The Journal of Arthroplasty 28 (2013) 598–603

Contents lists available at SciVerse ScienceDirect

The Journal of Arthroplasty

journal homepage: www.arthroplastyjournal.org

# Total Knee Arthroplasty With Fully Porous-Coated Stems For The Treatment of Large Bone Defects

Thomas P. Gross MD, Fei Liu PhD

*Midlands Orthopaedics, P. A., Columbia, SC, USA*

ARTICLE INFO

*Article history:*
Received 11 April 2012
Accepted 16 July 2012

*Keywords:*
total knee arthroplasty
fully porous-coated stem
large bone defect
revision knee arthroplasty
cementless fixation

ABSTRACT

Between February1999 and April 2006, 25 patients (28 knees) underwent a TKA by a single surgeon. At an average final follow-up of 7±2years (range, 3–10years), 34 (100%) of 34 fully porous stems had achieved bone ingrowth. However, one case (3%) had a component loosening due to the de-bonding of sheets of beads from the stem. The remaining cases remained well fixed. Three well-fixed stems in 2 patients failed from deep infection. There was one reoperation required for a femoral periprosthetic fracture. Our 10-year experience shows that fully porous-coated stems reliably achieve durable fixation in complex primary and revision TKA allowing the surgeon to bypass large bone defects and gain fixation in diaphyseal bone.



Total knee arthroplasty (TKA) has been a successful operation for end-stage knee arthritis for decades. With growth in the aging population in United States, the number and rate of primary and revision TKA have been steadily increasing for the last 10years [1,2]. Already in 2002, there were over 350,000 primary TKAs performed and 29,000 TKAs revised. Even though TKA is one of the most commonly performed orthopedic procedures in United States, it still remains a significant challenge to manage large bone defects around the knee during some complex primary and revision TKAs. Numerous recent studies have addressed options to solve this problem by using cement, metal augmentation, morselized or structural allograft, and custom designed or hinged prostheses together with long cemented or press-fit stems [3,4].

The long canal-filling nonporous-coated press-fit stem was introduced in the 1980s facilitating hybrid fixation of both femoral and tibial components as an alternative to cement fixation of both the component and stem [5]. Although it is not clear whether cement or hybrid fixation of revision knee components is superior [4,6,7], most knee revisions in the US now employ the hybrid fixation type with a canal-filling non-porous stem. The stem helps to share the load of the metaphyseal bone and transfers it to diaphyseal bone on both the tibial and femoral sides of the knee reducing the stress on the interface between the damaged bone and the implants. Because the stem is canal filling, it assists in recreating joint alignment. On the other hand, uncemented TKA revision using short non-canal-filling nonporous stems has met with limited success.

Because fully porous-coated stems have a high success rate in femoral revisions in total hip arthroplasty (THA), the senior author (T.P.G.) decided to investigate their utility in revision TKA. Our hypothesis was that reconstruction of either the tibia or the femur using a fully porous-coated stem could reliably achieve bone ingrowth in the diaphysis. Initial press-fit fixation of the stem was augmented by various methods of fixation of the femoral and tibial components themselves. Long porous-coated stems have the theoretical advantage of allowing implant fixation in relatively more healthy bone distal to the original implant bone interface. They do not rely on bulk allograft or cement for long-term fixation. The disadvantages include difficulty of implantation and difficulty in removal if the porous surface becomes bone ingrown. The purpose of this study was to review our mid-term clinical and radiological results of using long porous-coated stems to treat large bone defects on both the femoral and tibial bones during primary and revision TKAs.

## Materials and Methods

Between February 1999 and April 2006, 25 patients (28 knees) who had large bone defects around their knees underwent TKA by the senior author (T.P.G.). In all of these cases, a custom-made long straight cylindrical fully porous-coated stem was used in conjunction with a standard or custom designed TKA prosthesis. Three patients (three knees) died due to causes unrelated to their TKAs. Two of these patients (two knees) had their minimal 2-year follow-up in our database (3 and 4years) and are included in our study. The other one

The Conflict of Interest statement associated with this article can be found at http://dx.doi.org/10.1016/j.arth.2012.07.021.

Reprint requests: Fei Liu, PhD, Midlands Orthopedics, P.A., 1910 Blanding St, Columbiac, SC 29201, USA.

0883-5403/2804-0013$36.00/0 – see front matter © 2013 Elsevier Inc. All rights reserved.
http://dx.doi.org/10.1016/j.arth.2012.07.021

is excluded from the study because minimum 2-year follow-up was not available. For the remaining 24 patients (27 knees), one patient with one knee was lost to follow-up and was excluded from this study because the patient did not have minimal two years follow-up available. His knee was functioning well at the time of his last follow-up. The remaining 23 patients (26 knees) formed the study group (Table 1). There were two bilateral patients (cases 13 and 18 and cases 19 and 25). There was another patient, who had two different surgeries: one for the tibial component and the other for the femoral component with two years (cases 4 and14). The follow-up rate for the study group was 93% (26/28). At the time of surgery, the average age was 62 ± 10 years (range, 42–76 years), and the average weight was 202 ± 52 lbs (range, 100 to 335 lbs). There were 6 primary TKAs and 20 revision TKAs. There were 15 women and 8 men. Institutional review board (IRB) approval was obtained for this study.

The indications for primary TKA included tibial plateau fracture in five knees and distal femoral malunion with degenerative joint disease (DJD) in one knee. The indications for revision procedure included a loose tibial component in eight knees; loose femoral and tibial components in three knees; loose femoral, tibial, patella components in two cases; a loose tibial component combined with a malaligned femoral component in two knees; loose femoral and patella components in one case; a loose femoral component in one knees; infection in one knee; loose tibial and patella components combined with global instability in one knee; loose femoral and tibia components combined with instability in one knee.

Bone defects for each knee were categorized according to the Anderson Orthopaedic Research Institute (AORI) [8] bone defect classification and were listed in Table 1. Long fully porous-coated stems were used on 12 femoral components and 22 tibial components. Three different adjunct techniques were used for the purpose of proximal tibial fixation and management of defects. The first method was a combination of bulk allograft with a standard tibial baseplate and cement in four cases; the second method utilized standard

**Table 1**
Detail Information Demographic and Clinical Information.

| | Surgery Date | Duration of Follow-up (y) | AORI(Bone Defect Classification) | Wt(LB) | Age | Gender | Side | Diagnosis | Revision | Component Revised[a] | Component with Porous Stem[a] | Adjunction Fixation[b] | Constraint of Implant[c] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2/1999 | NA | NA | 290 | 74 | F | R | Nonunion proximal femur | Y | F,T | F | – | ML |
| 2 | 1/2001 | 10 | FØ,T1 | 335 | 53 | M | R | Loose tibial component | Y | T | T | C | CR |
| 3 | 6/2001 | NA | FØT3A | 135 | 53 | F | R | Loose tibial component | Y | T | T | C | H |
| 4 | 9/2001 | NA | F3,T3 | 260 | 60 | M | R | Loose tibial component | Y (tibial) | T | T | C | ML |
| 5 | 11/2001 | 10 | FØT2A | 230 | 42 | M | R | Tibial plateau fracture | N | – | T | Au | CR |
| 6 | 1/2002 | 9 | FØT2B | 225 | 58 | M | L | Tibial plateau fracture | N | – | T | C | ML |
| 7 | 1/2002 | NA | F3,TØ | 100 | 66 | F | L | Loose femoral component | Y | F | F | – | CR |
| 8 | 2/2002 | NA | FØT2A | 250 | 53 | M | R | Tibial plateau fracture | N | – | T | C | ML |
| 9 | 3/2002 | 9 | F2B,T1 | 165 | 62 | F | L | Loose femoral, tibial, patella components | Y | F,T, P | F | – | ML |
| 10 | 5/2002 | 9 | FØT2B | 175 | 60 | F | L | Loose tibial Component | Y | T | T | C | CR |
| 11 | 8/2002 | 6 | FØT2B | 270 | 73 | F | L | Loose patella and tibial components and global instability | Y | P,T | T | C | ML |
| 12 | 12/2002 | 8 | FØT2A | 190 | 60 | F | R | Tibial plateau fracture | N | – | T | C | PS |
| 13 | 12/2002 | 8 | F3T2B | 173 | 75 | F | R | Loose femoral and tibial components | Y | F,T | F,T | Au | ML |
| 14 | 2/2003 | NA | F3,T3 | 260 | 62 | M | R | Loose femoral and patella component | Y (femoral) | F, P | F | – | ML |
| 15 | 4/2003 | 8 | F1,T1 | 192 | 60 | F | L | Infected | Y | F,T, P | FT | Au | PS |
| 16 | 10/2003 | 8 | F2,T1 | 174 | 65 | F | R | Loose femoral tibia, instability | Y | F,T, P | T,F | Au | Ml |
| 17 | 1/2004 | 8 | F2B,T3 | 200 | 72 | F | R | Loose femoral, tibial, patella components | Y | F,T,P | F,T | A | ML |
| 18 | 1/2004 | 7 | F2BT2A | 173 | 76 | F | L | Loose tibial component, malaligned femoral component | Y | F,T | F,T | Au | PS |
| 19 | 2/2004 | 8 | FØ,T3A | 160 | 72 | F | R | Failed tibial component | Y | T | T | A | CR |
| 20 | 2/2004 | NA | FØT2B | 175 | 56 | M | R | Loose tibial component | Y | T | T | Au | ML |
| 21 | 3/2004 | 4 | F3.T1 | 158 | 48 | M | L | Femoral malunion with DJD | N | - | F | - | PS |
| 22 | 5/2004 | 7 | F2B,T3 | 215 | 57 | F | L | Loose tibial component, malaligned femoral component | Y | F,T | F,T | Au | ML |
| 23 | 10/2004 | 7 | FØT3A | 200 | 75 | M | L | Failed tibial component | Y | T | T | A | CR |
| 24 | 11/2004 | 3 | F1,T3 | 245 | 60 | F | R | Loose femoral and tibial components | Y | F,T | F,T | Au | ML |
| 25 | 12/2004 | 6 | FØ,T2A | 160 | 73 | F | L | Failed tibial component | Y | T | T | Au | CR |
| 26 | 10/2005 | 5 | FØT2A | 225 | 45 | M | L | Tibial plateau fracture | N | – | T | C | CR |
| 27 | 4/2006 | 6 | F2B,T2B | 295 | 59 | F | R | Loose femoral and tibial components | Y | F,T | F,T | Au | ML |
| 28 | 4/2006 | 5 | F1,T3 | 170 | 41 | F | R | Tibial plateau fracture | N | – | T | Au | PS |

Cases highlighted in yellow are those without the minimal 2-year follow-up; cases highlighted in red are failures.
[a] T: tibial; F: femur; P: patellar.
[b] A: Au; A: bulk allograft; C: custom porous baseplate; Au: cement augment.
[c] CR: cruciate retained; PS: posterior stabilized; ML: medial–lateral stabilized; H: hinge.

revision implants with cement and with or without augments in nine cases; the third method used custom porous-coated implants without cement in nine cases. The amount of constraint utilized was cruciate retained in eight knees; posterior stabilized in five cases and medial-lateral stabilized in twelve knees. A hinged implant was used in only one knee that already had a hinge in place. Nineteen implants from Biomet (Biomet, Warsaw, Indiana, USA), five implants from Depuy (Depuy Johnson and Johnson, Warsaw, Indiana, USA), and two implants from Zimmer (Zimmer, Warsaw, Indiana, USA) were utilized in this study.

*Surgical Technique*

Preoperative planning included taking additional AP and lateral long (10 inch by 14 inch) radiographs with correctly placed magnification markers of the distal femur and/or the proximal tibia depending on which bone required the custom stem. Cellophane templates that were 110% magnification in 2-mm diametrical increments were used to choose the best implant fit. The fact that reaming would be performed was taken into account. Either 80- or 120-mm long straight cylindrical stems were ordered in 2-mm increment diameters. The custom trials that came with the custom stems were always 0.5 mm smaller in diameter than the custom stem.

For placement of the porous stems, a technique analogous to preparing for a fully porous-coated hip femoral component was employed. First, the diaphysis was prepared with rigid straight reamers in 1-mm increments. When we reached a reamer size 0.5 mm smaller than the custom stem, reaming was discontinued. A trial stem that had the same diameter as the last reamer was inserted. The final stem would be 0.5 mm larger than the trial stem. After the trial stem was inserted, the cutting blocks for the corresponding femoral or tibial components were then attached to the trial stem. The final cuts were then made. Because the porous stem was rigidly fixed in the canal, position of the component was dictated by the stem position. It was therefore critically important to prepare for the stem first, and then guide the remaining cuts off of the trial stem. The components were either one-piece custom components, or more commonly there was a Morse cone taper junction between the stem and the standard revision implant. It was important to test that the trial component with the attached 0.5-mm undersized trial stem fit snugly into the prepared bone before attempting final implantation. Because the prepared canal was a cylindrical tube, the final implant always seated at a depth dictated by the main body of the implant. Estimating at what level to reconstruct the joint line was no different than the method used for a revision implant with a non-porous stem and was done prior to the trial step. The final implant always seated at the same level as the trial implant. Adjustments in the desired final implant position could always be made after the trial stage by modifying the augments or allograft blocks used adjacent to the tibial baseplate or femoral bearing implant and then repeating a trial step. The stem just had a tighter fit when it was driven down than what surgeons are accustomed to with non-porous stems. Extreme care was taken to start driving the implant with the correct rotational alignment, because only small rotational adjustments could be made during the implantation step. As the main body of the implant got close to seating, a rotational torque could be applied to the implant while it was impacted to fine-tune the final rotation.

*Implants*

Three implant brands and therefore three different porous coatings were used based on the special expertise of individual manufacturers. If the cases required revision of only one component, the custom implant was requested from the manufacturer of the implant being revised. One-piece custom constructs were used initially. However, most implants were based on a custom fully porous stem that could be attached to the full line of revision implants from the chosen manufacturer by a morse-cone taper junction. Because we expected the component stem junction to carry the patient's full load, we never used a modular stem that was not attached by a morse cone taper junction. Our preference was for a system with a titanium stem with plasma spray coating whenever both components were revised. The custom trials were designed to attach to the full line of revision components of the chosen company and also to attach to the cutting blocks.

Clinical and radiological assessments were made pre-operatively and post-operatively by the senior author (T.P.G.) (Fig. 1). Knee score

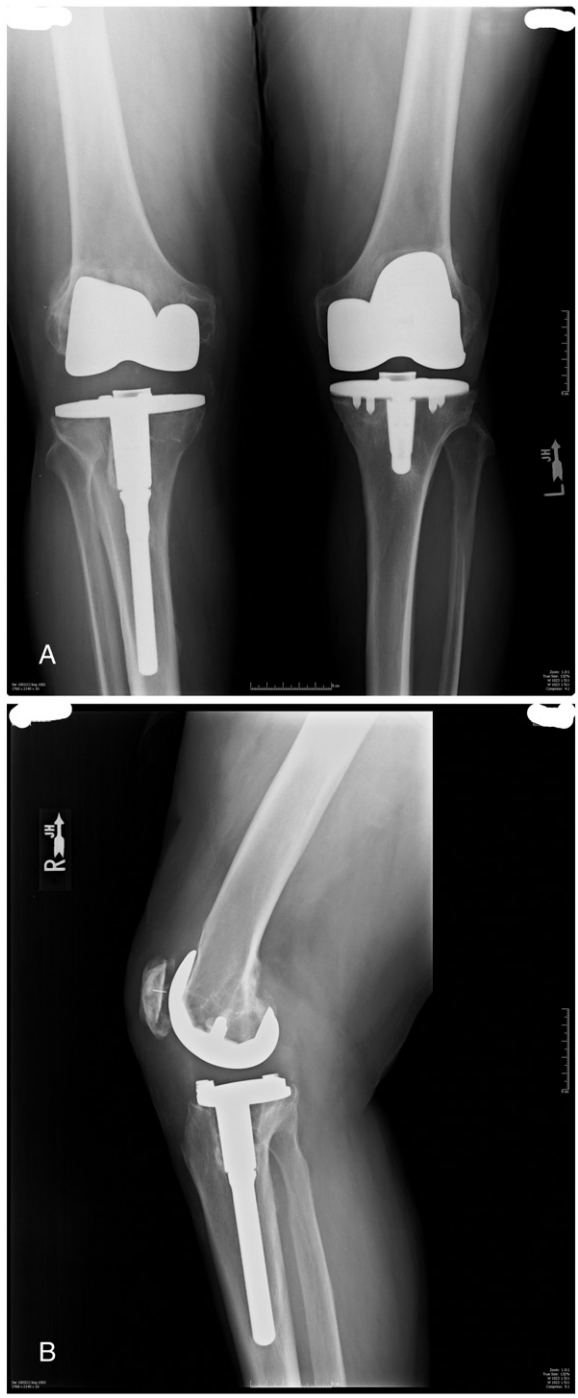


**Fig. 1.** Knee X-rays taken 10 years post-operatively with use of the fully porous-coated stem (case #2).

and knee function score were calculated according to the knee society clinical rating system [9]. Anterior–posterior and lateral X-rays were taken at the preoperative and at each post-operative visit and analyzed according to the knee society TKA radiographic evaluation and scoring system [10]. Defects were graded according to the AORI Knee defect scoring system. Initial and most recent X-rays were compared to assess for possible component migration in each case.

Statistical analysis was performed to compare the difference between the pre- and post-operative (at the latest follow-up) knee scores and knee function scores with a 95% confidence interval. Kaplan–Meier survival curves were plotted to estimate the survival rates with use of any component revised due to any reason as the end point and also any component revised due to fully porous-coated component loosening or due to infection as the end point.

## Results

### *Failures*

There was only one fixation failure (1/26; 4%), which was noticed at four year post-operatively (Table 2). The patient was a 67-year-old woman at the time of surgery. She had a loose femoral component with an AORI F3 defect. The femoral component and the tibial liner were revised. The femoral stem was a fully coated cobalt chrome beaded implant. The femoral component itself was cemented to the extremely deficient remaining distal femoral bone. At 4 years after operation, the patient presented with pain and radiographic evidence of debonding of sheets of beads from the stem. We suspect that this was a case of suboptimal porous coating application in this custom implant. She was not healthy enough to tolerate another revision. There were three cases (four porous stems) that required implant removal for chronic deep sepsis. All stems were well fixed at the time of failure.

The overall Kaplan–Meier survival rate, using failure of fixation of any reason as the end point, was 100% at 4-year follow-up, 96% at 6 years and 83% at 10 years (Fig. 2). The Kaplan–Meier survival rate, using failure of component fixation as the end point, was 100% at 4 years and 96% at the 6 and 10 years postoperatively. There were 3/26 cases (12%) that failed due to chronic deep infection in patients with significant medical co-morbidities. If the infection rate is expressed per stem it was 12% (4/34). All three stems in the infected cases were found to be well fixed at the time of surgery.

### *Complications*

One patient (cases 4 and 14) required a reoperation 1.5 years after his index surgery. The index surgery involved a revision of only the tibia with a long porous-coated stem. The patient was experiencing pain and there were partial radiolucencies around this fully porous-coated cobalt chrome beaded tibial stem. At the time of repeat revision surgery, the tibial component was found to be rigidly fixed, but the previously retained femoral component was now found to be loose and was revised with a fully porous-coated stemmed femoral component. Both of the fully porous-coated stems in this patient remained well fixed at the time of eventual revision for deep infection.

One patient (case 18) had a vascular complication that left him with a poorly functioning leg that was later amputated after it became infected. The fully porous-coated stem remained well fixed.

One late deep infection (case 6) was cured with debridement and antibiotics.

One patient (case 16) required reoperation for a periprosthetic femoral fracture which healed successfully after plating.

**Table 2**
Summary of the Failures and Complications.

| | Total | Case |
|---|---|---|
| Modes of failure | | |
| Component loosening | 1 | #7 |
| Infection | 3 | #3,4*,14*,20 |
| Modes of complications | | |
| Cured infection | 1 | #6 |
| Vascular complication | 1 | #20 |
| Periprosthetic femoral fracture | 1 | #16 |

* The same knee.

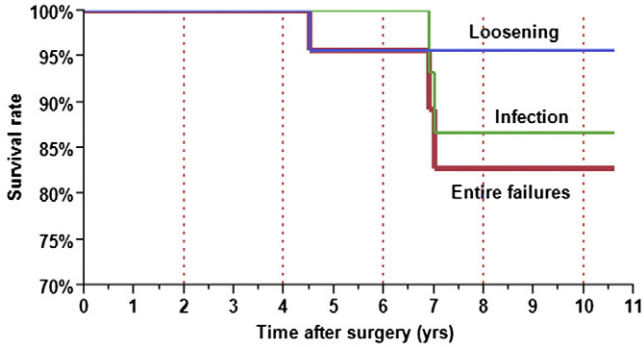


**Fig. 2.** The Kaplan–Meier survivorship curves with use of the failures due to component loosening, the failures due to infection and the failures due to any reason taken as the end point.

### *Clinical results*

The average follow-up for the study group was 7±2 years (range, 3–10 years). Revised cases were excluded from the following analyses. Preoperatively, the average knee score was 24±21 (range, 2–80); the average knee function score was 33±25 (range, 0–80); and the average total knee score was 56±37 (range, 7–160). At the latest follow-up, the average knee score improved to 81±20 (range, 19–100); the average knee function score improved to 61±35 (range, 0–100); and the average total knee score improved to 141±46 (range, 24–200). The postoperative scores were statistically better than the preoperative scores: for the knee score ($P<0.0001$), knee function score ($P<0.0001$) and total knee score ($P<0.0001$).

The average preoperative range of motion (ROM) was 91°±23° (range, 25°–125°) with average 3°±5° flexion contracture (range, 0°–15°) and average 94°±21° flexion (range, 40°–125°), and improved to 101°±22° (range, 30°–125°) ($P=0.12$) with average 0°±2° flexion contracture (range, 0°–10°) ($P=0.02$) and average 102°±22° flexion (range, 30°–125°) ($P=0.24$).

### *Radiographic results*

Final radiographic review showed no evidence of loosening or migration of any components with the exception of the one case of bead debonding mentioned previously. Partial radiolucencies were present in five knees at the initial postoperative radiological exam and in six knees at the final postoperative radiological exam. The knee society TKA radiographic evaluation and scoring system [10] was used. Five cases had >2-mm radiolucency at initial follow-up and showed no radiolucency at the final follow-up around the tibial or the femoral component; five case showed no radiolucency at the initial follow-up and showed >2-mm radiolucency at their final follow-up; and only one had >2-mm radiolucency both at the initial and final follow-up. There were no radiolucencies around the long porous-coated stem on the femoral side ($N=12$); there was only one case having partial radiolucency around the long porous-coated stem on the tibial side at 77-month follow-up ($N=22$). This exception was a

cobalt chrome beaded stem. It was, however, found to be well fixed at the time of reoperation.

Preoperatively, six knees had a varus tibial–femoral angle with an average of 12.5°±4.7° (range, 7°–17°); each of these knees improved to exhibit a valgus tibial–femoral angle with an average of 5.8°±3.3° (range, 0°–8°) at the initial postoperative follow-up. 17 knees had a valgus tibial–femoral angle with an average of 4.5°±5.6° (range, 0°-20°) at the preoperative radiographic exam; they improved to exhibit an average valgus tibial–femoral angle of 4.6°±2.5° (range, 0°–10°) at the initial postoperative radiographic exam.

## Discussion

In a small group of patients with large defects around the knee, in both primary and revision TKA cases, the hypothesis is proved that long fully porous-coated stems can reliably achieve bone-ingrowth fixation (100%), which is consistent with results in the total hip arthroplasty [11]. Bone ingrowth fixation was achieved in all 34 stems employed. Only one cobalt–chrome beaded stem suffered fixation failure due to the debonding of its porous surface in the face of a severe segmental distal femoral defect. At 10 years post-operatively, the Kaplan–Meier survivorship of fixation was 96%. However, we did experience 3 (12%) additional failures due to chronic deep infection.

In this study, long uncemented porous-coated stems were used in combination with a variety of adjunct methods of reconstruction of the bone defects themselves including standard and custom augments and bulk allografts and fixation of the proximal interface with cement or bone ingrowth. In our technique, reconstruction of the actual bone defect is not critical and can be accomplished in numerous fashions; the key to our technique is permanent fixation to healthy host bone beyond the damaged interface.

We are not aware of any previous reports of techniques where large bone defects around TKA were managed with fully porous-coated stems. We therefore compare our results to other methods to achieve fixation in revision and complex TKA. It is difficult to compare results because we typically only use long porous-coated stems when large bone defects are present. When smaller defects are present it is our practice to use the first two standard methods described below.

Most revision TKRs rely on cement fixation of the implant-bone interface for both initial and long-term fixation. The most common methods employ cemented components with cemented stems [12], or cemented components with canal-filling nonporous stems [6]. Poor results have been reported for fully porous-coated implants with small nonporous stems [5].

Techniques that have been used specifically to reconstruct large segmental defection TKA revision include the following:

1. Bulk allografts with cemented components and stems.
2. Bulk allografts with nonporous press-fit stems.
3. Impaction grafting with cemented components and stems.
4. Cemented components with porous tantalum sleeves and a press-fit nonporous or a cemented stem.
5. Uncemented components with press-fit nonporous stems and porous proximal bone-ingrowth sleeves.

In 2001, Clatworthy et al. [13] reported on technique #1 for femoral and tibial defects. In 52 cases (66 grafts) with a minimum of 5-year follow-up. The AORI class was not listed, but 48 grafts were truly massive circumferential type grafts. Twelve (23%) of 52 required repeat revision. Allograft survivorship declined from 92% at 5 years to 72% at 10 years. There were four chronic deep infections (8%).

In 2007, Engh and Ammeen [14] reported on the use of technique #2 for tibial defects. In 46 cases (AORI class not listed) there were 2 loosenings (5%) at an average of 96-month follow-up. There were five chronic deep infections (11%) and one periprosthetic fracture (2%) not requiring revision. In total 11/46 (24%) had significant knee complications.

In 2006, Lotke et al. [15] reported on technique #3. There were 48 cases with an average follow-up of 3.8 years without any loosenings. There was one chronic deep infection (2%) and two (4%) periprosthetic fractures.

In 2008, Meneghini et al. [16] reported on the use of technique #4 reconstructing large tibial defects with the use adjunct use of porous tantalum sleeves in revision TKR. In 15 cases with AORI class 2 AORI class 2B and 3 defects, there were no loosenings at an average of 34-month follow-up. Major complications included 2/15 (13%) chronic deep infections, and 1 (8%) periprosthetic fracture requiring revision.

In 2011, Howard et al. [17] from the same group reported on technique #4 in femoral revisions. There were 24 cases with AORI class 2B and 3 defects. There were no loosenings at an average of 33-month follow-up. Major complications included 2/24 (8%) periprosthetic fractures and 3 other reoperations. There were no deep infections.

In 2001, Jones et al. [18] reported on technique #5 with a hinged prosthesis. There were 16 cases with minimum but AORI class was not listed. At 2-year minimum follow-up there were no fixation failures. There were two intraoperative periprosthetic fractures (13%). There was one chronic deep infection (6%).

Multiple strategies have been employed to reconstruct knees with substantial defects at the time of complex primary and revision TKR. Most reports provide only short or mid-term follow-up. Often the degree of bone deficiency is not listed. Soft tissue deficiencies are also often present that are impossible to quantify. These cases often occur in older patients with multiple co-morbidities. The high rate of infection often reported in these cases is likely due to multiple factors including history of previous infection, possible undiagnosed infection at the time of revision, long surgical times, the use of allografts, and the high rate of co-morbidities in these patients. All of these factors make comparison of overall results between different techniques difficult. Therefore we focus on the fixation of the components, which is relatively easier to assess and to compare.

As with most other reports we had a significant rate of periprosthetic fracture (4%) not leading to implant fixation failure and a high failure rate due to deep chronic infection (12%). Deep infections do not seem to be related to the type of implant fixation chosen; other strategies must be explored to reduce this complication.

One disadvantage of our technique is that fully porous-coated uncemented stems are currently only available as custom devices. They are challenging to implant. However, they have a very high rate of durable bone ingrowth (96%) at 10 years post-operatively. Since the mechanical construct is not dependent on cement or allograft for long-term success, we can probably assume that long-term fixation will be similar to that of long fully porous-coated stems in femoral component revision in the hip [19–21], which have outperformed cemented stems for this purpose [22,23].

Another disadvantage of these stems is the extreme difficulty in removing them after they become well fixed. Therefore, we try to avoid using them in cases of re-implantation for infection. They are now routinely used as modular devices to facilitate revision. The main implant can be detached from its interface using standard techniques. The morse cone taper is then separated by impacting the main implant. Finally, trephines are used to remove the bone-ingrown stem. We have had to use this technique in the three stems that failed because of chronic deep infection.

Because bulk allografts are dead bone that rarely fully incorporates, late failures are predictable and in fact are reported in longer-term studies. Therefore it is best to devise revision constructs that do not significantly load these grafts. Our hypothesis is that revision mechanical constructs that achieve bone ingrowth into the prosthesis will ultimately be longer lasting. We therefore recommend that cement and bulk allografts should be used only for filling of defects and providing short-term initial fixation to increase the chances of stable ingrowth into the fully porous-coated stem. This

study demonstrates that a variety of adjunct techniques can be successfully employed to achieve this goal. All 34 stems achieved bone ingrowth; unfortunately one did suffer a material failure. We suspect that a titanium stem with plasma spray coating and a morse-cone taper junction to the body of the implant is the most durable combination, but we do not have adequate data to compare implant types.

Many promising techniques have been developed to help us reconstruct knees with substantial bone defects. The rate of fixation (96%) using fully porous-coated stems compares favorably with other mechanical constructs reported to solve this problem. Long-term follow-up will be required to determine which offers the most durable type of fixation.

## References


1. Kurtz S, Mowat F, Ong K, et al. Prevalence of primary and revision total hip and knee arthroplasty in the United States from 1990 through 2002. J Bone Joint Surg Am 2005;87(7):1487.
2. Mahomed NN, Barrett J, Katz JN, et al. Epidemiology of total knee replacement in the United States Medicare population. J Bone Joint Surg Am 2005;87(6):1222.
3. Radnay CS, Scuderi GR. Management of bone loss: augments, cones, offset stems. Clin Orthop Relat Res 2006;446:83.
4. Mabry TM, Hanssen AD. The role of stems and augments for bone loss in revision knee arthroplasty. J Arthroplasty 2007;22(4 Suppl 1):56.
5. Mow CS, Wiedel JD. Revision total knee arthroplasty using the porous-coated anatomic revision prosthesis: six- to twelve-year results. J Arthroplasty 1998;13(6):681.
6. Gustke KA. Cemented tibial stems are not requisite in revision. Orthopedics 2004;27(9):991.
7. Hanssen AD. Cemented stems are requisite in revision knee replacement. Orthopedics 2004;27(9):990.
8. Engh GA, Ammeen DJ. Bone loss with revision total knee arthroplasty: defect classification and alternatives for reconstruction. Instr Course Lect 1999;48:167.
9. Insall JN, Dorr LD, Scott RD, et al. Rationale of the Knee Society clinical rating system. Clin Orthop Relat Res 1989(248):13.
10. Ewald FC. The Knee Society total knee arthroplasty roentgenographic evaluation and scoring system. Clin Orthop Relat Res 1989(248):9.
11. Gross TP, Liu F. Metal-on-metal hip resurfacing with an uncemented femoral component. A seven-year follow-up study. J Bone Joint Surg Am 2008;90(Suppl. 3):32.
12. Fehring TK, Odum S, Olekson C, et al. Stem fixation in revision total knee arthroplasty: a comparative analysis. Clin Orthop Relat Res 2003(416):217.
13. Clatworthy MG, Ballance J, Brick GW, et al. The use of structural allograft for uncontained defects in revision total knee arthroplasty. A minimum five-year review. J Bone Joint Surg Am 2001;83-A(3):404.
14. Engh GA, Ammeen DJ. Use of structural allograft in revision total knee arthroplasty in knees with severe tibial bone loss. J Bone Joint Surg Am 2007;89(12):2640.
15. Lotke PA, Carolan GF, Puri N. Impaction grafting for bone defects in revision total knee arthroplasty. Clin Orthop Relat Res 2006;446:99.
16. Meneghini RM, Lewallen DG, Hanssen AD. Use of porous tantalum metaphyseal cones for severe tibial bone loss during revision total knee replacement. J Bone Joint Surg Am 2008;90(1):78.
17. Howard JL, Kudera J, Lewallen DG, et al. Early results of the use of tantalum femoral cones for revision total knee arthroplasty. J Bone Joint Surg Am 2011;93(5):478.
18. Jones RE, Skedros JG, Chan AJ, et al. Total knee arthroplasty using the S-ROM mobile-bearing hinge prosthesis. J Arthroplasty 2001;16(3):279.
19. Hamilton WG, McAuley JP, Tabaraee E, et al. The outcome of rerevision of an extensively porous-coated stem with another extensively porous-coated stem. J Arthroplasty 2008;23(2):170.
20. Hamilton WG, Cashen DV, Ho H, et al. Extensively porous-coated stems for femoral revision: a choice for all seasons. J Arthroplasty 2007;22(4 Suppl 1):106.
21. Dorairajan A, Reddy RM, Krikler S. Outcome of acetabular revision using an uncemented hydroxyapatite-coated component: two- to five-year results and review. J Arthroplasty 2005;20(2):209.
22. Masterson S, Lidder S, Scott G. Impaction femoral allografting at revision hip arthroplasty: uncemented versus cemented technique using a Freeman femoral component. J Bone Joint Surg Br 2012;94(1):51.
23. Holt G, Hook S, Hubble M. Revision total hip arthroplasty: the femoral side using cemented implants. Int Orthop 2011;35(2):267.