CLINICAL ORTHOPAEDICS AND RELATED RESEARCH
Number 417, pp. 203–209

Revision Total Hip Arthroplasty

The Limits of Fully Coated Stems

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Femoral revision with a 7-inch or 8-inch fully porous-coated stem may not provide reliable long-term results in patients with moderate bone loss. The purpose of this study was to evaluate the limits of fully porous-coated stems and to create a treatment algorithm for femoral deficiencies. Fifty-one patients with either a 10-inch or 9-inch calcar fully porous-coated stem, 10 patients with impaction bone grafting, and 10 patients with a modular tapered stem were evaluated at an average 4.2 years postoperatively. The mechanical failure rate among the 9-inch and 10-inch fully porous-coated stems was 0% in Type III B defects with femoral canals less than 19 mm (15 patients), 18% in Type IIIB defects with femoral canals greater than 19 mm (2 of 11 patients) and 37.5% in Type IV defects (three of eight patients). There were no mechanical failures observed among the bone packing or modular tapered stems. Patients with Type IIIB defects and a femoral canal less than 19 mm can be treated successfully with either a 10-inch or 9-inch calcar fully porous-coated stem. However, patients with a Type IIIB defect and an endosteal canal greater than 19 mm or a Type IV defect require alternative methods of reconstruction such as a modular tapered stem or a bone packing procedure.

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DOI: 10.1097/01.blo.0000096803.78689.0c

Total hip arthroplasty remains one of the most successful and reliable surgical procedures to relieve pain and improve function. Despite the overwhelming success of this operation, there are instances such as aseptic loosening, septic loosening, recurrent dislocation, and periprosthetic fracture where a femoral revision is required.

The choice of implant used during the femoral reconstruction will be based largely on the amount of femoral bone loss encountered at the time of revision surgery. The senior author previously described a femoral classification system that can assist the surgeon with preoperative planning and predict the extent of bone loss.[18] Many surgeons currently rely on a fully porous-coated cementless stem in the revision situation to obtain diaphyseal fixation because of the poor long-term results of cemented revision stems. [22,23] The 10- to 15-year results of femoral revision using 8-inch fully porous-coated femoral stems in patients with mild to moderate bone loss are excellent. However, the rate of mechanical failure dramatically increases when these implants were used in patients with more significant femoral defects. [26] Because of the high rate of loosening, the senior author began to use longer fully porous-coated implants or alternative techniques such as impaction bone grafting or modular tapered stems in patients with Paprosky Type III and Type IV defects.

The purpose of this study was to evaluate the results of 9-inch calcar and 10-inch fully porous-coated stems, impaction bone grafting, and modular tapered stems used during revision femoral surgery for Paprosky Type III and Type IV

femoral defects. An additional purpose of this study was to create a treatment algorithm that could be used to assist the surgeon during preoperative planning of femoral revisions.

MATERIALS AND METHODS

After obtaining approval from the institutional review board, a retrospective clinical and radiographic review was done on all patients who had a femoral revision using either a 10-inch or 9-inch calcar fully porous-coated stem, a modular Wagner-type prosthesis or impaction bone grafting between 1991 and 2001, at Central Dupage Hospital (Winfield, IL). Patients were identified through an operating room database retrieval system using standard current procedural terminology codes for revision total hip anthroplasty (THA).

A 9-inch calcar or a 10-inch Solution fully porous-coated femoral component (DePuy Johnson and Johnson, Warsaw, IN) was used in the patients who received extensively porous-coated components. A smooth Osteonics Restoration stem (Stryker Howmedica Osteonics, Mahwah, NJ) was used in all bone-packing procedures whereas either a Link (Link Orthopaedics, Pine Brook, NJ) or ZMR (Zimmer, Warsaw, In) prosthesis was used in the patients who received modular Wagner components. The modular tapered stems consisted of a corundumized, splined stem that provided axial stability through the tapered wedge design and rotational stability through the longitudinal splines. The corundumized surface promoted biologic fixation through bone ongrowth. A posterior approach with an extended trochanteric osteotomy was used in most patients. All extensively porous-coated stems were reamed line-to-line or overreamed by 0.5 mm to accept the femoral bow. Impaction grafting was done with a technique similar to that described by Gie et al.[11,12] Postoperatively, all patients' hips were placed in an abduction brace and the patients followed precautions with touch weightbearing for 6 weeks before being advanced to weightbearing as tolerated. The senior author initially used a fully porous-coated implant for all patients with severe bone loss (Type IIIB or Type IV). However, because of the concerns of early failure with this type of implant, he began to use either a bone packing procedure or a modular tapered stem in patients with similar femoral deficiencies.

Yearly radiographic review consisted of standard AP radiographs of the pelvis, AP radiographs of the femur, and Lowenstein lateral radiographs. Radiographs taken preoperatively, immediate postoperatively, and at the most recent followup were reviewed and consensually agreed by both of us. The AP radiographs taken preoperatively were graded according to the femoral defect classification of Krishnamurthy et al[18] (Table 1). The determination between Type IIIA, Type IIIB, and Type IV femurs was based on the amount of remaining isthmic bone available during the reconstruction. It was assumed that any remaining isthmic bone would provide endosteal contact with the prosthesis and allow a scratch-fit. Type IIIA defects had greater than 4 cm of remaining isthmic bone, Type IIIB defects had less that 4 cm of remaining isthmic bone, and Type IV defects had no isthmus and paper thin cortices. Subsidence was defined as distal migration of the femoral component

TABLE 1. Paprosky Classification of Femoral Defects

Type Of Defect	Description of Femur
I	Minimal defects, similar to primary total hip arthroplasty
II	Metaphyseal damage, minimal diaphyseal damage
IIIA	Metadiaphyseal bone loss, 4 cm scratch-fit can be obtained at isthmus
IIIB	Metadiaphyseal bone loss, 4 cm scratch-fit unable to be obtained
IV	Extensive metadiaphyseal damage, thin cortices, widened canals

greater than 5 mm and was defined as the difference in distance between the center of the femoral head and the lesser trochanter on radiographs taken immediately postoperative and radiographs taken at the final followup. Bone ingrowth was classified according to the criteria of Engh et al.[10]

RESULTS

Seventy-one patients had a femoral revision for a Type III or Type IV femoral defect between 1991 and 2001 using either a long stem cementless femoral component, a modular Wagner component, or a bone packing procedure. The average followup for the entire cohort of patients who had revision surgery was 4.2 years (range, 2–11 years) whereas the average followup for the patients with 9-inch or 10-inch stems was 6.0 years, the average followup for the patients with Wagner-type stems was 1.6 years, and the averrage followup for the patients with bone packing procedures was 3.1 years. Seven patients required femoral rerevision and three additional patients required placement of a constrained liner for recurrent dislocation. Among the patients requiring femoral rerevision, there were five patients with a fully-coated stem (three for infection, two for aseptic loosening), and two patients with a modular Wagner stem (two for septic loosening).

Seventeen patients with Paprosky Type IIIA, 26 patients with Type IIIB, and eight patients with Type IV femoral defects were treated with either a 10-inch or 9-inch calcar fully porous-coated stem. The surgical indication was aseptic loosening for 39 patients, fracture for nine patients, and second stage reimplantation for infection in three patients. One patient with a Type IIIB defect and one patient with a Type IV defect required femoral revision for aseptic loosening. Forty-four of the 51 cementless femoral components had radiographic evidence of bone ingrowth whereas four hips were stable fibrous and three hips were unstable fibrous radiographcally Component subsidence was seen radiographically in seven of 51 patients. All but three patients with initial stem subsidence now seem to have well-fixed components. The endosteal canal was greater than 19 mm in all patients who had revision surgery for aseptic loosening or patients who had radiographic evidence of loosening.

Ten patients with Type IV femoral defects were treated with impaction bone grafting, whereas seven patients with Type IIIB femoral defects and three patients with Type IV femoral defects were treated with a modular Wagner type tapered stem (Table 2). The surgical indication was aseptic loosening for all patients who received either a modular Wagner components or a bone-packing procedure with the exception of one patient who received a modular Wagner component and two patients who received a bone packing procedure for second-stage reimplantation after a deep infection. The average canal diameter of patients treated with a modular Wagner-type prosthesis was 23 mm (range, 18–26 mm) and there only was one patient who received a tapered stem with a canal less than 20 mm. No components were revised for loosening and none of the components showed subsidence.

The rate of mechanical failure of 9-inch and 10-inch fully porous-coated stems, defined as revision for aseptic loosening or radiographic evidence of unstable fibrous fixation, was 0% in patients with Type III B defects and femoral canals less than 19 mm (15 patients), 18% in patients with Type IIIB defects and femoral canals greater than 19 mm (two of 11 patients), and 37.5% in patients with Type IV defects (three of eight patients). Among patients treated with a modular tapered stem or a bone packing procedure, there have been no mechanical failures to date.

DISCUSSION

Total hip arthroplasty remains an effective procedure to relieve pain and improve function in patients with arthritic conditions affecting the hip. Despite the excellent long-term survival of current generation implants, revision hip arthroplasty continues to constitute 17% of hip procedures done on patients who receive Medicare.[5] Although the incidence of revision arthroplasty

TABLE 2. Component Survival

Component	Average Followup (*years*)	Femoral Defect	Number	Number Hip Revisions (*all causes*)	Number Femoral Revisions (*all causes*)	Number Femoral Revisions (*loosening*)	Number Femoral Loosening on Radiographs
Cementless	6.0	IIIA	17	0	0	0	0
		IIIB-all	26	4	3	1	1
		<19 mm	15	1	0	0	0
		>19 mm	11	3	3	1	1
		IV	8	2	2	1	2
Modular Wagner	1.6	IIIB	7	2	2	0	0
		IV	3	0	0	0	0
Bone Packing	3.1	IV	10	2	0	0	0

does not seem to be increasing, the total number of revision surgeries is escalating because of broadened surgical indications, earlier implant insertion, and prolonged patient survival.

Successful femoral reconstruction requires insertion of a component that will be axially and rotationally stable to physiologic stresses and will show stability throughout a functional range of motion. The femoral defect classification of Paprosky places the remaining femoral bone stock into one of four types. Type I defects have minimal damage to the proximal metaphysis and can be reconstructed using either a cemented or cementless stem. Type II defects have metadiaphyseal bone damage with an intact diaphysis. Type III defects have significant metadiaphyseal damage with Type IIIA allowing greater than 4 cm and Type IIIB allowing less than 4 cm of scratch-fit at the isthmus. Type IV defects are characterized by extensive metadiaphyseal damage with thin cortices and a widened femoral canal.[18]

Long-term followup studies of femoral revision have shown poor clinical results with cemented components.[22,23] The high rate of mechanical failure is hypothesized to be caused by the decrease in shear strength at the bone-cement interface.[6] As a result, many surgeons now will use an extensively porous-coated implant during routine femoral revision.[21] The senior author has reported his average 14-year results of revision femoral surgery with the use of either a 7-inch calcar or 8-inch fully porous-coated stem. The results from this study showed that reliable femoral fixation could be expected in more than 95% of patients.[26] Patients with Type II or Type IIIA defects had a mechanical failure rate of 5% compared with 21% of patients with Type IIIB defects. These poor results in patients with extensive bone loss prompted the senior author to evaluate the limits of fully porous-coated stems. The current study reviews the mechanical failure rate of his 9-inch calcar and 10-inch fully porous-coated stems in patients with Type III and Type IV femoral defects and compares them with a similar cohort of patients in whom impaction bone grafting or a modular tapered stem was used as an alternative technique for reconstruction.

In the current study, 71 patients with Type III or Type IV defects had revision femoral surgery with either a bone packing procedure, a modular Wagner type stem, or a cementless 9-inch calcar or 10-inch fully porous-coated stem. The mechanical failure rate among the 9-inch and 10-inch fully porous-coated stems was 0% in Type III B defects with femoral canals less than 19 mm (15 patients), 18% in Type IIIB defects with femoral canals greater than 19 mm (2 of 11 patients), and 37.5% in Type IV defects (three of eight patients). There were no mechanical failures observed among the bone packing or modular tapered stems. All of the patients with loose fully porous-coated stems were clinically symptomatic at the most recent followup. The one

patient with a Type IIIB defect who required femoral revision for aseptic loosening had a 21-mm, 10-inch stem and the one patient with a Type IIIB defect and radiographic loosening had a 19.5-mm, 10-inch stem. Similarly, the diameter of all the loose or revised stems in the patients with Type IV femurs was greater than 19 mm. We think that the high rate of mechanical failure using a fully porous-coated stem is unacceptable in these later two groups of patients. As a result, the senior author has begun to use alternative techniques such as modular tapered stems and impaction bone grafting for femoral reconstruction in Type IV and Type IIIB femurs with canals greater than 19 mm.

Reliable fixation of a cementless stem requires axial and rotational stability. Additionally, the prosthesis must be in intimate contact with the host bone to minimize micromotion and promote bone ingrowth. We think that the poor results observed in our cohort of patients using a long cementless porous-coated stem in Type IIIB femurs greater than 19 mm and in all Type IV femurs was attributed to the inability to obtain initial stability and eliminate micromotion. To use a 9-inch or 10-inch bowed stem, the femoral canal must be reamed line-to-line or slightly greater to accommodate the stem and minimize the risk of fracture during insertion. This is in contrast to a 7-inch or 8-inch stem in which the distal canal is underreamed by 0.5 mm. We think that this relative overreaming ultimately will affect the component stability and may result in a greater rate of loosening.

The high rate of mechanical failure among patients with fully porous-coated stems placed in Type IIIB femurs with an endosteal canal greater than 19 mm or in Type IV femurs has prompted the senior author to use alternative methods of reconstruction in this select group of patients. In our series, none of the patients who were treated with a modular tapered stem required femoral revision because of mechanical loosening. However, two patients had revision surgery secondary to deep sepsis. One of these patients initially was treated with a 22-mm ZMR component for a Type IIIB defect. He had component subsidence in the postoperative period and had persistent thigh pain. At the time of revision, he had occult septic loosening. Eventually, a custom 26-mm tapered stem was required at the time reimplantation to provide adequate canal fill. This patient currently is asymptomatic and ambulates without assistance.

The original fluted, tapered grit-blasted stem was the Wagner self-locking stem (Sulzer Medica, Baar, Switzerland). Several authors have reported their results with this stem during revision surgery with component survival rates of greater than 92% at 10 years.[2,4,15,25] However, one of the problems seen with the monoblock tapered stem was early subsidence.[1,24] This has prompted manufacturers to design implants with modular components to independently optimize the fit of the distal tapered stem against the isthmus and the proximal body against the remaining metaphyseal bone. Although modularity ultimately may show improved survival rates and a decreased prevalence of subsidence, the long-term results of this type of implant are lacking. In our cohort of patients, the average size tapered stem was 23 mm. The largest ZMR stem currently manufactured is 22 mm and the largest Link stem is 25 mm. Therefore, custom implants may be required to provide adequate canal fill. Many surgeons have concerns about the potential for fatigue failure at the modular junction. Consequently, the senior author will attempt to avoid the use of such implants in heavy patients and in patients younger than 65 years especially if the proximal femur is unsupported.

A bone packing procedure is another alternative in patients with severe femoral bone loss. In this study, 10 patients had impaction grafting with the use of a polished femoral stem. Although none of the patients had loosening of their femoral implants, two patients required revision surgery secondary to hip instability. Both of these patients had a 28-mm femoral head and a 72-mm acetabular shell inserted at the time of the initial revision surgery. The etiology of the dislocation in both patients was thought to be secondary to acetabular rim impingement and the patients required placement of a

constrained liner. Neither patient has had additional episodes of instability.

Bone packing procedures have the potential to restore bone stock and are able to be used in patients with irregular endosteal surfaces and ectatic canals.[7] This technique requires either an intact cortical shell or the ability to reconstruct the proximal femur with mesh or bone graft to allow containment of the morselized graft. If this criteria are unable to be met, an alternative method of fixation such as an allograft prosthetic composite should be considered. Early reports of impaction bone grafting have yielded mixed results. Some centers have reported excellent pain relief with reconstitution of the proximal femur whereas others have expressed concern about the high rate of intraoperative fracture and stem subsidence.[8,9,16,17,19,20] The senior author currently will consider a bone packing procedure in patients younger than 65 years with either a Type IV defect or a Type IIIB defect and an endosteal canal greater than 19 mm (Fig 1).

Allograft prosthetic composites can be used if the proximal femur is deficient. Similar to a bone packing procedure, an allograft prosthetic composite has the potential to preserve existing bone stock and may allow reconstitution of the proximal femur.[13] This type of reconstruction may be beneficial in the younger patient who likely will require future revisions.[14] The potential complications with the use of an allograft prosthetic composite include failure of graft incorporation, graft resorption, component loosening, infection and fracture.[3]

The current study is based on a select group of patients with extensive femoral bone loss requiring revision surgery. As a result, the number of patients enrolled in this study is small making statistical comparison among treatment groups difficult. This is a weakness of the current study along with the potential for selection bias among the different surgical interventions. The senior author began using a bone packing procedure or a modular tapered stem in patients with severe bone loss (Type IIIB or Type IV) as he began noticing poor results in some patients treated with extensively porous-coated stems. This accounts for the varying duration of followup and is a potential weakness of the current study. However, we think that the rates of mechanical failure can be compared because the stability of fully porous-coated stems, impaction bone grafting, and modular tapered stems is obtained within the first 2 years after implantation.

The majority of femoral revisions that an orthopaedic surgeon encounters on a daily basis can be treated with either a 7-inch or 8-inch extensively porous-coated stem. This type of

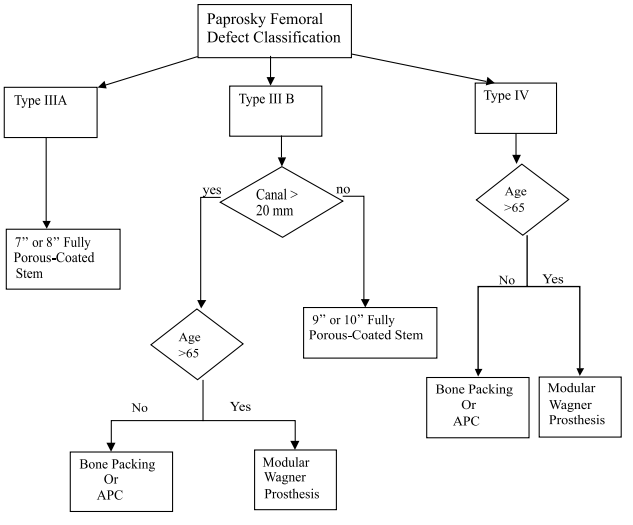

Fig 1. A treatment algorithm is shown for femoral defects based on femoral bone stock, patient age, and endosteal diameter.

implant will provide reliable initial fixation with a high propensity for bone ingrowth. However, patients with significant femoral bone loss (Paprosky Type III B and Type IV femoral defects) need either a longer cementless stem or an alternative mode of fixation. The senior author recommends that either a 10-inch or 9-inch calcar fully porous-coated stem be used only in patients with Type IIIB defects and a femoral canal less than 19 mm. Alternative methods of reconstruction such as a modular Wagner-type tapered stem or a bone packing procedure should be used in patients with Type IIIB defects and a canal greater than 19 mm or Type IV defects.

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