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Revision total knee arthroplasty with porous-coated metaphyseal sleeves provides radiographic ingrowth and stable fixation

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Abstract
Purpose Porous-coated metaphyseal sleeves are designed to fill bone defects and facilitate osseointegration when bone loss in encountered during revision total knee arthroplasty (TKA). The purpose of this study is to evaluate short-term results of porous-coated metaphyseal sleeves with regards to implant fixation and clinical outcomes.
Methods A retrospective review was conducted on 50 patients (79 sleeves—49 tibial and 30 femoral) who had a press-fit metaphyseal sleeve with revision TKA. Tibial and femoral bone loss was classified according to the Anderson Orthopaedic Research Institute (AORI) bone defect classification. Post-operative complications of infection, revision surgery, and dislocation were assessed. Follow-up radiographs were evaluated for signs of loosening using the criteria developed by the Knee Society. The median follow-up was 58.8 months (range 25.8–93.0 months).
Results The bone loss classifications were 1 type 1, 30 type 2a, 2 type 2b, and 17 type 3, and with regards to the femur, 5 were type 1, 8 type 2a, 31 type 2b, and 6 type 3. At final follow-up, 41/45 (91.1%) tibial and 28/29 (96.6%) femoral sleeves showed radiographic evidence of ingrowth. Of these 69 patients, all showed radiographic evidence of bony ingrowth. Three sleeves were revised for infection and two for loosening. The re-operation rate for loosening was 5/74 (6.8%) and for any reason was 14/74 (18.9%).
Conclusions Modular porous-coated press fit metaphyseal sleeves fill defects and provide evidence of radiographic ingrowth. Short-term stable fixation can be achieved with sleeves, which is helpful as more patients undergo revision total knee arthroplasty with greater bone loss. Longer duration studies are needed to ascertain the survival rate of these implants.
Level of evidence IV.

Keywords Total knee revision · Sleeves · Porous coating · Metaphyseal defect

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Introduction

The rate of revision total knee arthroplasty (TKA) is expected to increase by more than 600% between 2005 and 2030 [23]. While primary TKA has a proven long-term survival of >90% at 12 years, both clinical outcomes and survival analysis are far worse for revision total knee arthroplasty with failures as high as 42% at 5 years [14, 17, 18, 30]. Often patients requiring revision TKA have significant bone loss either due to lysis, infection, fracture, or simply as a result of multiple revision surgeries [31]. Historically, bone loss has been addressed with methods such as cement, modular augmentation with wedges or blocks, bone grafting, or through custom-made implants [7, 17, 27, 31]. Each method for addressing bone loss with revision TKA has unique benefits and limitations, and no one method has been shown to be consistently superior to others.

A promising alternative to address bone loss has been the development of metaphyseal implants. Two different techniques and types of implants have been evaluated in the literature: tantalum cones and porous-coated metaphyseal sleeves. The literature to date has shown tantalum cones to be a good option for metaphyseal fixation, with many studies showing good short- and mid-term outcomes [4, 5, 9, 13, 22, 25, 28, 29]. With this technique, a punch is used to shape the bone defect so that a tantalum cone can be press-fit, creating a platform for the prosthesis. The cone is usually bypassed with an intramedullary stem, which is cemented to the cone [7, 17, 27]. The downside of this design is that it may require additional bone grafting and stems are not attached to the cones through morse taper.

An alternative to this design is metaphyseal sleeves. The advantage of metaphyseal sleeves over tantalum cones are threefold: (1) metaphyseal sleeves utilize a broach technique to optimize the bone–implant interface; (2) metaphyseal sleeves are bonded to the implant with a morse taper rather than through a prosthesis–cement–prosthesis interface; and (3) metaphyseal sleeves add rotation stability, especially for femoral defects with posterior bone loss [19]. Other studies have shown promising short- and mid-term outcomes when using metaphyseal sleeves, but have not done these studies in only mobile-bearing implants. Many of these studies were performed using various implants, including hinged and semi-constrained implants and not all with mobile-bearing implants [1–3, 6, 8, 15, 16, 19–21]. The purpose of this study was, therefore, to evaluate the radiographic results and survival of tibial and femoral porous-coated metaphyseal sleeves used in revision TKA at a single institution. Our hypothesis is that metaphyseal sleeves provide high radiographic signs of ingrowth and low revision rates in short-term follow-up.

Materials and methods

A retrospective study was performed on 50 consecutive patients (79 sleeves—49 tibial and 30 femoral) who underwent a mobile-bearing revision TKA using a press-fit tibial and/or femoral metaphyseal sleeve from 2006 to 2008. Patients were included if undergoing revision TKA using a mobile-bearing system with metaphyseal sleeves. Patients were excluded if they were undergoing revision TKA using fixed bearing systems, if cones were utilized, and if they were lost to follow-up. Institutional Review Board approval was obtained prior to initiating this study. A senior surgeon performed all surgeries. The surgical technique has been previous described [24]. The Press-Fit Condylar (P.F.C.) Sigma Rotating Platform TC3 Revision Knee (DePuy Orthopaedics, Warsaw, IN) and the Low Contact Stress (LCS) complete Knee System for revision (DePuy Orthopaedics, Warsaw, IN) rotating platform knee systems were used. Both systems were combined with the M.B.T. Revision Tray and Metaphyseal Sleeve (DePuy Orthopaedics, Warsaw, IN). A DePuy Universal Femoral Metaphyseal Sleeve (DePuy Orthopaedics, Warsaw, IN) was used in select patients based on an intraoperative assessment of femoral bone stock. An uncemented tibial stem was used in all but three patients (three patients were treated with a press-fit metaphyseal sleeve and no stem) and an uncemented femoral stem was used in all patients who received a press-fit sleeve. Figure 1 demonstrates AP and lateral radiographs prior to revision, and Fig. 2 demonstrates AP and lateral radiographs after revision with both press-fit tibial and femoral metaphyseal sleeves.

All medical records and operative reports were retrospectively reviewed to determine the indication for revision surgery. Patients were contacted to determine the incidence of post-operative complications, including revision surgery, periprosthetic joint infection, and dislocation. Radiographs were assessed and tibial and femoral bone loss was classified according to the Anderson Orthopaedic Research Institute (AORI) bone defect classification [10]. AORI classification was reached by combining preoperative imaging and operative note documentation. Follow-up radiographs were evaluated for signs of loosening using the criteria developed by the Knee Society [12], by looking for lucent lines, migration, and implant subsidence. Femur, tibia and patella, if present, were scored. The scoring system for each of the three components was determined by measuring the width of the radiolucent lines for each of the zones in millimeters for each of the three components. The total widths were added for each zone for each of the three prostheses. The total produced a numerical score for each component. There were seven zones assigned for the tibia and femur, and five zones for the patella.

Fifty mobile-bearing revision TKAs were performed with a press-fit tibial and/or femoral metaphyseal sleeve on 50 patients. The average patient age at the time of revision was 65.6 years (range 41.0–90.0 years). There were 28 men and 22 women. The indications included 25 knees that were infected, 12 loosening, 6 with asymptomatic lysis, 4 with pain, and 3 for instability. A tibial sleeve was used in 49 knees and a femoral sleeve was used in 30 knees. One patient also required a medial tibial augment in conjunction with the sleeve. Of the 30 knees requiring femoral sleeves, posterior and distal femoral augments were used in 8 knees, posterior augments alone were used in 21 knees, and 1

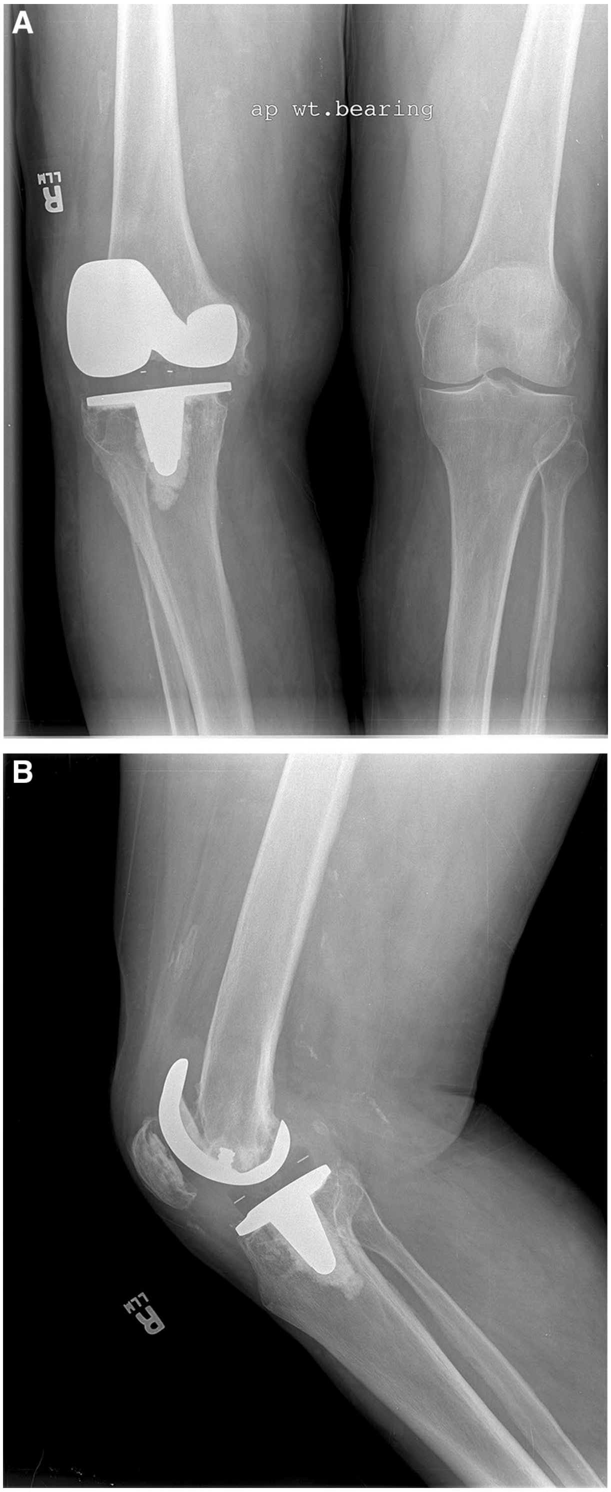

Fig. 1 **a** AP and **b** lateral radiographs before revision total knee arthroplasty with evidence of implant loosening

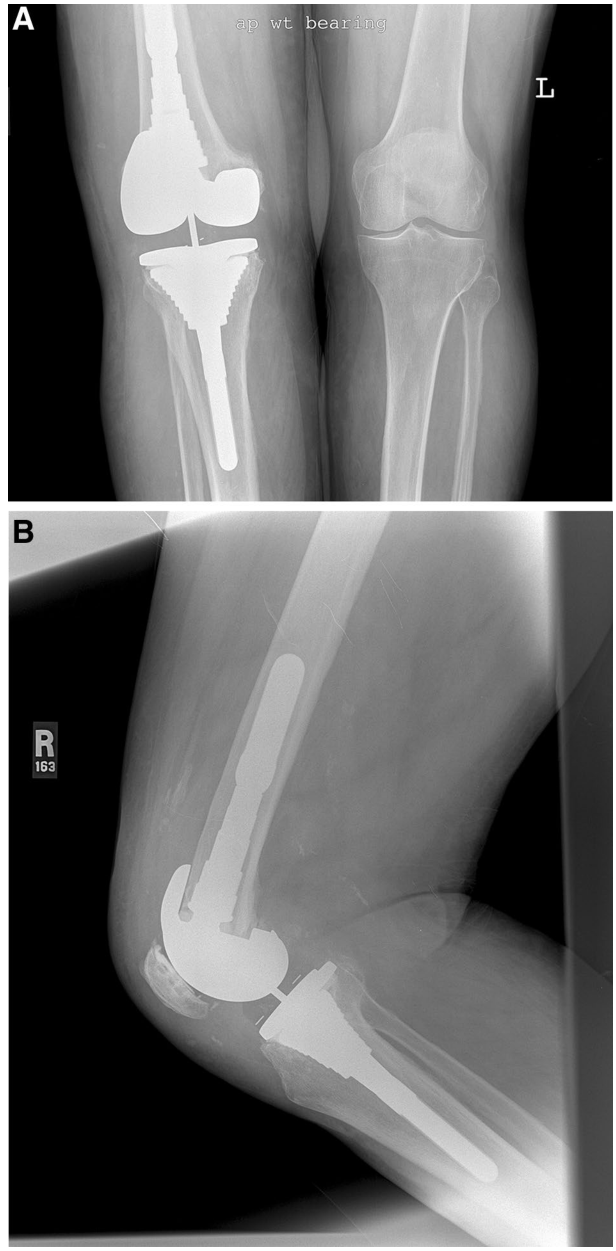

Fig. 2 **a** AP and **b** lateral radiographs after total knee revision with tibial and femoral metaphyseal sleeves demonstrating stable osseointegration

femoral revision did not require any additional augments. Though none of the sleeves were fully cemented into place, cement was used around the tibial tray and distally around the femoral component in all patients. An uncemented tibial stem was used in conjunction with 46 of the 49 tibial sleeves; three patients received a tibial sleeve without a stem. All patients receiving a femoral sleeve were also treated with an uncemented stem.

The bone loss was classified by the AORI classification system. With regards to the tibia, the bone loss classifications were 1 type 1, 30 type 2a, 2 type 2b, and 17 type 3, and with regards to the femur, 5 were type 1, 8 type 2a, 31 type 2b, and 6 type 3. The median follow-up was 58.8 months (range 25.8–93.0 months). Four patients were lost to follow-up in the immediate post-operative period, leaving 46/50 (92.0%) patients and 45 tibial and 29 femoral sleeves available for radiographic follow-up at a minimum of 2 years. Institutional review board approval was obtained prior to initiating this study (University of Pittsburgh, PRO10110263).

Statistical analysis

Descriptive statistics were performed on radiographic ingrowth and revision rates. Microsoft Excel (Seattle, WA, USA) was utilized to perform calculations.

Results

Forty-one of 45 tibial sleeves (91.1%) remained in place and 28 of 29 femoral sleeves (96.6%) remained in place at last follow-up. Of the 5 sleeves that required revision, 2 tibial sleeves showed lucent lines around the implant and were revised for aseptic loosening, with one at 5 months and one at 30 months. The other three sleeves that required revision were due to infection and radiographs showed lucent lines and subsidence. The overall re-operation rate for any reason was 14/74 (18.9%). The indications for re-operation included 2 for aseptic loosening, 2 for infection, 3 irrigation and debridements for post-op hematoma, 2 revisions for wound necrosis, 1 loosening of a femoral component without a sleeve, 1 open debridement, 1 polyethylene exchange for instability, 1 patient required a rotation flap, and 1 ORIF of a periprosthetic fracture. Of the 41 remaining tibial sleeves and the 28 remaining femoral sleeves, all showed radiographic evidence of bony ingrowth.

Using the Knee Society total knee arthroplasty roentgenographic evaluation and scoring system, the areas with the greatest radiolucent lines were Zone 1 of the femur and Zone 1 of the tibia from the AP view [11]. There were no radiolucent lines in Zones 5–7 of the femur, Zones 3 and 5–7 of the tibia from the AP view, Zone 3 of the tibia from the lateral view, and none on the patella (Table 1). There was no migration and no subsidence. There is bone loss noted in the preoperative radiographs, but in the postoperative radiographs, there were no radiolucencies around any of the metaphyseal sleeves. No sleeves migrated or had any radiologic signs of loosening. There were no patients awaiting revision. There were no complications regarding the mobile-bearing articulation. There were no episodes of spinout or dislocation. Clinically, there were no complaints of stem pain (mid tibia or mid femur) at the last follow-up. There was no metallosis in any of the patients at revision TKA.

Table 1 Radiographic analysis of sleeve constructs using the Knee Society Total Knee Arthroplasty Roentgenographic Evaluation and Scoring System [19]

Region	Zones	Sum of radiolucent lines (mm)
Femur	Zone 1	13
	Zone 2	4
	Zone 3	1
	Zone 4	2
	Zone 5	0
	Zone 6	0
	Zone 7	0
Tibia—AP	Zone 1	17
	Zone 2	2
	Zone 3	0
	Zone 4	1
	Zone 5	0
	Zone 6	0
	Zone 7	0
Tibia—lateral	Zone 1	5
	Zone 2	1
	Zone 3	0
Patella	Zone 1	0
	Zone 2	0
	Zone 3	0
	Zone 4	0
	Zone 5	0

Discussion

The most important findings of the present study were that metaphyseal sleeves demonstrate high radiographic signs of ingrowth and low revision rates. In the present study, 93.2% of porous-coated metaphyseal sleeves used for AORI types 2 A/B and 3 tibial and femoral bone defects remained stable without evidence of loosening. In all, only five of 74 (6.8%) sleeves required revision, with only two of 74 (2.7%) requiring revision for aseptic loosening. There were no dislocations or bearing failures.

The findings of this study are similar to other studies in literature that show good results with metaphyseal sleeves in the short term. Agarwal et al. reported a 1.9% revision rate for aseptic loosening of metaphyseal sleeves at short-term follow-up in their series of 104 patients [1], Dalury and Barrett stated that they had a 2.2% revision rate for failure of ingrowth of a metaphyseal sleeve at 2 years [8], Graichen et al. reported a 2.1% revision rate for aseptic loosening at a minimum of 2-year follow-up [16], and Huang et al. reported a revision rate of 2.7% at short-term follow-up [19]. These rates were similar to our aseptic revision rate of 2.7% for metaphyseal sleeves.

Other studies with short-term follow-up have demonstrated radiographic osseous in-growth with well-fixed metaphyseal sleeves [2, 3, 6, 26], similar to the patients in our study.

Two previous reports in literature demonstrated osteointegration into porous tantalum cone which were also used to fill large tibial defects [25, 27]. In both reported series, bone graft was used to fill gaps around the cones. The bone graft was necessary because it was difficult to hand shape the cones such that a tight bone implant interface was achieved circumferentially around the cone. This may be avoided with metaphyseal stems as a broaching technique is utilized to prepare the metaphysis for the sleeve. Much like a fit and fill technique for femoral stems in total hip arthroplasty, intimate bone–sleeve contact can be obtained using the broach technique. No additional bone graft was required to fill gaps using metaphyseal sleeves. Thus, using metaphyseal sleeves is ideal in situations where there is bone loss on both sides of the metaphysis, while tantalum cones may be more useful when there is unilateral bone loss.

Similar results with the broach technique have previously been reported in conjunction with a hinged prosthesis [21]. Jones et al. reported 2-year follow-up on 16 knees that were treated with press-fit diaphyseal stems and metaphyseal sleeves with the S-ROM mobile-bearing hinge prosthesis. They reported no loosening and complete bone apposition in nearly all patients. They did not have any reported cases of metallosis due to the morse taper. Although metallosis is a known risk factor, we were not aware of any reported cases of clinically significant metallosis using this implant system.

There are multiple limitations to our study. This is a retrospective review with relatively short-term follow-up, although there is a minimum of 2-year follow-up. There also can be no conclusions drawn about how the patients were doing clinically without appropriate pre-operative or post-operative clinical outcome scores. However, based on the clinical notes at final follow-up, all patients who did not undergo revision were doing well clinically (60/74, 81.1%). Also, the series lacks a control group; so it is impossible to affirm this system over another. However, this series does demonstrate similar short-term formation of a stable implant interface as other systems and highlights several potential advantages of the current system. The broaching technique provides excellent stability immediately after implantation. With the tibial tray secured to the sleeve through a modular interface, the implant does not rely on a cement mantle for stability. This could be positive if the interface remains stable without motion at the modular interface. If there is motion at the modular interface, the potential exists for the generation of metallic debris which could lead to metallosis and extensive tissue damage. However, at short-term follow-up, this was not seen in our series.

In all, stable fixation is one of the keys to long-term success of any implant. Metaphyseal sleeves seem to offer early stable fixation on the tibial and femoral side. In this paper, we reported the earliest series of sleeves that represented our learning curve. Even when implementing this instrumentation early on, there were minimal complications, no fractures, and a low revision rate when using metaphyseal sleeves. However, long-term studies are needed for more definitive answers about the longevity and clinical outcomes of these metaphyseal sleeves.

Conclusion

Short-term stable fixation can be achieved with modular porous-coated press-fit metaphyseal sleeves, which fill defects and provide evidence of radiographic ingrowth. Longer duration studies are needed to ascertain the survival rate of these implants.

Compliance with ethical standards

Conflict of interest LSC receives royalties from DePuy/Synthes related to the topic of this study. The remaining authors do not have any conflicts related to the topic of this study.

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