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Custom-made endofemoral sleeves in knee revision surgery: case report and technical notes

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Summary

Revision total knee arthroplasty is a challenging procedure for every orthopaedic surgeon, especially when a megaprosthesis is involved. Possible surgical solutions in case of distal femur megaprosthesis revision are total femoral replacement (TFR) or amputation/disarticulation. TFR is affected by an extremely high rate of complications, while amputation/disarticulation leads to unacceptable functional results. We report the case of a 59-year-old woman who underwent a staged left knee megaprosthesis revision for infection with massive femoral and tibial bone loss and complete disruption of extensor mechanism following 7 prior surgeries. To manage these problems, we developed a new, custom porous titanium endofemoral sleeve for the femoral side and a custom porous titanium cone for tibial reconstruction that were tailored to the patient's specific bone loss and matched with the tumor prosthetic design used. A custom-made endofemoral sleeve may be a viable solution introducing an intermediate step between distal femur megaprosthesis and total femur substitution. Accurate and detailed surgical planning as well as intraoperative management of soft tissues and residual bone stock are key factors for optimal outcomes.

Key words: revision TKA, megaprosthesis, custom-made, endofemoral sleeve, periprosthetic joint infection

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Introduction

In the last 20 years, the number of total knee arthroplasties (TKAs) has massively increased and the number is projected to increase even further. In addition, revision TKA procedures are expected to grow proportionally [1]. Although surgeons have witnessed a rapid growth in technology and materials for arthroplasties, aseptic loosening, periprosthetic joint infection (PJI), periprosthetic fractures, major osteolysis, extensor mechanism problems, instability, and stiffness still represent common causes for TKA failure. In particular, the current PJI rate is between 0.5 and 2%, but the number of complications is expected to rise. This percentage increases among total knee revisions, as this type of procedure often has additional surgical challenges both for the surgeon and patient. In this specific setting, complex metaphyseal and diaphyseal bone defects often challenge orthopaedic surgeons who must choose the correct therapeutic option to treat the different amount of bone loss.
Although mid-term clinical and radiological data may be optimal, in cases of large metadiaphyseal bone defects none of the "off the shelf" devices can effectively

solve the problem. Moreover, in cases of megaprosthesis failure, very few options are available. Amputation/disarticulation leads to unacceptable functional results, while total femoral replacement (TFR) is an established procedure but is burdened by an extremely high failure rate mainly dependent on the age at initial reconstruction.

We report the case of a 59-year-old woman who underwent a staged left knee megaprosthesis revision for infection with massive femoral and tibial bone loss and complete disruption of extensor mechanism following 7 prior surgeries. To manage these problems, we developed a new, custom porous titanium endofemoral sleeve for the femoral side and a custom porous titanium cone for the tibial reconstruction that were tailored to the patient's specific bone loss and matched with the tumor prosthetic design used. Extensor mechanism reconstruction was performed with a medial gastrocnemius flap.

Case report

A 59-year-old overweight woman came to our clinic for consultation with progressive left knee pain (8/10 on Visual Analogue Scale) mainly unrelated to activity levels. Specific medical comorbidities were hypothyroidism which was managed with replacement therapy and sulfonamide allergy.

The patient reported her first left knee surgery in 1987 after a tibial plateau fracture with subsequent metalwork removal and post-traumatic osteoarthritis with gross knee instability. She underwent primary left TKA in February 2015 with a hinged prosthetic implant (Fig. 1). After 5 months, she was revised for knee instability with poly exchange and two months later, she was diagnosed with a PJI due to extended-spectrum beta-lactamases (ESBL) Klebsiella pnemoniae with subsequent sepsis. PJI was managed with staged protocol with a first spacer (January 2016) that was later revised with spacer exchange for persistence of infection. The patient received her second total joint replacement in June 2017 with a megaprosthesis for bone loss management on the femoral side.

On physical examination, the involved knee showed a partially retracted parapatellar scar extended from the thigh to the mid portion of the tibia with severe soft tissue damage and gross purulent drainage from a fistula located on lower portion of the scar. Another two limited surgical incisions were located on the lateral aspect of the knee. Local swelling and inflammation signs were present. Her limb alignment was neutral. She was able to walk with two crutches for a limited amount of time (about 5 minutes) and was unable to carry out daily self-care activities. Passive left knee range of movement was painful and limited from 0° to 40°. Actively, no flexion was available. Her hip examination results were unremarkable. Her body mass index was 29.4 kg/m^2. Radiographic analysis performed at the time of our first evaluation showed tumor prosthesis with fully cemented femoral and tibial stems (Fig. 1). Extensor mechanism rupture with patella alta (Caton-Deschamps index: 2.8) were observed.

Serologic tests showed high levels of C-reactive protein (CRP) (75 mg/L; range, 0.0 mg/L to 5 mg/L) and erythrocyte sedimentation rate (ESR; 94 mm/h; range, 0 mm/h to 30 mm/h). Arthrocentesis and synovial fluid analysis were performed. Synovial white blood cell count and percentage were 4508 cells/μL and 92%, respectively. Leukocyte esterase test showed a 3+ result and microbiological analysis demonstrated methicillin-resistant Staphylococcus epidermidis (MRSE) infection.

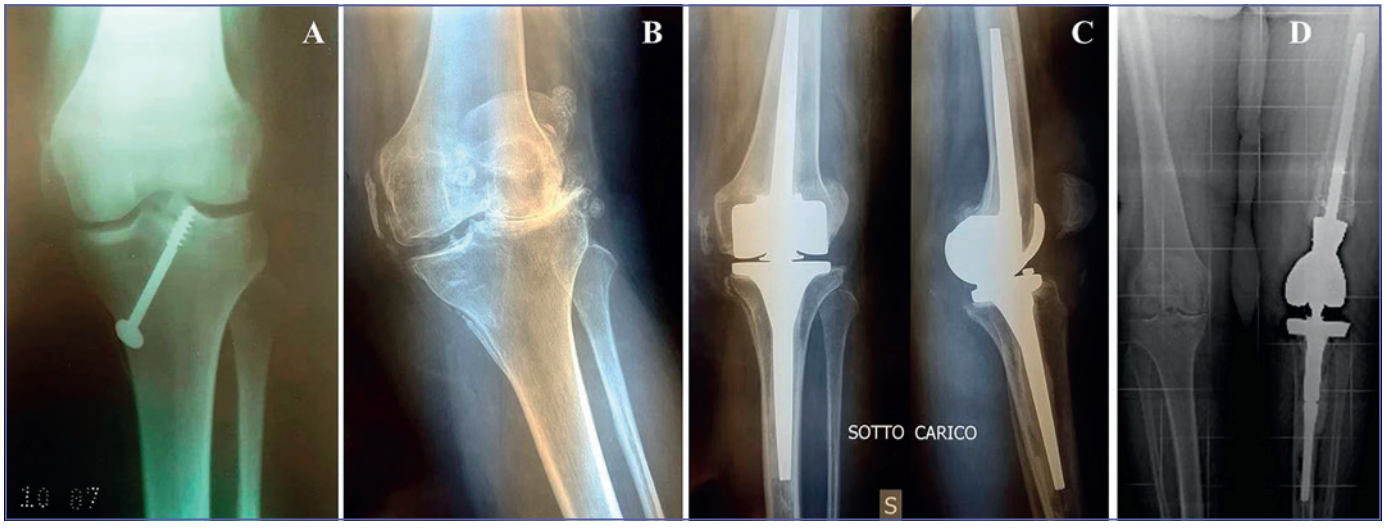

Figure 1. x-ray of previous surgeries. A) tibial plateau osteosystesis (1987); B) post-traumatic osteoarthritis (2014); C) TKA with an hinged prosthesis (2015); D) TKA with a femoral megaprosthesis after a staged revision for infection (2017). TKA: total knee arthroplasty

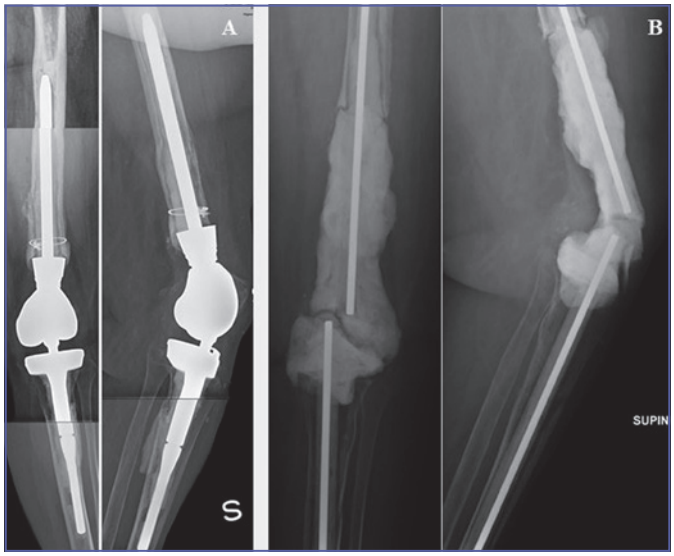

Figure 2. A) preoperative X-ray analysis; B) Aantibiotic-loaded static spacer.

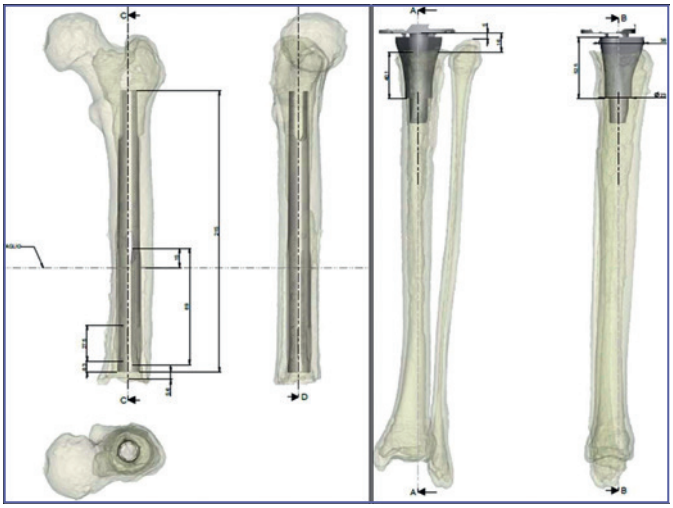

Figure 3. Femoral (A) and tibial (B) custom made implant proposals.

Knee arthrodesis was not contemplated as an option because of the massive bone loss on the femoral side that would have prevented a final optimal bone fusion. Prosthesis retention and debridement were not indicated because of the presence of a difficult-to-treat germ, soft tissue impairment and chronic infection. Above-the knee amputation and antibiotic suppressive therapy were evaluated but considering their unacceptable results and the young patient's age, a further two-stage procedure was attempted. The patient gave her personal written and informed consent before each surgical procedure.

First, we performed TKA removal with extensive debridement of the infected tissues and bone cement. The extensor mechanism was completely degenerated and required a radical debridement with complete patellectomy. A hand-made stemmed antibiotic-impregnated static cement spacer (Palacos® R+ G - Heraeus Medical GmbH, Wehrheim, Germany) armed with two 15x200mm external fixation rods was placed (Fig. 2). Intraoperative cultures confirmed the presence MRSE, which we treated with an intravenous 6-week course of daptomycin and ertapenem. Accurate follow-up with serological CRP, ESR, and preoperative synovial fluid aspiration was performed during the interstage period.

During the interstage period, we produced a new, custom-made porous titanium sleeve on the femoral side and a custom-made cone that matched the specific patient's bone loss on the tibial side (Fig. 3). The aim was to preserve and strengthen the proximal femur to spread weight-bearing stresses on the residual bone. Both the custom devices aimed to achieve optimal bone ingrowth and joint line restoration using the available residual bone. We used the contralateral knee as a reference configuration.

In cooperation with industry engineers (Adler Ortho S.p.A., Cormano, Milano, Italy), the custom-made implants were tailored and designed based on the preoperative computed tomography (CT) scan with the spacer in situ. The custom-made femoral device was created with an external diameter of 17.3 mm and had 215 mm of scratch fit interface on the diaphysel region for bone ingrowth. The internal diameter was 13 mm. Due to femoral procurvation; an osteotomy line was planned 85.4 mm proximally to the distal femoral bone cut. Five 89-mm antirotational wings were created on the distal portion of the sleeve. The proximal tip has a thin diapason section in order to better distribute load stresses on the proximal femur and allow a future short hip stem implantation. Relatively to this final point, a reference mark on the distal side of the sleeve was present in order to guide the diapason portion in the correct anteversion. The tibial device was designed with a mean metaphyseal outer diameter of 30.5 mm and 41 mm of scratch fit. The inner diameter was 19.5 mm.

The patient underwent TKA reimplantation with distal femur tumor prosthesis (Zimmer Biomet, Warsaw, IN, USA) according to preoperative planning 16 weeks after the first stage (Fig. 4). The extensor mechanism disruption was managed with a medial gastrocnemius flap.

The patient was mobilized from the third postoperative day. She was allowed toe-touch weight bearing for six weeks, and full extension of the operated leg was maintained for 2 weeks. According to our department's protocol, antibiotic therapy was prolonged until the results of the intraoperative cultures were obtained. Eleven days after surgery, antibiotic therapy was discontinued after the intraoperative culture results were negative. After the 45-day clinical and radiological evaluations, the patient started 50% weight-bearing and reached 100% weight-bearing at four months after surgery. At 1-year fol-

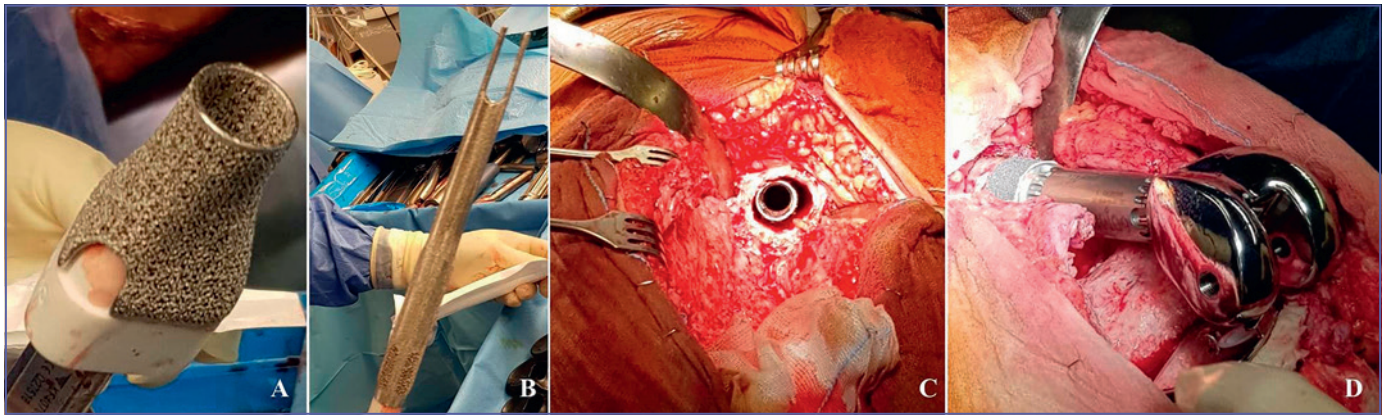

Figure 4. Intraoperative details. A) custom-made tibial device; B) custom-made endofemoral sleeve; C) endofemoral sleeve in situ; D) final femoral component implantation.

low-up, she could perform daily-life activities with 0° to 60° of range of movement, no pain, and she rated her outcome as satisfactory. Radiographic analysis performed during follow-up showed excellent implant alignment and adequate cementation with no radiolucent lines or migration (Fig. 5).

Discussion

Revision TKA is a challenging procedure for every orthopaedic surgeon, especially when a megaprosthesis is involved. Possible surgical solutions in case of distal femur megaprosthesis revision are TFR or amputation/disarticulation.

TFR is a viable solution in a perspective of limb salvage reconstruction. The most compelling advantage of TFR is the achievement of immediate fixation, which permits early mobilization and ambulation recovery. Although good long-term outcome can be obtained even in cases of the so-called "shattered" femur, TFR is affected by an extremely high rate of complications with up to a 72% failure rate [2]. Moreover, some authors have suggested that TFR performs poorly in the setting of infection. In a recent paper, Toepfer et al. [3] retrospectively reviewed 22 patients with TFR at a mean follow-up of 63 months. Nine underwent TFR for oncologic reasons and 13 for failed revision arthroplasty. Overall, the failure rate for TFR was 59.1%.

In this complex panorama, we report a case of distal femur megaprosthesis revision with a custom made endofemoral sleeve. This particular solution has several advantages. Firstly, it preserves the proximal femur for further possible revisions or substitution. The patient was a 59-year-old woman with no major comorbidities and a long-life expectancy. Further revision is highly anticipated and in such possible situation, TFR can still represent a limb salvage option.

From a biomechanical point of view, bone stress and the relative load transferred to the bone are key factors that are strictly

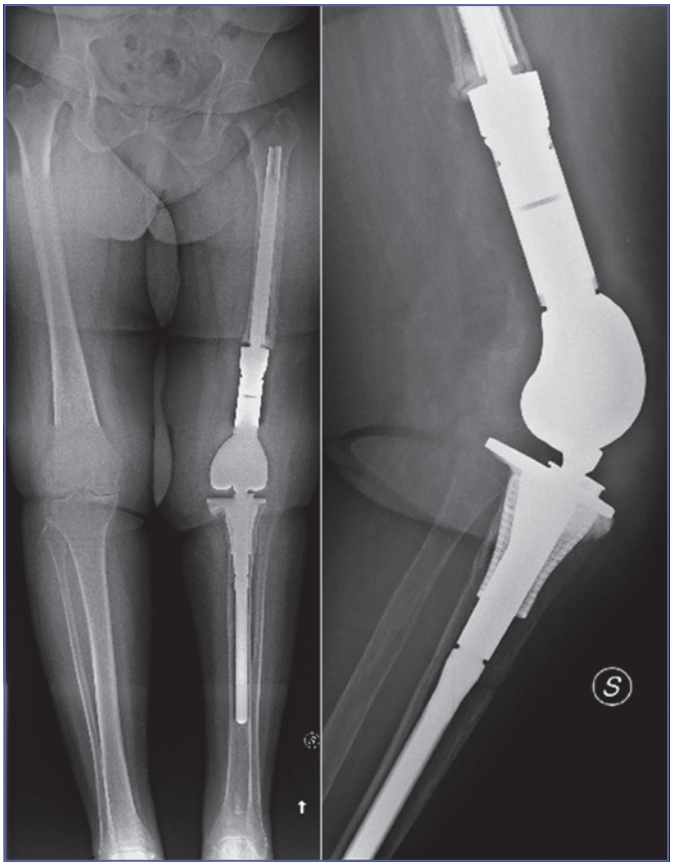

Figure 5. Postoperative x-rays at 1-year follow-up showing optimal alignment and no radiolucent lines, loosening or implant migration.

related to the life expectancy of each reconstructive technique. The authors believe that the proposed endofemoral sleeve may provide a better transmission of loads on the residual femoral bone, thereby reducing the risk of stress-shielding and in-

Table I. Summary of the four cases treated with custom-made devices.

Case	Case 1	Case 2 (case report)	Case 3
Sex	F	F	M
Age	67	59	36
Side	R	L	R
Reason for revision	PJI	PJI	PJI
Number of previous surgeries	6	7	8
Extensor mechanism status	Good	Disrupted (medial gastrocnemius flap)	Disrupted (medial gastrocnemius flap)
KSS (final follow-up)	78	83	84
Complications	No	No	No
Final follow-up (months)	27	20	18

L, left; R, right; PJI, periprosthetic joint infection.

creasing the implant stability. Fully cemented stems of pure press-fit stems may concentrate load on small parts of bone creating stress raisers. This device may be able to provide a low stress gradient on the bone during daily activities, preventing the patient from feeling pain and the risk of loosening and periprosthetic fractures. Moreover, porous titanium allows firm osseointegration with the residual host bone, strengthening the femoral diaphysis and improving implant stability.

Custom-made devices are a new and promising option in several complex surgical settings [4].

Burastero et al. firstly reported the experience with custom porous titanium cones in complex knee revision surgery showing optimal short-term clinical and radiological outcomes [5]. These results are confirmed by Cherny et al. [6].

Although the practice of porous custom-made cones has obtained successful clinical and radiological in the short-term, no reports of custom endofemoral sleeves in knee megaprosthesis failure management are present in literature. To our knowledge, this is the first report of such surgical approach in knee tumor prosthesis revision.

Since 2018, we have treated three cases using custom-made porous titanium endofemoral sleeves for megaprosthesis failure and had optimal clinical and radiological results in the short-term, with no instances of loosening, component migration, or mismatches between preoperative planning and intraoperative findings (Tab. I).

Knee megaprosthesis failure is a catastrophic event and represents one of the most challenging procedures, even for experienced orthopaedic surgeons. In such limb salvage scenarios, further steps are needed and include TFR (exposing patients at high risk of early failure) or amputation/disarticulation that yield unacceptable results. A custom-made endofemoral sleeve may be a viable solution by introducing an intermediate step between distal femur megaprosthesis and total femur substitution. Accurate and detailed surgical planning as well as intraoperative management of soft tissues and residual bone stock are key factors for optimal outcomes.

Ethical consideration

None.

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Conflict of interest

The Authors declare no conflict of interest.

Author contributions

The Authors contribuited equally to the work.

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