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ORIGINAL PAPER

Treatment of periprosthetic femoral fractures with modular stems

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Abstract
Purpose The purpose of this study was to analyse the efficacy of modular femoral stems for the treatment of certain post-operative periprosthetic fractures in patients with hip arthroplasty.
Methods Of a total series of 61 modular revision stems, 17 were used to address periprosthetic femoral fractures and 12 of these are the object of this study. The average follow-up was 3.7 years (range 1–14 years). The evaluations were performed at three and six months, and then annually using the HHS score and radiographic studies for the assessment of loosening, subsidence and bone integration of the stem.
Results Seven cases had type B2 fractures and five type B3 ones. All patients walked freely, eight of them using canes. HHS improved to a post-operative mean of 78 (range 72–83). Radiographically, fracture healing was observed at three months in nine cases. In six cases stem subsidence of a mean of 3.9 mm (range 2–12 mm) was observed, which stabilized a year following implantation and did not need revision surgery. In two cases a subsequent dislocation (at three and seven months after surgery) occurred, which were treated with constrained acetabular systems. In nine cases hypotrophy of the cortex in the diaphyseal area was noted, which did not alter the patients' clinical course.
Conclusion Modular femoral stems are an acceptable treatment in type B2 and B3 periprosthetic fractures.

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Keywords Total hip arthroplasty · Periprosthetic fracture · Modular stem

Introduction

The use of total hip arthroplasty (THA) has experienced a steady growth in recent years, which is expected to continue in coming decades [1]. This fact, together with the higher average age of patients undergoing the procedure, suggests that complications of this operation are likely to increase considerably. Periprosthetic femoral fractures (PFF) occurring after implantation of THA constitute the fifth most common cause of revision surgery after aseptic loosening, osteolysis, pain and dislocation [2].

The reported incidence of PFF varies according to the length of follow-up, patient demographics and the implants and techniques used. Currently, the prevalence of PFF has been estimated at 0.5–1 % for primary THA, and between 1.5 and 5.3 % for revision THA [2–5]. However, recent studies have shown that the annual rate of post-operative PFF has increased from 4.2 to 7 %. This higher incidence has been shown to affect above all elderly females, which is of grave concern as they tend to endure long hospital stays, ambulate without support for extended periods of time and, as a result, have a high mortality rate [6]. There are certain features of post-operative PFFs that make their prognosis worse than that of other fractures, increasing the morbidity of patients who sustain them. PFFs usually occur in bone that has undergone significant osteoporotic changes, which makes long-term prosthetic fixation a difficult endeavor. Mortality following surgery has been reported at 1.6 % at three months and 3.3 % at 12 months and a higher death rate is to be expected when the surgery is delayed more than five days after trauma [7]. Pre-PFF loosening has been reported at between 50 and

75 % of cases and low-energy falls lead to the fracture in 75 % of primary and 56 % of revision cases [2].

The advanced age of patients sustaining PFFs, the particular bone structure in which these fractures occur and the fact that these patients must be put back on their feet again as soon as possible make it necessary to resort to modular femoral stems as a definitive solution to some types of PFF. Revision of the femoral component is recommended for Vancouver type B2 and B3 fractures [8]. This strategy addresses both the loose component and the fracture and provides intramedullary stability by virtue of the long femoral stems typically used for revision. We report our experience with the utilization of a tapered fluted modular titanium femoral stem for the operative management of B2 and selected B3 PFFs.

Materials and methods

Over the last 14 years we have treated 86 PFFs of which 61 were addressed with a modular implant. Forty-eight of these were classified as Vancouver type B2 and B3 fractures and were treated with non-modular stems in 21 cases, modular stems in 17, tumour prostheses in six and conservatively in four cases. Our study focuses on the use of modular stems in these types of PFFs (17 cases).

Average follow-up was 3.7 years (range 1–14 years), and mean patient age was 67 years (range 51–92). Of the 17 PFFs, 11 occurred in women and six in men. In all cases, the fracture had been caused by a fall to the ground, and all fractures presented as isolated injuries. The initial indication for the implantation of the primary prosthesis was hip arthritis in 12 patients and fracture of the hip in five.

In 11 cases an uncemented acetabular component was used, and six cases required a cemented acetabular cup. The original stems were metaphyseal fixation stems in 12 cases and cemented stems in five. In no case did the PFF result in cup loosening. Femoral loosening was diagnosed by means of plain films and from the displacement of the stem in relation to the bone. It was eventually confirmed by surgery.

The mean interval between index prosthesis implantation and PFF was 143 months (range 1–218 months). Since 2010, our radiographic measurements have been performed using a computer-based PACS system. Our PACS system utilizes a 25-mm calibration ball to adjust for magnification. The system assists us in determining head centre, offset, best articulating surface, appropriate geometry and the length and diameter of the femoral component before surgery.

An extended transfemoral trochanteric approach was used in all cases, similar to that used for the extended osteotomy carried out during femoral revision surgery. The essential removal of muscle tissue was performed, one to two prophylactic distal cerclages were placed and the existing cement or cementless stem was extracted with careful manoeuvring. If it was deemed necessary to increase the femoral window an oscillating saw was used, followed by an osteotome. The modular distal stem was implanted ensuring that at least 7–10 cm diaphyseal fixation was obtained. The metaphyseal body thickness and length were in all cases decided preoperatively. Several cerclages were used to secure the bone fragments in the metaphyseal area. Cortical strut allograft was used in five cases. A constrained cup was used in four cases where intra-operative instability was observed (Fig. 1).

A Restoration Modular Revision Hip System (RMRHS) (Stryker Orthopaedics, Mahwah, NJ, USA) and a Dall-Miles Cable System were used in all cases. The modular stem was fluted, tapered and made from grit-blasted titanium. The system offers three distal segment lengths of varying diameters, four body segments and five head segments.

Patients began partial weight-bearing of the limb immediately after surgery. Weight-bearing progressed based on the patient's clinical symptoms and stability of the implant on follow-up radiographs. At six weeks patients were allowed full weight-bearing with or without the aid of canes. Patients were reviewed at three and six months after the surgery and then annually. A clinical questionnaire and the Harris Hip Score (HHS) were administered. The annual radiographs were performed to examine the degree of stem ingrowth as well as to assess for loosening and subsidence.

Results

Twelve cases were analysed retrospectively in March 2015. One case was lost to follow-up at two years. Another four patients died within one, three and four years from surgery. Of the 12 cases analysed, fractures were type B2 in seven cases and type B3 in five. All patients walked freely, eight of them using canes. The HHS score improved to a postoperative mean of 78 (range 72–83). Radiographic fracture healing was observed at three months in nine cases (Fig. 2) and at six months in the other three. In six cases stem subsidence was observed of 3.9 mm on average (range 2–12 mm). This occurrence stabilized one year after implantation and did not need revision surgery (Fig. 3). In one patient the system disassembled following a further fall in the immediate post-operative period. This was resolved with a new procedure to reduce the displacement of the fracture and place new cerclage wiring. In four patients, new fractures occurred during surgery. These were fixed with cerclage and did not alter the patients' evolution. In two cases, a subsequent dislocation occurred (at three and seven months after surgery), which was treated with a constrained acetabular system. In nine cases, hypotrophy of the diaphyseal cortex was observed, which did not alter the patient's clinical course.

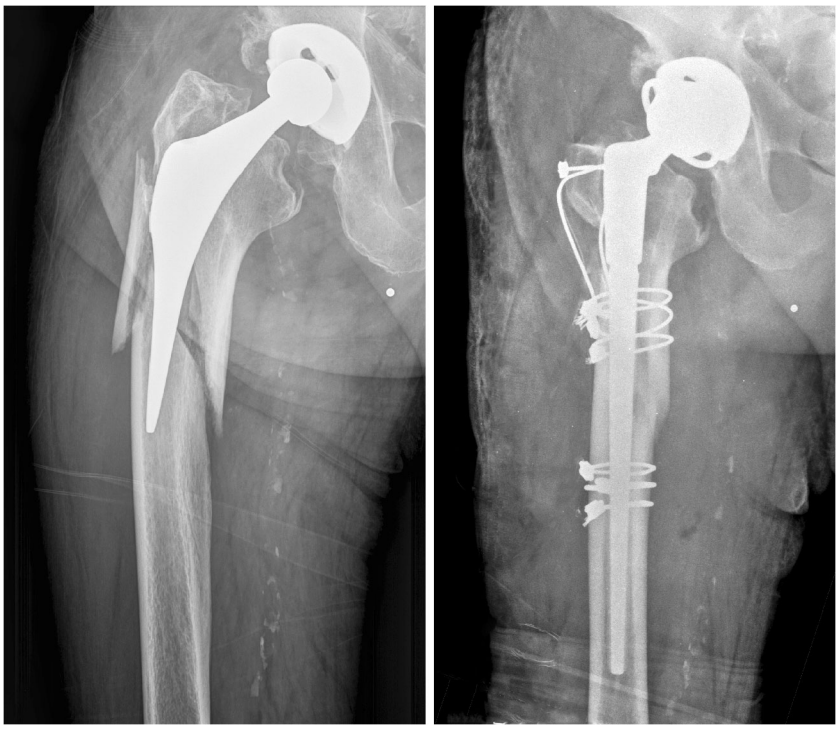

Fig. 1 PFF type B3. Radiograph two years after modular stem prosthesis and acetabular constriction system

Discussion

PFFs are associated with high failure rates and mortality, particularly within the first year post-op. Füchtmeier et al. [9] documented a total surgical revision rate of 16.5 % within the first year, and the one-year mortality rate was 13.2 % in a series of 121 consecutive patients with PFF. The type of initial hip fracture, older age, a higher ASA score and dementia were associated with a higher mortality rate. Reports from the Swedish National Hip Registry have identified a postoperative complication rate in PFFs in excess of 18 % [3].

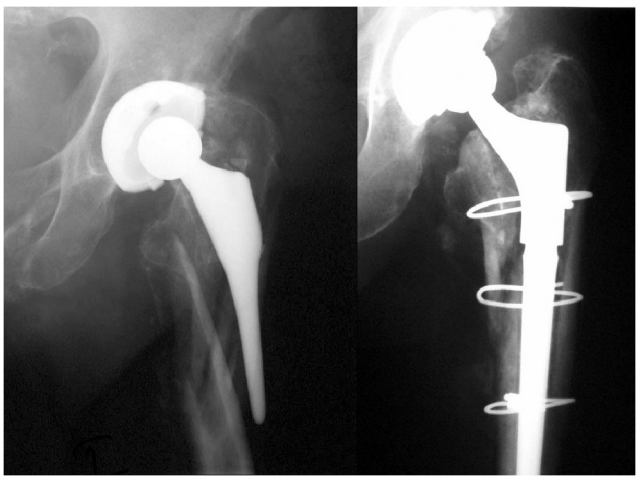

Fig. 2 Radiographic signs of consolidation of the periprosthetic femoral fractures (PFF) at three months after surgery

The high rates of major complications, re-operations, early mortality, and poor clinical outcomes entail substantial morbidity for patients with a PFF and consequently high healthcare costs.

The type of fixation of the original implant and the proximal bone stock quality are the factors that can most significantly alter the therapeutic regimen of PFF [10], and most classifications focus on these aspects. We have used the Vancouver classification [8], which remains valid despite having been published 20 years ago. Not only does it locate and classify the fracture but also focuses on the best possible treatment. Other classifications like the one recently published by Duncan and Haddad [11] may be useful to encompass and classify all fractures located in the vicinity of joint implants. Although PFFs associated with a loose stem require complex revision arthroplasty, fractures associated with a stable femoral stem (B1 and C) can be managed effectively with osteosynthesis [12, 13]. According to some series, B2 and B3-type fractures account for 65 % of all PFFs following primary surgery and 41 % of PFFs following revision surgery [3]. Use of a long modular stem to address type B2 (loose femoral component and adequate bone stock) and B3 (loose femoral component and inadequate bone stock) PFFs has gained support. The chosen implant needs to be stable and able to minimize the risk of further fracture, which means that stress risers should be bypassed by at least two femoral cortical diameters. In managing inherently unstable transverse fracture patterns it may be advantageous to use onlay cortical strut grafts to augment the intramedullary fixation achieved by the implant.

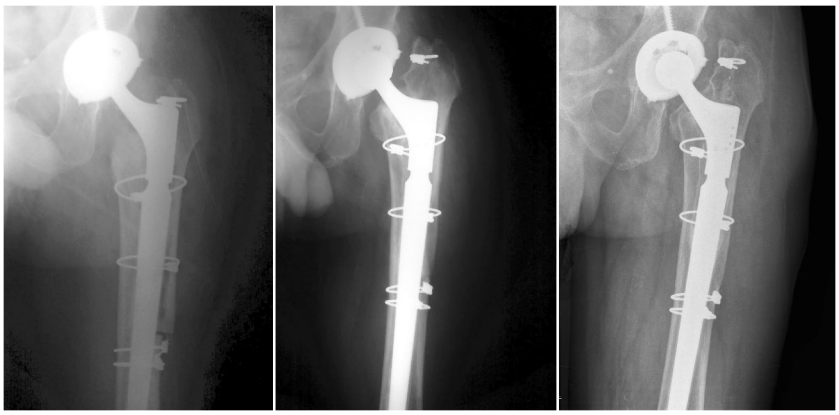

Fig. 3 Subsidence of the femoral stem at six months. Stabilization of the collapse at one year. Radiography at 11 years

In type B3 fractures, not only is the stem loose, but the quality of the remaining bone stock is compromised needing more advanced techniques to bypass or replace the deficient bone stock. It is important to recognize that the bone loss encountered at the time of surgery is likely to be much greater than that predicted from radiographs [5]. Revision options include secure distal fixation with complex reconstruction of the deficient proximal femur, segmental substitution of the proximal femur with a tumour prosthesis, an allograft-prosthesis composite, and a distally fixed prosthesis with scaffold reconstruction of the proximal femur around the modular device [2]. The use of ancillary bone grafting with either autograft or allogenic bone is recommended to facilitate bony ingrowth in all of these fractures. Although in our series allografts were used in five cases to increase the consistency and stability of the fracture, we believe that the need for allograft use is questionable given the good evolution we observed in cases where that option was not used.

Loosening will be adequately addressed by revision surgery at the time of definitive treatment to reduce the risk of subsequent revision in type B1 and B2 fractures. In some series [14], 25 % of PFFs needed a further operation after failure of their initial management. Fractures classified as type B1 had a significantly higher risk of failure, and the strongest negative factor was the use of a single fixation plate. It is likely that many fractures classified as type B1 were actually unrecognized B2 fractures with a loose stem. The difficulty in separating type B1 from type B2 fractures [15] suggests that the prosthesis should be regarded as loose until proven otherwise. It is recommended that if there is any doubt about the status of the implant, it should be deemed to be loose and treated as such.

Modular stems offer an acceptable alternative to revision surgery in the presence of large bone defects, reaching 93 % survival at seven years [16]. According to published series on their indications, between 5 and 17 % of such stems have been implanted to address a PFF [16–18]. In the series of Munro et al. [19] survivorship at a mean of 54 months was 96 %. The study showed maintenance or improvement of bone stock in 89 % of cases with high rates of femoral union. The rate of new revision surgery in cases of PFF is between 1.4 and 5 % and that of intra-operative fractures stands between 1 and 18.6 % [19]. In our series we only observed one case of disassembly of the system by a further fall one month after placement of the stem. This required reconstruction of the fracture with new cerclage wires without modifying the distal part. We also had two dislocations, which required a re-operation for implantation of an acetabular constraint system. At one year all patients were walking without pain using canes and neither their clinical situation nor their radiographic evolution had changed over the years (Fig. 4). In four cases intra-operative fractures occurred, which were reduced and secured with cerclages. As said earlier, such fractures did not in any way alter the patients' subsequent development.

Although being a valuable option in PFF and revision THA, modular stems are not free of complications. One repeatedly reported complication in the literature is subsidence. Meta-analyses of different series report that it ranges from 0 to 52 mm [20]. In our series, some degree of subsidence was appreciated in six of 12 stems, although the mean did not exceed 4 mm. In one case there was a subsidence of 12 mm which stabilized at one year; the patient remains asymptomatic and uses a special shoe to correct limb length discrepancy. Commonly, and in line with other series, subsidence always appeared in the first six months and went on to stabilize later on. Not once did it result in a re-operation but rather, as indicated by other authors, it always remained a radiographic finding [17, 21]. By contrast, in some series [18, 22], subsidence was so significant that it resulted in a rate of almost 10 % revision surgery. Reported causes of this complication include patient weight higher than 80 kg and femoral stem press-fit distance of less than 2 cm. Also, stems tended to be radiographically undersized, which emphasizes the importance of the learning curve. There are other potential disadvantages associated with modular hip systems, including modular junction fretting and fracture at or near the trunnion. Such complications did not occur in our series, probably due to a relatively short follow-up period. We had no cases of

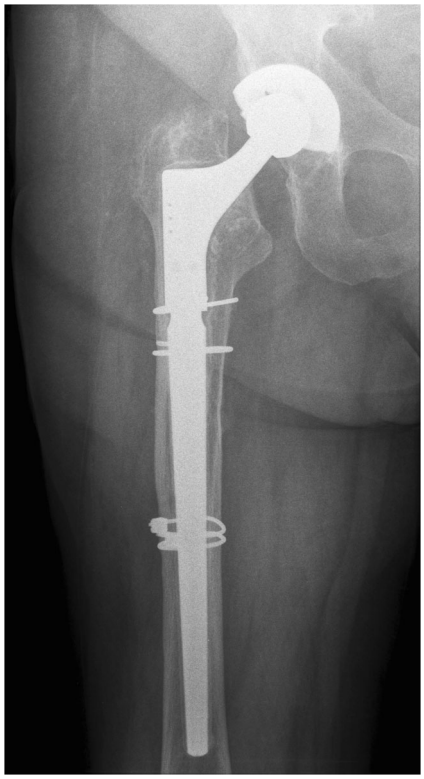

Fig. 4 Modular stem in periprosthetic femoral fractures (PFF). Radiography 14 years after surgery

refracture or femoral revision surgery in the cases where the modular prosthetic model was used.

Other authors have already reported on their results following the use of RMRHS [17, 23, 24]. According to these authors, in cases of significant proximal femoral bone deficiency, this stem demonstrated improvement in clinical outcomes with good results at short-term follow-up. A prospective study that included 118 patients [17] at a minimum follow-up of two years showed improvement in the average values of all functional outcome evaluations (distal bone ingrowth, fixation and stability) at the latest follow-up.

Our work has some limitations. It is a retrospective study and the evidence level is low, the number of cases in this heterogeneous population is small, and the results are based on medium-term observations. Another limitation is that we only looked at one implant system. Our study lacked a comparison group, which means that we cannot comment on the success of the RMRHS as compared to other systems.

When implanting a non-modular stem, the surgeon must be cognizant of the distal fit while at the same time optimising implant position to restore leg length and version [25]. Moreover, larger diameter extensively coated stems in cases of significant bone loss have been shown to be associated with high failure rates. One further disadvantage of this stem is that it does not restore bone stock, which can pose a problem in younger patients who may need further revisions during their lifetime. The first priority of the treatment of PFF is to secure adequate initial fixation of the femoral component, which hopefully then translates into secure long-term fixation. Modular stems add up to the modularity, flexibility, rapid consolidation, regeneration of metaphyseal bone and allow early weight-bearing. These properties meet the objectives of the treatment of B2 and B3-type PFF.

Conflict of interest The authors declare that they have no conflict of interest.

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