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Case Report

Management of tibial nonunion and osteoarthritis using a 3D-printed titanium cone: A case report

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ABSTRACT

The use of customized 3D-printed structures has been gaining popularity in non-union management, as it allows for bypassing the defect while promoting osseointegration. Additionally, porous titanium implants minimize stress shielding due to their stiffness and elastic modulus being closer to that of bone. The interconnected channels increase the surface area and provide space for cell adhesion and proliferation. This study presents the case of a 62-year-old female patient with concomitant knee osteoarthritis recalcitrant aseptic atrophic nonunion in the tibial proximal metaphysis. Due to the small distance between the nonunion site and the joint line, nonunion treatment had to be included in the treatment plan, as it would result in a lack of mechanical stability of the tibial component, and techniques such as plating were not an option. A customized 3D-printed porous titanium cone was used to bypass the fracture site and support the stem used with the CCK prosthesis, allowing for simultaneous nonunion and osteoarthritis management.

Introduction

The treatment plan for aseptic nonunion should prioritize both rapid consolidation and limb rehabilitation [1], and as a diamond concept, mechanical stability and biological conditions should be equally emphasized to optimize healing in long bones [2]. The construct should provide adequate mechanical stability, creating proper biological conditions to promote osteogenic cells while at the same time creating an osteoconductive bone matrix.

As a novel treatment option, 3D-printed customized porous titanium cones have been gaining popularity in recent years for bypassing nonunion sites. They provide adequate stability while minimizing stress shielding because their mechanical properties are close to the bone. The interconnected channels on their outer surface increases their surface area and provide cell adhesion and proliferation space, resulting in superior bone regeneration. A minimum pore size of 300μm and porosity greater than 60 % have been shown to result in optimal osseointegration [3,4].

This study will present recalcitrant aseptic atrophic nonunion in the tibial proximal metaphysis of a 62-year-old woman with concomitant knee osteoarthritis. challenge is This case's main fixation of the nonunion while using the total knee prosthesis. A patient-

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specific 3D-printed porous titanium cone was used for this purpose allowing for simultaneous nonunion and osteoarthritis management.

Informed consent was obtained from the patient, and the local ethics committee approved the study protocol.

Case presentation

Patient was a 62-year-old female who has previously undergone hip hemiarthroplasty, and ORIF using double plating technique and BMP-loaded allograft for treatment of a femoral neck and a proximal tibial fracture caused by an accident in Feb 2021. Three months postoperatively, full weight bearing was permitted to accelerate fracture union (Fig. 1).

In the ninth-month follow-up evaluation, patient reported debilitating right knee pain and difficulty walking. Full standing X-Ray revealed a tibial fracture nonunion and stage four osteoarthritis based on the Kellgren and Lawrence classification.

Two options were presented to the patient: A) Re-fixation using an iliac autograft during the first stage and total knee arthroplasty in the second stage after one year and satisfactory union. B) Simultaneous management of the nonunion, accompanied by total knee arthroplasty. Patient chose option B after thorough explanation of both approaches.

A two-stage approach was chosen to ensure the nonunion site was aseptic. Preoperative assessments indicated ESR and CRP levels were within the normal range, and device removal was carried out during the first stage in June 2022. Removal of two screws that were deeply embedded in the bone was left for the main surgery (Fig. 2).

Intraoperative cultures were negative after 14 days, and inflammation factors returned to the normal range after 3 weeks, therefore, the patient was a candidate for TKA with a long tibial stem to bypass the nonunion site.

The main challenge was the close proximity of the nonunion site to the joint, making it difficult to achieve the desired level of stability. Plating was not feasible due to the lack of space for sufficient number of screws and the long tibial stem would not provide sufficient stability at the nonunion site.

A patient-specific porous titanium implant was used to address the nonunion fixation. The porous structures promote osseointegration and biological fixation by allowing extensive bodily fluid diffusion through the implant pores and increasing the bone-implant contact surface. Also, the implant was designed based on the patient's anatomy to bypass the nonunion fracture site providing mechanical stability. The 3D model of the patient's bone was reconstructed from the CT scan and the implant was designed based on the simulation of the TKA and the nonunion site allowing the tibial stem to pass through. The pore size of the porous structure was chosen to be 500 μm with 70 % porosity to maximize osseointegration. The implant was manufactured using medical-grade titanium alloy (Ti6Al4V ELI) and was then sterilized using gamma irradiation (Fig. 3).

On Sep 2022, with no sign of infection, the patient underwent primary TKA using LCCK prosthesis (NexGen, Zimmer, Warsaw, IN, USA) for arthritis by hybrid fixation (cemented metaphysis and non-cemented diaphysis). The femoral component was fixed using a fully cemented 13×60 (mm) straight stem, and the tibial component was fixed with a cementless 12×100 (mm) straight stem and the customized implant to bypass the nonunion site.

The post-operative radiography showed satisfactory alignment and the position of the customized implant was in agreement with the preoperative simulation.

After 6 weeks, follow-up radiographic evaluations confirmed the solid union and osseointegration in were taking place. After 6 months, full union was observed, and the patient returned to full activity with a full knee range of motion, with no evidence of pain,

Fig. 1. Anteroposterior and lateral radiographs after fixing the proximal tibial fracture by a double-plating technique.

Fig. 2. Postoperative AP and lateral view of first-stage device removal, showing the proximal tibial nonunion and medial compartment osteoarthritis.

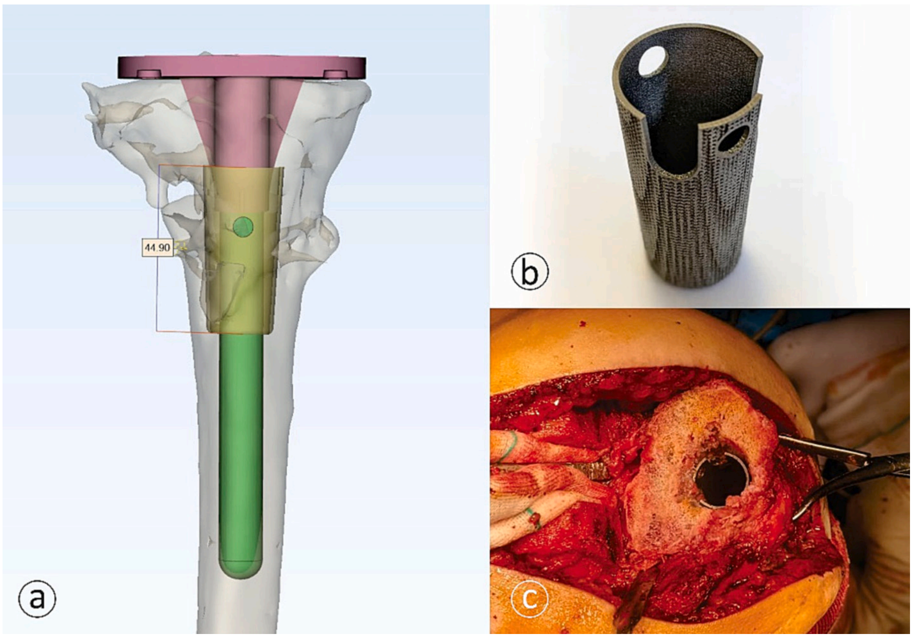

Fig. 3. (a) Preoperative cone design and surgical planning simulation (b) Printed customized porous titanium cone (c) Intraoperative placement of customized cone.

instability, or stiffness (Fig. 4).

Discussion

A number of treatment approaches exist for management of nonunion in proximal tibial stress fractures in osteoarthritic knee

Fig. 4. AP and lateral view radiographs at 6 months, in which full bone union is observed.

depending on the location, which include performing TKA using cemented long stem [5,6], cementless long stem with bone graft [7], or using a compression plate and bone graft [8].

In studies, where nonunion of HTO and knee osteoarthritis were reported, the treatment of nonunion was excluded, and TKA using tibial stem had satisfactory results [9].

In the presented case, due to the close proximity of the nonunion site to the joint line, it was not possible to exclude the nonunion treatment due to mechanical instability for the prosthesis placement, and techniques such as plating were not feasable because of insufficient space.

Simultaneous management of both knee osteoarthritis and nonunion, using a customized 3D-printed porous titanium cone was chosen which promotes creeping substitution by providing suitable rigid fixation while bypassing the nonunion site and supporting the fixation.

One of the advantages of designing patient-specific cones using CT scan is the possibility of matching the geometry of the medullary canal, the length of the lesion, and the length required to achieve proper fixation and stability [10].

Based on the results of the presented case, treatment of knee arthritis using TKA combined with a 3D-printed patient-specific cone can be suggested in cases where there is not enough space between the aseptic nonunion site and the joint line.

Declaration of competing interest

The authors declare that they have no conflicts of interest.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.tcr.2023.100937.

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