

Case Report

Tibiototalcaneal Arthrodesis Using Custom 3D Printed PEKK Implant for Treatment of Talar AVN

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Abstract

Historically custom implants have been made from metal, bulk allograft, and PEEK, among others. PEKK has seen increased utilization in medicine, specifically in custom implants due to its higher tensile strength and also its molecular composition that aids in promoting cellular activity, such as bone healing. In this case report, we present a 72-year-old female who initially presented with a collapse of her talus after failed attempted ankle arthrodesis. A custom PEKK talus implant was designed, implanted and secured via tibiototalcaneal arthrodesis using an intramedullary nail. The patient had significant improvement in AOFAS (17 to 92), FFI (90 to 8), and VAS (9 to 0) from preoperative evaluation to the final 1.5-year postoperative follow-up. This is one of the only case reports that documents the utilization of a custom PEKK implant for lower extremity reconstruction. Although more studies are needed, this case report shows promising results with PEKK implants, especially in limb salvage procedures. Level of Clinical Evidence: 5, Case Report.

Keywords: polyetherketoneketone; PEKK; ankle fusion; AVN talus; custom implant; 3D printing

1. Introduction

Implant design and composition remain at the forefront of orthopedic medicine as we continuously try to develop implants that can not only withstand the forces of the human body but can also integrate into the surrounding bone and tissue. To date, there are orthopedic implants that aim to integrate into the surrounding bone, or in fact even turn into bone without sacrificing the strength of conventional metallic hardware. Bone voids are encountered during reconstructive surgery all across the human body, and commonly within the foot and the ankle. Historically, these have been filled in with bulk auto/allograft or metal alloys. Titanium, cobalt, chromium have been used for a multitude of different reasons, such as offering good biocompatibility, allowing for a high degree of osseous integration, and providing the strength to withstand weightbearing forces [1,2]. Metallic implants, although rigid, often have concerns about their integration with surrounding bone as well as the weight of these materials.

There is a continuous push to find a product that most mimics human bone while withstanding weightbearing forces of the human body. Polyetheretherketone (PEEK) is one such material and has seen increased utilization due to its fracture resistance, overall strength and rigidity, lightweight nature, and osseous integration [3]. PEEK has a modulus of elasticity similar to that of human bone and is at the same time radiolucent



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on radiographs, which allows the surgeon to directly visualize the implant and assess osseous incorporation [4].

Polyetherketoneketone (PEKK) is relatively new as an orthopedic implant material similar to PEEK [5]. However, PEKK has higher tensile strength, higher elasticity modulus, and higher thermal stability [6]. PEKK has seen increased utilization due to its ability to promote cellular behavior which in turn helps promote new bone formation [7]. Biocomposite materials have gained increased popularity in orthopedic implants due to their ability to match normal human anatomy and physiology. In this case report, we present the use of a custom PEKK implant in talus replacement during tibiotalocalcaneal arthrodesis for a patient with complete talar collapse after attempted ankle arthrodesis several years prior for Charcot reconstruction. To the author's knowledge, this is one of the few publications of its kind highlighting the utilization of PEKK in foot and ankle surgery.

2. Case Report

In this case report, we present a 72-year-old female with a history of attempted ankle arthrodesis who was referred due to a non-union with talar avascular necrosis and collapse. She was offered multiple alternative treatment options, in the form of the utilization of a pneumatic walking boot for the rest of her life or an elective below-knee amputation. She ultimately presented to the clinic for a second opinion. Routine in-office weightbearing radiographs revealed complete collapse of her talus with failed ankle arthrodesis and retained hardware (Figures 1–3). Preoperative CT scan confirmed complete talar collapse as well as non-union of her ankle joint, but also extensive arthropathy of her subtalar joint. She was counseled in our office about potential surgical intervention; the majority of the intervention revolved around the talus which would require a bone void filler after talectomy was performed. A PEKK implant (Oxford Performance Materials (OPM), South Windsor, CT) was chosen for the patient after obtaining a contralateral CT scan to guide with the design of the custom talar implant (Figure 4).



Figure 1. Preoperative AP foot radiograph.



Figure 2. Preoperative AP ankle radiograph.



Figure 3. Preoperative lateral ankle radiograph.

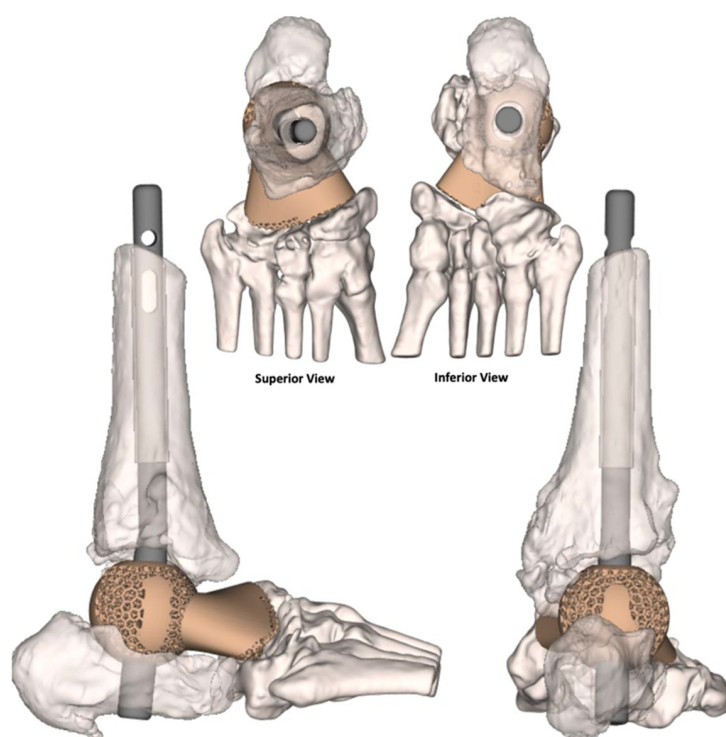


Figure 4. Preoperative custom device plan based on the contralateral extremity CT scan.

Surgical Technique

The patient was brought to the operating room under sedation and placed on the operating room table in the supine position. A well-padded pneumatic thigh tourniquet was applied with the standard preparation of the extremity. A percutaneous Achilles tendon lengthening was performed. A lateral transfibular approach was then utilized to expose the remnant of the fibula and the ankle/subtalar joints. The previous retained screws from the arthrodesis were quickly visualized and removed. The small portion of the talus that remained was excised. Careful preparation of the tibial and subtalar joint surface was performed using combination of anatomical power rasp and curettes. Fenestration of the subtalar joint surface was also performed with a drill bit. Trial sizers (Figure 5) for the talus were utilized to visualize proper fit, and the nominal implant was chosen. With the trial sizer still inserted to hold position, sequential reamers for the tibiotalocalcaneal (TTC) nail were used in retrograde fashion. Bone allograft as well as autograft from the reamers were placed in/on the final talar implant (Figure 6) which was then inserted into the ankle and foot (Figure 7). The TTC nail was then inserted according to the manufacturer's instructions and secured using several screws in the foot and tibia (Figures 8 and 9).

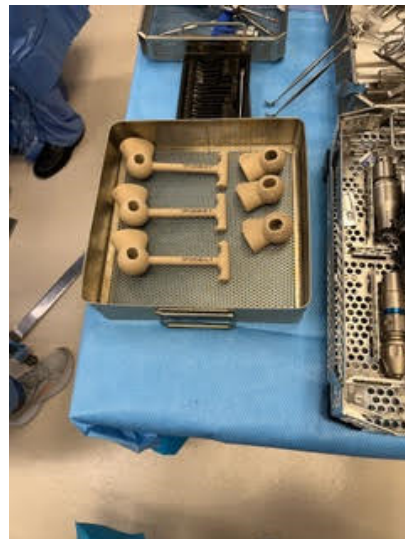


Figure 5. Custom 3D implant sizing tray.



Figure 6. PEKK Implant prior to insertion with graft applied.



Figure 7. Device implanted into ankle.

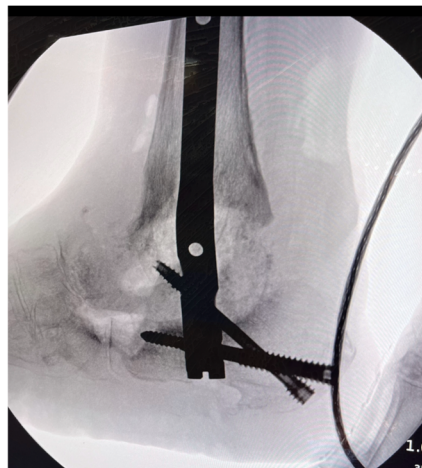


Figure 8. Final intraoperative lateral x-ray.



Figure 9. Final intraoperative AP ankle radiograph.

The patient was placed in a well-padded posterior splint and seen in the office for routine postoperative follow-up. A bone stimulator was also used during the postoperative period. She remained non-weightbearing in the posterior splint or short leg cast for 8 weeks with transition to non-weightbearing in a tall walking boot until postoperative week 12.

She then progressed to weightbearing in the walking boot and began physical therapy. She transitioned into an ankle brace at 4 months until 1 year postoperatively. Radiographs taken at 1 year displayed stable positioning of all hardware and the PEKK implant, with a rectus position of the ankle and hindfoot demonstrated radiographically and clinically (Figures 10–12). Radiographic bone incorporation around the implant was also observed, although this was not confirmed on CT. The patient continued to ambulate pain-free at 1.5 years post-surgery at the most recent follow-up. Preoperative to postoperative AOFAS (17 to 92), FFI (90 to 8), and VAS (9 to 0) all improved at the final follow-up. She had been using a cane due to ipsilateral hip arthritis and pain with plans for total hip arthroplasty.

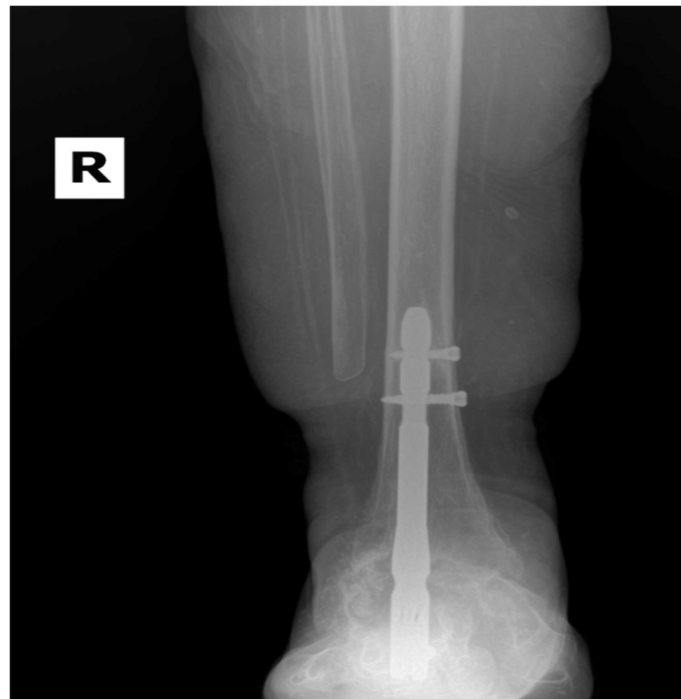


Figure 10. AP Ankle radiograph 1.5 years post-surgery.



Figure 11. Lateral ankle radiograph 1.5 years post-surgery.



Figure 12. Ankle mortise radiograph 1.5 years post-surgery.

3. Discussion

This is one of the only case reports in the literature pertaining to the utilization of PEKK implants for foot and ankle reconstruction and limb salvage. At the final 1.5 year follow-up, we have observed radiographic signs of stable tibiototalcalcaneal arthrodesis with hardware and osseous stability with the PEKK implant.

Orthopedic implants continue to improve as different materials and technology become more readily available. Yang studied the effects of PEKK on a cellular level in regard to increasing osteointegration and promoting cellular behavior [8]. They found that PEKK-enhanced mesenchymal stem cell proliferation and differentiation with subsequent bone integration. Cheng found in their research that PEKK has a higher tensile strength, higher thermal stability, and higher modulus of elasticity as compared to PEEK [6].

Little evidence exists in the literature regarding the use of PEKK implants in foot and ankle surgery, with no direct clinical comparative studies. However, PEKK has been widely used in oral and facial reconstruction, as well as spinal corpectomy. Refai compared PEEK and PEKK in a randomized controlled trial regarding partial denture implants. That study found a statistically significant increase in the required force to dislodge the PEKK implant compared to the PEEK implant [9]. Koehler performed a comparative study using autologous iliac crest bone graft versus a custom PEKK implant in one- or two-level anterior cervical corpectomy with vertebral fusion. He found good outcomes in both groups, with risk of harvest site complications in the autograft group and a higher risk of hardware complication in the PEKK group. He concluded that higher-level prospective studies are needed to further clarify these results [10]. Ha investigated a composite of PEKK and titanium alloy in 29 patients requiring large bone defect facial reconstruction. They found no cases of implant rejection, and low rates of any complications. They went on to state custom printed biocompatible material provided more predictable results in these complicated large facial bone defect reconstructions [11].

Historically, larger osseous deficits especially in the ankle were spanned utilizing titanium in the form of either truss systems or custom titanium replacements. Parry reported the outcomes of their study with the utilization of custom-made 3D printed titanium trusses for spanning large periarticular defects with an overall 91.7% successful limb salvage rate in 12 patients [12]. Remhamadany also presented findings associated with custom titanium trusses designed specifically for avascular necrosis [13]. They ultimately concluded that these titanium trusses are able to provide mechanical stability with great patient-reported outcomes, with an average follow-up at 32 months.

PEKK has been utilized in the foot and ankle for Charcot reconstruction. Fallat used a custom designed a talar PEKK implant for talar collapse from Charcot neuroarthropathy [14]. Similar to our present study, a tibiototalcaneal arthrodesis was also performed to provide stability to the hindfoot and ankle. At the 3-year follow-up, the patient demonstrated continued arthrodesis and was ambulating without pain.

This case report has some limitations. First, this is a single patient retrospective case report. Second, this present study only reports on the results at 1.5 years. Although there is evidence of bony consolidation and incorporation on plain radiographs, there is no CT confirmation for this patient. With evidence of radiographic stability and absence of pain, CT was not pursued. Future studies could benefit from larger sample sizes, multicenter approach, and longer-term outcomes, and CT confirmation of bony incorporation. Studies directly comparing PEKK and PEEK would also be beneficial in any surgical application, including foot and ankle reconstruction.

In conclusion, we present a favorable outcome for a patient undergoing tibiototalcaneal arthrodesis with custom PEKK talar implant with radiographic evidence of stability of the implants and surrounding bone. Further investigation is needed, but early evidence shows promise with the use of PEKK in foot and ankle reconstruction.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study. Written informed consent has been obtained from the patient(s) to publish this paper.

Data Availability Statement: The original contributions presented in this study are included in the article. Further inquiries can be directed to the corresponding authors.

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Abbreviations

The following abbreviations are used in this manuscript: PEKK (Polyetherketoneketone). PEEK (Polyetheretherketone). CT (computed tomography). TTC (Tibiototalcaneal).

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