CASE REPORT

Knee Reconstruction Using 3D-Printed Porous Tantalum Augment in the Treatment of Charcot Joint

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Background: Charcot joint disease is a rare neurogenic lesion of the joint characterized by progressive joint destruction with dislocation or subluxation. However, whether a joint replacement should be performed for severe joint damage is controversial.

Case presentation: This paper reports a case of severe Charcot joint disease with a large bone defect that was treated with arthroplasty assisted by a customized 3D-printed porous tantalum. The patient was admitted to the hospital with a 9-year history of bilateral knee pain that had aggravated in the past 2 months. Radiography showed osteogeny and sclerosis in both knees, free bone fragments, heterotopic ossification, new bone, and osteophyte formation, irregular margins, apparent narrowing of joint space, and severe joint damage (Anderson Orthopedic Research Institute classification type III). Based on the present illness, history, imaging, and laboratory examination, Charcot joint disease was confirmed. Conservative treatment has been reported in the literature. There are limited reports on the surgical treatment of severe Charcot joint disease. We followed up with the patient for a year after the operation, and the imaging and clinical evaluation results were good. Postoperative X-ray examinations showed good alignment of force lines, good joint space, and no evidence of loosening. The patient was mobile and did not need crutches.

Conclusions: Through accurate surgical evaluation and preparation of 3D-printed porous tantalum implants, severe AORI classification type III Charcot joint disease can effectively restore the range of motion of the knee joint, the lower limb alignment, and finally achieve good functional results of walking without crutches.

Key words: 3D-printed porous tantalum augment; Charcot joint; Knee reconstruction; Revision joint surgery

Introduction

Charcot joint disease is a rare neurogenic lesion of the joint caused by syringomyelia or other diseases. It often manifests as joint swelling, limited movement, and joint instability. However, pain symptoms are often inconsistent with imaging results, presenting as joint damage with mild pain or a history of trauma. Previously, Charcot’s joint was considered inoperable. Because the biggest problem is how to fill large bone defects and solve joint instability. However, with the progress of surgical techniques and materials, a large number of Charcot’s joints have achieved a relatively satisfactory prognosis. Nevertheless, there is considerable debate on whether to perform the joint replacement for severe joint damage. With the development of 3D printing technology, joint replacement is now possible for severe Charcot joint disease to solve joint pain, instability, and large bone defects that are difficult to repair.

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Received 9 October 2021; accepted 9 August 2022
**Case Presentation**

**General Condition**
A 53-year-old man presented to our hospital with a 9-year history of pain in both knees that had aggravated in the past 2 months. Radiography showed osteogeny and sclerosis in both knees, as well as free bone fragments, heterotopic ossification, new bone, and osteophyte formation, irregular margins, apparent narrowing of joint space, and severe joint damage (Anderson Orthopedic Research Institute [AORI] classification type III). The patient was diagnosed with the Charcot’s joint in both knees. He had no history of hypertension, diabetes, or drug allergy. Laboratory tests revealed no obvious abnormalities (Fig. 1A–C).

**Physical Examination**
The patient was 165 cm tall, weighed 70 kg, and had a body mass index of 25.7 kg/m². His left leg was 2 cm shorter than the right leg, and his left knee joint had a valgus deformity and a fusiform swelling. The left knee was tender outside the joint and around the patella. Patellar ballottement was positive. The patient’s flexion and extension activities were limited due to joint pain. The range of motion was 100° of flexion, 5° of extension, and 15° of valgus at the left knee and 110° of flexion and 5° of extension at the right knee. There was no numbness or discomfort in the lower limbs, and the peripheral circulation was good.

**Radiological Examination and Preoperative Preparation**
Based on preoperative x-ray (Siemens DR Aristos FX Plus, Frankfurt, Germany) and computed tomography (Siemens CT Definition Flash, Frankfurt, Germany), the model of bone defect in the knee joint was reconstructed using a computer by CAD and 3-Matics software (Materialise, Leuven, Belgium). According to the defect’s severity and the knee joint’s normal anatomy, a 3D-printed porous tantalum (3D-P-pTa) was designed. Additionally, 3D-printed technology and tantalum powder were used in this study. We printed high-purity tantalum powder (99.99%) into pre-designed porous tantalum augment through selective laser melting technology (SLM) by using a SLM apparatus (FS271 M Farssoon, Inc., Changsha, China) of Zhuzhou Printing Additive Manufacturing Co. LTD., China. The whole manufacturing process is in a high argon atmosphere, using laser power 250W and scanning speed 100 mm/s. Finally, porous tantalum augment with a pore size of about 450 μm and porosity of 65%–80% is printed. Before the operation, the 3D-P-pTa was sterilized and assembled on the model (Fig. 2A–D).

**Surgical Procedure and Postoperative Recovery**
Depending on the type of bone defect and collateral ligament function, 3D-P-pTa and rotary-hinge prostheses were considered for the right knee. A 3D-P-pTa augment with four screws was used to fix the tibial defect. A 120-mm femoral medullary cavity extension rod, 6-mm offset, and 120-mm tibial medullary cavity extension rod were installed to obtain the initial stability of the femur and tibia. The right knee was fitted with a size four tibial plateau and a size five femoral prosthesis (Depuy Synthes, West Chester, PA, USA). Further, a 13-mm intercondylar liner was selected to balance the stretch and flexion gaps. After placement of the prosthesis, there was a skin defect measuring 10 cm × 1 cm on the right knee, and free flap transplantation was performed. The constrained condylar knee prosthesis was selected for primary knee replacement because of the mild defect in the left knee. The tibial plateau defect was filled with bone cement and fixed with screws. A 60-mm medullary cavity extension rod, 6-mm offset, and 60-mm tibial medullary cavity extension rod were installed. A size four tibial plateau prosthesis and size five femoral prosthesis were used for the left knee.

![Fig. 1 A 53-year-old man with Charcot’s knee disease. (A) Lateral radiograph of the right knee joint. (B) Anteroposterior radiograph of both knees. (C) Lateral radiograph of the left knee joint](image-url)
Fig. 2 Preoperative CT modeling and 3D-P-pTa repair of the bone defect. (A) Preoperative CT modeling and measurement of bone defect shape and size. (B) The shape, size, and screw hole position of porous tantalum are designed according to the modeling. (C) Preoperative physical simulation is performed to evaluate the size of the augment. (D) The 3D-P-pTa is perfectly matched with the bone defect.

Fig. 3 Postoperative X-ray examination showed good alignments in lower limbs, good joint space, good integration of porous tantalum and prosthesis with the host bone, and no obvious bone resorption. (A) Full length of both lower limbs and lateral radiographs of both knees 3 days after surgery. (B) Anteroposterior and lateral radiographs of both knees 3 months after surgery. (C) The total length of both lower limbs and lateral radiographs of both knees 1 year after surgery.
(Smith & Nephew Legion, Memphis, TN, USA). A 13-mm intercondylar liner was selected to improve the joint pronation and rotation stability. Postoperative x-ray examinations (at 3 months and 1 year) showed good alignment of force lines, good joint space, and no evidence of loosening (Fig. 3A–C).

Discussion

Charcot joint disease is often associated with a large number of bone defects, limiting the need for joint replacement. The present case had AORI type III bone defect that severely accumulated in the femoral and tibial plateaus. These defects result in severe bone deficiency in the joint, which cannot provide an adequate bone bed to support the prostheses. The previous use of autogenous, allogeneic, and heterogeneous bone to fill bone defects has drawbacks. Autologous bone transplantation has an excellent clinical effect. However, owing to its limited quantity, it cannot meet the demand for large bone defects. Furthermore, it can lead to donor complications, prolonged operation time, and increased blood loss and infection risk. Allogeneic and heterogeneous bones have weak bone conduction and induction properties, and it is difficult to match the shape of a large bone defect.

Trabecular metal is the only commercially available tantalum implant for clinical use in orthopedics. Porous tantalum has a microstructure similar to human cancellous bone. Its pore size, porosity, and elastic modulus are between the human cancellous bone and cortical bone, which can reduce the stress shielding effect of the material. A higher friction coefficient increases the initial stability of the implant, and the porous structure promotes the growth of new blood vessels into the implant and bone integration. However, this commercial tantalum metal is a modular prosthesis that cannot be customized. The 3D-P-pTa developed by our research group can be customized to repair complex bone defects while retaining the original advantages, significantly improving the clinical effect of surgery and reducing the incidence of surgical risks and complications.

Tantalum is an inert metal that does not react with human body fluids or their contents. Furthermore, a porous structure design can promote osseointegration. The 3D-P-pTa can be used to fill bone defects that are difficult to repair, and good bone ingrowth enables adequate and stable fixation. As a result, the difficulty of revision total knee arthroplasty placement will be significantly reduced, resulting in better prosthesis stability and recovery of knee function in patients. However, porous tantalum is expensive. It takes time to design and manufacture, and long-term follow-up is still needed to determine its long-term stability.

Conclusion

In conclusion, accurate surgical evaluation and preparation of 3D-P-pTa implants before surgery significantly improve the treatment of severe Charcot joint disease. Surgery is more accurate, effective, and convenient for treating severe knee disease. It is of great theoretical significance and practical value to provide a new solution for treating severe Charcot joint disease.

Authors’ contributions

LH collected and analyzed the data of the patients. LH was a major contributor to the manuscript. YH performed the surgical treatment on the patient. YH and PL were the designers of the experiment. All authors read and approved the final manuscript.

Ethics Approval and Consent to Participate

This study was subject to approval by the Ethics Review Committee of Xiangya Hospital (202008242).

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