Revision total hip arthroplasty in patients with extensive proximal femoral bone loss using a fluted tapered modular femoral component

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Revision total hip arthroplasty (THA) is challenging when there is severe loss of bone in the proximal femur. The purpose of this study was to evaluate the clinical and radiographic outcomes of revision THA in patients with severe proximal femoral bone loss treated with a fluted, tapered, modular femoral component. Between January 1998 and December 2004, 92 revision THAs were performed in 92 patients using a single fluted, tapered, modular femoral stem design. Pre-operative diagnoses included aseptic loosening, infection and peri-prosthetic fracture. Bone loss was categorised pre-operatively as Paprosky types III-IV, or Vancouver B3 in patients with a peri-prosthetic fracture. The mean clinical follow-up was 6.4 years (2 to 12). A total of 47 patients had peri-operative complications, 27 of whom required further surgery. However, most of these further operations involved retention of a well-fixed femoral stem, and 88/92 femoral components (97%) remained in situ. Of the four components requiring revision, three were revised for infection and were well fixed at the time of revision; only one (1%) was revised for aseptic loosening. The most common complications were post-operative instability (17 hips, 19%) and intra-operative femoral fracture during insertion of the stem (11 hips, 12%). Diaphyseal stress shielding was noted in 20 hips (22%). There were no fractures of the femoral component. At the final follow-up 78% of patients had minimal or no pain.

Revision THA in patients with extensive proximal femoral bone loss using the Link MP fluted, tapered, modular stem led to a high rate of osseointegration of the stem at mid-term follow-up.

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The number of revision total hip arthroplasties (THAs) performed in the United States is increasing, and is projected to grow further over coming decades.1,2 The achievement of durable femoral fixation is challenging in revision surgery, particularly in the presence of bone loss, femoral deformity or peri-prosthetic fracture. In patients with substantial bone loss, several strategies have been used, including long cemented stems, impaction bone grafting and various types of uncemented component, including extensively coated and distally locked stems.3-18 However, none of these strategies have completely eliminated problems with fixation in patients with severe loss of proximal femoral bone stock. Fluted, tapered femoral stems engage the diaphyseal cortex, creating axial and rotational stability,19,22 and were designed to achieve immediate stability even in the presence of extensive metaphyseal bone loss.

Various investigators have reported the results of femoral revision using fluted, tapered, modular stems, with good results at short- to mid-term follow-up.23-26 However, less is known about the outcomes of these devices at longer follow-up times, and when used for patients with severe proximal bone deficiency. The purpose of this study was to report the clinical and radiographic results of revision THA using the Link MP (Link Orthopaedics, Pine Brook, New Jersey) fluted, tapered, modular femoral stem in a large cohort of patients with marked proximal femoral bone loss, from a single centre.

Materials and Methods

The inclusion criteria for this retrospective study were all patients with severe pre-operative bone loss undergoing revision THA using the Link MP fluted, tapered modular femoral stem. Patients with a pathological fracture secondary to malignancy, and those with < two years of follow-up, were excluded. Between January 1998 and December 2004, a total of 2816 revision THAs were performed. From this group, a series of 126 consecutive, non-oncological uncemented revision THAs
were identified where the Link MP stem had been used. Of these, 13 had < two years of follow-up and were excluded.

The degree of pre-operative bone loss was categorised by the authors (DJB, DFA, JLH, TMM) according to the Vancouver classification in those with peri-prosthetic fracture and the Paprosky classification in all others. An additional 21 stems in 20 patients were also excluded (13 Paprosky Type II, 7 Vancouver B2 fractures, and 1 Vancouver C fracture) in order to focus exclusively on those hips with severe loss of bone. The remaining 92 revision THAs (92 patients) formed the study group.

The prosthesis consists of a fluted titanium tapered distal stem with a 70 μm microporous surface that promotes osseointegration through bone ongrowth. It is available in lengths of 160 mm, 180 mm, 210 mm, 290 mm and 330 mm, and in 2 mm increments from 12 mm to 25 mm. The titanium modular proximal neck segment has a round cross-section of fixed diameter (20 mm) and the same porous surface as the distal stem. Femoral length, version and offset may be adjusted independently by using different femoral neck segments following implantation of the distal stem. The proximal segment attaches to the distal stem by interlocking teeth, and is secured with an expansion bolt.

Clinical data for all patients were recorded prospectively in our institutional total joint registry until death or failure of the implant. The age, height, weight, body mass index, number of previous hip procedures and operating time were recorded for each patient at the time of revision surgery (Table I). All patients underwent routine clinical and radiographic evaluation at one, two and five years following revision THA, and every five years thereafter.

The mean clinical follow-up time was 6.4 years (2 to 12) and the mean radiographic follow-up was 5.8 years (2 to 13.5). The most common indication for revision THA was aseptic loosening, followed by infection and peri-prosthetic fracture (Table I). A femoral head of > 28 mm was used in most patients; larger femoral heads (≥ 32 mm) only became available later in the study period (Table II). All patients undergoing revision for infection had a two-stage procedure, with the definitive stem being implanted at the second stage.

The pre-operative, immediate post-operative and most recent radiographs were reviewed (DJB, DFA, JLH, TMM) and the degree of osseointegration of the distal femoral stem, and any evidence of loosening, osteolysis, subsidence, stress shielding and implant failure were recorded. Stems were considered stable and osseo-integrated if there was no circumferential lucency at the distal fixation, and if there was no migration of the stem beyond one year following implantation. The immediate post-operative and most recent radiographs were further reviewed for potential osseointegration and the restoration of the proximal bone stock.

The operative and clinical notes were reviewed to provide the clinical findings. The Harris hip score (HHS) at the most recent follow-up was available for 88/92 patients (96%).

Complications were also recorded. Re-operation was defined as surgical intervention for any reason. Implant failure was defined as revision of any component of the THA for any reason. This group was subcategorised into three groups: those where the distal femoral stem was removed for infection; those where it was removed for aseptic reasons; and those where it was retained during the revision procedure.

Statistical analysis. Continuous variables are reported as means and standard deviations (SD). Categorical variables are reported as absolute values and percentages.

Results

Complications, revisions and re-operations. At the latest follow-up 18 hips had been revised. In 14, the distal femoral stem was retained, therefore 88 stems (97%) remained in situ (Fig. 1). Of the four hips requiring revision with removal of the distal femoral stem, three were well-fixed and were removed for infection, and one was removed for early aseptic loosening with subsidence and lack of osseointegration (Fig. 2). Of the 14 revisions with retention of the stem, 11 were for instability, of which eight were treated with exchange of the femoral head and liner and three were treated with revision of the proximal body of the femoral component. The remaining three were revised for failure of the acetabular component and did not involve the femoral component other than exchange of the femoral head. There were no fractures of the femoral component.

Including the revisions outlined above, there were 56 complications in 47 patients requiring 27 further operations (29%). There were 11 intra-operative fractures during insertion of the stem (12%): six were treated with

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Table I. Mean characteristics of the patients (sd)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Mean (SD)</th>
</tr>
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<tbody>
<tr>
<td>Age (yrs)</td>
<td>68.6 (10.8)</td>
</tr>
<tr>
<td>Gender (n) (male:female)</td>
<td>51:41</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>170 (9)</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>83 (21)</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>28 (6)</td>
</tr>
<tr>
<td>Previous hip surgery (n)</td>
<td>291 (3.2 per patient)</td>
</tr>
<tr>
<td>Operating time (mins)</td>
<td>286 (86)</td>
</tr>
</tbody>
</table>

BMI, body mass index; SD, standard deviation

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Table II. Pre-operative loss of bone

<table>
<thead>
<tr>
<th>Paprosky classification</th>
<th>n (%)</th>
</tr>
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<tbody>
<tr>
<td>IIIA</td>
<td>43 (47)</td>
</tr>
<tr>
<td>IIIB</td>
<td>28 (30)</td>
</tr>
<tr>
<td>IV</td>
<td>15 (16)</td>
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<table>
<thead>
<tr>
<th>Vancouver classification</th>
<th>B3</th>
</tr>
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<tbody>
<tr>
<td>n (%)</td>
<td>6 (7)</td>
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</table>
cerclage wires, four with cerclage wires and strut allograft, and one (a fracture of an extended trochanteric osteotomy) did not require formal reconstruction. Prophylactic femoral cerclage wiring had not been used in any of the ten patients who had an intra-operative diaphyseal fracture of the femur. There were seven post-operative peri-prosthetic fractures (8%): four of the greater trochanter, one of the calcar, one of the lesser trochanter, and one Vancouver C fracture of the femur. The Vancouver C fracture and three fractures of the greater trochanter were treated with open reduction and internal fixation; the remainder were treated non-operatively.

In all, 17 hips (19%) had at least one post-operative dislocation. Further surgery was required in 12 of these hips: open reduction in one, revision of the head or liner in eight (three of which required a constrained liner), and revision of the proximal body of the femoral component in three (as detailed in the previous section). In all cases of further surgery for instability, the well-fixed distal femoral stem was retained. Deep infection was diagnosed in six hips (7%): three required removal of all components, and three were treated with irrigation and debridement with retention of the stem. The risk of infection based on the pre-operative diagnosis was as follows: aseptic loosening (0 of 67 hips), two-stage exchange for infection (four of 19 hips, 21%) and peri-prosthetic fracture (two of six hips, 33%). There were 11 other post-operative complications: three failures of the acetabular component (3%), one psoas tendon impingement requiring surgical release (0.9%), two patients with significant heterotopic ossification (2%), two deep venous thromboses (2%), one sciatic nerve palsy (1%), one chronic common peroneal nerve irritation (1%) and one stroke (1%).

**Radiographic follow-up.** All the retained distal femoral stems had radiographic evidence of osseointegration. As three of the four femoral revisions were of well-fixed stems, 91 of 92 stems (99%) had radiographic evidence of osseointegration (Fig. 1).

In 84 of the 88 patients (95%) in whom the distal stem had not been revised, the proximal body of the femoral component was in contact with the host bone on the immediate post-operative radiographs. There were continuous radiolucencies in 35/84 hips (42%), indicating at least partial osseointegration of the proximal body in the remaining 49 (58%). There was evidence of at least partial restoration of proximal bone stock in 42 hips (50%).

Mid-zone stress shielding was seen in 26 (30%) of the retained distal femoral stems (Fig. 3) and distal stress shielding was seen in 20 (23%) (Fig. 4). Although stress-shielding was common, clinically relevant subsidence or aseptic loosening was rare. Within the first year, six stems had > 5 mm of subsidence (7%). Of these, three achieved stability after < 7 mm of subsidence and did not require further surgery. Two well-fixed distal femoral stems required exchange of the proximal body or femoral head to restore stability following subsidence. Isolated revision of the proximal body segment of the femoral component was straightforward and there were no complications associated with such revisions. One distal femoral stem subsided by > 1 cm; this was the only hip with aseptic loosening requiring revision of the distal femoral stem (Fig. 2).

**Clinical follow-up.** The mean HHS, which was available for 88 patients, at final follow-up was 69 points (SD 20). There were 26 with good or excellent HHSs (30%), 24 with fair (27%), and 38 with poor scores (43%). The mean score on the pain subscale was 33 out of a possible 44 points, with 69 patients (78%) reporting minimal or no pain. The specific location of pain (e.g. thigh, trochanter, groin) was not recorded as part of this study.

**Discussion**

Revision THA in patients with severe proximal femoral bone loss represents a complex reconstructive challenge. Although extensively porous-coated femoral components are reported to have > 95% survival with > 10 years’ follow-up after revision THA, the rate of failure is higher in the presence of proximal bone deficiency. In patients with type IIIB or type IV femoral bone loss. Fluted, tapered modular femoral components have the potential to achieve long-term biological fixation, even in the presence of extensive bone loss. All the patients in our
study had severe proximal bone loss according to the Paprosky or Vancouver classification systems.\textsuperscript{27,28} Despite this high degree of bone loss, the Link MP fluted, tapered modular stem performed well up to 12 years following surgery. Only one patient required revision for aseptic loosening (1%), and all retained stems had radiographic evidence of osseointegration.

This series supports the favourable findings of other series of stems with similar design principles. A series of 129 revisions using the Wagner self-locking stem (Wagner SL, Sulzer Medica, Baar, Switzerland), a monoblock tapered fluted stem, reported only six patients (5%) requiring further revision after a mean of four years.\textsuperscript{21} Other fluted, tapered monoblock stem designs have demonstrated favourable short- and mid-term results, with 92% survival having been reported at a mean follow-up of ten years.\textsuperscript{21,36,37} Fluted tapered modular designs offer several potential advantages over monoblock designs.\textsuperscript{38} The fluted
tapered distal segment is secured in the femoral diaphysis, creating axial and rotational stability. Modular designs allow the surgeon to implant the distal segment independently of the proximal body, allowing leg-length, offset and version to be optimised by the choice of proximal body once diaphyseal fixation has been achieved. The results of modular femoral stem designs are similar to those of monoblock designs, with 87% to 97% survival at a mean follow-up of > three years.25,26 Longer-term follow-up will be required to determine whether modular or monoblock designs confer improved survival, as failure at the modular junction is a well-described complication.39 Furthermore, the results of this stem will need to be compared with those of other modular stems, some of which allow greater variation in proximal geometry potentially providing better engagement with any remaining proximal bone.

In this study 79% of patients reported minimal or no pain. Thigh pain is a well-described finding following uncemented femoral revision.4,30 However, as the location of pain was not collected as part of this study, we are unable to describe the prevalence of thigh pain in this group. Despite reasonable levels of pain relief, the mean HHS was only 69 points, with 43% of patients having an HHS classified as poor. We believe the poor functional outcomes reported in this series relate to the severe proximal bone loss, compromising many of the muscular attachments of the hip, and the fact that many had undergone several previous procedures on the operated hip, resulting in severe baseline functional limitation.

Radiographic subsidence is a concern with fluted, tapered monoblock femoral stem designs. Böhm and Bischof21 reported a mean of 5.9 mm of subsidence using the Wagner SL revision stem, with 20% of the stems having > 10 mm of subsidence. Isacson et al19 reported five of 43 stems (12%) having > 20 mm subsidence. Radiographic subsidence of tapered femoral stems may in part be related to undersizing and would be expected to improve with the surgical learning curve.38 In some cases monoblock designs led the surgeon to seat the implant based on leg length rather than axial stability, and the ability to control leg length and axial stability independently of one another may explain the lower rate of subsidence reported in this series.38 However, despite this advantage, in other series of modular stems, between 2 mm and 9 mm of mean subsidence have been reported.25,26 In our series only six stems (7% of the total) had > 5 mm of radiographic subsidence.

In spite of the modularity of this system, instability was the most common complication in this series, accounting for 19% of all cases. We believe this high rate to be related to the inclusion specifically of patients with severe proximal femoral bone loss, which compromises the attachments of the abductor musculature to the greater trochanter, and the fact that about half of the cases were performed before large-diameter femoral heads were routinely available for revision THA at our institution.

Although there was only a modest degree of proximal osseointegration and restoration of proximal bone stock, the fluted, tapered modular femoral stem used in this study showed a high rate of diaphyseal osseointegration, with 96% of stems remaining in situ at the latest follow-up. The successful distal osseointegration of this stem design is the critical feature when managing patients with severe proximal bone deficiency. The most common post-operative complication was instability, but this was addressed with retention of the femoral stem in all cases.

Fluted, tapered modular femoral stems represent a reasonable and reliable option for revision THA when proximal femoral bone stock is compromised.


