Fibula Strut Allograft with Proximal Tibia Autograft for Treatment of Humerus Nonunion: A Case Report and Review of Oligotrophic Nonunion Management

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ABSTRACT

Due to their high incidence and frequent need for reoperation, nonunions of the humerus present a significant challenge in orthopaedics. Using fibular struts to treat nonunions have demonstrated excellent results. While fibular autografts provide both biologic and structural benefit, high donor site morbidity must be considered. Although their application in midshaft humeral nonunions remains limited, fibular allografts avoid donor site morbidity. Enhancing fibular strut allografts with biological components offers a promising strategy for treating fractures that have failed prior revisions. This case study presents a 36-year-old woman with an aseptic oligotrophic midshaft humeral nonunion who had an unsuccessful revision surgery. Definitive treatment with a fibular strut allograft and a tibial autograft led to improvements in both clinical symptoms and radiographic healing. This case underscores the benefits of combining fibular strut allografts with tibial autografts for successful outcomes, emphasizing the need for further research in this area.

Keywords: Allograft; Bone Transplantation; Fracture Healing; Humeral Fractures; Reoperation

INTRODUCTION

Fractures of the humerus account for 5.0% of all fractures in orthopaedics, with approximately 15.0% progressing to nonunion.[1,2] Adding to the challenge, 33.0% of nonunions are associated with repair-related complications.[3,4] Nonunions occur most often in the proximal humerus, with a smaller percentage affecting the midshaft. Treatment options for humeral nonunions include external fixation, open reduction internal fixation (ORIF) with plating, and intramedullary nailing.[5] These are often augmented with autograft, allograft, stem cells, platelet-rich plasma, demineralized bone matrix, and bone morphogenetic proteins. Current literature lacks a consensus on a standard treatment approach, emphasizing the importance of patient-specific factors for each repair.

Fibular strut allografts have shown promise in the treatment of humerus fracture nonunion.[6,7] While there is strong evidence supporting their use in proximal humerus fractures, research on their application to midshaft nonunions, particularly for oligotrophic ones and in combination with tibial autograft, are limited. The authors present a case of a 36-year-old patient with an aseptic oligotrophic humeral midshaft nonunion that was ultimately treated with a fibular strut allograft with tibia autograft augmentation.

CASE REPORT

Following ejection from an all-terrain vehicle, a 36-year-old woman sustained multiple pelvic fractures with labial hematoma, right distal radius fracture, and a right minimally displaced humeral shaft fracture. Two days after the injury, she underwent ORIF of the humerus. She remained hospitalized for six weeks to treat a labial abscess complicated by sepsis, which required multiple debridements. Two months postoperatively, the humerus showed interval callus formation without evidence of hardware loosening (Figure 1). Four months after surgery, the patient showed callus formation over the lateral cortex of the humerus, but a visible fracture line remained along the medial cortex. At 11 months, the humerus had developed a nonunion, leading to further evaluation (Figure 2).

The patient demonstrated elevated inflammatory labs, including erythrocyte sedimentation rate and C-reactive protein. However, the interventional radiology bone biopsy showed no bacterial growth, and revision ORIF was subsequently performed. Intraoperatively, prior

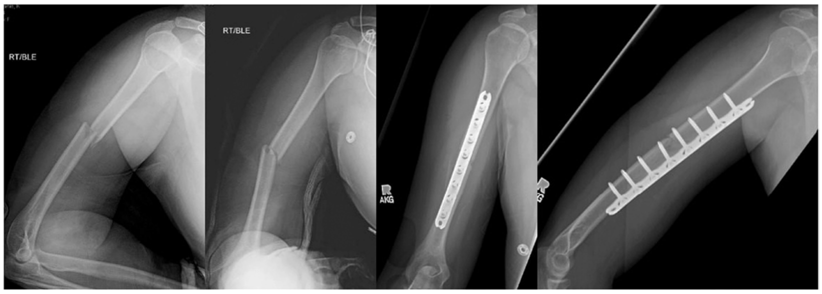

Figure 1. *X-ray of initial fracture and two-month follow-up after primary open reduction and internal fixation.*

Figure 2. *X-rays of initial open reduction and internal fixation 11 months postoperatively.*

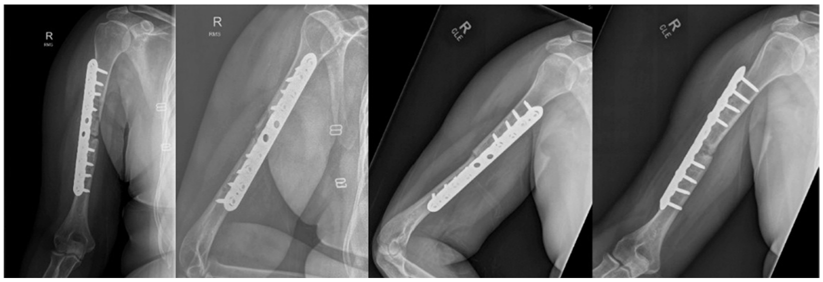

Figure 3. *X-ray of revision open reduction and internal fixation postoperatively and one-year follow-up.*

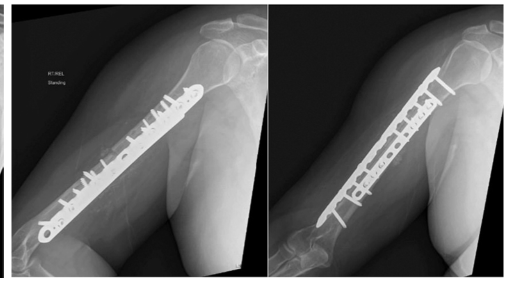

Figure 4. *Two-week post definitive operation.*

implants were removed, the fracture site was debrided to healthy bleeding bone, and there were no signs of infection. A 10-hole compression plate was placed with demineralized bone matrix surrounding the fracture site. Despite the revision ORIF, the patient did not achieve bony healing and showed signs of hardware loosening 12 months later (Figure 3). Infection was once again ruled out with a negative bone biopsy. At this time, the patient began experiencing shoulder pain and weakness attributed to a possible rotator cuff injury that magnetic resonance imaging was unable to discern, due to metal artifact. Therefore, the decision was made to perform another revision ORIF, using a fibula allograft strut and proximal tibia autograft.

In the operating room, a tourniquet was applied to the right lower extremity, and a 2-centimeter vertical incision was made over the anteromedial proximal tibia metaphyseal flare under fluoroscopy. Blunt dissection was then performed to expose the cortical bone. The Zimmer-Biomet Avitus Pilot Hole was used to enter the metaphysis, and a harvesting curette extracted 10 milliliters to 15 milliliters of bone graft.

Attention was then turned to the humerus. An anterolateral approach was used through the patient's prior incision. All implants were removed, and the fracture was debrided to healthy bleeding bone. Next, the humeral canal was proximally and distally reamed to size 11. Irrigation was preformed, and the fibular bone allograft was shaped, inserted into the canal, and filled with a mixture of the harvested tibia autograft and cancellous bone allograft. A 12-hole compression plate was then positioned across the fracture site, ensuring that the screws did not engage with the fibula allograph to allow for proper compression. An additional 10-hole plate was placed anteriorly. Finally, the remainder of the bone graft mixture was placed over the fracture site. The wound was closed in standard fashion. Postoperatively, the patient was instructed to remain non-weight bearing on both the right upper and lower extremities, while maintaining full range of motion at the elbow. She received 24 hours of cefazolin and was prescribed 100 milligrams of doxycycline two times per day for seven days.

The patient demonstrated no postoperative complications at her two-week and two-month postoperative visits (Figure 4). She reported minimal pain in her right humerus and noted a significant improvement in her symptoms, along with improved strength on rotator cuff examination. Her radiographs showed progress in healing, with callus formation, and no signs of implant failure or malalignment.

DISCUSSION

Due to high rates of complications and revisions, humerus nonunions pose significant challenges. Surgical decision-making relies on several factors, including the patient's biological healing environment, biomechanics, and overall health. An important early distinction in nonunion management is septic versus aseptic nonunion. In this case, both the biopsy and intraoperative samples were culture-negative, indicating an aseptic nonunion. Another important factor in nonunion management is assessing the degree of bone formation, as hypertrophic, oligotrophic, and atrophic nonunions require different treatments.[8] This patient exhibited oligotrophic nonunion, characterized by limited callus formation and incomplete fracture consolidation.

Managing oligotrophic nonunions is challenging due to their overlapping characteristics with both hypertrophic and atrophic nonunions. A literature review conducted from 2014 to 2024 using PubMed and Embase databases identified four case reports and five case series outlining treatment approaches for oligotrophic humeral non-unions (Table 1). Common findings across these studies suggest a trend toward combining mechanical support with biological augmentation, resulting in union rates exceeding 90.0%.

Structural support can be accomplished through plating, intramedullary nails, or external fixation. For fractures that have failed previous intervention with change in the biological environment, intramedullary nailing has shown promise in promoting successful healing.[9–12] Gessmann et al[13] and Singh et al[14] enhanced this approach by combining intramedullary nails with locking compression plating in their case reports on oligotrophic nonunions, achieving successful union. However, due to the rotator cuff injury, which is a relative contraindication to intramedullary nailing, this approach was avoided in this patient.

Regarding biological augmentation, iliac crest autograft—either cancellous or tricortical—was the most commonly used adjunct, used in seven out of the nine studies reviewed. Other biological strategies include recombinant human bone morphogenetic protein-2 (rhBMP-2) combined with autogenous bone grafting, as described by Choi et al,[15], who reported 100.0% union across 24 long-bone fractures (including one humerus). Nei et al[16] chose to use platelet-rich plasma (PRP) and demineralized bone matrix for biological augmentation, successfully achieving union in an average of 15 months.

Fibula allograft struts have been previously used in long-bone nonunions for their ability to provide adequate fracture fixation without periosteal disruption. While they have been employed in osteoporotic and atrophic humeral nonunions, their use in oligotrophic nonunions remains uncertain.[17] In their series of long-bone nonunions, Yadav found that autologous fibular struts effectively provide bony stability and osteogenic factors, although a seperate study from Vail highlighted the significant donor site morbidity in fibular autografts.[18,19]

Table 1. *Recent Approaches to Management of Oligotrophic Humerus Nonunions*

	Number of Patients	Time to Union (from definitive surgery)	Fixation Type	Biological Augmentation	Union Rate	Complications
Patient in this study (2024)	1	3 months	Fibular strut allograft, dual LCP	Tibial cancellous autograft	1.0	None
Unal et al[20] (2023)	10	N/A	5 Single LCP 5 Dual LCP	Autograft, Allograft, or combined (unspecified)	N/A	None
Polat et al[10] (2021)	8	5 months	InSafeLOCK® humeral nail	Tricortical iliac crest autograft	1.0	Not Reported
Ziveri Et al[21] (2020)	1	6 months	LCP	Tricortical iliac crest autograft	1.0	None
Feng et al[22] (2020)	1	8 months	Dual LCP	Tricortical iliac crest autograft	1.0	None
Arikan et al[23] (2018)	18	4.4 months	LCP	Tricortical iliac crest autograft	0.95	None
Singh et al[14] (2017)	1	6 months	IMN + LCP	Iliac crest cancellous autograft	1.0	None
Gessmann et al[13] (2016)	34 (atrophic & oligotro-phic)	3 months	IMN & anterior compression plate	Iliac crest cancellous autograft	1.0	1x Radial nerve palsy
Nie et al[16] (2021)	2 (humeral)	15 months	Plate	Demineralized bone matrix, autologous PRP	0.94 (total)	None
Choi et al[15] (2015)	1 (atrophic)	6 months	Plate or nail (not specified)	BMP-2 com-bined with autogenous bone	0.95	None

Similar to this case, Fink et al[5] reported a case series of humerus nonunion with fibular allograft intramedullary fixation, where the majority (77.0%) of patients achieved bony union postoperatively.

As a strategy to promote healing after significant bone loss due to tumor resection, fibular strut allografts have previously been combined with tibial bone autograft in the reconstruction of large osseous defects in orthopaedic oncology.[24,25] Priano et al[26] demonstrated success in applying a similar approach for nonunion repair, using a fibular strut allograft combined with autograft growth factors in a pediatric radius nonunion. In this case, the combination of a fibular strut allograft and tibia autograft was selected to provide both structural and biologic support to promote bone growth. To the authors' knowledge, this is the only report of using fibular allograft combined with tibial cancellous autograft bone augmentation for nonunion repair.

The proximal tibia has become a popular harvest site due to its larger harvest volume and lower complication rates, ranging from 1.0% to 4.0%.[27-29] Candidates for proximal tibia bone harvest have a lower functional baseline, due to the potential risks of harvest site fractures, as documented in a previous case report.[30] This patient's activity level was limited to daily living activities; however, the authors would reconsider this harvest site for individuals who are highly active or have baseline osteoporosis.

At her most recent follow-up, the patient demonstrated significant clinical improvement and radiographic evidence of callus formation, indicating successful bony union. This case and review emphasize the challenges in treating oligotrophic humerus nonunions and highlight recent trends in management. The combination of fibular strut allograft and tibial autograft provides a promising balance of mechanical stability and biological support, while avoiding the morbidity associated with iliac crest harvest. Continued research and clinical reporting are essential to refine these techniques.

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