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Open Access Case Report

Custom Endoprosthetic Distal Fibula Reconstruction Following Chondrosarcoma Resection: A Case Report

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Review began 10/03/2026
Review ended 11/01/2026
Published 11/05/2026

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DOI: 10.7759/cureus.119183

Abstract

Primary malignant tumors of the distal fibula are rare and present a unique reconstructive challenge, as wide resection of the distal fibula includes the lateral malleolus, which plays a critical role in ankle stability and function. We report the case of an otherwise healthy 18-year-old man who presented with an 18-month history of progressively worsening right ankle pain. Physical examination demonstrated swelling and tenderness over the lateral malleolus, with pain during ankle range of motion. Radiographs and MRI demonstrated an aggressive-appearing, expansile lesion of the distal fibula with extension into the syndesmosis. CT-guided biopsy findings were suggestive of intermediate-grade (grade 2) conventional chondrosarcoma, which was subsequently confirmed by final histopathological examination. The patient underwent staged treatment consisting of en bloc resection of the distal fibula with placement of an articulating antibiotic spacer and splint immobilization, followed by definitive reconstruction using a patient-specific osteoarticular distal fibular endoprosthesis. The custom implant was designed to restore fibular anatomy and facilitate reconstruction of the lateral soft-tissue stabilizers while preserving the native ankle joint. At six months of follow-up, the patient was ambulating independently without pain or instability. At 19 months of follow-up, he continued to do well, with stable implant fixation, ankle alignment, and no evidence of local recurrence or metastatic disease. This case demonstrates the feasibility of joint-preserving reconstruction of the distal fibula using a novel patient-specific osteoarticular endoprosthesis following oncologic resection.

Categories: Oncology, Orthopedics
Keywords: 3d-printed prosthesis, ankle reconstruction, bone tumor, chondrosarcoma, distal fibula, endoprosthetic reconstruction, lateral malleolus, limb-sparing surgery, orthopedic oncology, patient-specific implant

Introduction

Primary fibular bone tumors are uncommon, most often involve the proximal segment, and are overwhelmingly benign. Malignant tumors of the distal fibula are exceedingly rare, with chondrosarcoma among the most commonly reported malignant histologic subtypes [1,2]. Wide surgical resection remains the standard of care for chondrosarcomas. Distal fibular resection presents a unique reconstructive challenge because the lateral malleolus and its associated ligamentous structures are critical to ankle stability. Failure to restore these structures may result in progressive deformity, altered gait mechanics, and subsequent degenerative changes of the ankle [3,4].

Reconstructive options after distal fibular resection include soft-tissue stabilization, autograft or allograft reconstruction, arthrodesis, and endoprosthetic replacement; however, no consensus exists regarding the optimal reconstructive technique [3]. Patient-specific three-dimensional (3D)-printed implants can allow anatomic restoration while incorporating customized bony fixation and soft-tissue attachment sites. Published data on distal fibular reconstruction remain limited [5,6]. We describe a staged, joint-preserving reconstruction using a custom osteoarticular distal fibular endoprosthesis following en bloc resection of an intermediate-grade distal fibular chondrosarcoma. Unlike previously reported reconstructions, this approach combines staged oncologic resection with patient-specific replacement of the lateral malleolus and dedicated fixation sites to anatomically reconstruct the lateral ligamentous complex and superior peroneal retinaculum.

Case Presentation

Patient information

An otherwise healthy 18-year-old man presented with an 18-month history of progressively worsening right ankle pain. His symptoms were exacerbated by weight-bearing activities and improved with rest. He was initially evaluated by an outside provider and subsequently referred for orthopedic oncologic evaluation.

On examination, the patient had right ankle swelling without an observable mass. He was tender to palpation over the lateral malleolus and experienced ankle pain with active and passive range of motion. He

otherwise demonstrated intact sensation and motor strength throughout the lower extremity.

Clinical findings

Initial radiographs showed an expansile lucent lesion at the lateral malleolus with cortical thinning and endosteal scalloping, with no evidence of fracture (Figure *1A*-*1B*).

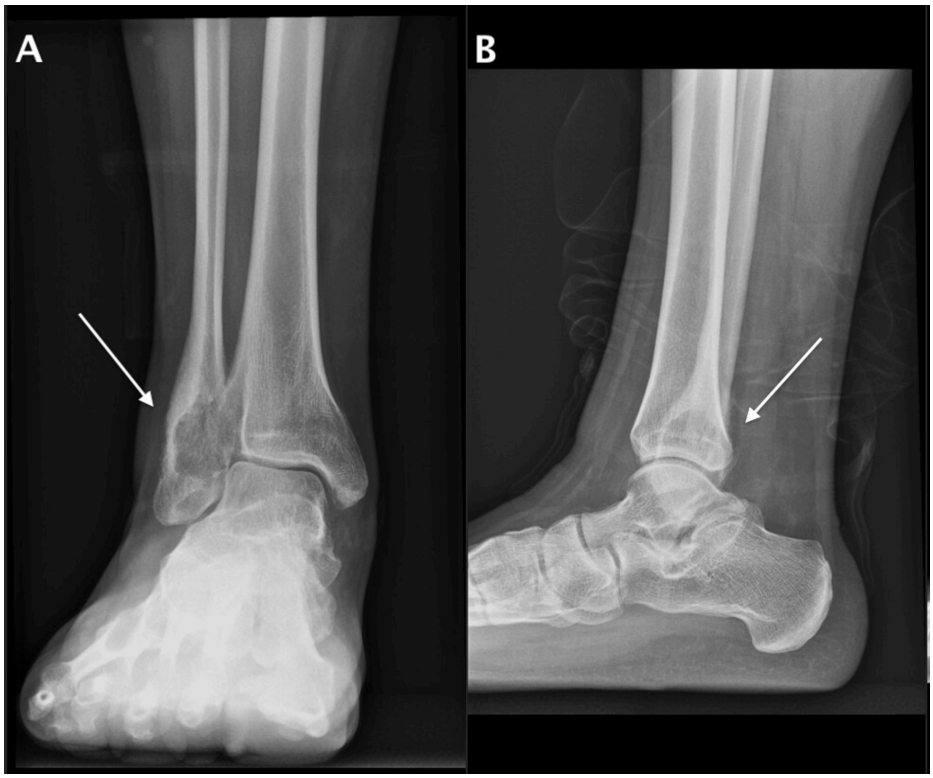


FIGURE 1: Initial ankle radiographs

Anteroposterior (A) and lateral (B) radiographs of the right ankle at initial presentation. The radiographs show an expansile lucent lesion of the lateral malleolus with associated cortical thinning and endosteal scalloping of the distal fibula.

MRI obtained prior to referral demonstrated a 2.1 cm x 2.0 cm expansile intraosseous lesion of the distal fibula with syndesmotic extension (Figure *2A*-*2C*).



FIGURE 2: Prior MRI

Sagittal (A), coronal (B), and axial (C) views of a preoperative MRI of the right ankle show a 2.1 x 2.0 cm expansile intraosseous lesion of the distal fibula extending into the syndesmosis.

MRI: magnetic resonance imaging

The lesion's expansile morphology, syndesmotic extension, and associated radiographic findings, in the setting of progressive symptoms, raised concern for an aggressive osseous neoplasm and prompted further diagnostic evaluation. CT-guided biopsy demonstrated a cartilaginous tumor with morphologic features suggestive of a grade 2 chondrosarcoma.

Diagnostic assessment

The case was reviewed with the institutional multidisciplinary sarcoma tumor board. Given the patient's unusually young age for conventional chondrosarcoma, alternative diagnoses, including chondroblastic osteosarcoma, were considered. The consensus was to proceed with oncologic resection, which would be necessary for any primary bone malignancy, and to tailor definitive care based on the final pathology. If the final pathology confirmed chondrosarcoma, surgical resection would be definitive treatment. If osteosarcoma of a grade warranting systemic treatment were identified, adjuvant chemotherapy would be initiated.

Treatment options were discussed extensively with the patient and his family. Given some diagnostic ambiguity and concern that this was a chondroblastic osteosarcoma, a staged reconstructive approach was recommended, consisting of initial en bloc tumor resection with placement of an articulating antibiotic spacer to preserve limb length and soft-tissue tension while awaiting a definitive diagnosis. Definitive reconstruction with a patient-specific distal fibular endoprosthesis was planned after confirmation of the final pathology and surgical margins and, if indicated, administration of adjuvant chemotherapy. The main alternative treatment discussed was primary ankle arthrodesis without fibula reconstruction.

Therapeutic intervention

For the first surgery, the patient was positioned supine without a tourniquet. Under fluoroscopic guidance, the lesion was localized, and a longitudinal lateral incision was made over the distal fibula. Following careful subcutaneous dissection, the peroneal musculature was elevated from the fibula and retracted posteriorly to expose the distal fibula. Before tumor resection, a lateral locking plate (Globus Medical, Audubon, PA, USA) was temporarily secured to the fibula by drilling the shaft holes proximal to the planned osteotomy site to establish appropriate plate length and alignment while avoiding contamination of the planned oncologic margins. The plate was then removed. The distal fibula was subsequently dissected circumferentially to release its ligamentous attachments, and an osteotomy was performed at the predetermined proximal margin using a microsagittal saw. The distal fibula containing the tumor was then mobilized and excised en bloc, and the specimen was sent for permanent pathological analysis.

The lateral locking plate was then secured to the remaining distal fibular shaft, and an articulating antibiotic polymethylmethacrylate spacer was molded around the distal portion of the plate to recreate the native morphology of the distal fibula (Figure *3A*-*3B*).

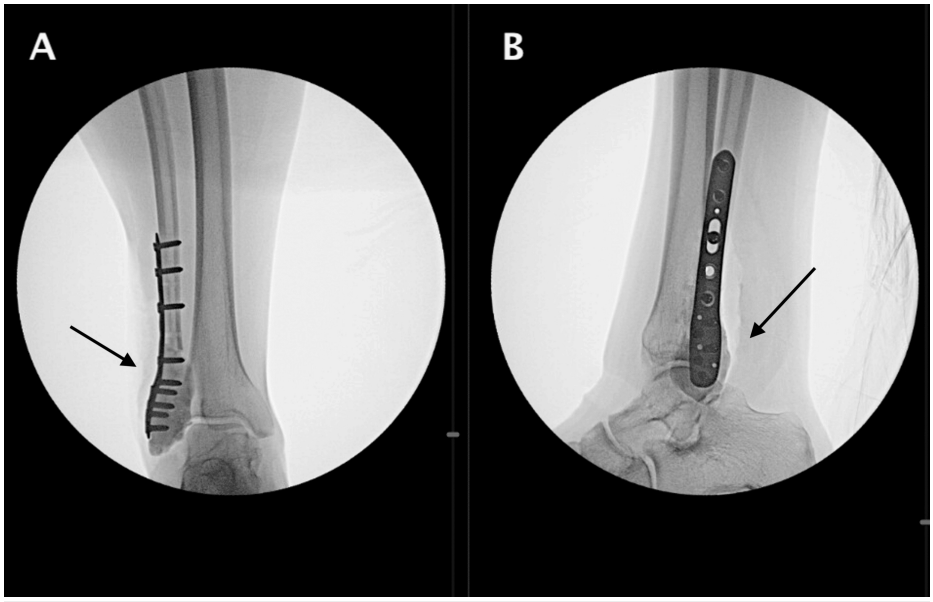


FIGURE 3: Temporary spacer and fixation

Intraoperative anteroposterior (A) and lateral (B) fluoroscopic images demonstrating distal fibular resection and temporary reconstruction with a lateral fixation plate and antibiotic cement spacer.

This allowed temporary maintenance of alignment, length, and stability to preserve the defect for planned second-stage reconstruction. After satisfactory implant position was confirmed under fluoroscopy, the wounds were irrigated and closed in a layered fashion, and the ankle was placed in a standard trilaminar short-leg splint. The patient remained non-weight-bearing for four and a half months prior to undergoing the second-stage procedure and was prescribed aspirin 81 mg twice daily for six weeks for venous thromboembolism prophylaxis.

Postoperative pathology and reconstruction planning

The patient's initial postoperative recovery was uncomplicated. Final pathology confirmed grade 2 conventional chondrosarcoma with negative surgical margins. He subsequently entered our institutional sarcoma surveillance protocol consisting of clinical evaluation with CT of the right tibia/fibula and CT of the chest every three months during the first two postoperative years, every four months during the third year, every six months during years four and five, and annually thereafter through ten years. After confirming the diagnosis, bilateral ankle non-contrast CT imaging was obtained to facilitate design and manufacture of a patient-specific distal fibular endoprosthesis. The orthopedic oncology and orthopedic foot and ankle teams, along with the engineering and design teams at Onkos (Parsippany, NJ, USA), designed the implant.

Therapeutic intervention

Given the patient's condition, a custom-made device was considered the most appropriate treatment option because no commercially available prosthesis could reconstruct the distal fibula while providing adequate fixation to the remaining fibular shaft. The primary alternative was an osteoarticular fibular allograft; however, allograft reconstruction carries a risk of decreased ankle range of motion, nonunion, and fracture over time. The anticipated benefits of using the custom-made device were considered to outweigh its risks, as the customized distal fibular implant offered an opportunity to restore ankle joint function and facilitate reconstruction of the surrounding ligaments.

Definitive reconstruction using the custom distal fibular implant was therefore planned. Because of the unique design features and coordination requirements between Onkos and Arthrex (Naples, FL, USA), implant design, production, and delivery required 4.5 months. The patient subsequently underwent second-stage reconstruction using the custom distal fibular implant.

The custom implant consisted of cobalt-chromium (CoCr) with commercially pure (CP) titanium plasma-sprayed surfaces and included a 66 mm proximal fixation plate and a 57 mm distal fibular component. Titanium plasma spray was applied along the fibular resection and tibial interfaces, while the distal articulating surface consisted of polished CoCr. A 3-mm aperture with a posterior recess accommodated a suture-button construct. Additional suture holes were incorporated into the implant, including anterior holes positioned 2 mm from the implant edge and curved posterior tunnels connecting to the existing lateral-to-medial suture holes. Fixation was designed to accommodate four 4.0-mm Synthes cortical screws

through the fibular plate and two 4.5-mm Synthes cortical screws extending through the implant body into the tibia (Figures 4-5).

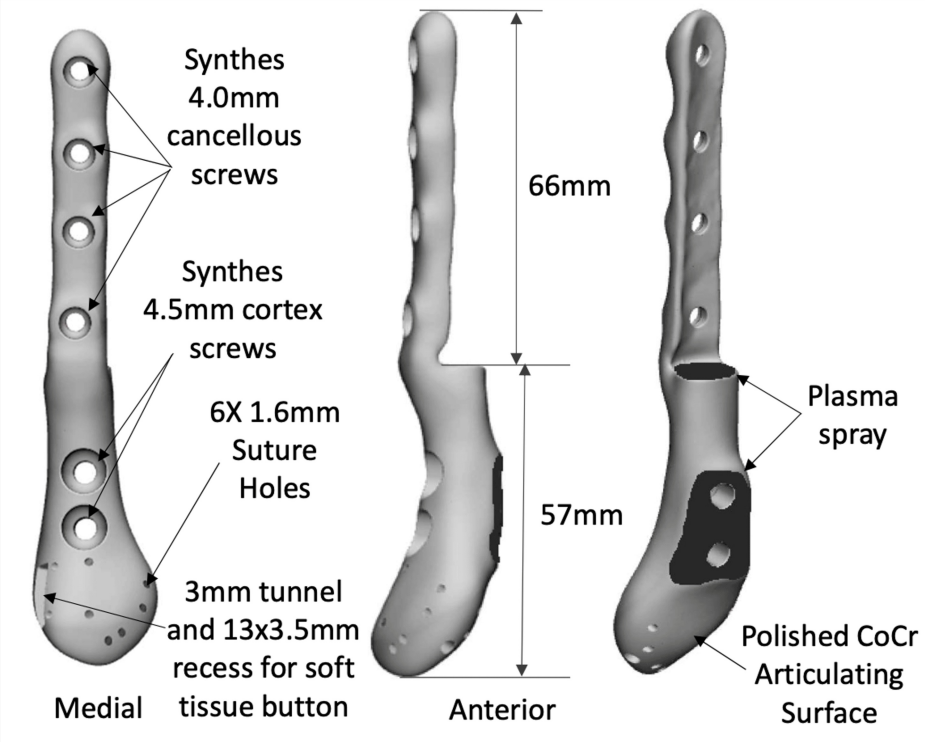


FIGURE 4: Preoperative implant design

Planned patient-specific distal fibular endoprosthesis, including the proximal fixation plate, distal fibular component, and dedicated fixation points for ligamentous reconstruction.

CoCr: cobalt-chromium

Images courtesy of Onkos Surgical. Reproduced with permission.

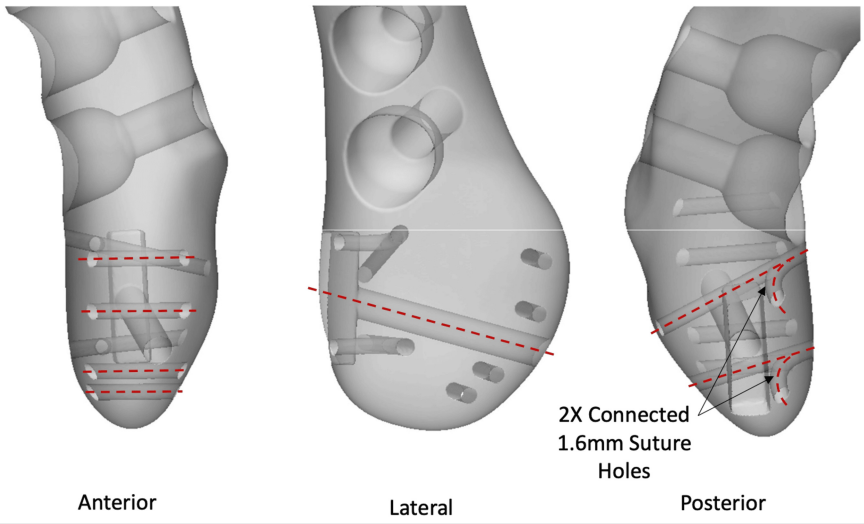


FIGURE 5: Preoperative implant design

Planned suture-hole locations and trajectories for ligament reconstruction, including anterior suture holes and curved posterior tunnels.

Courtesy of Onkos Surgical. Reproduced with permission.

The previous lateral incision was reopened. The peroneal tendons were identified, mobilized, and protected while the temporary fixation plate and antibiotic spacer were removed. The incisura was prepared by removing all remaining cartilage from the tibial surface with a curette and rongeur. This was followed by joint surface preparation with a 2.4-mm drill and curved osteotome. Care was taken to preserve the lateral ligamentous structures during this process.

Definitive reconstruction was performed using the custom-designed, patient-specific osteoarticular distal fibular endoprosthesis. A patient-specific cutting guide was secured to the remaining fibula using a previously established screw hole for anatomic registration. The guide facilitated precise resection of the remaining distal fibula while preserving the planned fibular length. Guided by the custom jig, a microsagittal saw was used to complete the planned osteotomy, and the remaining distal fibular segment was excised and sent for pathological evaluation.

The implant was then provisionally pinned into place, and fibular length, rotation, and alignment were confirmed clinically and under fluoroscopy. Definitive fixation was achieved using a combination of cortical and locking screws, with screws placed into the remaining fibular shaft followed by screws across the distal tibiofibular interface. No bone grafting was used.

Next, soft-tissue reconstruction was performed. The remnant anterior talofibular ligament and calcaneofibular ligament were identified and repaired to the custom implant using 0.9-mm suture tape constructs passed through predesigned fixation tunnels within the prosthesis. Additional FiberTape (Arthrex, Naples, FL, USA) was passed through a dedicated implant tunnel to create an augmented lateral ankle ligament construct. The FiberTape was secured to the lateral aspect of the talus using a 4.75-mm SwiveLock anchor (Arthrex, Naples, FL, USA) under fluoroscopic guidance.

The superior peroneal retinaculum was reconstructed by securing it to dedicated posterior fixation points on the prosthesis using interrupted absorbable sutures in a pants-over-vest configuration. Dynamic examination through passive ankle circumduction confirmed stable containment of the peroneal tendons within the reconstructed fibular groove, with no evidence of subluxation. Final fluoroscopic evaluation demonstrated stable implant fixation across the distal tibiofibular interface, restoration of fibular length and alignment, and a congruent ankle mortise (Figure *6A*-*6B*).

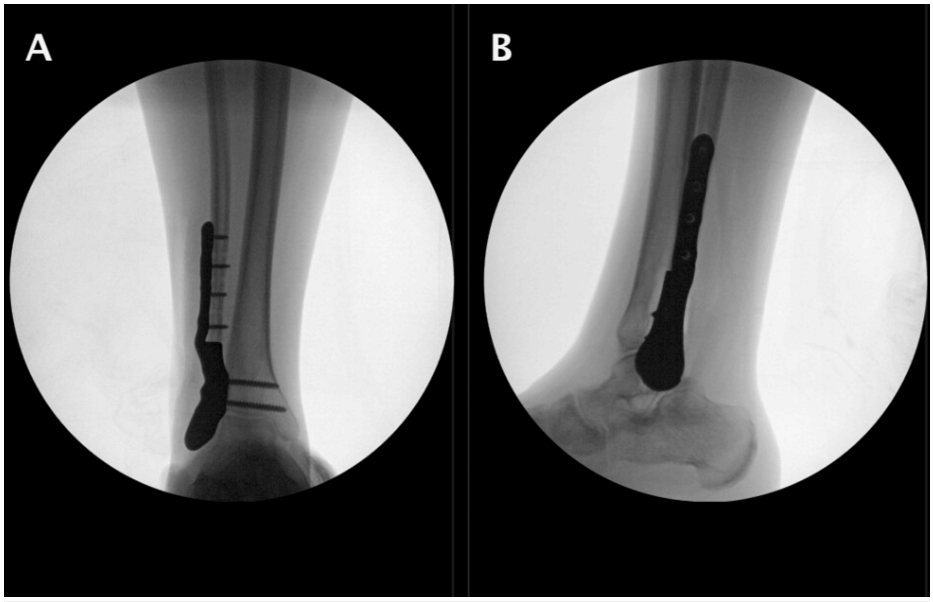


FIGURE 6: Intraoperative imaging

Intraoperative anteroposterior (A) and lateral (B) fluoroscopic images after endoprosthetic reconstruction.

Follow-up and outcomes

The patient remained non-weight-bearing for six weeks postoperatively, after which he began progressive protected weight-bearing in a brace and formal physical therapy. High-impact activities were restricted until four months postoperatively. By six months after surgery, the patient was ambulating unassisted without a limp and denied any pain or instability. Ankle range of motion was symmetric to the contralateral side, the ankle was stable on anterior drawer testing, and there was no subluxation or dislocation of the peroneal tendons with circumduction of the ankle and foot. The patient reported returning to work, school, and his baseline activities without limitations (Figure 7).



FIGURE 7: Clinical photograph

Postoperative clinical photograph demonstrating the patient bearing full weight.

Throughout follow-up, the patient underwent serial postoperative radiographs to assess implant fixation, alignment, and preservation of the ankle mortise (Figure *8A*-*8C*).

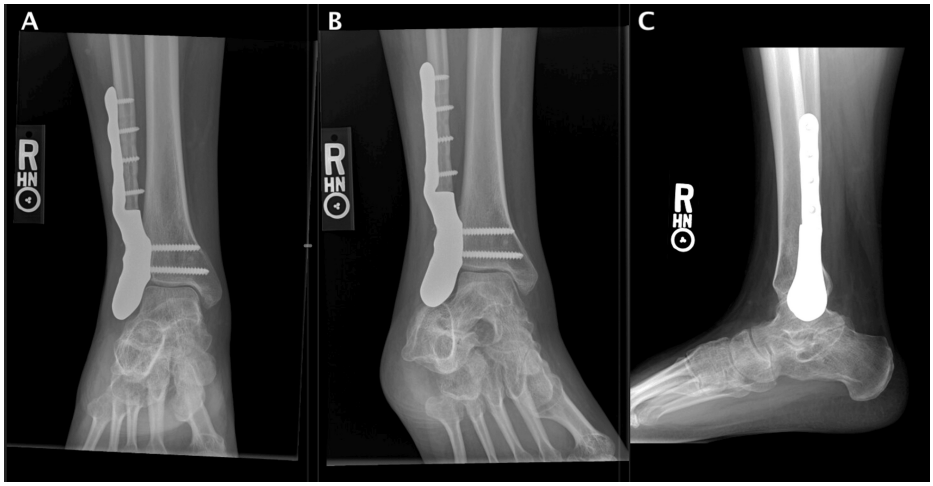


FIGURE 8: Postoperative radiographs

Anteroposterior (A), oblique (B), and lateral (C) radiographs demonstrating the custom distal fibular endoprosthesis at one year postoperatively.

An ankle CT obtained at 10 months postoperatively demonstrated stable alignment of the reconstruction and syndesmotic fixation, without evidence of hardware loosening or periprosthetic lucency (Figure *9A*-*9C*).

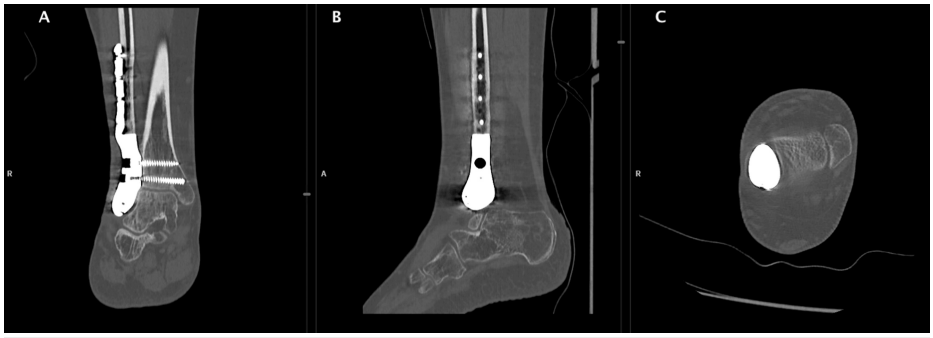


FIGURE 9: Postoperative CT

Coronal (A), sagittal (B), and axial (C) CT images demonstrating the custom distal fibular endoprosthesis at 10 months postoperatively.

CT: computed tomography

However, because the reconstruction involved a metal-bone interface rather than a conventional bone-to-bone arthrodesis, osseous fusion could not be assessed using conventional criteria. Serial sarcoma surveillance imaging demonstrated no evidence of local recurrence or distant metastatic disease.

Discussion

Surgical management of primary bone sarcomas involving the distal fibula presents a unique reconstructive challenge because the lateral malleolus and its associated ligamentous structures are essential for maintaining ankle stability and normal joint biomechanics. Consequently, wide distal fibular resection can disrupt both osseous restraint and soft-tissue stability, predisposing the ankle to valgus translation, recurrent instability, altered gait mechanics, and progressive tibiotalar degeneration [3,4,7]. We describe an innovative staged, joint-preserving reconstruction using a patient-specific osteoarticular distal fibular endoprosthesis designed to restore native osseous anatomy, facilitate anatomic soft-tissue reconstruction, and preserve ankle motion following oncologic resection.

Reconstruction of the distal fibula following tumor resection has historically encompassed a broad spectrum of techniques, including soft-tissue stabilization alone, autograft and allograft reconstruction, and ankle arthrodesis. Osteoarticular allograft reconstruction has demonstrated successful union and ankle stability in small series [8], while arthrodesis remains an alternative following extensive distal fibular resection when joint preservation is not feasible [9]. Soft-tissue stabilization techniques using the peroneal tendons have

also demonstrated satisfactory ankle stability following distal fibular resection [10]. While each strategy offers advantages and limitations regarding ankle stability, durability, donor-site morbidity, and preservation of joint motion, the optimal reconstructive approach remains uncertain, particularly in young, active patients [3]. Soft-tissue stabilization alone may be insufficient to restore the structural support provided by the lateral malleolus, while autograft and allograft reconstruction carry risks of nonunion, graft fracture, and, with autografts, donor-site morbidity. Ankle arthrodesis provides stability at the expense of tibiotalar motion, which is particularly undesirable in young, active patients.

Advances in 3D printing technology have enabled patient-specific implants that reproduce complex osseous anatomy and integrate soft-tissue components. Patient-specific 3D-printed cutting guides have also demonstrated utility in orthopedic oncology by facilitating planned tumor resection and subsequent reconstruction while maintaining oncologic margins [11,12]. In the present case, patient-specific planning enabled restoration of distal fibular length and alignment while incorporating dedicated fixation sites to reconstruct the lateral ligamentous complex and superior peroneal retinaculum. However, as this technology continues to develop, long-term outcomes remain unknown.

The staged approach required a 4.5-month interval between oncologic resection and definitive reconstruction to confirm the final diagnosis and surgical margins and to allow patient-specific implant planning and fabrication. Although this strategy permitted definitive oncologic assessment before reconstruction, prolonged immobilization and non-weight-bearing may increase the risk of ankle stiffness, muscle atrophy, and soft-tissue contracture. These changes may also complicate subsequent surgical exposure, fibular length restoration, and postoperative rehabilitation. In the present case, definitive reconstruction was successfully completed, although the independent contribution of the prolonged interval to surgical complexity could not be determined. This potential trade-off should be considered when planning staged reconstruction, particularly in young, active patients.

Currently, reports of patient-specific 3D-printed distal fibular endoprostheses are limited. Cheng et al. described successful reconstruction of a traumatic distal fibular defect using a custom titanium prosthesis designed from contralateral CT imaging. At two-year follow-up, the patient showed restored ankle stability with satisfactory functional outcomes [5]. However, this case did not involve oncologic resection, staged reconstruction, or restoration of the lateral ligamentous complex. More recently, Xie et al. reported reconstruction following resection of an alveolar soft-part sarcoma of the distal fibula using a patient-specific implant [6]. Unlike our case, the distal fibula and its native ligamentous attachments were preserved, and the prosthesis reconstructed only the proximal fibular defect, avoiding the challenges of recreating the lateral malleolus and its soft-tissue stabilizers.

Our case builds on these early reports by demonstrating staged reconstruction after en bloc resection of a grade 2 distal fibular chondrosarcoma using a patient-specific osteoarticular distal fibular endoprosthesis. Unlike previously published reports, our implant was designed to restore bony anatomy and facilitate anatomic reconstruction of the anterior talofibular and calcaneofibular ligaments, superior peroneal retinaculum, and peroneal tendon groove through preplanned fixation points incorporated into the prosthesis. This comprehensive reconstruction restored lateral ankle stability while preserving the native tibiotalar articulation and ankle range of motion.

This report is limited by its retrospective description of a single patient and relatively short follow-up duration. Although the patient demonstrated satisfactory early oncologic and functional outcomes, longer-term surveillance is necessary to assess implant durability, maintenance of ankle biomechanics, and risk of degenerative arthrosis. Furthermore, the study did not obtain objective functional assessments, including quantitative measurements of ankle dorsiflexion and plantarflexion, validated patient-reported outcome measures, or gait analysis. As with other patient-specific implant technologies, the specialized design and manufacturing processes may limit widespread adoption and require further evaluation regarding reproducibility, cost, and long-term clinical effectiveness. Despite these limitations, this case demonstrates the technical feasibility of this staged reconstructive approach and provides a foundation for future investigation.

Conclusions

This case demonstrates that staged reconstruction with a patient-specific osteoarticular distal fibular endoprosthesis is a feasible joint-preserving procedure following chondrosarcoma resection. Patient-specific endoprostheses may restore distal fibular anatomy and lateral ligamentous stability while preserving the native tibiotalar articulation. At 19 months of follow-up, the patient demonstrated stable implant fixation, pain-free independent ambulation, and no evidence of local recurrence or metastatic disease.

Although these early functional and oncologic outcomes are encouraging, extended follow-up is necessary to evaluate implant durability, sustained ankle function, degenerative changes, and disease recurrence. Further studies with larger patient cohorts and objective functional measures are needed to better define the role of patient-specific endoprosthetic reconstruction in managing distal fibular tumors.

Additional Information

Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

Concept and design: Madeline Carroll, Amy Huang, Russell Stitzlein, Naudereh Noori

Acquisition, analysis, or interpretation of data: Madeline Carroll

Drafting of the manuscript: Madeline Carroll, Amy Huang

Critical review of the manuscript for important intellectual content: Russell Stitzlein, Naudereh Noori

Disclosures

Human subjects: Informed consent for treatment and open access publication was obtained or waived by all participants in this study. **Conflicts of interest:** In compliance with the ICMJE uniform disclosure form, all authors declare the following: **Payment/services info:** All authors have declared that no financial support was received from any organization for the submitted work. **Financial relationships:** All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. **Other relationships:** All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

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