



Surgical Reconstruction of the Talus Using 3D-Printing Technology

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Abstract

Avascular necrosis and severe structural loss of the talus present significant reconstructive challenges, often leaving joint fusion or below-the-knee amputation as the only viable options. Custom patient-specific 3D-printed implants offer a novel, motion-preserving alternative for complex talar defects. This case describes a healthy 64-year-old healthcare professional and former bodybuilder sustained a traumatic open ankle injury in a motor vehicle accident, resulting in a fracture of the lateral malleolus, an avulsion fracture of the medial malleolus, and extrusion of the right talus. After declining amputation, the patient underwent staged reconstruction, including temporary joint space preservation, external fixation, and implantation of a patient-specific 3D-printed talus created from CT imaging of the contralateral ankle. United States Food and Drug Administration (FDA)-authorized patient-specific 3D-printed talus implants are a recent innovation and have rarely been used for traumatic talus loss. In carefully selected patients, this approach may preserve limb function, restore meaningful mobility, and provide an alternative to amputation, although return to high-impact functional and athletic activities remains uncertain. Postoperative rehabilitation was modeled after a total ankle replacement protocol emphasizing progressive weight bearing, gait restoration, and restoring range of motion, strength, and neuromuscular control. At one-year follow-up, the patient had returned to independent activities of daily living (ADL's) and recreational activities including hiking, swimming, and cycling. Although additional research is needed to establish long-term outcomes and optimal patient selection criteria, this case adds to the growing body of evidence supporting patient-specific 3D-printed total talus replacement as a promising limb-salvage strategy for carefully selected patients with traumatic talar extrusion.

Keywords: Patient-Specific 3D-Printed Implant, 3D-Printing Technology, Talar Extrusion, Limb Salvage

Background

Complete talar injuries, including extrusion and loss of the talus, represent severe orthopedic trauma associated with high rates of complications and poor functional outcomes. Historically, management options have included reimplantation, arthrodesis, or amputation, often resulting in substantial loss of ankle motion and long-term functional limitations [1-3]. The unique vascular anatomy

of the talus makes it particularly susceptible to avascular necrosis following injury, further complicating treatment decisions and increasing the risk of long-term joint degeneration [4].

Recent advances in surgical technology have introduced patient-specific 3D-printed total talus replacements as a potential limb-salvage alternative. Early reports (primarily in cases of avascular necrosis) demonstrate encouraging outcomes including improved joint congruency, restoration of hindfoot alignment, and preservation of function [5-7]. However, literature describing the use of custom talar implants following complete traumatic extrusion remains limited. This case report describes staged limb salvage with multiplanar external fixation followed by implantation of a patient-specific 3D-printed talus after traumatic loss, highlighting surgical decision-making, rehabilitation progression, and early functional outcome.

Case Report

The patient in this case was a relatively healthy 64-year-old female healthcare professional and previous body builder who was in a car accident on October 5, 2024. First responders successfully removed the patient from the vehicle and transported her to the nearest hospital via ambulance for emergency evaluation. The patient's chief complaint was severe right ankle pain accompanied by visible deformity, an open wound, and inability to bear weight. The patient's past medical history was significant for hypertension and hypothyroidism. Surgical history included hysterectomy, salpingo-oophorectomy, parotid tumor removal, and breast augmentation. There was no known history of cardiovascular disease or adverse reactions to anesthesia.

Initial assessment by prehospital and emergency department personnel identified a severe open wound to the right lower extremity with significant blood loss, necessitating emergent surgical intervention. No alternative differential diagnoses were suspected given the extent and mechanism of injury.

During the initial surgery, physicians identified a large laceration that extended from the talonavicular joint posteriorly along the medial tibia to the medial malleolus. The posterior tibial artery and vein were traumatically severed but hemostatic at the time of surgery, and the tibialis anterior tendon was ruptured. The posterior tibialis, flexor hallucis longus, and flexor digitorum longus tendons

were intact. Physicians also found a complete extrusion of the talus. Recognizing a more severe injury than suspected, physicians ordered radiographic images.

Images revealed a fracture of the lateral malleolus, an avulsion fracture of the medial malleolus, and complete dislocation of the tibia from the talus. Significant soft tissue swelling was present and there was no evidence of foreign bodies. Based on clinical and imaging findings, the patient was diagnosed with a traumatic open right ankle fracture-dislocation with complete talar extrusion and associated vascular and tendon injury.

Treatment

The patient initially underwent emergent irrigation and debridement of the open wound. Intraoperatively, a temporary surgical spacer was placed to preserve the tibiotalar joint space and protect the surrounding anatomical structures pending definitive management. Following the procedure, the patient was counseled that a below-the-knee amputation (BKA) represented the most predictable treatment option given the severity of the injury and was advised that preservation of the limb would likely result in substantial functional limitations.

The patient declined BKA surgery and sought a second opinion at the medical center where she was employed. After a comprehensive evaluation, the surgical team determined that limb salvage with advanced reconstructive techniques, including a 3D-printed talus implant, was a feasible option. The patient was thoroughly counseled regarding the experimental nature of the proposed treatment, the potential for reconstructive failure, and the possibility that BKA surgery would remain the recommended course of treatment if limb salvage proved unsuccessful. After discussing the risks, benefits, and alternatives, the patient elected to proceed with the reconstructive approach.

On October 12, 2024, the patient underwent a second surgical procedure consisting of repeat irrigation and debridement, placement of a physician-fabricated antibiotic spacer, and application of a multiplanar circular Ilizarov external fixation (ex-fix) frame. The antibiotic spacer was used to maintain the joint space and provide local antimicrobial delivery, while the ex-fix construct restored and maintained neutral ankle alignment in preparation for definitive reconstruction. The patient was counseled that successful limb salvage depended on achieving and maintaining appropriate alignment throughout the treatment period and that failure to do so could necessitate reconsideration of BKA surgery to minimize the

risk of long-term complications. The patient was placed on a strict non-weight-bearing (NWB) protocol for the duration of fixation. Throughout this period, rehabilitation emphasized strict adherence to NWB restrictions to optimize soft tissue healing, protect the surgical structures, and maintain proper anatomical alignment in preparation for definitive reconstruction. The primary goals were to preserve joint alignment, control edema, and maintain proximal strength and overall conditioning while minimizing stress on the affected extremity. Rehabilitation interventions included isometric strengthening exercises, passive and active range-of-motion (ROM) exercises for uninvolved joints, and general conditioning activities consistent with the patient's weight-bearing restrictions.

The ex-fix was successfully removed on April 23rd, 2025. During the 6-month period between surgeries, high-resolution CT scans of the contralateral limb were used to create a digital model of the patient's talus. Using the scans, a Patient-Specific Talus Spacer (a 3D-printed implant designed to replicate the patient's natural bone structure) was developed. The scans allowed for customization of implant dimensions, material composition, and ensured overall anatomical compatibility. This individualized approach aimed to restore joint congruency and preserve functional movement following implantation.

The patient underwent a fourth and final surgical procedure for the implantation of the 3D-printed talus prosthesis a few days following the removal of her ex-fix frame. Intraoperative assessment confirmed appropriate implant positioning and restoration of joint alignment. Postoperatively, the patient was placed in a short-leg splint in neutral dorsiflexion for immobilization and protection of the surgical reconstruction.

Postoperative rehabilitation was modelled after traditional total ankle replacement (TAR) programs with modifications to account for the extent of soft tissue injury and the staged surgical reconstruction. Early postoperative rehabilitation emphasized gradual restoration of joint mobility, continued edema management, and initiation of protected weight-bearing as tolerated (WBAT) based on physician clearance. As rehabilitation progressed, focus shifted toward restoring joint mobility, improving gait mechanics, enhancing neuromuscular control, restoring functional strength, and gradually progressing to increased WBAT. Target outcomes included achieving dorsiflexion of approximately 10 degrees and plantarflexion of 35 degrees, as well as restoration of 5/5 lower extremity strength. Table 1 describes timelines, goals, and exercises used for this patient's rehabilitation program.

Timeline	Exercises	Goals
Weeks 6-10	- Active and passive stretching of muscles of the lower leg, ankle, and foot - Hip and core strengthening - Gait training - Potential soft tissue and joint mobilizations	Improve range of motion
Weeks 10-14	- Continue stretching, soft-tissue and joint mobilizations as needed - Begin resistive strength and proprioception exercises - Progress hip and core strengthening - Continue gait training	- Improve range of motion and strength - Progress weight-bearing and improve ambulation - Work on proprioception and balance
Weeks 14-16	- Continue gait training - Progress proprioception exercises to single-leg exercises - Progress resistive strength exercises	- Progress weight-bearing and improve ambulation - Achieve desired range of motion (full) and strength (5/5)
Weeks 16+	Begin functional exercises, including exercises that mimic activities of daily living	Gradual return to functional activities

Table 1. Post-operative Rehabilitation Program, Timelines and Goals

Note: This program closely follows the Physical Therapy Guidelines for Total Ankle Arthroplasty from Massachusetts General Hospital Orthopaedics and *Physical Therapy. Massachusetts General Hospital Physical Therapy Services.* Physical therapy guidelines for total ankle arthroplasty. Massachusetts General Hospital; n.d.

Outcomes and Follow-Up

The patient demonstrated high adherence to the prescribed rehabilitation program throughout all phases of recovery. At approximately five months postoperatively, the patient was able to ambulate independently without assistive devices and showed continued improvements in stability, balance, and range of motion (ROM).

At one-year follow-up, the patient had returned to independent ADL's and recreational activities including hiking, swimming, and cycling. However, due to the complexity of the injury and reconstructive procedure, return to high-impact activities such as running and jumping was not recommended. Despite these limitations, the patient achieved meaningful functional recovery and demonstrated sustained progress toward long-term mobility and independence.

Discussion

This case report describes successful staged limb salvage with more than one year of postoperative follow-up after patient-specific 3D-printed total talus replacement for complete traumatic talar extrusion with associated vascular and tendon injury. The patient's recovery demonstrates that in carefully selected individuals, advanced reconstructive techniques may provide a viable alternative to BKA surgery or traditional salvage procedures. At more than one year following implantation, the patient demonstrated independent ambulation without assistive devices, sustained improvements in ankle stability and ROM, and no evidence of implant instability or deep infection. These findings suggest that patient-specific total talus replacement may preserve joint function while supporting meaningful functional recovery.

Traumatic talar extrusion is an uncommon but devastating injury associated with high rates of infection, avascular necrosis, posttraumatic arthritis, and long-term functional impairment.²⁻⁴ These complications are largely attributable to the talus' limited vascular supply and the extensive soft tissue damage that often accompanies high-energy trauma [4]. Historically, treatment options have included reimplantation, talectomy, arthrodesis, or BKA surgery. Although arthrodesis reliably provides pain relief, it sacrifices ankle motion and may accelerate adjacent joint degeneration, while talectomy frequently results in limb shortening and altered biomechanics [3-4, 8].

Recent advances in additive manufacturing have expanded reconstructive options through patient-specific total talus replacement (TTR). Using high-resolution computed tomography (CT) imaging, implants can be designed to accurately reproduce the patient's native anatomy which can improve implant fit, joint congruency, and preoperative surgical planning [5, 8]. Early clinical studies have demonstrated encouraging improvements in pain, function, and preservation of ankle mechanics following TTR [6, 7]. However, the current literature remains limited to small case series with relatively short-term follow-up, and most reported cases have involved patients with talar avascular necrosis rather than acute traumatic extrusion [5-7].

The present case is unique because it demonstrates successful application of a patient-specific 3D-printed talar prosthesis following complete traumatic talar extrusion. Unlike reconstructive procedures performed for degenerative conditions, acute traumatic injuries present substantial challenges related to soft tissue disruption, vascular compromise, contamination, and joint instability. The staged treatment strategy (including serial irrigation and debridement, temporary external fixation with an antibiotic spacer, and delayed implantation after restoration of alignment and soft tissue stabilization) provided an opportunity to optimize the biological environment before definitive reconstruction. This approach is consistent with emerging recommendations for managing complex talar injuries while preserving limb function [5].

Creation of the implant from CT imaging of the contralateral talus enabled accurate anatomical replication and restoration of joint congruency. Patient-specific implants may also incorporate porous lattice architectures that mimic trabecular bone, promoting osseointegration and biological fixation while improving load transfer across the implant-bone interface [8]. Although the patient has demonstrated successful implant function at more than one year postoperatively, longer-term outcomes, including implant survivorship, wear characteristics, and adjacent joint degeneration, remain unknown.

Successful limb salvage in this case was likely influenced by several favorable patient-specific factors. Despite the severity of the injury, there was no significant vascular insufficiency or extensive osseous destruction beyond the talar extrusion. In addition, the patient's overall health, absence of major comorbidities affecting healing, and high preinjury level of physical conditioning likely enhanced her ability to tolerate multiple surgical procedures and participate in an intensive rehabilitation program.

Several limitations should be acknowledged. As a single case report, these findings cannot be generalized to broader patient populations. Although this patient has maintained favorable clinical outcomes beyond one year postoperatively, longer-term follow-up is necessary to evaluate implant survivorship, polyethylene wear, component loosening, adjacent joint degeneration, and the potential need for revision surgery. Continued longitudinal follow-up and larger prospective investigations are necessary to better define the durability and indications for this reconstructive technique.

Conclusion

This case demonstrates that meaningful functional recovery is achievable following catastrophic talar injury through staged surgical reconstruction, patient-specific implant design, and individualized rehabilitation. At more than one year following implantation, the patient regained independent ambulation, returned to recreational activities, and remained free of major implant-related complications. Although high-impact activities such as running and jumping remain limited, restoration of independent mobility and quality of life represents a clinically meaningful outcome for an injury that historically often resulted in amputation or substantial long-term disability.

For rehabilitation professionals, this case highlights the importance of patient advocacy for alternative treatment options, interdisciplinary collaboration, and careful functional loading throughout recovery following complex lower extremity reconstruction.

Although additional research is needed to establish long-term outcomes and optimal patient selection criteria, this case adds to the growing body of evidence supporting patient-specific 3D-printed total talus replacement as a promising limb-salvage strategy for carefully selected patients with traumatic talar extrusion. As implant technology and surgical techniques continue to evolve, this approach may offer an opportunity to preserve mobility, improve functional outcomes, and reduce the need for amputation following otherwise devastating talar injuries.

Few reports have described outcomes beyond one year following patient-specific total talus replacement for acute traumatic talar extrusion. Continued surveillance of this patient will be important to monitor implant survivorship, adjacent joint health, and long-term functional performance; however, the present findings provide encouraging evidence that durable limb salvage is possible in carefully selected patients.

Declarations

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Private and/or institutional funding was not sought after for this research project.

Conflicts of interest/competing interests

There are no relevant financial or non-financial interests to disclose.

Patient Consent

The patient in this case signed the consent form and was advised on their rights to withdraw the paper at any time. All information collected was anonymized and the patient cannot be identified through the manuscript.

Author Contributions

Brittany A. Clason: Substantial contributions to concept or design, interpretation of data collected, drafting of original manuscript, review and editing of subsequent drafts.

Gabriella Gonzalez: Substantial contributions to concept or design, acquisition of information, and literature review.

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