Treatment of Malunion and Nonunion at the Site of an Ankle Fusion with the Ilizarov Apparatus

Surgical Technique

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INTRODUCTION

Nonunion rates after primary ankle arthrodesis have been reported to be as high as 30%1. In addition, the rates of other complications, including malunion, osteoarthritis of adjacent joints, neurovascular injury, and wound-healing problems, have been reported to be as high as 60%1. Failed ankle fusions are often associated with limb-length discrepancy. The Ilizarov apparatus is used to realign and repair the failed ankle fusion while simultaneously lengthening the limb. Obtaining appropriate limb length and anatomic realignment of the hindfoot and ankle can decrease the progression of osteoarthritis in the surrounding joints and optimize functional outcomes.

SURGICAL TECHNIQUE

Repair and Realignment of Failed Ankle Fusion

The patient is placed supine on the operating table with a bump under the ipsilateral buttock, which positions the pelvis approximately 45° oblique to the table. A second, sterile bump is necessary so that the foot can rest on the table in a lateral position when the knee is bent to 90° (Fig. 1). While the patient is under general anesthesia, the lower limb that is to be operated on is prepared and draped in a normal aseptic manner. Using still images obtained with video fluoroscopy, the surgeon examines the anteroposterior

ABSTRACT

BACKGROUND:

Malunion and nonunion of an ankle fusion site are associated with pain, osteomyelitis, limb-length discrepancy, and deformity. The Ilizarov reconstruction has been used to treat these challenging problems.

METHODS:

We reviewed the results in twenty-one ankles that had undergone a revision of a failed fusion, with simultaneous treatment of coexisting pathologic conditions, with use of the Ilizarov technique. Eight patients had undergone ankle fusion only, eleven had undergone ankle and subtalar fusion, and
view of the limb. The surgeon then marks the skin to indicate the level of the failed ankle fusion and the medial and lateral aspects of the ankle. While examining a lateral view of the

**FIG. 1**

The patient is positioned supine with a bump under the ipsilateral buttock. The knee is bent to 90° so that the foot can rest in a lateral position on the operating room table. While examining the limb on the lateral fluoroscopic view, the surgeon marks the anterior and posterior borders of the tibia on the skin, and a longitudinal lateral incision is made between the anterior and posterior borders of the tibia.

**FIG. 2**

The fibula, the lateral wall of the talus, and the lateral cortex of the tibia are reamed with use of a small cheese-grater-type acetabular reamer. The bone fragments created by the reaming are saved and used later for bone graft.

**ABSTRACT**

Two had undergone pantalar fusion. Eighteen patients with an average limb-length discrepancy of 4 cm underwent limb lengthening simultaneously with the revision surgery. The average patient age was forty years. Indications for treatment were malunion (eleven patients), aseptic nonunion (eight patients), and infected nonunion (two patients). Clinical, subjective, objective, gait, and radiographic analyses were performed after an average duration of follow-up of 83.4 months.
The surgeon marks the skin to indicate the anterior and posterior borders of the tibia and the level of the failed ankle fusion. Typically, a longitudinal lateral incision is made between the anterior and posterior borders of the tibia (Fig. 1). If substantial shortening is

**RESULTS:**
Solid union was achieved in all ankles. The functional result was excellent for fifteen patients, good for three, fair for two, and poor for one. The bone result was excellent for ten ankles, good for nine, fair for one, and poor for one. All eighteen patients who underwent gait analysis had a heel-to-toe progression gait, and twelve achieved normal walking velocity with their shoes on. A plantigrade foot was achieved in each case, and only two patients had $>5^\circ$ of residual deformity. During the Ilizarov treatment, forty-one minor complications (treated conservatively) and twenty major complications (treated surgically) occurred. After removal of the circular frame, seven other complications, which required four additional operations, occurred.

**CONCLUSIONS:**
In patients with a failed ankle fusion, infection, limb-length discrepancy, and foot deformity can be addressed simultaneously with use of the Ilizarov apparatus to achieve a solid union and a plantigrade foot, usually with a clinically satisfactory result.
FIG. 5
In the sagittal plane, the foot-to-tibia alignment is initially obtained with a large Steinmann pin. The foot should be plantigrade and positioned beneath the tibia (the tibial mid-diaphyseal line coincides with the lateral process of the talus).

FIG. 6
In the axial plane, the foot-to-tibia alignment is initially obtained with a large Steinmann pin. Note that the heel position is in neutral to 5° of valgus and that the heel is slightly lateral to the mid-diaphyseal line of the tibia.
anticipated (e.g., after removal of an ankle replacement or when there is bone loss secondary to débridement due to osteomyelitis), a lateral transverse incision is made. After the surgeon draws the marks on the skin, the thigh tourniquet is elevated and the incision is made. The fibula is exposed with use of atraumatic dissection techniques. A small acetabular reamer is used to ream the fibula, the lateral wall of the talus, and the lateral cortex of the tibia (Fig. 2). The surgeon should carefully retract the skin edges during reaming. We also recommend a technique that ensures that the reamer maintains its starting point. To create a starting point for the reamer, we use an 8-mm osteotome to create a small, flat surface on the convex lateral aspect of the fibula. The bone fragments created by the reaming are saved and used later for bone graft.

Our technique of fibular reaming consists of a single step but serves a dual role: providing autograft bone while obtaining access to the failed ankle fusion site. Resection of the fibula is a good approach for revision of an ankle fusion. In cases in which

**FIG. 7**

Local fibular, tibial, and talar bone autograft that has been obtained from the reaming is placed along the anterior and lateral aspects of the arthrodesis site. Bone graft is used only to fill the osseous defects at the site of the ankle arthrodesis.
Figs. 8-A through 8-G Illustrations showing a percutaneous Gigli-saw osteotomy of the proximal part of the tibia. (Redrawn, with permission, from: Paley D. Principles of deformity correction. Berlin: Springer; 2002. p 395-8.) Figs. 8-A, 8-B, and 8-C Two transverse incisions are made, the periosteum is elevated, and a suture is passed subperiosteally from posteromedial to anterolateral with use of a right-angle and a curved clamp.
FIG. 8-D
The Gigli saw is tied to the suture and is pulled through from posterior to anterior. It is helpful to make a slight bend on the leading edge of the Gigli saw to allow it to pass more easily around the sharp posterolateral corner of the tibia.

FIG. 8-E
The posterior and lateral cortices and the medullary canal are cut with the saw under the protection of two periosteal elevators.
The periosteum of the medial cortex is then elevated, and the medial cortex is cut by flattening out the direction of the pull of the saw.

The saw is then cut and pulled out.
primary arthrodesis of the ankle is indicated, maintaining the fibula may be advantageous if, at a later date, the ankle fusion is taken down and a total ankle joint replacement is performed. In such cases, the fibula is cut and is rotated externally and posteriorly on its soft-tissue attachments.

Two 2-mm Steinmann pins are then placed perpendicular to the distal part of the tibia (one is placed percutaneously from anterior to posterior, and one is placed lateral to medial through the lateral incision) to guide the saw cut of the distal part of the tibia (Fig. 3). After cutting the tibia, the surgeon places the patient’s foot on a board and makes the talar cut parallel to the plantar aspect of the foot through the bone of the talus (Fig. 4). The distal tibial and talar cuts are performed as close to the failed ankle fusion site as possible. If the patient has experienced nonunion of the ankle, the cuts are performed so that the bone surrounding the nonunion is removed. If the patient has experienced infected nonunion of the ankle, it is critical that all of the infected bone be removed at the time of the acute shortening. We recommend that the cuts be positioned to resect as little bone as possible while maintaining enough bone to ensure proper healing. The cut bone segments are then removed. The medial malleolus can be removed through a separate small transverse medial incision or it can be carefully removed through the lateral incision. (The medial ap-

**CRITICAL CONCEPTS | continued**

**PITFALLS:**

- To prevent improper realignment of the repaired ankle fusion, the intraoperative positioning of the foot-to-tibia alignment should be performed as outlined above and according to the description of the proper position. Intraoperative fluoroscopy and use of a 2-mm Steinmann pin for temporary fixation of the ankle fusion site help to obtain the optimal transverse, sagittal, and axial alignment.

- Inadequate resection of infected bone and soft tissue can be prevented by aggressive débridement of the bone and soft tissue to the level of healthy bleeding tissue.

- Tibial procurvatum and valgus deformities occur secondary to the proximal tibial lengthening and should be residually corrected with external fixation before consolidation.

- Overlengthening or underlengthening of the tibia can be avoided by making the appropriate radiographs. Erect long-standing radiographs should be measured from the top of the femoral head and should incorporate the foot heights. Lateral radiographs of both tibia that include the feet are also useful to calculate the tibial length discrepancy. The goal, for optimization of gait, is to ensure that the affected limb is 1 cm shorter than the unaffected limb.

- Consolidation can be premature or delayed when the lengthening rate is inappropriate (too slow or too fast). Typically, we use a rate of 0.75 mm per day for proximal tibial lengthening in an adult; however, the rate can be varied depending on several host factors such as age, medications, and smoking.

- Pin breakage is not a common complication, but it can occur when the biomechanical forces of the external fixator are exceeded by the lengthening process and weight-bearing. Pin breakage is a common problem in patients with Charcot arthropathy. The complication can be avoided by placing the pin in a biomechanically advantageous position, with use of multiple points of fixation when necessary, and by limiting weight-bearing by neurologically compromised patients.

- Pin-site infections are common and can be prevented and treated with orally administered antibiotics. Pin-site infections rarely require removal of the pins or surgical débridement of the site.

- Wound problems can be avoided with proper preoperative planning of the placement of incisions. For example, when acute shortening of the limb occurs because of extensive bone resection or the removal of a failed total ankle replacement, a transverse incision should be considered.

- When a tarsal tunnel syndrome occurs, we recommend decreasing the rate of lengthening and performing nerve decompression.
proach is preferred.) While examining the limb with the use of fluoroscopy, the surgeon re-aligns the foot at the tibia by compressing the cut surfaces of the talus and tibia, externally rotating the foot to the limb, obtaining a neutral-to-valgus heel position, and maintaining a

**FIG. 9-A through 9-I** A thirty-eight-year-old woman with diabetes presented with a failed ankle fusion (nonunion) and a limb-length discrepancy of 4 cm. **Fig. 9-A** Anteroposterior radiograph of the ankle showing the ankle nonunion. **Fig. 9-B** Lateral radiograph showing the failure of the internal fixation device at the site of the ankle nonunion.
plantigrade foot position. The surgeon should also translate the foot posteriorly or anteriorly and medially or laterally as needed to achieve proper alignment. A large-diameter Steinmann pin is then inserted from the plantar aspect of the foot, beginning at the calcaneus and extending.
through the talus and into the tibia. The foot-to-tibia alignment is checked on the axial, lateral, and anteroposterior fluoroscopic views. The foot should be plantigrade (with the sole of the foot at 90° to the tibia), beneath the tibia (i.e., in the sagittal plane, the tibial mid-diaphyseal...
The line should coincide with the lateral process of the talus, and externally rotated 10° to 15° with the heel in neutral to 5° of valgus (Figs. 5 and 6). Local fibular, tibial, and talar bone autograft is placed along the anterior and lateral aspects of the arthrodesis site (Fig. 7). If the amount of local bone graft is insufficient, then harvesting of the iliac crest is warranted. We do not think that it is necessary to use synthetic bone graft. The lateral wound is then closed over a drain. During surgery, it is important to preserve the subtalar joint by not exposing it.

Osteotomy for Lengthening of the Proximal Part of the Tibia

While examining the limb with the use of fluoroscopy, the surgeon identifies the level of the proximal Gigli-saw osteotomy of the tibia (just distal to the tibial tuberosity) and makes two percutaneous transverse incisions on the limb. One incision is made just lateral to the tibial crest, and the second is made along the posteromedial border of the tibia. The incisions are then deepened with a hemostat. The periosteum on the lateral and posterior aspects of the tibia is elevated with a periosteal elevator. With use of two clamps, a suture is passed around the tibia. The Gigli saw is tied to the suture and is pulled around the bone. The osteotomy is completed after application of the external fixator (Figs. 8-A through 8-D).

Application of the External Fixator

The ring external fixator is applied with a proximal 2/3 ring mounted on a lateral-to-medial wire that crosses the proximal part of the tibia and is perpen-
Clinical photograph of the limb and the external fixator. Note that the arched wires in the talus compress the ankle arthrodesis site while providing distraction of the subtalar joint. The foot did not require midfoot or metatarsal wires because the patient did not have a preexisting foot deformity. Although the forefoot was not fixed, a forefoot splint (a custom-molded, rigid plastic device that cups the sole of the foot and attaches to the frame with the use of Velcro) was fashioned for the patient to maintain a plantigrade foot and toe position. After the regenerated bone (proximal tibial lengthening site) and the arthrodesis site healed, the fixator was removed.
Perpendicular to its long axis. The ring is centered on the limb, and the wire is then tensioned to 90 kg. One 6-mm anterior half-pin is inserted through a two-hole cube off the inner hole of the master tab of the 2/3 ring. A middle ring with two half-pins is placed perpendicular to the tibia. Six struts are added between the upper two rings. The third ring, a special foot ring, is placed on the foot.
The ring is fixed in place with wires, and six struts are then attached distally. The remainder of the fixation includes the placement of two more half-pins proximally, another half-pin in the middle ring, and more wires in the foot. In total, the foot has two crossing calcaneal wires, two talar wires, and two forefoot wires. Distraction of the subtalar joint is performed by rotating the fixation bolt of each talar wire by using the Russian tensioning technique. The Russian tensioning technique also helps to compress the ankle fusion site by pushing proximally on the talus. All of the smooth wires are 1.8 mm in diameter. All wires are tensioned, all screws are tightened, and skin tenting is released.

After the application of the external fixator has been completed, the Gigli-saw osteotomy is performed in the typical fashion (Figs. 8-E, 8-F, and 8-G). The Gigli-saw incisions are then closed. The tourniquet is inflated only during the ankle-fusion part of the procedure and while the Gigli saw is being passed, but it is released before application of the fixator. Finally, anteroposterior and lateral radiographs of the foot, including the tibia, and a long axial radiograph of the calcaneus and tibia are obtained before the patient is woken. Dry, sterile dressings and pin/wire sponges are applied (Figs. 9-A through 9-I).

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