The partial talus replacement (PTR) – An alternative treatment for severe osteochondral lesions of the talus utilizing a custom 3D printed talar hemiarthroplasty implant: A case report and technique guide

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Large osteochondral lesions of the talus can lead to severe pain and disability. Various surgical interventions have been described in published literature. Customized implants developed through additive manufacturing are increasing in popularity with favorable results within foot and ankle surgery. This case study reports a 52-year-old male who has a history of failed prior surgical interventions with severe left ankle pain associated with a large osteochondral lesion of the talus. The patient underwent resection of the diseased bone with the aid of patient specific instrumentation followed by implantation of a custom 3D printed partial talus implant to resurface the talar dome. At a final follow up of 24 months, the patient continued to experience significant improvement in functional outcomes without radiographic evidence of implant complications.

**Keywords:** 3D printing, partial talus, osteochondral lesion, additive manufacturing

Ankle injuries leading to significant degeneration or cystic changes of the talus can severely diminish quality of life. Etiologies for osteochondral lesions of the talus (OLT) and talar collapse include trauma, avascular necrosis, failed implants, failed total ankle arthroplasty, charcot neuroarthropathy and various neoplasms [1,2]. Osteochondral lesions of the talus that are less than 1.5 cm² typically respond to treatments involving bone marrow stimulation [3,4]. In recalcitrant cases, OLTs can continue to progress in severity and require more aggressive surgical approaches. Previous literature has proposed multiple treatments to address large symptomatic OLTs which include allograft application, total ankle arthroplasty, ankle fusion, takedown [1,2]. Despite these various operative strategies, OLTs remain a difficult pathology to treat and can result in progression of symptoms if treatment is not effective. Recent advances in 3D printing have expanded surgical options for foot and ankle surgery. 3D Printed customized implants have the advantage of being specifically tailored to the patient's anatomy which optimizes the contour of the implant to native articular surfaces [5]. Customized implants through additive manufacturing have grown in popularity with the use of total tali in the setting of talar avascular necrosis. Johnson, et al., found promising short to mid-term outcomes in their systematic review. However, there is inadequate data for long term outcomes [6]. The question also remains of the stability of the total talus prosthesis after complete resection of the talus which sacrifices ligamentous attachments. Various complications have been reported which include medial malleolus fracture, wound healing complications and adjacent joint arthritis [6,7]. There have also been reports of complications with subsidence of the metal to the adjacent joint/bone interfaces. Harroongroj and Vanadurongwan first described the use of talar implants to address talar collapse and necrosis with the use of first-generation talar body implants [8]. These implants attempted to maintain ankle function by resurfacing the talar articular surface. Unfortunately, there were reports of loosening of the talar body fixation to the talar neck. Newer generation 3D printed implants, such as the one presented in this case study, now have the option to include a smooth surface for articulation and an optimized porous surface for bony integration, thus addressing subsidence or collapse [9].
This case study highlights a novel approach to the treatment of severe osteochondral lesions of the talus utilizing a custom 3D printed talar hemiarthroplasty implant. We propose that a partial talus replacement (PTR) is a safe and effective treatment for severe osteochondral lesions of the talus while maintaining ligamentous attachments of the talus. If needed, this approach could also be converted to a total ankle arthroplasty, total talus replacement or ankle fusion. To our knowledge, this is the first reported case utilizing a custom partial talus replacement.

**Case Report**

A 52-year-old male with no significant past medical history presented to our clinic with chief complaint of left ankle pain which has been present for 3 years. The patient had a history of multiple ankle sprains which occurred when he was a youth. Three years prior to his initial presentation he suffered a severe ankle sprain which aggravated his ankle pain. He underwent cast immobilization and a cortisone injection from an outside provider. His ankle continued to worsen, and he sought a 2nd opinion from another foot and ankle specialist. An MRI of the left ankle was obtained at that time which was positive for an osteochondral lesion on the central dome of the talus. Operative treatment was then performed which included an ankle arthroscopic synovectomy, microfracture of the OLT and a Broström lateral ankle ligament stabilization. After 6 months of rehabilitation, the patient’s improvement plateaued, and he experienced a recurrence of his symptoms.

At nine months postoperative his pain level exceeded his preoperative pain. He was then referred to our clinic for further management.

The patient expressed that he had a constant limp due to significant pain to his left ankle. He reported the inability to perform any type of physical activity for more than 30 minutes at a time. Examination revealed pain and guarding with left ankle range of motion and deep palpation. Anterior drawer test was negative without any obvious laxity of the collateral ligaments. An MRI of the left ankle was obtained which demonstrated a large cystic lesion with surrounding marrow edema within the central portion of the talar dome measuring approximately 13.3 x 19.6 x 21.7 mm. Furthermore, the MRI displayed healthy cartilage and subchondral bone on the distal tibial articular surface (Figure 1). Given the significance of the MRI findings along with the patient’s clinical symptoms, surgical interventions were explored. Several reconstructive surgical options were considered once it was determined that prior interventions failed to alleviate the patient’s chief complaint. Due to the centralized location and extent of the OLT, it appeared that the next step would likely include a total joint destructive procedure such as a total ankle replacement or ankle fusion. Upon further discussion, the patient expressed desire to maintain ankle range of motion and to avoid fusion. While a total ankle replacement was considered, we explored the possibility of using a customized solution to resurface only the damaged side of the joint with the use of a partial talar (dome) replacement.

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**Figure 1** Sagittal, Axial and Coronal MRI of left ankle.
Figure 2 Digital planning and custom implant design.

Implant Design/Digital Planning and Rationale

A CT scan was ordered of bilateral ankles. This is necessary for accurate anatomic mapping and contouring. The unaffected talar shape is flipped in chirality and overlaid on the affected side. The CT imaging scans were transferred to the Additive Orthopedics bone segmenting and planning software (Additive Orthopedics, Little Silver, NJ). Once the data files were configured into digital 3D models (.stl), it was determined that the involved talus had retained its original shape, despite the large OLT. The size and depth of the lesion as measured on the MRI study was then used to calculate the depth of the cut required to remove the compromised portion of the dome.

According to the digital plan, it appeared that the proposed level of resection would allow for the resurfacing of the entire dome while demonstrating that the foundation was amenable for fixation and anchoring of the proposed talar component (Figure 2A). Patient specific cut guides were developed to achieve accurate resection and placement of the implant. (Figure 2B). Another consideration in implant design was the optimal style of fixation. Since the partial talus would be placed without any modifications of the tibia, we chose two short fixation pegs with a slight posterior angulation. This would also minimize any damage to the remaining talar body to preserve future salvage/revision options such as conversion to a total ankle with a flat top talar design, hybrid ankle with a total talus or an ankle fusion.

Figure 3 Comparison of resected bone with talar implant.

An additional anterior medial to posterior laterally oriented screw slot was placed to reinforce the initial fixation (Figure 2C). The partial talus implant would also include a porous plantar surface for ingrowth and polished dome surface for articulation with the tibia (Figure 2D). Another vital consideration in implant design was the clearance of the prosthesis for implantation within the tibiotalar joint. In our experience, tibial resection is typically necessary for optimal placement of the talar prosthesis in total ankle replacement. For this reason, a total talus implant was also developed as a backup procedure should the talar prosthesis have suboptimal placement due to adjacent structures or in the setting of unexpected necrosis of the underlying bone. The final implant material was composed of a titanium alloy (Ti6Al4V) (Additive Orthopedics, Little Silver, NJ).

Surgical Technique

The patient was placed in the supine position with a hip bump. No tourniquet was used following the primary surgeon’s (AP) total ankle protocol. A standard linear anterior ankle incision approximately 10 cm in length was made just lateral to the tibialis anterior tendon. An interval was created between the tibialis anterior and extensor hallucis longus tendon. The extensor retinaculum was divided and care was taken to ensure the neurovascular bundle was retracted laterally.
portion was then compared to the actual implant to ensure accuracy (Figure 3). The base of the talar resection was then inspected and was noted to have a bone cyst which was debrided and packed with bone marrow aspirate mixed with demineralized bone matrix. The trial sizer was placed and proper fit was confirmed visually along with fluoroscopic guidance. The trial appeared to have good contour along the tibiotalar articulation. The peg and screw holes were then drilled using the trial guide ensuring correct orientation. The final implant was positioned within the ankle and impacted into place. A 3.0 x 28 mm locking screw was then placed within the implant screw slot from slightly dorsal medial to plantar lateral. After successful placement of the implants, ankle range of motion was noted to be smooth without any crepitus. The final implant position was noted to have a smooth contour without any noticeable step offs or prominence (Figure 4). Closure of the tibialis anterior tendon sheath and extensor retinaculum was achieved with 2-0 Vicryl followed by subcutaneous closure with 3-0 Monocryl. Skin staples were utilized to approximate skin edges and an incisional vacuum was placed (Smith and Nephew, London, UK). Final fluoroscopic images were obtained which confirmed optimal placement of the implant (Figure 5).

**Postoperative Period**

At 2 weeks postoperative, the staples were removed and the patient was cleared for partial weightbearing with gradual return to full weightbearing over the next 3 weeks as per the primary surgeon’s (AP) total ankle protocol. The patient reported minimal pain postoperatively with adequate control through standard acetaminophen and NSAIDs every 4-6h PRN. Physical therapy and gradual return to regular activities was initiated at 6 weeks. Serial radiographs were obtained at that visit which showed no changes in implant position or evidence of subsidence/failure. The patient did not experience any incisional complications. At 10 weeks postoperative the patient reported significant improvement in pain and increased ability to perform physical activities. He was cleared to return to work. Examination revealed painless and smooth ankle range of motion. Longer term follow up was then initiated given the patient’s clinical and radiographic improvement.

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**Figure 4** Position of final implant.

**Figure 5** Intraoperative AP and lateral.

Capsular incision was performed and blunt dissection was utilized to free remaining soft tissue to the anterior distal tibia and anterior superior aspect of the talus which extended to the talonavicular joint. Any excess osteophytes or loose bodies were removed at this time. The custom cut guide was then placed over the talar neck and temporarily fixated following the digital plan. A sagittal saw was then utilized to perform the talar dome osteotomy and the talar dome fragment was removed as a single piece. The resected
At 24 months postoperative, the patient reported being able to perform golf and other physical activities (biking, walking, swimming etc.) with minimal pain. He does report slight discomfort after prolonged distances of walking but is overall satisfied with the outcome of his procedure. Examination displayed maintenance of range of motion with mild tenderness at maximal dorsiflexion. No pain or instability was noted with inversion or eversion stress. Radiographs were obtained which showed no changes in position and no evidence of hardware failure (Figure 6).

Discussion

Large osteochondral lesions of the talus remain a difficult pathology to address. The use of a 3D printed custom partial talar implant allows for treatment of the lesion while maintaining ligamentous stability of the tibiotalar joint. The patient in this case was experiencing minimal pain after prolonged activities and maintained ankle range of motion after a follow up of 24 months. Johnson, et al., found similar results in their systematic review of total talar prosthesis cases and noted that adjacent joint arthritis was a common complication [6]. Fortunately, the patient did not experience any adjacent joint symptoms, nor did he have any evidence of adjacent joint degeneration on radiographs. This approach can serve patients with severe lesions of the talus that have failed conservative and prior surgical interventions. It is also important to note that the lack of disease in the tibia was a major driving factor in procedure selection. Patient specific instrumentation limited the amount of bony resection that would be typically involved in addressing this type of pathology effectively. In this case, patient expectation and education were vital as the patient was adamantly against fusion. The primary surgeon felt it unnecessary to treat with a total ankle replacement which would resect healthy unaffected portions of the tibia.

Lerch, et al., [10] recently described an ankle hemiarthroplasty technique with a standardized, generic talar resurfacing implant. The indication for the implant includes post-traumatic and primary osteoarthritis of the ankle joint. The technique minimizes bony resection to the talar articular surface and is considered bone sparing. Their study included ten implants and demonstrated improvement in AOFAS, EFAS and pain scores. A major limitation in their study is the short-term follow up of 3 months. Another weakness in this implant is that it can progressively advance the wear on the tibial surface because it is standardized and therefore does not contour anatomically to the tibia. This may increase peak pressures on certain areas of the tibial cartilage. By utilizing 3D printing, our implant design approach provides anatomic contour of the talar dome and minimizes peak pressures on the distal tibia.

Our customized approach can also reduce shearing forces at the metal to bone interface which can lead to improved implant longevity and outcomes. Furthermore, advanced digital planning can aid surgeons in obtaining accurate results. In preparation for this case, the implants and cut guides utilized intraoperatively were examined and handled preoperatively. This allows the surgeon to rehearse portions of the procedure prior to performance. Jastiğer, et al., described this approach and the use of digital planning for preoperative surgical simulation to improve outcomes with deformity correction in foot and ankle surgery [11].

Finally, as demonstrated in this case, patient specific cut guides can provide accurate and reproducible osteotomies which optimizes implant positioning. Duan, et al., utilized customized guides for placement of subtalar joint K wires and found that their technique was reproducible and demonstrated reduction in fluoroscopy and operative times [12].
total ankle arthroplasty, the use of patient specific instrumentation has gained popularity. Daigre, et al., demonstrated accurate tibial implant alignment within 5 degrees of target in 100% of patients and accurate prediction of implant size in 98% of patients using patient specific instrumentation [13].

Conclusion

This case report demonstrates a successful outcome with the partial talus replacement (PTR). This surgical approach is a safe and effective alternative treatment for severe osteochondral lesions of the talus. The implant design allows for anatomic contouring and minimizes tibial peak pressures. The partial talus approach also maintains ligamentous stability of the talus within the mortise. Finally, if revision is required, this implant can be converted to a total talar prosthesis, standard total ankle arthroplasty with a flat cut talus, a hybrid total ankle, or an ankle fusion. Future research involving the use of customized implants and patient specific instrumentation is needed to expand the use of this technology. Longer term follow up is required to explore the longevity and survivability of ankle hemiarthroplasty implants. To our knowledge, this is the first reported case study utilizing a Custom 3D Printed Partial Talar Hemiarthroplasty implant.

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