had undergone removal of a brain tumour 11 months after revision. Both had a painless hip. Neither came for radiological assessment and both were excluded from the radiological analysis. There were therefore 54 patients (56 reconstructions) who underwent radiological review at a mean of 54.4 months (24 to 144).

No patient developed a deep wound infection. Two (3.5%) required further revision because of aseptic loosening and painful subsidence of the stem. The first had a preoperative defect of Endo-Klinik grade-2 with a large osteolytic lesion at the tip of a cemented Charnley stem. He underwent revision with impacted, morcellised bone, but without the Primary instrumentation. The grafting technique was judged to be inadequate because the proximal filling of the canal with graft and the distal cement were both insufficient. He developed a trochanteric nonunion, but had a painless reconstruction for the first five years. Thereafter, he developed painful loosening of the stem and recurrent dislocation. When revised again after 96 months the stem was loose, had subsided, and was rotated into 30° of retroversion. The patient had a further operation using the same technique with no evidence of failure at follow-up of 17 months. The second patient was a 61-year-old woman with a grade-3 defect. She developed painful subsidence of the stem 36 months after surgery and underwent a further cemented revision at another institution. Of the remaining 54 patients (56 reconstructions), none is scheduled for further revision.

Intraoperative complications. Intraoperative fracture of the femur while impacting the bone graft occurred in one patient (1.7%) with a defect of Endo-Klinik grade-2. It was stabilised by two cortical strut allografts and cerclage wires.
before insertion of the stem. The fracture healed uneventfully with no subsidence or loosening detected at a follow-up of 45 months (Fig. 1). In ten reconstructions (17%), extrusion of cement from the femoral canal was observed on the postoperative radiographs through either cortical perforations or incomplete hoop fractures. There were nine grade-3 defects and one of grade-4. All patients had an uneventful postoperative course with no displaced fractures detected during the follow-up period.

**Alignment of the stem and grafting technique.** The alignment of the stem was neutral in 43 hips (73%). Because of eccentric impaction of the morcellised graft the stem was not centred within the femoral canal in four hips but was displaced laterally or medially. Of these four, two had received surgery without the Primary instrumentation. Varus alignment of the stem was detected in 11 revisions (19%) (mean 2.7°; range 2 to 5) and valgus alignment in five revisions (8%) (mean 2.6°; range 2 to 5).

**Wound complications.** Three patients developed wound complications (5%). One presented with a superficial infection which was treated successfully by irrigation, debridement and intravenous antibiotic therapy. Two patients developed a wound haematoma, both of which drained spontaneously without significant consequences.

**Trochanteric nonunion and dislocations.** Ten patients (17%) developed a trochanteric nonunion. One had a fibrous union with a separation of less than 10 mm and without functional impairment. In the remaining nine patients in whom the trochanter had migrated, one had a Trendelenburg gait and required the use of a stick (1.7%). Three patients (5%) dislocated of whom one developed recurrent dislocation associated with trochanteric nonunion and subsidence of the stem. The second patient had four dislocations beginning 14 months after surgery and used a brace for three months, with no further dislocations identified in the last 24 months. The third patient had two dislocations in the first postoperative month but no more had occurred at a follow-up of 37 months.

**Clinical and radiological results and subsidence at the last follow-up.** At the last follow-up, 54 patients (56 original reconstructions) were available for analysis. The mean Merle d’Aubigné and Postel hip score was 5.8 (5 to 6) for pain, 5.4 (3 to 6) for gait, and 4.8 (3 to 6) for mobility. One patient had a low gait score because of a loose contralateral total hip arthroplasty. Radiographs available for 56 reconstructions (54 patients) showed a fixed stem, with subsidence not greater than 5 mm and no progressive radiolucencies (Fig. 2) in 52 (93%). Two asymptomatic patients (3.7%) were considered to have loose stems because of subsidence of 13 and 20 mm, respectively, when seen after 120 months. Two patients required another revision (3.7%). At the last follow-up the mean subsidence was 1.18 mm (0 to 20). If only fixed stems are considered (Fig. 3) the mean subsidence was 0.38 mm (0 to 4). The mean subsidence in failed reconstructions (either loose or rerevised) was 12.5 mm (2 to 20). Heterotopic ossification developed in 25 patients (46%); in 15 of class I, in seven of class II and in three of class III.

**Discussion**

To our knowledge, this is the first report of the clinical and radiological results of femoral revisions with impacted, morcellised bone and a Charnley prosthesis. In 59 patients, the rate of further revision was 3.5% at a mean follow-up of 56.7 months. When both revision and loosening were considered, the rate of failure was 7%. The two patients with loose stems at their last follow-up remain asymptomatic 120 months after surgery.

The clinical and radiological results of our study are similar to those reported for the use of double-tapered, polished stems for which this technique was originally advocated. Gie et al described two further revisions (3.6%) in 56 hips with impaction grafting and the use of a highly-polished, double-tapered Exeter stem (Howmedica, Rutherford, New Jersey) at a mean follow-up of 30 months (18 to 49). Subsidence in this series was observed predominantly at the cement-stem interface and was not associated with failure. This has also been seen in primary arthroplasties with the same design of stem. Since this initial report, there has been increasing enthusiasm for the technique, demonstrated by several series with follow-up ranging from 12 to 63 months. Rates of failure including loosening...
Polished, tapered stems have theoretical advantages for revision using impaction grafting. They allow for subsidence within the cement mantle and transmit compressive forces to the cement-bone and cement-graft interface, promoting healing of the graft and protecting the cement-bone interface. Other authors have observed a relationship between subsidence and failure when using polished, double-tapered designs of stem. Eldridge et al.\textsuperscript{10} reported subsidence of greater than 10 mm in nine of 79 revisions (11\%) using the Exeter and CPT (Zimmer, Warsaw, Indiana) stems, with eight requiring another revision. Masterson et al.\textsuperscript{12} reported significant subsidence of the component in the first six months after surgery in four of 34 revisions using impaction allografting and the Exeter prosthesis. The measured subsidence ranged from 11 to 34 mm and was associated with fracture and fragmentation of the cement mantle.

Other authors have used stems with a rough surface finish which can restrict subsidence. Recently, Leopold et al.\textsuperscript{4} reported the results of 29 patients revised with a collared, rough, straight stem (Harris Precoat; Zimmer, Warsaw, Indiana). After a mean follow-up of 63 months (48 to 82), four reconstructions failed (13.7\%) with three (10\%) requiring rerevision. No subsidence was detected in successful reconstructions. In our series using a third-generation Charnley stem and a matt surface finish with flanges to resist subsidence, none of the 52 successful revisions subsided more than 5 mm. Several factors prevent a reliable comparison between series. These include the surgical approach, the design of the stem and surface finish, indications for surgery, classification of bone loss, rating of the results, and the rehabilitation protocol.

Initial fears about graft healing after impaction grafting of the femur have been allayed by reports of bone remodelling and restoration of bone stock.\textsuperscript{17-20} Roffman, Silbermann and Mendes\textsuperscript{21,22} have investigated the fate of autogenous bone grafts under a layer of polymethylmetha-
crylate using an animal model. They demonstrated that the bone graft, even when covered with the cement, and despite exposure to exothermic polymerisation, still retained its viability and osteogenic potential.

We did not carry out an analysis of the cement mantle in our reconstructions and we were unable to find differences in the clinical and radiological results of patients operated on before and after the introduction of the Primary instrumentation. However, the use of specialist instrumentation allows the surgeon to achieve a reproducible cement mantle, which is essential for the survival of the revision. The predictability of the cement mantle produced by the Primary instrumentation has been validated when used with a Charnley-like modular prosthesis (Elite and Elite Plus, De Puy). In 50 reconstructions Masterson et al reported a cement mantle of >2 mm in 76.7% of the zones of Gruen, McNeice and Amstutz.

This procedure is technically demanding and can be associated with local complications. In a review of published series of impaction allografting, the incidence of infection ranged from 0% to 4% and neurological complications from 0% to 7%. Leopold et al reported a prevalence of major complications of 24% including four femoral fractures, two nerve palsies with an incomplete recovery, and a gluteal compartment syndrome after six hours of surgery. The incidence of wound complications in our series was 5%, although none resulted in failure of the procedure. The incidence of trochanteric nonunion of 17% observed in this study is of concern. van Biezen, ten Have and Verhaar reported a rate of trochanteric nonunion of 33% albeit for grade-3 and grade-4 defects.

Our dislocation rate was 5%. Rates reported by other authors range from 3% to 13% when using heads of larger diameter. Our rate may be related to the surgical approach. The most relevant complication associated with this revision technique is femoral fracture, reported in 5% to 22% of hips. This can occur during dislocation of the hip when the deficient femur is subjected to torsion, particularly when surgery is done through a posterolateral approach. Conversely, dislocation through a transtrochanteric approach in the dorsal decubitus position, used in our series, can be achieved by gentle traction and abduction, without torsion. We have not observed intraoperative femoral fractures during dislocation. Such fractures can occur during forceful impaction of an oversized plug, or during graft impaction, as we observed in one patient. Routine reinforcement wiring of the proximal femur can be undertaken before dislocation. In the presence of cortical deficiencies reinforcement with cortical allografts or metallic mesh should be considered. The extensive exposure of the femur necessary to implant a mesh may potentially jeopardise the periosteal vascular supply.

Fractures of the femur can occur late, often months or years after the reconstruction, especially when the stem leaves a distal deficiency unprotected (grade-4 defect) or when the graft fails to incorporate proximally. We did not observe late fractures in our series, although Berry et al reported four (7%) distal to the tip of the stem in a series of 55 patients. van Biezen et al had two late fractures (10%) in a series of 20 revisions with defects of Endo-Klinik grade-3 and grade-4.

Impaction grafting in patients with defects of Endo-Klinik grade-2, grade-3 and grade-4 can be safely carried out through a transtrochanteric approach in the dorsal decubitus position, but the high incidence of trochanteric nonunion is of concern. Although the clinical performance of the modern Charnley prosthesis has been recently questioned by Dall et al our experience of impaction grafting with a Charnley, flanged stem showed limited subsidence, restored bone stock, and long-lasting fixation of the stem in 93% of hips.

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