Temporary Intentional Leg Shortening and Deformation to Facilitate Wound Closure Using the Ilizarov/Taylor Spatial Frame

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Summary: Infected tibial nonunions with bone loss pose an extremely challenging problem for the orthopaedic surgeon. A comprehensive approach that addresses the infection, bone quality, and overlying soft-tissue integrity must be considered for a successful outcome. Acute shortening with an Ilizarov frame has been shown to be helpful in the treatment of open tibia fractures with simultaneous bone and soft-tissue loss. Cases in which the soft-tissue defect considerably exceeds bone loss may require an Ilizarov frame along with a concomitant soft-tissue procedure; however, there are a number of potential difficulties with vascularized pedicle flaps and free tissue flaps, including anastomotic complications, partial flap necrosis, and flap failure. The technique described in this report involves acute shortening and temporary bony deformation with the Ilizarov apparatus to facilitate wound closure and does not require a concomitant soft-tissue reconstructive procedure. Once the wound is healed, osseous deformity and length are gradually corrected by distraction osteogenesis with the Ilizarov/Taylor Spatial frame.

Key Words: Ilizarov, Taylor Spatial frame, nonunion, acute shortening, deformity correction, wound closure

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The Ilizarov method has been described alone or in combination with soft-tissue reconstruction for the management of open tibia fractures, limb shortening, deformity, joint contractures, and infections. Shortening with bifocal compression-distraction has been successfully used in the treatment of open tibia fractures with primary wound closure or delayed primary wound closure.[1–3] The technique is called bifocal because there are 2 segments with activity. One segment (the defect) is undergoing compression/shortening, and 1 segment (the bony regenerate) is undergoing distraction/lengthening to maintain the length of the limb. Bone defects < 3 cm can usually be acutely shortened, and defects of > 3 cm should usually be gradually shortened.[1] Acute shortening is easier and safer to accomplish in the acute rather than chronic situation. Acute shortening of > 3 cm may be safe if the vascular physical examination does not change. Bifocal compression-distraction not only leads to solid osseous union but also corrects limb length discrepancy, deformity, joint contractures, and infection throughout the treatment period. The Ilizarov method does not eliminate or "correct" the infection solely because it is applied to the bone. Removal of the dead bone, sequestrum, debridement, irrigation, local, and systemic antibiotics, etc., all contribute to the elimination of the infection from the bone. It does supply stability as an adjunct to the whole process. Additionally, the absence of internal fixation may be safer in the setting of active or history of infection.

In the present article, the authors present the technique of acute shortening and intentional temporary bony deformation to facilitate wound closure, thereby avoiding a soft-tissue flap, along with an illustrative case example. With the leg stabilized in the Ilizarov/Taylor Spatial frame (TSF; Smith & Nephew, Inc., Memphis, TN), the wound was allowed to completely heal in the deformed position. The deformed leg was gradually corrected until anatomic reduction of the bony fragments was achieved, and through a second tibial osteotomy, the leg was lengthened to correct the leg length discrepancy (LLD). The TSF, which is particularly useful for this technique, is an evolution of the Ilizarov frame that allows simultaneous correction of length, angulation, translation, and rotation about a virtual axis.[4–6] With the TSF, a crooked frame mounted on a deformed bone can be used to gradually correct the leg deformity.[4]

SURGICAL TECHNIQUE

Surgery is usually performed under regional anesthesia. Preoperative antibiotics are withheld until after intraoperative cultures are obtained. Bony edges are debrided with the goal of removing all dead bone. The bony edges are cut flat and perpendicular to the axis of the tibia with a power saw cooled with saline. An equal-sized segment of the fibula must be removed at about the

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same level. The soft-tissue wound is debrided with the goal of removing nonviable tissue and contouring the edges to enable wound closure. For example, an elliptical-shaped incision closes well with shortening. It is important to avoid leaving bone exposed to avoid desiccation. Next, a circular ring is applied orthogonal to each bone segment with wires and half-pins (Fig. 1A, B).

Pulses and capillary refill are checked for comparison. One ring is chosen to be the *reference ring* (Fig. 2). The *origin* is a point chosen on the edge of one bone segment at the defect site. A *corresponding point* (CP) on the other bone segment is chosen with the goal of reducing the CP to the origin. *Mounting parameters* define the location of the origin relative to the reference ring. Mounting parameters are defined by the spatial relationship between the center of the reference ring and the origin in the coronal, sagittal, and axial planes. This defines a virtual hinge around which the deformity correction will occur. Next, the acute shortening and deformation is performed to optimize wound closure. The rings are stabilized in this deformed position with 6 TSF strut connections (Fig. 1C). Care is taken avoid loss of pulses, which would suggest kinking of the arteries. If this were to occur, then one would have to settle for less shortening and deformity, even if the wound edges were pulled apart. In this case, one could gradually increase the deformity to help close the wound.

After the wound heals, a gradual correction of the deformity is performed with adjustment of the TSF struts. Compression at the nonunion follows once there is good contact and no deformity (Fig. 1D).

A bifocal approach can be used to avoid limb shortening. With this approach, a tibial osteotomy for lengthening is performed outside the zone of injury. Gradual lengthening at a second level is performed by adding another circular ring and using the principles of distraction osteogenesis (Fig. 1E).[1,2]

CASE EXAMPLE

A 20-year-old man was involved in a motor vehicle accident sustaining an open (Gustilo Anderson Grade 3A) right tibia and fibula fracture. He was initially evaluated and treated at an outside hospital with an external fixator of the tibia and multiple irrigation and debridements of the open wound. Two weeks after the initial procedure, the external fixator was removed and an intramedullary tibial nail was placed. The patient was discharged without antibiotic therapy.

Five months after the original injury, the patient presented to us with persistent purulent draining sinus at the junction of the middle and distal third of the tibial with surrounding erythema. The neurovascular examination of the right lower extremity was unremarkable. Plain radiographs demonstrated a fracture of the distal third of the tibia and fibula and the presence of an intramedullary nail with proximal and distal interlocking screws. The patient underwent removal of the right intramedullary tibial nail, irrigation, and debridement of the draining sinus tract of the tibia, and application of temporary external fixation (Fig. 3). The open wound measured 2-cm × 2.5-cm. The patient was then referred to a different member of the orthopaedic trauma service for management with the Ilizarov method.

Vertical extension of the open pretibial wound was performed to provide exposure of the tibia. The tibia was noted to have irregular bone edges and a notable bone defect. The oscillating saw cooled with normal saline irrigation was used to resect bone until viable bone tissue was evident and to flatten the bone edges to a transverse orientation. The resulting bone defect was 6 cm. Multiple intraoperative cultures were obtained from the proximal and distal segments. At this juncture of the case, the decision was to perform acute shortening with the Ilizarov/TSF to address both the bone defect and the open wound. The wound edges were debrided until areas of

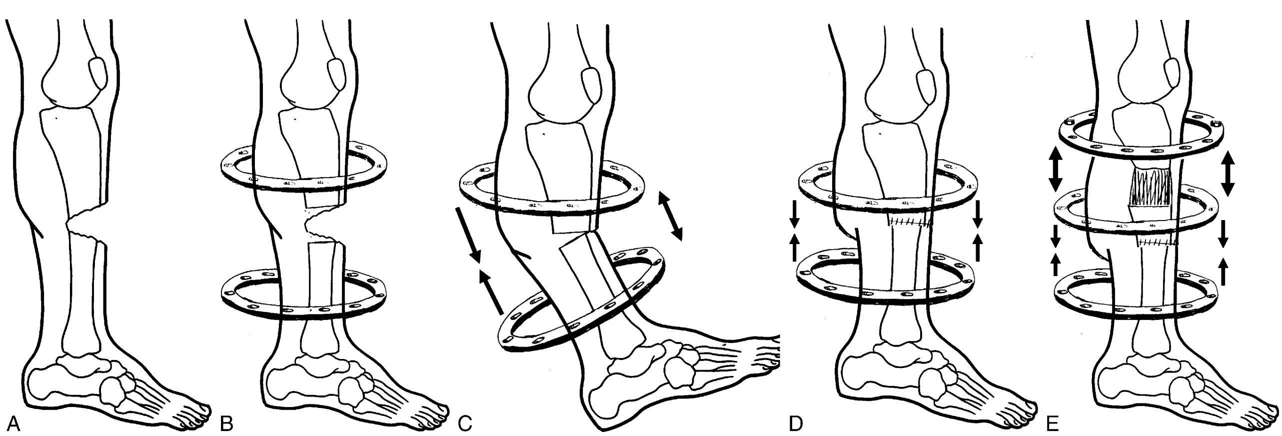

FIGURE 1. Schematic illustration of the stages of the procedure. A, Bone and soft-tissue defect. B, Debridement of bony edges and application of rings orthogonal to each bone segment. C, Acute shortening and bony deformation to enable wound closure. D, Gradual correction of the deformity and compression at the nonunion site after wound healing. E, After addition of proximal ring and tibial osteotomy for lengthening.

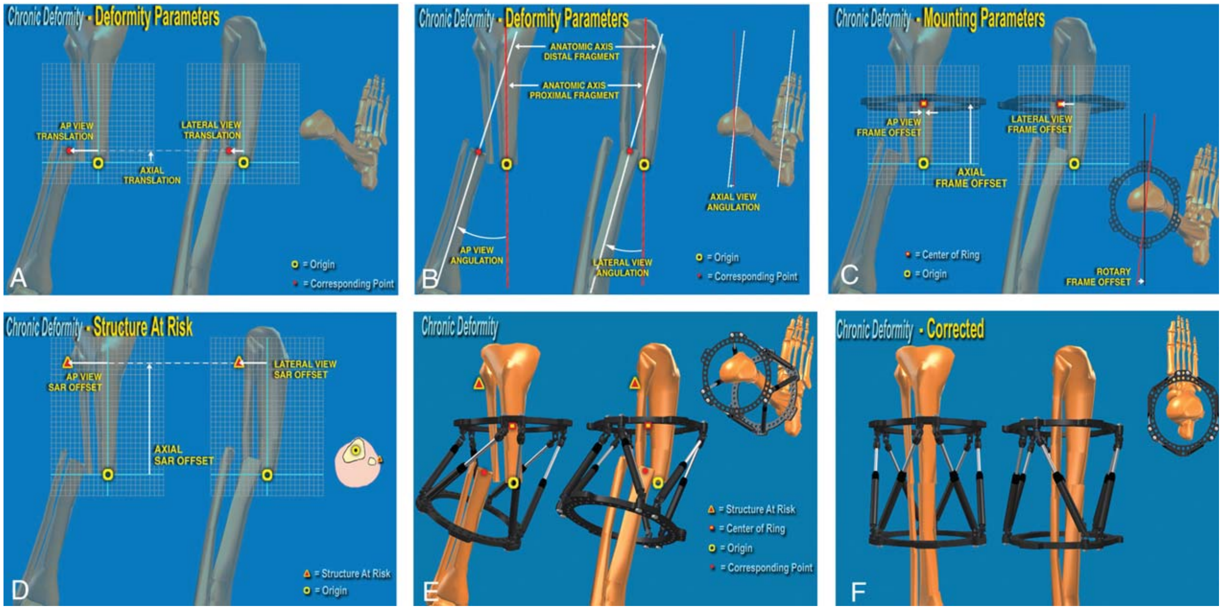

FIGURE 2. Taylor Spatial frame concept and language. A, Measurement of translation deformity parameters. B, Measurement of angulation deformity parameters. C, Measurement of mounting parameters. D, Structure at risk relative to origin. E, Before correction. F, After correction.

punctuate bleeding were visualized. After subperiosteal dissection of the fibula from a lateral approach, a segment was resected at the same level of the tibial defect. Before the acute shortening maneuver, the patient had a 1+ dorsalis pedis pulse and 2+ dorsalis pedis pulse with a warm foot. The tibia was acutely shortened and deformed into recurvatum to allow optimal release of tension of the wound, and as a result, primary closure of the wound was possible. A 2-ring construct with the Ilizarov/TSF was applied (Fig. 4). Again, the pulses were assessed and found to be stable.

FIGURE 3. Preoperative clinical and radiographic evaluation in the temporary external fixator. A, Front view of leg demonstrating open wound over anterior aspect of leg. B, AP radiograph of nonunion.

Intraoperative cultures grew *Staphylococcus aureus* and the patient received intravenous cefazolin for 6 weeks. The wound healed and sutures were removed at 3 weeks at which time the correction of deformity was begun. This occurred gradually during 40 days and was followed by axial compression at the nonunion site for 1 month. An osteotomy of the proximal tibia for lengthening and an addition of a proximal tibial ring were performed 5 weeks after the last surgery (acute shortening of the bone defect). Gradual lengthening of 60 mm was accomplished (Fig. 5). The frame was removed 6 months after the proximal tibia osteotomy (bone healing index of 1 month/cm) and 7 months after the acute defect shortening. He was protected in a high short leg cast with 50% weightbearing for 2 weeks. At 6 months after frame removal (Fig. 6), the patient's knee motion range of motion was 0°–130° and ankle range of motion was 20° dorsiflexion and 40° plantar flexion. He had no deformity, equal leg lengths (by both physical examination and 51-inch bipedal standing x-ray), and no pain. He has a patella baja on the affected side, which does not cause pain or limit knee motion. He had a normal gait and did not use any assistive devices. There has been no recurrence of infection. At 12-month follow-up, he has continued to do well.

DISCUSSION

Posttraumatic osteomyelitis is a serious complication of open and closed tibia fractures adversely affecting prognosis and increasing the risk for loss of limb.[7,8]

FIGURE 4. One month after application of TSF. A, Front view of leg demonstrating primary closure of wound. B, Side view of leg shows recurvatum deformity. C, Lateral radiograph demonstrates 20° recurvatum deformity and posterior translation of the distal fragment. This deformity and shortening helped reapproximate the wound edges and averted the need for a flap.

Meticulous debridement with wide excision of the involved bone and accompanying soft tissue is critical in the surgical management of osteomyelitis. The elimination of infected bone and necrotic tissue and improvement of the local blood supply with soft-tissue coverage are important principles for the treatment of chronic osteomyelitis.[9,10] Once the necrotic infected tissue has been removed, the remaining osseous and soft-tissue defects require stabilization with soft-tissue closure or coverage. When pedicle or free flaps are used, 89% success as a single procedure[11] is reported and 91% to 96% success as a staged procedure is reported.[1,12,13]

The Ilizarov technique alone or in combination with soft-tissue reconstructive procedures may be used to treat segmental bone defects, soft-tissue loss, and osteomyelitis. Depending on the size of bone loss, single- or double-bone transport with Ilizarov frame has been shown to be a reliable method to treat segmental bone loss with authors reporting between 75% to 100% success.[1,14–21] The lack of soft-tissue coverage may further complicate the problem, and early soft-tissue coverage has been shown to decrease local infection rates, decrease time to union, and improve strength of osseous union.[22,23] Use of the Ilizarov apparatus with soft-tissue reconstruction has been shown to be effective without compromising the vascularized tissue flaps.[24]

There are situations where an alternative to flap coverage may be desirable. Occasionally, the treating plastic surgeon will declare a patient is not a candidate for a flap. Reasons may include unavailability of local soft tissue, poor potential vascular supply to a free tissue transfer (single vessel limb, after a revascularization procedure, or plaque disease of vessels), and medical comorbidities that are a contraindication to a long free

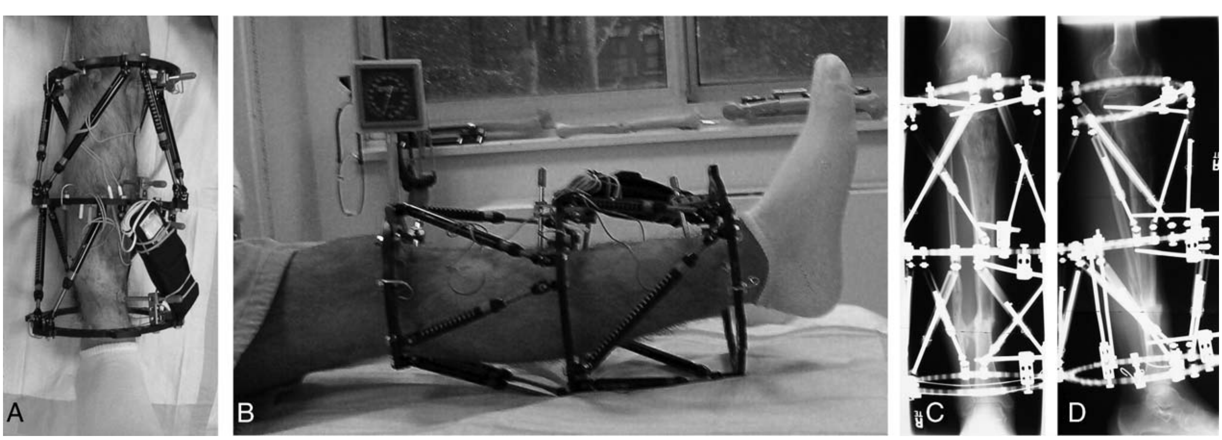

FIGURE 5. Four months after application of the second level of the TSF showing correction of distal deformity and proximal tibial lengthening. A, Front view of leg with well-healed wound. B, Side view of leg with normal alignment. C, AP radiograph without coronal plane deformity. D, Lateral view without sagittal plane deformity. Radiographs show good alignment, contact at the nonunion site, and proximal tibial lengthening.

FIGURE 6. Six months after removal of the Ilizarov/TSF. A, AP radiograph demonstrating excellent coronal plane alignment and bony union. B, Lateral radiograph with excellent sagittal plane alignment and bony union. C, Front view of legs showing equal leg lengths and the absence of deformity.

flap procedure. Additionally, revision flap coverage may not be an option after previous flap necrosis, in which case the patient's remaining standard option is amputation. Also, in many areas of the world, microvascular free tissue transfer surgery is not available.

Acute shortening with an Ilizarov frame has been used to treat open tibia fractures with simultaneous bone and soft tissue. Sen et al[1] has recently reported 23 of 24 patients with good or excellent functional outcomes, and all 24 patients demonstrated good or excellent bone assessment according to the classification system described by Paley et al.[25]

There have been three published reports of combining bone shortening and angulation for the treatment of bone and soft tissue loss.[2,3,26] Bundgaard and Christensen[2] described a single case of bone loss in the tibia of 9 cm and fibula of 3 cm with soft-tissue defect measuring 10-cm × 15-cm over the anterior and lateral compartments infected with *Staphylococcus aureus*. An Ilizarov external fixator was applied and the bone defect was acutely shortened by 3 cm followed by gradual anterior angulation until the proximal and distal ends of the open wound were in contact. This was followed by proximal tibial osteotomy, bone transport, and gradual correction of the deformity. The Ilizarov frame was removed after 1 year and the external fixation index[2] was 40 days per cm. The authors report that the described technique allows the treatment of the bone defect by distraction osteogenesis and the soft tissue and muscle defect by distraction histiogenesis.[2]

Lerner et al[3] reported on the use of acute shortening with Ilizarov frame to treat severe bone and soft-tissue loss. All 12 patients had Gustilo-Andersen type IIIB open fractures with a mean Mangled Extremity Score of 6.7 and mean bone loss of 7.9 cm. All patients underwent acute bone shortening, and 3 patients additionally underwent anterior angulation of 50° to 60° at the fracture site to minimize the bone and soft-tissue defect. Of these 3 patients, 1 required a local flap with overlying skin graft and 2 patients received skin grafts. The authors waited 3 weeks until the wounds healed and then gradually corrected the malalignment during a period of 3 additional weeks.

Lerner et al[26] in a case report of extreme bone lengthening after trauma described their use of the technique of acute shortening with apex posterior angulation. They used it in the acute setting with an Ilizarov frame.

The surgical technique of shortening with angular deformity has been described in the acute setting.[2,3] The current report illustrates acute shortening with intentional temporary deformation in the setting of chronic infected nonunion with persistent overlying deep wound infection obviating the need for further soft-tissue reconstruction. In the case presented in this report, acute shortening alone was not enough to enable wound closure. With implementation of additional deformity, the wound edges were able to be reapproximated without tension. As the wound healed, the Ilizarov/TSF was adjusted to correct bone length and deformity. The ability of TSF to correct complex deformity is particularly useful in these situations. The *rings first method*[2] of TSF use allows independent application of orthogonal rings to each segment and then the optimal deformation is performed. The subsequent deformity correction is accomplished with adjustment of the frame.

It is a matter of philosophy whether the acute shortening technique reported should be used as a last resort only when flap coverage is not an option or whether it should be used as the initial option to avoid the need for a flap. Flap coverage works well[24] with bone transport under a healthy soft-tissue envelope. This report and others[1–3] also show that acute shortening with angulation can be successful and avoid the need for a flap. The final choice will depend on the surgeon's preference and availability of plastic surgery expertise. We are more likely to choose a flap for a patient with a large soft-tissue defect and to choose acute shortening with angulation for patient with a smaller soft-tissue defect. Other factors, such as vascular anatomy and medical comorbidities, also will be considerations.

Infected nonunions with bone loss pose an extremely challenging problem for the orthopaedic surgeon. A comprehensive approach that addresses the infection, bone quality, and overlying soft-tissue integrity must be considered for a successful outcome.[24] Temporary intentional shortening and bony deformation with the Ilizarov/TSF is a technique that may be implemented for a bone and soft-tissue defect. This can avert the need for a complex soft-tissue reconstruction procedure.

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