



Case report

Repair of distal fibular and lateral malleolus defects with individualized 3D-printed titanium alloy prosthesis: The first case report from China

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ABSTRACT

Introduction and importance: This case report describes the reconstruction of the traumatic distal fibular and lateral malleolus defects with a novel method of using individualized 3D printed titanium prosthesis for the first time.

Case presentation: A 63-year-old male farmer was hospitalized in emergency because of open injury and distal fibular and lateral malleolus defects in the left leg caused by a car accident. 3 months after debridement and latissimus dorsi muscle flap transplantation and skin graft operation, the patient re-hospitalized because of distal fibular and lateral malleolus defect and local pain. We examined the bilateral ankle joint with three-dimensional CT, obtained data about the missing left distal fibular and lateral malleolus through the mirror principle. The corresponding titanium alloy prosthesis then was designed and printed using a 3D metal printer. The patient had no obvious contraindication for surgery, so the prosthesis was surgically implanted. The patient was followed up for 2 years. There was no discomfort at the surgical site. The function of the operated ankle was satisfied by the patient, the AOFAS (American Orthopaedic Foot & Ankle Society) score was 85 (Kitaoka et al., 1994 [1]).

Clinical discussion: Individualized 3D printed titanium alloy prosthesis consistent with the anatomical structure of lost distal fibula and lateral malleolus. The proximal end of the prosthesis was designed with four nail holes to install screws to fix the fibula together with it. The lower tibiofibular and talofibular joint surfaces of the prosthesis were designed smoothly. In order to improve the stability of the lower tibiofibular joint, anchors were placed at the attachment of the anterior and posterior tibiofibular ligaments to reconstruct these ligaments.

Conclusion: The structure and function of the reconstructed distal fibular and the lateral malleolus were close to normal. Individualized 3D printed prosthesis might have considerable advantages over traditional treatment methods. The individualized 3D printed titanium alloy prosthesis provides a new method for the repair and reconstruction of similar bone defects. The use of 3D printed prosthesis for surgical repair needs to be further examined in the future through long-term follow-up studies and in more cases.

1. Introduction and importance

Loss of stability of the ankle joint following distal fibular and lateral malleolus defects can seriously affect the function of the ankle joint. However, the repair of distal fibular and lateral malleolus defects poses a problem to clinicians. At present, the main treatment methods are bone transplantation and fibula lengthening, but these methods have many limitations [2]. Scholars have reported good results with vascularized autonomous fibula head transplantation. However, the procedure is

complicated and observation of the survival of the bone flap after vascular anastomosis is difficult. Additionally, removal of the autonomous fibular head causes donor site damage, and there is a risk of injury to the peroneal nerve [3,4]. Importantly, decrease in knee joint stability is one of the reported complications. Another promising method is transplantation of a second metatarsal bone flap with vascular pedicle [5]. However, the procedure required expert microsurgical techniques, and was time-consuming, difficult, and risky. Additionally, it was impossible to repair large defects, and normal foot function was

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affected. Ko et al. [6] used the double-bundle artificial Achilles tendon allograft to reconstruct distal fibular and lateral malleolus defects, but radiography showed that the talofibular joint space was narrow. Moreover, the shape of the reconstructed distal fibular and lateral malleolus was not normal, and the long-term effect was not clear. Thus, the currently used methods are associated with considerable trauma, risk of complications such as infection and nerve injury, a long treatment cycle and healing time, mismatch of the joint surface, and poor recovery of joint function [7,8]. There is a clear need for the new treatment method that can overcome these limitations.

3D printing technology, a recently emerged technique in orthopedics, may provide a promising alternative for the treatment of distal fibular and lateral malleolus defects [9]. 3D printed prostheses consistent with the defected site could be accurately and rapidly created through mirroring the healthy side, without the need for special models [10,11]. Further, with the help of porous bionic technology, the internal micropore structure can be improved for good biocompatibility. Such prostheses promote the adhesion and proliferation of cells and fusion of bone tissue.

Here, we have described a case of distal fibular and lateral malleolus defects that were treated using the 3D printed prosthesis and have reviewed the relevant literature. This case was reported in line with the SCARE 2020 criteria [12].

2. Case presentation

A 63 years old male farmer was sent to Xijing Hospital by ambulance due to open injury of left lower limb caused by car accident in August 2018. The patient was in good health and had no family history of mental illness and genetic diseases. Physical examination showed that there was 15×9 cm soft tissue defect around the distal lateral side of the left lower limb and the lateral malleolus. X-ray showed distal tibial fracture, distal fibula and lateral malleolus defects, with a length of about 5.2 cm. After hospitalization (Orthopaedic department, Xi Jing Hospital, Air Force Military Medical University), the patient underwent emergency debridement and external fixation of tibial fracture. Skin and soft tissue defects were covered by vacuum sealing drainage (VSD) at the emergency operation and repaired with latissimus dorsi muscle flap and skin graft 12 days later. After above procedures, the wound healed well, but the distal fibular and lateral malleolus defects remained. The patient hospitalized again in December 2018 because of the distal fibular and lateral malleolus defects with pain. He hoped to continue to walk with weight and take care of himself in the future. Physical examination showed that a $15.0 \text{ cm} \times 9.2 \text{ cm}$ postoperative skin scar could be observed around the left distal fibular and lateral malleolus area with a hard dark red surface, poor elasticity and no exudation. There was a sense of emptiness when pressing the lateral malleolus site. The front and lateral side of the ankle joint was tender. Metatarsal flexion of the ankle was 0° - 15° , and the dorsal extensions were limited (Fig. 1). Peripheral circulation and sensory function of the ankle joint were normal. Preoperative radiography revealed a 3.0 cm bone defect from the end of the ankle to the upper part around the tibiotalar joint (Fig. 2). The longitudinal force line of the tibia was good.

We removed the external fixator 3 weeks before this hospitalization. Erythrocyte sedimentation rate (ESR), hypersensitive C-reactive protein (CRP), and blood routine tests were performed after hospitalization to exclude infection. With the help of three-dimensional CT examination of both the left and right ankle joint, missing data for the left distal fibular and lateral malleolus defects were obtained based on the mirror principle. According to the data obtained from the above mirror principle, the shape of the prosthesis matched with the distal fibula and lateral malleolus defects of the patient was designed (Shaanxi Dongwang Technology Company, 3DMeng-01, Fig. 3). The corresponding titanium alloy prosthesis was printed out on a 3D metal printer. Cefazolin sodium was given intravenously within 48 h after operation to prevent infection. The left lower limb was fixed with short leg brace for 2 weeks.



Fig. 1. Preoperative antero-posterior (A) and lateral radiographs (B) of the patient. The radiographs show that the distal fibula and lateral malleolus are defective, but the alignment of the distal tibia fracture was good.

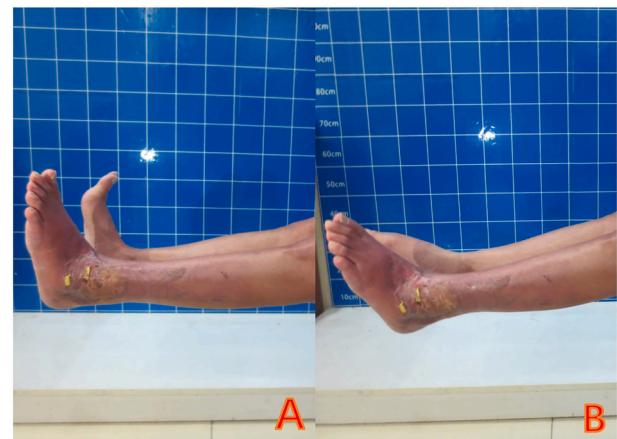


Fig. 2. Preoperative functional appearance of the affected ankle (A and B). Ankle dorsiflexion and plantar flexion were partially limited.

Emergency operation and implantation operation were performed by Professor Meng Guolin and his team. Prof. Meng, MD and PhD, has 20 years of clinical experience in orthopedics. Latissimus dorsi flap transplantation and skin grafting were completed by Professor Songtao Xie and Dr. Hongyi Hou.

3. Results

The wound healed well without signs of infection. The patient could cooperate with the rehabilitation exercise requirements of the doctor and had good compliance with reexamination. Unloaded ankle flexion and extension exercises were performed 2 weeks after the implantation operation. The affected limb avoided weight-bearing within 6 months after operation. The affected limb began to step on the floor scale for weight-bearing exercise 6 months after operation. Weighted stepping exercises were started from one-third of the weight and increased by 1 kg every day, until the affected limb could stand on one leg. At two years follow-up, the patient had no complaints about any difficulty in walking and has no discomfort. The appearance and the function of the ankle joint were close to normal and there was no valgus deformity. The AOFAS (American Orthopaedic Foot & Ankle Society) score was 85 [1].

4. Clinical discussion

In this present case, the 3D printed prosthesis was used to repair the

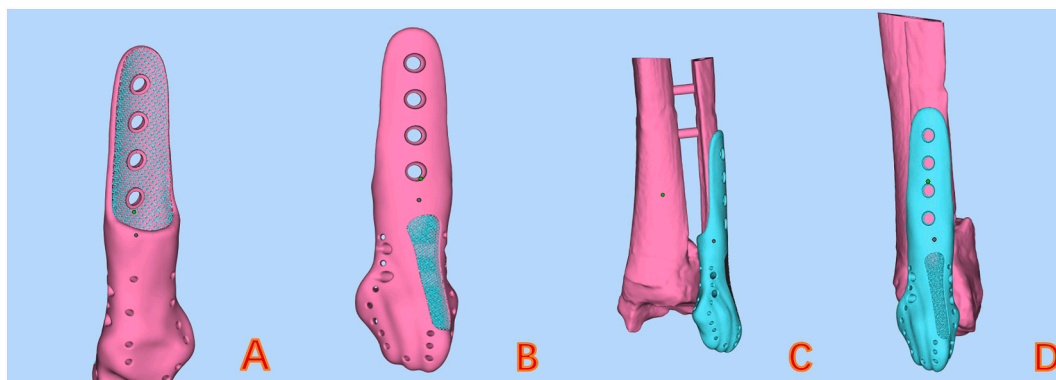


Fig. 3. External (A and B), front (C), and lateral view (D) of the design of the 3D printed prosthesis. The 3D-printed prosthesis matched the distal fibula and lateral malleolus precisely.

distal fibular and lateral malleolus defects. The diameter of the medullary cavity of the prosthesis fibula is slightly larger than that of the original fibula, so the fibula stump could be easily placed into the prosthesis in order to improve stability. The prosthesis proximal end was designed with four nail holes to install screws to fix the fibula. The hollow design allowed for the implantation of autogenous cancellous bone inside the prosthesis. The inner surface of the prosthesis had a microporous structure. The micropore structures in the inner surface were beneficial for the growth of cancellous bone tissues, so that the prosthesis and the fibula could be “healed” as a whole. This improved fatigue resistance and service life of the prosthesis. The lower tibiofibular and talofibular joint surfaces of the prosthesis were designed smoothly in order to reduce the friction coefficient and the chances of traumatic arthritis. There were suture holes at the distal end of the prosthesis. In order to improve the stability of the lower tibiofibular joint, anchors were placed at the attachment of the anterior and posterior tibiofibular ligaments to reconstruct these ligaments. The above techniques are also applicable to patients with similar injuries.

Considering the poor stability of the prosthesis in the initial stage after implantation, the functional exercises were relatively conservative and weight-bearing exercises were gradually increased. After the procedure, the appearance of the patient's ankle was close to normal. The patient has been followed up for 2 years. Radiographs taken 2 years after surgery showed that the inferior tibiofibular screw was broken, but the prosthesis showed no sign of loosening (Fig. 4). The patient felt no pain or other discomfort, and the function of the ankle was close to normal (Fig. 5). There was no valgus deformity. Because the lower tibiofibular



Fig. 5. Functional appearance of the affected ankle 2-years post-operation. Ankle flexion (A) and extension (B) were close to normal.

joint has a small degree of movement, in order to avoid fatigue fracture of the screw stabilizing the joint, it is generally necessary to remove the screw 3 months or half a year after surgery. The screw used to fix the lower tibiofibular joint in this patient should also have been removed 3 months or half a year after the surgery. Nonetheless, fracture of the screw had no adverse effect on postoperative function.

5. Conclusion

The structure and function of the reconstructed distal fibular and the lateral malleolus were close to normal. The findings of this present case indicate that the use of 3D printing prosthesis for the reconstruction of the distal fibular and lateral malleolus defects might have considerable advantages over traditional treatment methods. The individualized 3D printed titanium alloy prosthesis provides a new method for the repair and reconstruction of similar bone defects. The use of 3D printed prosthesis for surgical repair needs to be further examined in the future through long-term follow-up studies and in more cases. Specifically, it offers the benefits of less trauma, a short treatment period, and good functional recovery. The patient was able to walk and jog without pain or discomfort 2 years after the procedure.

At present, only one patient has undergone individualized designed 3D printed titanium alloy distal fibula and lateral malleolus prosthesis replacement, which has certain limitations. In the future, more patients needed to get a good prognosis by using this technical method, which will be more convincing.

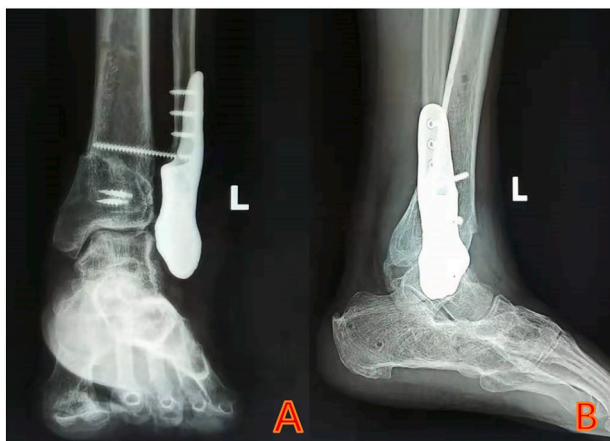


Fig. 4. Anteroposterior (A) and lateral (B) radiographs 2-years post-operation. The images indicate that the lower tibiofibular screw was broken, but the 3D-printed prosthesis was not loose.

Provenance and peer review

Not commissioned, externally peer reviewed.

Consent

Written informed consent was obtained from the patient for the publication of this case report and accompanying images. A copy of the signed written consent form is available for review by the Editor-in-Chief of this journal on request. We are sure that any images/figures/photos are suitably anonymised with no patient information or means of identifying the patient. We decide that color should be used for all figures in print.

Ethical approval

Ethical approval was not needed for writing a case report in our settings.

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Guarantor

Guolin Meng.

Research registration number

Not applicable.

CRedit authorship contribution statement

Guolin Meng: corresponding author, performed the operation and wrote the paper; Zhengyu Li: co-corresponding author, analyzed the data and drafted the manuscript; Jiangang Cheng, Yang Gao and Zhuoyu Long managed the treatment for the patient and wrote the paper; Guoxian Pei corrected the paper.

All authors reviewed the manuscript.

Declaration of competing interest

None of the authors have any conflicts of interest.

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