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Distal Tibial Periarticular Nonunions: Ankle Salvage with Bone Transport

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SUMMARY

A nonunion of the distal tibial metaphysis in close proximity to the articular surface is a challenging clinical problem. Many of the commonly utilized techniques in a surgeon's treatment armamentarium can be ineffective due to the relative lack of distal bone stock. This study describes a technique of en bloc excision of all infected or nonunited distal tibial bone with application of a circular external fixator and limb shortening. After treatment with parental antibiotics, when appropriate, and docking of the distal excision site, distraction osteogenesis of the proximal tibia is performed with a second circular frame.

KEY WORDS

Distal tibial nonunion, bone transport, circular external fixator

INTRODUCTION

Tibial nonunions are a challenging clinical problem often encountered by orthopaedic trauma surgeons. This difficulty is especially evident in cases that require extensive debridement of all nonviable or infected bone resulting in a large bone defect. Various treatment methods exist for addressing tibial nonunions with significant bone loss and the choice of technique is dictated by the personality and extent of the injury, surgeon experience, patient preference and implant availability. Possible treatment methods include primary autogenous bone grafting, a vascularized free fibula transfer, creation of an induced membrane with subsequent bone grafting (i.e. Masquelat technique) or bone transport.[1-5] Arthrodesis or amputation should also be considered for cases involving substantial distal metaphyseal tibial bone loss in close proximity to the ankle joint.[6-8]

Periarticular distal tibial nonunions within 2-cm of the ankle joint present a unique treatment challenge due to the relatively small size of the distal articular bone fragment. The small articular fragment can limit the extent of stable screw fixation and therefore may preclude some of the more commonly employed treatment methods. We present our surgical technique for patients with a periarticular distal tibial nonunion treated with en bloc excision of all nonunited or infected bone, acute limb shortening and staged proximal tibial lengthening using a Taylor Spatial Frame (TSF; Smith & Nephew, Inc., Memphis, TN). All patients had a distal tibial articular bone fragment that was less than 2-cm in longitudinal length and a nonunion that was best managed with excision.

SURGICAL TECHIQUE

Patients were first clinically examined and orthogonal radiographs of the tibia and ankle were obtained (Figure 1). Basic laboratory blood tests including a complete blood count (CBC), C-reactive protein (CRP) and erythrocyte sedimentation rate (ESR) were collected. CT imaging of the distal tibia was also performed in all cases for preoperative planning purposes (Figure 2).

After obtaining informed consent the patients were brought to the operating room and positioned supine on a radiolucent table with a bump under the ipsilateral hip. A non-sterile tourniquet was then applied to the proximal aspect of the operative extremity. After standard prepping and draping, the extremity was elevated and the tourniquet was inflated to 250 mmHg. All antibiotics were held until collection of microbiology cultures.

The distal tibial nonunion site was approached using either the prior skin incision or a standard anteromedial ankle incision (Figure 3). Subperiosteal dissection was then performed and Hohmann retractors were placed to protect the anterior and posterior neurovascular structures. 1.8-mm wires were next placed perpendicular to the mechanical axis of the tibia at the proximal and distal extent of the nonunion site based on the preoperative imaging (Figure 4). A microsagittal saw was used to excise the nonunion with emphasis on making the cuts parallel to the previously placed wires (Figure 5). Frequent cooling of the microsagittal saw was performed using saline and intermittent pauses to minimize the extent of osseous thermal necrosis. The bone was then removed either enbloc or piecemeal with the use of a ronguer. The bone and surrounding soft tissue was sent as five separate cultures to the microbiology lab and one specimen was sent to our institution's musculoskeletal pathologist. Any remaining bone that was suspected to be nonviable or infected was either debrided or additional horizontal cuts with the microsagital saw was made until adequately excised. Finally, the proximal and distal surfaces of exposed tibia were trephinated with a 1.8-mm wire and fish scaled with a sharp 3-mm osteotome in areas with sclerotic bone.

The fibula was exposed utilizing a direct lateral approach. Any retained implants were removed. With fluoroscopic assistance, a comparable length of fibula was excised to match the adjacent tibia (Figure 6). At this point both incisions were copiously irrigated, the tourniquet was deflated and hemostatsis was achieved. All nonviable or grossly infected surrounding soft tissue was then debrided and any sinus tracts, if present, were excised. Intravenous antibiotics were administered and the incisions were closed in a layered fashion.

After skin closure the circular external fixator was applied. A 155-mm full ring was first secured 10-12 cm proximal to the distal tibial bone defect using a tensioned wire that was placed in a lateral to medial direction. Two anteromedial 6.0-mm hydroxyapatite-coated half pins were then placed for additional ring stability. Of note, the ring size was chosen based on the width of the patient's extremity. Ideal ring size allows for two fingerbreadths between it and the patient's skin to accommodate for postoperative swelling.

The distal tibial segment was then secured in all patients with three tensioned wires as it was judged to be too small for the placement of a half-pin. Of these wires, one was a tibiofibular wire for syndesmotic stabilization and the remaining two were opposing olive wires placed in a lateral to medial and a posteromedial to anterolateral direction. Of note, great care was taken during distal wire placement given the relative lack of bone stock within the distal segment and risk to the posteromedial neurovascular structures. A full ring was also used for the distal tibial segment. Both rings were positioned perpendicular to the tibial mechanical axis in both the coronal and sagittal planes. Additional distal segment stabilization and equinus contracture prevention was accomplished by adding a foot ring that typically consisted of two tensioned calcaneal body and one talar neck wires. In one patient who already had developed an equinus contracture, hinges were placed between the foot and distal tibial rings in line with the ankle axis which allowed simultaneous gradual contracture correction.

Next, the six struts of the circular frame were applied after fluoroscopically confirming acceptable coronal and sagittal alignment of the two tibial fragments. The tibial bony defect was acutely shortened approximately 2-3 cm in all three cases (Figure

7). This amount of shortening was chosen to limit the potential wound or neurovascular complications possible with excessive acute limb shortening. In all cases, no acute change in the distal pulses occurred and the wounds were not excessively stressed with the acute shortening. The residual tibial bony defect was then gradually shortened and compressed postoperatively using the TSF software (Smith & Nephew, Inc., Memphis, TN) at a rate of 3-mm a day after recording the strut lengths as well as the deformity and mounting parameters.[9,10]

Six weeks after excision of the distal tibial nonunion and completion of an intravenous antibiotic regimen, a proximal tibial lengthening was performed. In all three cases an additional 155-mm two-third ring with the opening between struts 4 and 5 was secured to the proximal tibial metaphysis using two tensioned wires and two 6.0-mm hydroxyapatite-coated half pins. Half pins were placed into the anteromedial and anterolateral portion of the proximal tibia. The proximal ring was perpendicular to the tibial mechanical axis in the coronal and sagittal planes. Struts were then placed between the proximal and middle ring from the index procedure. After recording the strut lengths and mounting parameter measurements, an osteotomy was performed. A 1-cm incision was made over the anterior aspect of the tibia distal to the tibial tubercle. Multiple transverse drill holes were then made using a 4.8-mm drill. The osteotomy was then completed with an osteotome and gentle manual osteoclasis making sure to limit the amount of periosteal and surrounding soft tissue damage. The struts were reattached and the osteotomy incision was irrigated and closed with nylon suture.

The deformity parameters for the proximal tibial segment were calculated based on the amount of limb length discrepancy measured from a preoperative 51-inch standing hip-to-ankle film and entered into the TSF software (Smith & Nephew, Inc., Memphis, TN) to produce the daily strut adjustment schedule. Distraction osteogenesis was accomplished at a rate of 1-mm per day starting on the seventh postoperative day. Limb length discrepancy was followed with repeat 51-inch radiographs and any residual shortening and deformity was corrected with a new schedule. All patients were allowed to weight bear as tolerated on the first postoperative day.

The Total Residual Mode of the TSF software (Smith & Nephew, Inc., Memphis, TN) was used for both the proximal tibial osteotomy as well as the distal tibial docking site. The most proximal ring was used as the reference ring for the lengthening osteotomy site and the most distal ring was used as the reference ring for the docking site. The common peroneal nerve proximally and the posterior tibial neurovascular bundle distally were used as the structures at risk (SAR).

Finally, the decision to remove the circular external fixator was based on various clinical factors including the radiographic appearance of regenerate, the total time within the frame, the length of distraction osteogenesis achieved and whether additional stabilization techniques for the regenerate were to be performed such as a lengthening and then nailing (LATN).[11] A LATN procedure was used in two of our patients in order to reduce the time in the frame (Figure 8).

CLINICAL SERIES

Three patients were identified who had an extra-articular distal tibia fracture (OTA/AO 43.A1-A3)[12] nonunion that was within two centimeters of the ankle joint and had undergone limb salvage using the aforementioned surgical technique. All three patients were female with an average age of 51.3 years (range 49-53). The patients initially suffered open injuries as a result of differing mechanisms in each case (e.g. motor vehicle accident, pedestrian struck and a fall from a height).

The average longitudinal length of resected nonunited distal tibia and the remaining distal tibial articular fragment was 5.1 cm (range, 3.0-7.5) and 1.8 cm (range, 1.5-2.0), respectively. The calculated average external fixator index (EFI) for our patients was 1.36 months/cm (range, 1.26-1.42).

Clinical follow-up was greater than one year for all patients (average 3.2 years; range, 1.0-6.2). At final follow-up all patients had clinical and radiographic evidence of bony union and were weight bearing as tolerated. There were no complications involving the distal tibial docking or proximal tibial lengthening sites. One patient required an ankle joint debridement and exostectomy five years after nonunion correction for impingement symptoms due to anterior tibial and talar osteophytes. No patients to date have had an ankle arthrodesis or amputation and there are no clinical signs of indolent infection. Table 1 summarizes the operative characteristics and postoperative outcomes of our study cohort.

DISCUSSION

The Ilizarov method of circular external frame fixation and distraction osteogenesis has been extensively used for post-traumatic extremity reconstruction. This method has given clinicians an important tool for addressing cases involving limb length inequalities, infected nonunions with bone loss, angular, translational and rotational limb deformities, joint contractures as well as fracture fragment stabilization in patients with a compromised surrounding soft tissue envelope. In this study we have demonstrated its successful use in a patient cohort with distal tibial periarticular bone loss within 2-cm of the ankle joint as a result of a fracture nonunion. In particular, ankle joint salvage and limb length equalization were achieved in addition to nonunion repair and eradication of suspected infection. It is the first known study to specifically describe the surgical technique of staged shortening and lengthening using a circular external fixator for this unique and challenging patient population.

The use of a circular external fixator was instrumental in our clinical success because of its ability to accomplish stabilization of the distal tibial fragment using small-diameter tensioned wires. The lack of distal tibial bone in such cases can limit the extent of screw purchase and preclude the use of intramedullary devices or plates for fragment stabilization. The Maquelet technique, in particular, is a popular method for addressing infected tibial nonunions with bone loss.[13-15] However, this technique requires fragment stabilization for successful induced membrane formation around the temporary cement spacer. In periarticular cases with a limited distal fragment size there is an increased risk for screw pull-out and construct failure due to the lack of bone for adequate screw purchase. We therefore believe that such cases are ideal for the use of a circular external fixator with tensioned wires for stabilization of the distal articular fragment.

The limitations of this surgical technique paper are numerous. One of the biggest weaknesses was our inability to objectively compare differences of our surgical technique to that of prior publications. Specifically, we performed an acute shortening of 2-3 cm and then created a gradual shortening schedule at a rate of 3-mm per day postoperatively to aide in closure of the longitudinal incisions. Other groups have acutely shortened as much as is possible before causing distal vessel occlusion.[16] Prior publications have indicated that 3-4 cm is the maximum distance of acceptable acute tibial shortening.[17-19] Another difference in our technique was that we performed a staged shortening and then lengthening instead of a simultaneous procedure (e.g. bone transport). Our primary rationale for a staged approach was to separate the initial infected resection and shortening surgery from the proximal lengthening osteotomy. Furthermore, a simultaneous proximal tibial osteotomy could interfere with a necessary below knee amputation (BKA) if the distal nonunion repair had early catastrophic failure. The staged approach also allowed us to greatly accelerate the docking of the distal segments thereby eliminating the typical need for later bone grafting at the docking site while still achieving bony union in all three cases. While a staged procedure also simplifies the daily strut adjustments for the patient, it lengthens the patient's time in the frame. We were able to reduce the total frame time for two patients by performing a LATN technique. Our final EFI was 1.36 months/cm and compares favorably with the two other studies for this particular patient population.[16,20] While no definitive conclusions can be made about the preferred amount of acute shortening or simultaneous versus staged procedures, we have shown that our technique yielded minimal limb length discrepancies, successful osseous union and high patient satisfaction in this challenging cohort of patients.

In conclusion, we have shown that a circular external fixator can successful treat a periarticular distal tibial nonunion cohort using en bloc resection and shortening with staged proximal tibial lengthening.

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FIGURE LEGENDS

Figure 1: Preoperative anterior (a) and posterior (b) clinical photographs of Patient #1 demonstrating a varus deformity of the right leg. Mortise (a) and lateral (b) radiographs of the periarticular distal tibial fracture nonunion.

Figure 2: Preoperative coronal (a) and sagittal (b) CT images demonstrating the nonunited distal tibia fracture as well as its close proximity to the ankle joint.

Figure 3: Intraoperative photograph demonstrating the degree of distal tibial bone loss after debridement of all nonviable bone.

Figure 4: Intraoperative fluoroscopic image of the 1.8-mm wires being placed perpendicular to the mechanical axis of the proximal and distal tibial segments

Figure 5: Intraoperative photograph after en bloc excision of the infected and nonunited portion of distal tibia and adjacent fibula. The periosteal elevator is pointing to the remaining distal tibial fracture segment.

Figure 6: Final fluoroscopic image after excision of all infected nonunited distal tibia and an equal length of adjacent fibula.

Figure 7: Intraoperative AP (a) and lateral (b) images after placement of the proximal and distal 155-mm full rings and an acute defect shortening of two centimeters.

Figure 8: Final full length AP (a) and lateral (b) tibial radiographs after frame removal and LATN procedure. 51-inch hip to ankle radiograph (c) demonstrating equal limb length between the operative and nonoperative lower extremities.

TABLE LEGENDS

Table 1: Operative findings as well as details of postoperative distraction osteogenesis and complications.

Patient	Operative Culture Results	Tibia resected (cm)	Remaining distal tibia (cm)	Months in frame	Distance of DO (cm)	EFI (months/cm)	Complications
#1	*P. acnes*, *S. epidermidis*	3.0	1.5	6.7	4.7	1.42	Pin site infection
#2	Negative growth	4.8	2.0	5.5	4.4	1.26	None
#3	*S. epidermidis*	7.5	2.0	10.3	7.3	1.41	Incisional cellulitis
Average		5.1	1.8	7.5	5.5	1.36	


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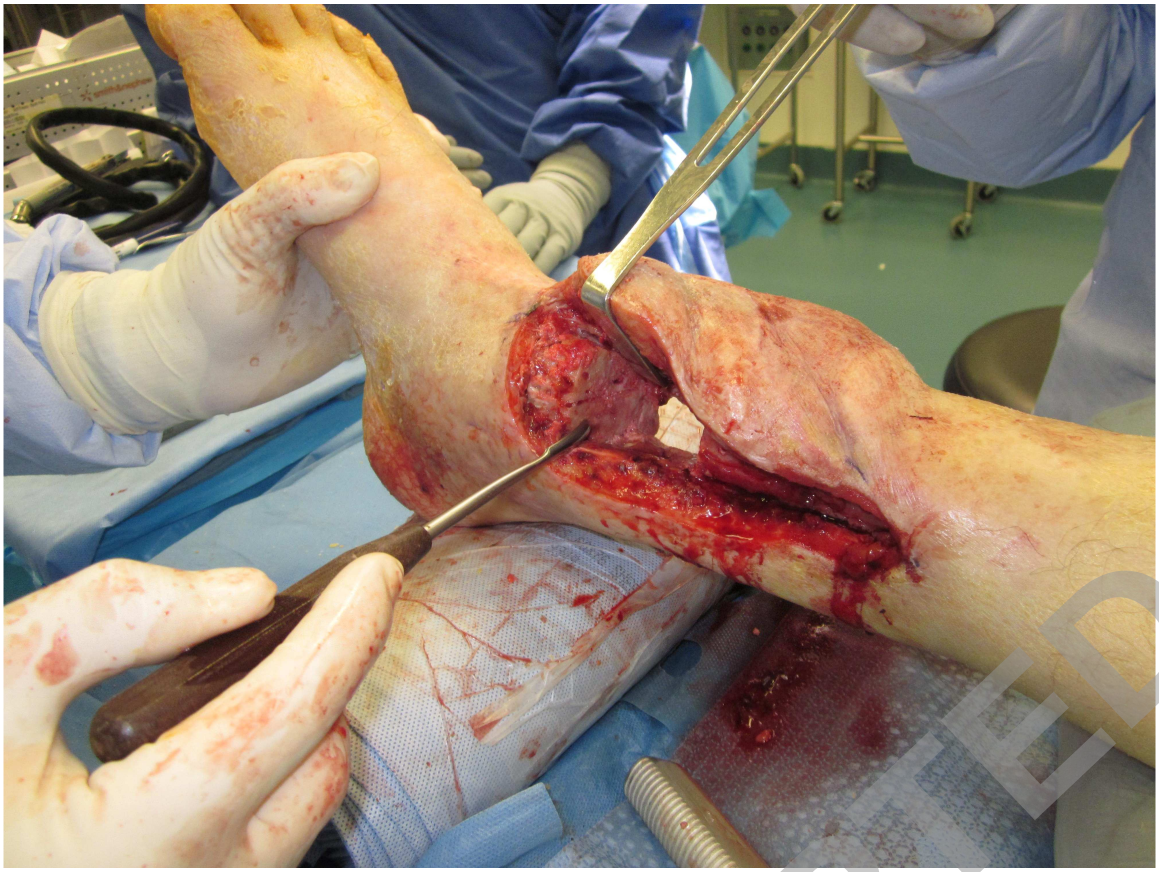


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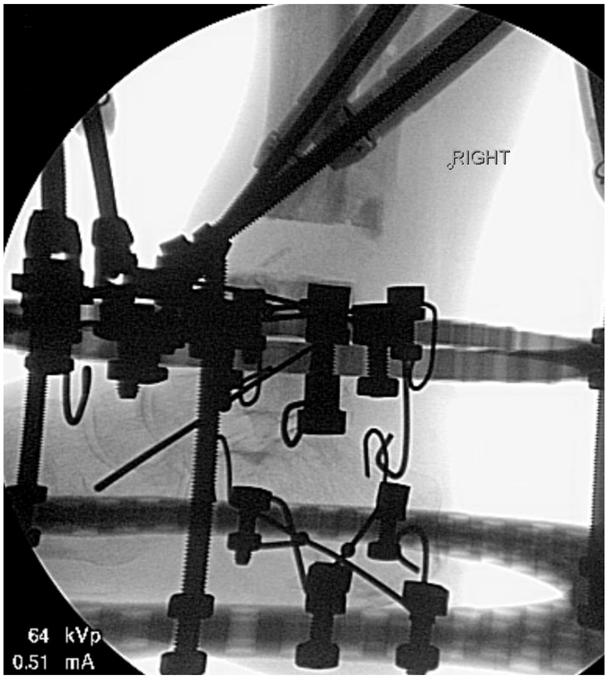
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