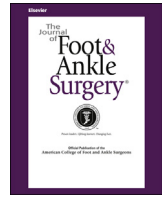




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Vascularized Pedicled Fibula Onlay Bone Graft Augmentation for Complicated Tibiotalocalcaneal Arthrodesis With Retrograde Intramedullary Nail Fixation: A Case Series

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ABSTRACT

Tibiotalocalcaneal arthrodesis stabilized with retrograde intramedullary nail fixation is associated with a high incidence of complications. This is especially true when performed with a bulk structural allograft and poor soft tissue quality. In select high-risk limb salvage cases, we have augmented tibiotalocalcaneal arthrodesis procedures stabilized using retrograde intramedullary nail fixation with a vascularized pedicled fibular onlay bone graft. We present the data from 10 such procedures with a mean follow-up period of 10.9 ± 5.4 (range 6 to 20) months involving 10 patients (9 males and 1 female). The etiology was avascular osteonecrosis of the talus and/or distal tibia and a resultant large volume cavitary bone defect (8 ankles), severe equinovarus contracture (1 ankle), and failed total ankle replacement (1 ankle). A frozen femoral head bulk allograft was used twice, a whole frozen talus allograft once, and a freeze-dried calcaneal allograft once. The fibula was mobilized with intact musculoperiosteal perforating branches of the peroneal artery as a vascularized pedicle onlay bone graft fixated with a screw and washer construct. The mean fibular graft length was 10.2 ± 2.3 cm. The mean interval to radiographic fusion was 2.6 ± 0.6 months and to weightbearing was 3.1 ± 1.4 months. Two stable bulk allograft–host bone and fibular graft–host bone nonunions occurred after intramedullary nail hardware failure. Tibiotalocalcaneal arthrodesis augmented by vascularized pedicled fibular graft stabilized with retrograde compression intramedullary nail fixation offers a reliable option for complex salvage situations when few other options exist.

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The concept and technique of performing tibiotalocalcaneal arthrodesis as a salvage procedure for severe nonreconstructable hindfoot/ankle deformities, avascular osteonecrosis of the tibial plafond and/or talus, end-stage arthrosis of the hindfoot/ankle secondary to trauma, or failed total ankle replacement is not new. When tibiotalocalcaneal arthrodesis is necessary, a retrograde compression intramedullary nail will provide stout, reproducible fixation with external and/or internal compression and the option for dynamization postoperatively. However, retrograde compression intramedullary nail fixation has historically been considered to result in high overall complication rates. Jehan et al (1) and Franceschi et al (2) conducted a systematic review of the published studies to determine the clinical outcomes, complications, and union rates for

tibiotalocalcaneal arthrodesis performed with retrograde compression intramedullary nail fixation. Jehan et al (1) conducted their systematic review from 1950 to 2010 and included 613 tibiotalocalcaneal arthrodeses fixated with myriad retrograde intramedullary nail fixation devices, most which were not specifically designed for hindfoot/ankle arthrodesis. Their review determined that the overall complication rate was 55.7%, with a 16.8% rate of hardware removal, 13.3% of nonunion, with 26% of these requiring revision arthrodesis, 8.4% rate of infection, and 1.5% rate of below-the-knee amputation. Franceschi et al (2) conducted their systematic review from 1994 to 2014 and included 865 tibiotalocalcaneal arthrodeses fixated with modern, anatomically specific retrograde compression intramedullary nail fixation. Their review determined that the overall complication rate was 40%, with an 11.8% rate of infection, an 8.9% rate of hardware removal, a 7.5% rate of nonunion, and a 3.2% rate of below-the-knee amputation. More recent data (3–7) are available that meet the inclusion criteria for the systematic review by Franceschi et al (2). These studies add an additional 207 cases of tibiotalocalcaneal arthrodesis, with an overall complication rate of 45%, nearly identical to the 40% complication rate identified

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by Franceschi et al (2) for similar patient populations. Evaluating the systematic review data, one can conclude that satisfactory results can be achieved with tibiototalcalcaneal arthrodesis using retrograde intramedullary nail fixation. However, a relatively low union rate and high incidence of complications should be anticipated even with use of a modern, anatomically specific, retrograde compression intramedullary nail.

The technique to perform tibiototalcalcaneal arthrodesis with a bulk structural allograft interposed between the distal tibia and talus to fill large osseous defects fixated with a retrograde compression intramedullary nail has been described in detail by Thomason and Eyres (8). This limb salvage technique poses a greater challenge compared with the closely apposed bone surfaces in primary tibiototalcalcaneal arthrodesis and, thus, results in a correspondingly greater complication rate. Jeng et al (9) evaluated 32 patients who had undergone limb salvage attempt using tibiototalcalcaneal arthrodesis with a bulk structural allograft interposed between the distal tibia and talus fixated with modern anatomic retrograde compression intramedullary nail fixation. Nonunion occurred in 50% and below-the-knee amputation was required in 19%. Bussewitz et al (10) evaluated 25 patients who had undergone a limb salvage attempt using tibiototalcalcaneal arthrodesis with a bulk structural allograft interposed between the distal tibia and talus and secured with modern anatomic retrograde compression intramedullary nail fixation. Nonunion occurred in 52%, hardware removal was required in 28%, infection occurred in 20%, and below-the-knee amputation was required in 16%. Of note, 76% of the patients had bone growth stimulation applied at the time of the index surgery. Donnerwerth and Roukis (11) performed a systematic review of this technique specifically for salvage of failed total ankle replacements. A total of 61 patients with 62 failed total ankle replacements were included in the study. Complications occurred in 62.3% of the patients. These included nonunion in 24.2%, with revision arthrodesis required in 60%, hardware removal in 9.7%, infections in 4.9%, and below-the-knee amputation in 1.6%. Attempts to reduce the complication rate after tibiototalcalcaneal arthrodesis with critical-size osseous defects between the distal tibia and talus fixated with a retrograde compression intramedullary nail have included autogenous structural iliac crest bone graft (12), ankle arthrodesis with proximal tibial corticotomy and bone transport; plate fixation (13,14); autologous circular pillar fibula augmentation (15); spinal cage filled with morselized autogenous bone graft (16,17), and trabecular metal cones (18). These techniques have only recently been published as small case series, and the overall complication rates, at face value, were similar to those identified for tibiototalcalcaneal arthrodesis with bulk structural allograft fixated with a retrograde compression intramedullary nail.

One reason for the high incidence of complications with this technique might be that the fibula is nearly universally resected. The use of the fibula as a nonvascularized onlay graft for tibiototalcalcaneal arthrodesis was first described in 1940 by the Royal Air Force Orthopaedic Service in London, England (19). They reported hemisection of the fibula and an onlay into a trough created between the tibia, talus, and calcaneus, secured with compression screws or retrograde intramedullary nail fixation. Osseous union was achieved in 94% (30 of 32 limbs). However, an autogenous iliac crest cancellous bone graft was used, the patients did not require structural bone grafting for critical-size osseous defects. The patients were non-weightbearing for a period of ≥ 12 weeks. Although convenient as a source of autogenous corticocancellous structural bone graft, nonvascularized autogenous fibula onlay grafts are less favorable in certain situations, especially those requiring a bulk structural allograft interposed between the distal tibia and talus or when bone resection to viable cancellous substrate results in a large-volume cavitary defect. This is because their success depends on the viability of the surrounding soft tissues,

which are often in poor condition secondary to previous traumatic injury/surgery and the lack of revascularization of the transplanted bone owing to the presence of a large surface area occupied by the nonvascularized bulk allograft. In contrast, vascularized bone grafts (1) have immediate viability because the osteoprogenitor cells and corticocancellous vascularity are maintained; (2) heal more rapidly because they negate the need for creeping substitution, with incorporation occurring by primary and secondary osseous healing; (3) have more pronounced adaptation to the new mechanical loading (i.e., graft hypertrophy) and are $>50\%$ stronger at the index surgery because they are transferred with maintenance of structural integrity; and (4) possess neovascularization potential into the surrounding soft tissues, allowing for greater survival and consolidation rates in poor recipient bed conditions (20–25).

Evaluation of the vascular supply to the distal fibula revealed that it is quite robust and amenable to vascularized transplantation. In 1981, Guo (26) carefully analyzed the arterial supply to the fibula for successful transplantation of a vascularized fibular graft. In addition to the main fibular nutrient foramen, significant minute foramina are present on the periosteum of the fibula that receive the muscular branches from the peroneal artery (i.e., musculoperiosteal branches). These branches surround the fibula in the muscle layer and leave the bone cortex at distances of 1 to 10 mm (26), supplying the muscles and periosteum. Thus, the dominant blood supply to the distal fibula shaft is the nutrient artery and segmented musculoperiosteal branches from the peroneal artery feeding the periosteum. Three centimeters proximal to the distal tibiofibular syndesmosis, the peroneal artery penetrates the interosseous membrane and divides into a perforating branch and posterior branch (27). The perforating branch continues anteriorly as the lateral tarsal artery and the posterior branch continues as the lateral calcaneal artery. Both the anterior and posterior perforating branches provide a robust arterial supply to the fibula at the level of the distal tibiofibular syndesmosis. The lateral malleolus itself also has a rich vascular supply by way of the perimalleolar arterial circulation, including the anterolateral malleolar artery and fibular metaphyseal artery, which originate from either the anterior tibial or dorsalis pedis artery and anastomose with the perforating peroneal artery (28,29).

The use of a vascularized free fibular bone graft with microvascular anastomosis for tibial defect reconstruction has been in clinical use since first described by Taylor et al (30) in 1975. However, Bishop et al (31) are the first, and only, investigators to report a small series of ankle arthrodeses with osseous defects of ≥ 4 cm performed with a vascularized free fibular bone graft and microvascular anastomosis. Free tissue transfer with microvascular anastomosis is a highly specialized and complex procedure intended for massive osseous defects not routinely performed by foot and ankle surgeons. Maintaining the vascular pedicles to the fibula intact and performing a pedicled onlay graft is technically challenging but maintains the benefits of vascularized tissue. Although transplantation of the fibula for management of tibial defects was first performed in 1903 by Huntington (32), surprisingly little has been written about vascularized pedicled fibular onlay bone grafts for ankle or tibiototalcalcaneal arthrodesis. Casadei et al (33) described the use of a vascularized pedicled intercalary fibular bone graft used in 3 patients for ankle arthrodesis after distal tibia bone tumor resection. Their technique involved impacting the vascularized fibula segment into the talus and tibial medullary canal and securing it with compression screws, a plate-and-screw construct, or an onlay graft press-fit into a trough along the posterior aspect of the tibia and talus. The osseous defects encountered were 8.5, 9, and 16 cm long. Details regarding the specific arterial supply to the fibula were not provided. The non-weightbearing immobilization period was a mean of 4.5 months. Liwen et al (34) reported their technique for a vascularized pedicled

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