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Case Report

Revision Distal Femoral Replacement Using Custom-made Stem and Cone to Augment Proximal Fixation

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ABSTRACT

Achieving bone fixation during megaprosthesis revision presents a formidable challenge in view of the substantial bone loss. We report treatment of a failed revision distal femoral replacement in an active 36-year-old male mechanic remotely treated for osteosarcoma. A custom stem and cone were manufactured to augment fixation and preserve bone stock within a short segment of the remaining proximal femur. The patient returned to regular function without the need for assistive devices. Follow-up imaging demonstrated stable implant fixation at 1-year follow-up. While cones and sleeves have vastly improved fixation in revision knee arthroplasty, a custom-made cone for the proximal femur was used to augment fixation of a revision megaprosthesis and obviate the use of a total femoral replacement.

Introduction

Modular megaprosthesis implantation has been a widely utilized reconstructive strategy after segmental bone resection for tumors [1]. In comparison with primary arthroplasties, higher complication rates continue to limit the survival of megaprostheses, particularly in young and active patients that have overcome cancer. Previously published literature documents revision rates approaching 40% at 15 years [2]. Despite advancements in implant design, novel strategies to improve fixation and preserve native bone stock should be considered in anticipation of future revisions.

The use of highly porous metal cones and sleeves has become a successful strategy for augmenting fixation in revision knee arthroplasty [3-5]. Cones provide structural support with biologic fixation in lieu of cement. They can reconstruct large uncontained defects and mitigate many of the downsides of structural allografts such as graft nonunion, fracture, and resorption.

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In this report, we present an active 36-year-old male mechanic with aseptic loosening of a revision distal femoral replacement (DFR) previously utilized to treat osteosarcoma. Due to a very short segment of the remaining proximal femur, a custom-made distal femoral implant and a custom-made cone were utilized to achieve fixation in the proximal segment and salvage the native hip joint. The patient was informed that data concerning the case would be submitted for publication, and he provided consent.

Case history

A 36-year-old male with a history of left distal femoral osteosarcoma presented to our institution with left thigh pain. Prior to presentation at our institution, patient was treated with chemotherapy and a left distal femoral megaprosthesis at the age of 12 years old. Four years later, the implant was revised due to aseptic loosening of the femoral stem with the addition of a cortical strut allograft anteriorly fixed with a plate. His past medical history was significant for chemotherapy-induced heart failure, for which he was taking diuretic and antihypertensive medications. He is otherwise active and healthy, cancer-free, and works as a truck mechanic.

After his second surgery, the patient was symptom-free up until a year prior to his presentation. The pain was situated in the

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proximal half of the left thigh without radiation to the hip. It was present with activity and was exacerbated by weight-bearing. It was associated with progressive shortening of the ipsilateral lower extremity over the past year. No history of trauma or infectious symptomatology was noted.

On physical examination, the surgical scars were well healed without signs of infection. A limb-length discrepancy of 4 centimeters with moderate quadriceps atrophy and varus alignment in comparison with the contralateral lower extremity was present. No mass or tenderness on palpation of the whole left lower extremity was noted. Full range of motion of hip and knee was preserved with terminal pain in the hip. The distal neurovascular exam was normal. The patient used a cane to ambulate due to pain and was having difficulty at work.

Laboratory investigations revealed a normal complete blood count without leukocytosis. The values of C-reactive protein and erythrocyte sedimentation rate were 1.80 mg/L and 16 mm/h, respectively. Microbiological analysis of an implant fluid aspiration conducted under image guidance showed no sign of bacterial or fungal growth. Preoperative imaging is displayed in Figure 1 demonstrating aseptic loosening of femoral implant, which had subsided proximally and breached the anterolateral cortex. Furthermore, plain radiographs and computed tomography scan demonstrated a well-preserved native hip joint without signs of osteoarthritis.

Surgical planning and technique

In order to preserve the patient's hip joint and augment fixation in the remaining short segment of the proximal femur, a custom-made cone and stem were designed using a metal suppression computed tomography scan, as shown in Figure 2. The stem was designed to interface with the existing GMRS (Stryker, Mahwah, NJ) DFR but had no flanges on the taper so that the anteversion/rotation could be adjusted freely. A 13-mm cylindrical cemented stem was designed with 2 holes and custom aiming arm to accommodate two 6.5-mm reconstruction locking bolts to be placed through the stem and into the femoral head. A custom, three-dimensional (3D) printed cone made of highly porous titanium was designed to augment fixation in the proximal femur. A 2-degree taper (larger distal, smaller proximal) was employed so that the existing 2-degree reamers for the restoration modular implant (Stryker, Mahwah, NJ) could be used to prepare the bone prior to cone insertion.

The surgery was performed under general anesthesia. The patient was placed on a radiolucent table in a right lateral decubitus position with radiolucent hip positioners. The previous anterolateral incision was utilized to approach the implant. After anterior retraction of the vastus lateralis muscle, a pseudocapsule was encountered around the implant. A fresh frozen sample and 3 tissue culture specimens were sent for pathological and microbiological analysis, respectively. The implant was grossly loose and subsided in varus, rotating freely at the implant-bone interface. The taper between modular interconnects was disengaged, and the entire femoral implant was removed (retaining the well-fixed tibial component). Under fluoroscopic guidance, the broken proximal cement was carefully removed with Moreland instruments (DePuy, Warsaw, IN). Due to poor bone stock proximally, effacement and reaming of bleeding host bone was also performed under fluoroscopic guidance. Next, the cone was impacted in place to fill the defect left by the previous implant. Subsequently, the stem was inserted, and a temporary Kirschner wire was inserted through the proximal part of the implant into the femoral head using the aiming device (Fig. 3). The locking screw holes were drilled accordingly. The rotation of the custom-made implant was marked on the bone, and then the implant was removed and the canal was prepared routinely. Antibiotic-impregnated medium viscosity cement was vacuum-mixed and injected into the proximal femoral canal (and cone) in a retrograde fashion without pressurization. The final implant was then inserted under fluoroscopic guidance, followed by the insertion of 2 lag screws through the implant before the cement cured (Fig. 4). In order to reestablish his length, the entire

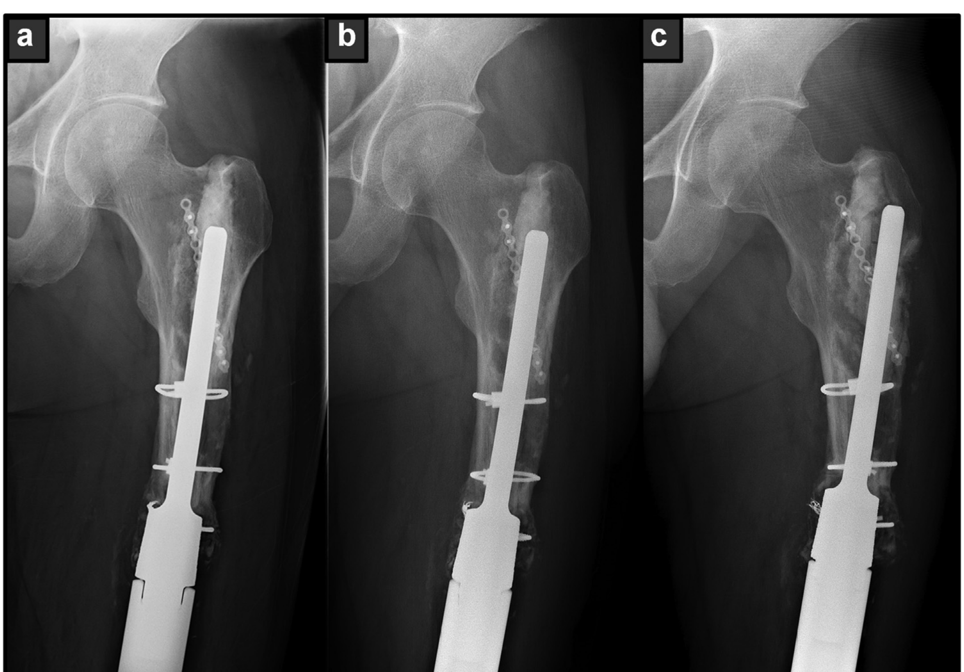

Figure 1. Three anteroposterior views of the left hip demonstrating chronological progression of loosening and subsidence of the femoral stem with breach of the anterolateral cortex. (a) 2016 (b) 2018 (c) 2020.

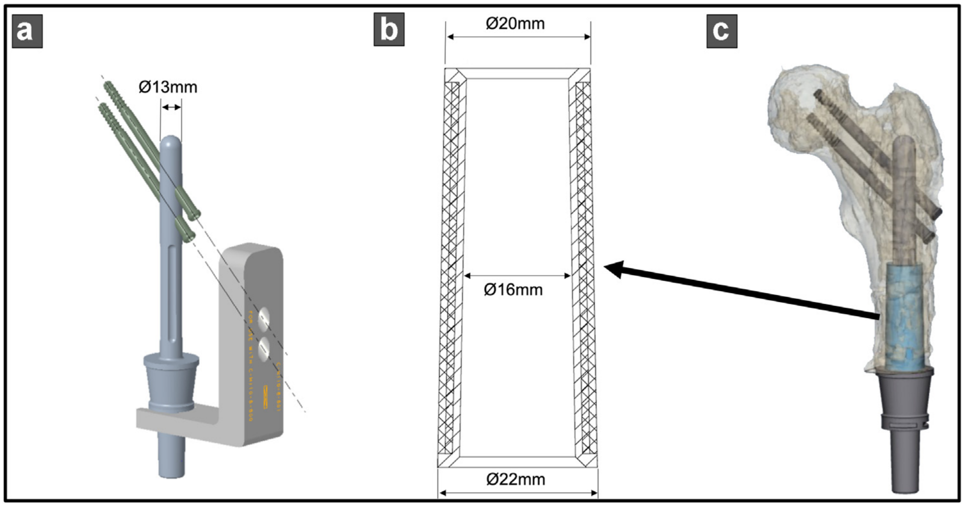

Figure 2. Preoperative templating and implant design. (a) Custom femoral stem, custom screw guide, and 2 lag screws. (b) Magnified view of the custom cone design with dimensions. An incorporated retrograde taper allows use of a 1.5 mm and 0.5 mm cement mantles distally and proximally, respectively. (c) A metal suppression three-dimensional reconstructed computed tomography scan of the proximal femur after final implant insertion.

pseudocapsule was sharply excised, and a new DFR was inserted and connected to the tibial component. The wound was then thoroughly irrigated and closed in layers. An incisional vacuum-assisted closure device was then placed for 7 days.

At the 1-year follow-up postoperatively, the patient had returned to his regular work as a mechanic without pain or the need for assistive devices. Physical examination demonstrated a full arc of painless range of motion. Preoperative and postoperative functional scores at 1-year were recorded. The Harris hip score increased from 36 preoperatively to 100 postoperatively. The Western Ontario and McMaster Universities Osteoarthritis Index was used to objectify pain, stiffness, and physical function. These were 15, 2, and 48, respectively, in the preoperative period. One-year after the surgery, all 3 domains went down to 0. The short-form health survey (SF-12) was utilized to determine overall physical and mental health. Both components demonstrated improvement postoperatively. The physical component score increased from 35 to 55, and the mental component score increased from 45 to 61. Radiographs showed well-aligned implants with adequate bony ingrowth and femoral head flattening that was not present preoperatively (Fig. 5).

Discussion

In addressing the challenge of a failed megaprosthesis in a young, active patient with a short proximal femoral segment, there were 2 goals/aims: 1) achieving fixation in a short proximal femoral segment with compromised bone stock, and 2) preservation of the native hip joint. To meet these challenges, a custom-made distal femoral implant and custom-made cone were created.

The option of repeat structural allografting with implant exchange was contemplated. This had previously failed in our patient.

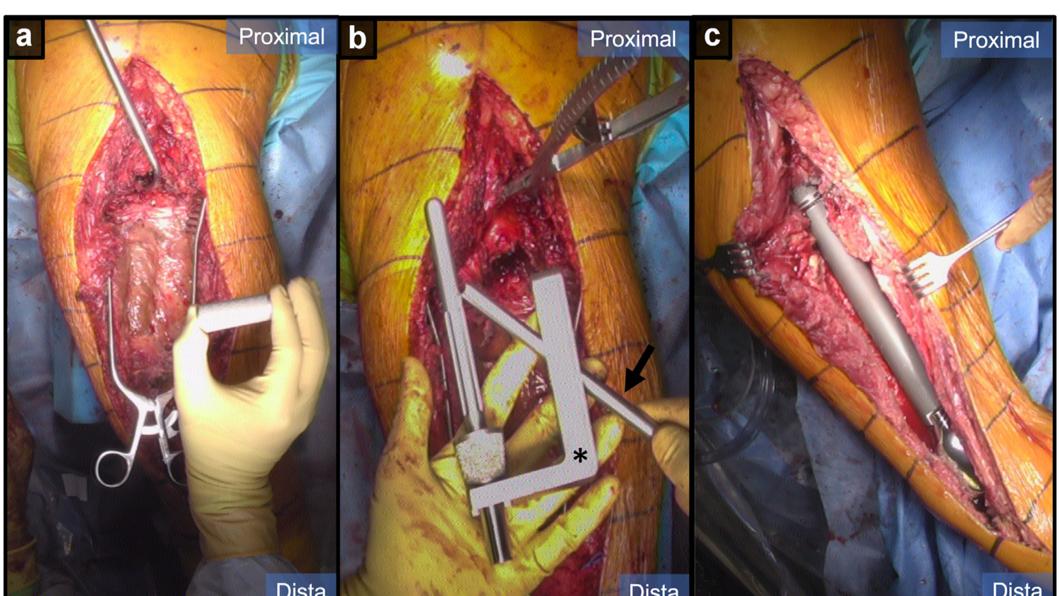

Figure 3. Intraoperative images: (a) Custom highly porous cone prior to implantation. (b) Custom femoral stem assembled with custom screw guide (asterisk) and sleeve (arrow) for lag screw insertion. (c) Final custom implant interfacing with a global modular replacement system (GMRS) implant.

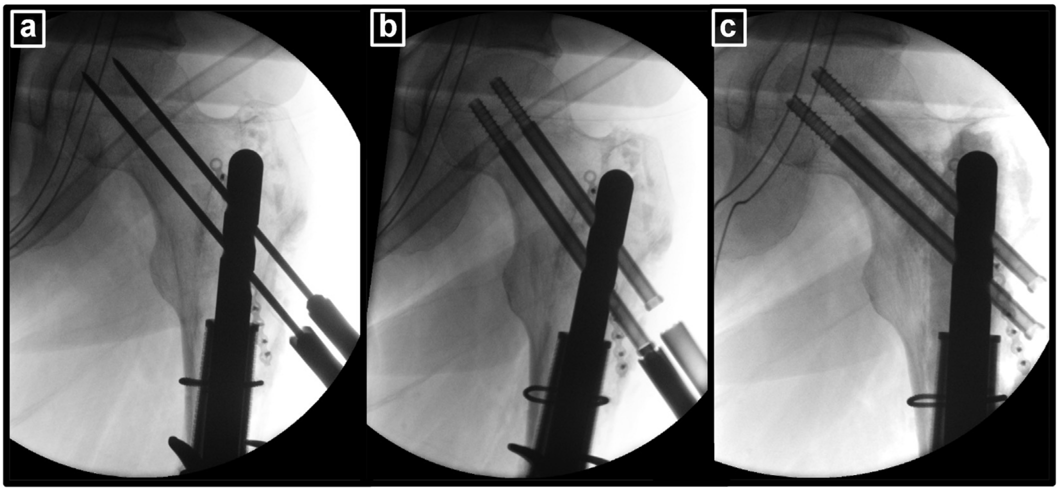

Figure 4. Sequential intraoperative fluoroscopic images: (a) Two Kirschner wires inserted through custom aiming guide with corresponding sleeve. (b) Drilling pathway for 6.5 mm locking screw prior to cementation. (c) Final construct after cementation and 6.5 mm locking screw insertion.

Additionally, a retrospective case series published by Cisneros et al. [6] demonstrated a high failure rate with use of a structural allograft in patients younger than 40. In all 6 cases enrolled in their series, the implanted structural allografts had failed and were removed in exchange for a modular megaprosthesis. The cause of failure was mostly attributed to nonunion of the structural allograft and aseptic loosening in all involved cases. Debates regarding the use of allograft-prosthesis composite as opposed to modular megaprosthesis implantation lack a clear consensus in cases similar to the presented one.

Total femur replacements were first introduced for Paget's disease in 1956 by Buchman [7]. Improvement in implant design and modularity has allowed for their utilization in an array of oncologic and nononcologic conditions [8-11]. Despite this evolution, recent literature shows a 33% failure rate of total femur replacements in the setting of revision surgery in a relatively young patient population with nononcologic conditions [12]. To our knowledge, long-term clinical outcomes of total femur replacements for non-oncologic diagnoses in a young population have not been established.

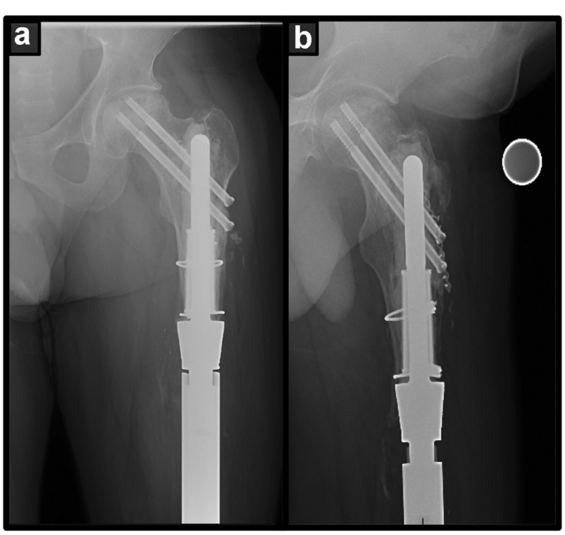

Figure 5. (a) One-year follow-up anteroposterior and (b) lateral views of the left hip demonstrating adequate fixation with residual femoral head flattening.

Preservation of the patient's proximal femur bone stock was paramount given his young age and the absence of osteoarthritic changes present in the hip joint. The use of porous-coated metaphyseal cones and sleeves in the setting of revision arthroplasty has empowered surgeons when tackling bone loss in revision knee arthroplasty. Cones provide hybrid fixation through bony ingrowth onto their highly porous titanium surface while allowing cementation of a stem through the cone. This provides biologic fixation to achieve long-term stability [13]. Furthermore, adding the cephalomedullary locking bolts through the stem provided additional axial and rotational stability to the construct.

Three-dimensional printing of custom cones has shown encouraging results when used to accommodate defects in revision knee arthroplasty. In short-term follow-up, Tetrault et al. [14] report good 2-year survivorship when using 3D-printed titanium metaphyseal cones. Furthermore, 3D-printed patient-specific designs may serve as effective alternatives in addressing significant bone loss in revision knee replacements, as shown by Cherny et al. [15]. In this case, we utilized a custom cone to augment our fixation in a very short segment of the remaining proximal femur and obviate the use of a total femoral replacement.

Summary

Revision arthroplasty surgeries in young patients with previously implanted megaprostheses present a major challenge. The use of a custom stem and cone provided an attractive alternative to total femoral replacement and has the advantage of offering better long-term fixation and function to a young and active patient.

Conflicts of interest

The authors declare there are no conflicts of interest.
For full disclosure statements refer to https://doi.org/10.1016/j.artd.2023.101158.

Informed patient consent

The author(s) confirm that informed consent has been obtained from the involved patient(s) or if appropriate from the parent, guardian, power of attorney of the involved patient(s); and, they have given approval for this information to be published in this case report (series).

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