

Personalized 3D Printing Implants for Post-Traumatic Reconstruction After Complex Orthopaedic Injury

- Orthopaedic trauma surgeons at Penn Medicine are combining three-dimensional printing and radiologic studies to create personalized, implantable metal devices for patients with talar osteonecrosis and other challenging and complex reconstructions.

The talus is considered the universal joint of the foot. Articulating with the calcaneus (heel) below, the tibia and fibula above and the bones of the forefoot, the talus is designed to channel and distribute body weight. The bone has three distinct regions, a forward head and posterior body separated by a thin, concave neck comprised of cortical bone. Injuries to the talus are uncommon, but when they do occur, 50% occur at the neck.

The blood supply to the talus is extremely sensitive to injury as it is largely retrograde and vulnerable to disruption in talar neck and body fractures.¹ At the talus, any interruption of this tenuous vascular network by obstruction, compression or disruption vastly increases the likelihood of avascular necrosis (AVN). Among fractures involving comminution, separation at the talar neck, joint subluxation, displacement of the talus from its conjoining bones, or open injuries, the incidence of AVN rises to between 50% – 100%. Talar AVN often results in post-traumatic arthritis and arthrosis of the subtalar and ankle joints.

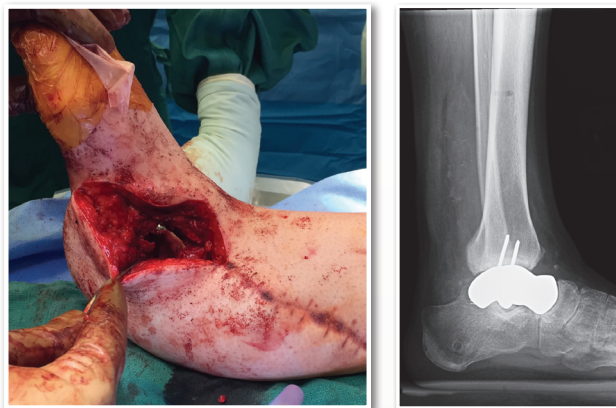
Treatment of talar AVN is determined by severity. Limited osteonecrosis at the talus can be treated by extended restriction on weight bearing with the addition of a cast or brace. Traditional treatment of severe, advanced AVN of the talus, however, requires secondary or salvage procedures, including talectomy, bone grafting, fusion, or in cases with extensive necrosis beyond the talus, below-knee amputation.

Recently, surgeons at the Penn Trauma and Fracture Program introduced prosthetic total talar replacement as an option for patients with advanced osteonecrosis of the talus. The advantages of prosthetic replacement to more traditional alternatives for the treatment of talar AVN include improvement in pain, preservation of leg length and joint function and a faster recovery time with limited weight-bearing restrictions.

Developed more than a decade ago, prosthetic talar replacement has been limited somewhat by the need to produce an accurate, individualized reproduction of the talar shape and size. To overcome these concerns, Penn orthopaedic trauma surgeon Samir Mehta, MD, and colleagues have called upon a company that produces orthopaedic implants with 3D printing technology. To produce a talar implant identical to that of the removed bone, a three dimensional radiological image of the opposite talus is created, then reversed for the 3D printer. This perfect replica is then recreated as a full-metal prosthesis and implanted to replace the necrotic talus.

Reference

1. Timothy O White, Samuel P Mackenzie, Alasdair J Gray. McRae's Orthopaedic Trauma and Emergency Fracture Management 3rd edition. Pg 518.



► **Figure 1:** (Left) Preparation for implantation of a personalized talar prosthesis developed by scanning the talus of the opposite foot to create a 3-D print replica of the original bone.

► **Figure 2:** (Right) One year lateral view of a prosthetic total talar replacement in a 27-year-old patient who experienced avascular necrosis following a non-united fracture of the talus.

CASE STUDY

Mr. J, a 27-year-old civil engineer, self-referred to the Orthopaedic Trauma and Fracture Service eight weeks after sustaining a fracture of his talus. He was treated by a local foot specialist at the time of his acute injury with open irrigation and debridement and the application of an external fixator. Mr. J remained in the external fixator device without further stabilization of his talus for six weeks until the wound started to break down.

An MRI was obtained revealing a non-united, infected, avascular talus. Mr. J's wound was assessed by the orthoplastic service at Penn Medicine. After a lengthy multi-disciplinary discussion regarding his options, which took into account his age, desired activity level, and recovery time, Mr. J chose to proceed with a staged reconstruction of his ankle. The first stage involved repair of the medial side of the tibia, debridement of the infected, necrotic talus, insertion of a nonbiodegradable antibiotic spacer shaped like the talus and a pedicled soft tissue flap closure. During the post-operative healing period, a three-dimensional image of Mr. J's opposite (left) talus was created, and used to build the full-metal right-sided talar prosthesis through a commercial partner. The building process was a multi-national effort, including conference calls and CAD model reviews. One month later, a second surgery was performed at the now-healed site of injury to remove the spacer and implant the talar prosthesis.

At Mr. J's one-year follow-up, an X-ray (see Figure 2 above) found the prosthesis was stable, and there was minimal post-traumatic change in the surrounding bones. Mr. J reported no pain or substantial issues with mobility, was bearing full weight on the leg and wearing a regular shoe. He has returned to work and some recreational activity.

FACULTY TEAM

The Penn Trauma and Fracture Service, the largest and most complete program in the Philadelphia region, provides comprehensive trauma care for a full spectrum of musculoskeletal fractures, traumatic injuries, and injury-related disorders and complications.

► **Performing Total Talar Prosthesis Surgery at Penn Medicine**

Orthopaedic Surgery

Samir Mehta, MD

*Chief, Division of Orthopaedic Trauma
Associate Professor of Orthopaedic Surgery*

Jaimo Ahn, MD, PhD

Assistant Professor of Orthopaedic Surgery

Derek J. Donegan, MD

Assistant Professor of Orthopaedic Surgery

L. Scott Levin, MD, FACS

*Chair, Department of Orthopaedic Surgery
Paul B. Magnuson Professor of Bone and Joint Surgery
Professor of Plastic Surgery in Surgery*

Orthopaedic Foot and Ankle Service

Keith L. Wapner, MD

*Chief, Foot and Ankle
Clinical Professor of Orthopaedic Surgery*

Wen Chao, MD

Clinical Associate Professor of Orthopaedic Surgery

Daniel C Farber, MD

Assistant Professor of Clinical Orthopaedic Surgery

Kathryn M. O'Connor, MD, MSPT

Assistant Professor of Clinical Orthopaedic Surgery

Plastic Surgery

Stephen J. Kovach, III, MD

Associate Professor of Surgery

ACCESS

Penn Musculoskeletal Center

Penn Medicine University City
3737 Market Street, 7th Floor
Philadelphia, PA 19104