Ilizarov External Fixator for Stump Salvage in Infected Nonunions

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abstract

Infected nonunions are potentially difficult complications to treat in the context of complex tibial fractures. Often, such complications necessitate amputation to prevent further sequelae, such as fulminant sepsis and complete loss of the limb. As such, the eradication of infection, the decision regarding when to amputate, and the length of the residual stump are important factors to optimize patient outcome. The authors present a unique scenario whereby an Ilizarov external fixation device was used to treat an infected tibial nonunion while simultaneously salvaging stump length to enable fitting for a below-knee prosthesis. The use of the Ilizarov device can prevent abrupt dissemination of infection, stabilize the fracture, and bridge nonunion gaps. This is augmented by the unique ability of the construct to be periodically readjusted and realigned where needed to permit osteogenesis and proper alignment. The result in this case was complete eradication of infection, with the use of continuous antibiotics as a pharmacological adjunct, union of the tibial fragments, and a below-knee amputation with adequate stump length and prosthetic fit. The success of this treatment strategy was predicated on the above factors, with an emphasis on amputation level and its effect on function. The Ilizarov external fixator is a device that has been widely used to treat limb-length discrepancies, correct deformities, and induce osseous growth in bony nonunion. The authors present the Ilizarov device as a viable option for the treatment of infected tibial nonunions and stump length salvage.
The Ilizarov apparatus has been widely used since the 1940s for limblengthening, filling in bony defects, and treating nonunions\(^1\)\(^-\)\(^5\) and osteomyelitis.\(^6\)\(^,\)\(^7\) The concept of compression-distraction osteogenesis central to the use of the Ilizarov system is often used to preserve, lengthen, and correct limb deformity but can also be applied to the treatment of infected tibial nonunions following a below-knee amputation. To the authors’ knowledge, such an application of the Ilizarov external fixation device for chronically infected nonunion after amputation has yet to be reported.

This article presents a patient who underwent a below-knee amputation of a concomitantly infected proximal tibial nonunion. The patient was surgically treated for multiple failed attempts at fixation and fusion of a comminuted segmental fracture that was subsequently infected. The importance of amputation level when deciding to amputate, its effect on limb function, and the use of the Ilizarov external fixator to preserve length in a nonunion amputation stump are discussed.

**CASE REPORT**

A 38-year-old man sustained a grade IIIB segmental tibial fracture and extensive soft tissue loss of his right leg following a motorcycle accident.\(^8\) The 2-part fracture divided the tibial shaft into 3 segments. The proximal fracture site was at the tibial tubercle and distal site at mid-tibial shaft (Figure 1). At injury, the patient was treated via wound debridement, skin grafts, gastrocnemius free flap, and a spanning external fixator, which was later converted to a hybrid nonspanning external fixator below the knee. One month after treatment, no signs of bony union existed, and the patient developed infection of both nonunion sites. Over the course of 18 months, all surgical interventions, including wound debridement and skin grafting, to treat fracture and repair soft tissue were attempted but failed.

Taking into account the chronicity of infection and nonunion, amputation was likely; therefore, all possible attempts at limb salvage were explored. To exhaust all options for limb salvage, a successful free flap transfer needed to be in place. However, this flap failed and left a large soft tissue defect over the medial aspect of the tibia. Considering the sequela of suboptimal neurovascular status at proximal tibial nonunion sites, a high probability of a future above-knee amputation existed.\(^4\)\(^,\)\(^9\)\(^,\)\(^10\) Amputation levels may have significant effects on prosthetic fitting and gait; therefore, aggressive management to optimize limb-prosthetic function and overall clinical outcome was indicated.

The patient consented to a below-knee amputation at the level of the mid-tibial shaft. A more proximal level would have left him with a stump so short that it would compromise prosthetic fit and, ultimately, limb function. It was felt that amputation at the distal nonunion site and repair of his proximal nonunion site would afford him sufficient stump length to optimize limb-prosthetic fit and function. Given the patient’s history of osteomyelitis, it was decided that a circular external fixation frame would provide the safest method to fuse the nonunion. In addition, an infectious disease specialist was consulted to implement an appropriate intravenous antibiotic regimen to treat the infected nonunion.

The patient subsequently underwent a below-knee amputation and fixation of the proximal tibial nonunion site via the Ilizarov external fixator using bone autografts and bone morphogenic protein to augment fusion. The distal two-thirds of the tibia was degloved and amputated, and the overlying skin was dissected in a slay or filet of foot fashion, leaving all muscular and soft tissue components behind as 1 large myocutaneous flap (Figure 2).\(^11\)\(^,\)\(^12\) This was accomplished with the specialized assistance of a plastic surgeon. Fine wires were later added to increase stability of the construct, allowing the patient to bear weight for physical therapy (Figure 3).

Six to 10 weeks after amputation, radiographs showed progressive improvements marked by interval healing of the nonunion and adequate callus formation. Five months after amputation, the hardware was removed, and radiographs showed bridging bone across the fragment ends (Figure 4). The patient was successfully fitted with a lower-limb prosthetic device 1 month after hardware removal and continued physical therapy for 4 more months. No sign of infection existed at last follow-up. The patient was able to bear weight and ambulate well with the prosthesis.

**DISCUSSION**

The Ilizarov external fixator device has been widely used to correct limb-lengthening defects.
discrepancies, lengthen limb and amputation stumps, and treat myriad bony deformities, defects, and nonunions.\textsuperscript{1,2,6} To the current authors’ knowledge, no published cases exist in the North American literature demonstrating its use in the setting of an infected tibial nonunion after amputation where it simultaneously salvages stump length and fuses a nonunion.

Tibial nonunion is a common complication of high-energy traumatic injuries.\textsuperscript{13} Tibial nonunions pose significant difficulties in their medical and surgical management, especially when confounded with infection. Nonunions can often be a result of wound neglect, infection, excessive alcohol consumption, smoking, osteoporosis, diabetes mellitus, substandard surgical care, medication, or poor nutritional status.\textsuperscript{14,15} The patient described in the current case report had a history of seizure disorders and was on anticonvulsant therapy, one of several medications known to affect bone healing.

Vascular insufficiency in the context of nonunions, whether from preexisting comorbidities or direct vascular injury, significantly predisposes the bony defect to microbial colonization and delayed healing. However, even with clinical evidence of good blood flow, free flaps may fail, necessitating more interventions and hospital time. Despite numerous attempts at limb salvage via tissue debridement, vascular reconstruction, and several fixation attempts using uniplanar-type external fixation, the patient developed a chronically infected nonunion. Although myocutaneous free flaps and vascular anastomosis have proven to be successful and vital therapeutic requisites for limb salvage following traumatic injuries,\textsuperscript{14} they are not always successful.\textsuperscript{15,16} As such, meticulous scrutiny of patient compliance, medical history, socioeconomic status, clinical judgment, and evidence-based medicine are essential to implement the best course of treatment.

Amputation level is critical when trying to achieve excellent prosthetic fit and good functional outcome postoperatively. The knee joint is preserved in a below-knee amputation; in return, the energy cost and demand are less compared with a more proximal above-knee amputation.\textsuperscript{17} After any amputation, significant compensation exists from the residual ipsilateral limb-prosthesis to achieve proper kinematics during gait and strength for propulsion off the ground. This makes ambulation more difficult and less efficient than the unamputated limb. Studies have shown that the metabolic costs of walking following amputation can be up to 200% greater than normal walking.\textsuperscript{18-20} In terms of below-knee vs above-knee amputation, Marshall and Stansby\textsuperscript{21} reported that walking with a prosthesis compared with normal ambulation required 25% to 40% more energy expenditure for a below-knee prosthesis vs 65% to 100% for an above-knee prosthesis. Hence, careful and early assessment of indications for a below-knee vs an above-knee amputation is important when considering amputation as a therapeutic option. Besides a lower energy expenditure, a below-knee amputation uses a longer stump, which affords better prosthetic fitting and optimizes limb function.
The principle behind treating nonunions is to recreate an environment whereby osteoinductive factors and mesenchymal cells can interact to form new bone and bridge a nonunion gap. Such an environment requires adequate blood supply and mechanical stresses across the surface area of the fragment ends. When treating septic nonunions, prophylactic measures must be taken to prevent the spread of infection because it may potentially lead to fatal fulminant sepsis; for that reason, an external fixator is preferred.

The fixator in the current case was a hybrid Ilizarov external fixation system comprising small wires, five-eighths-inch circular fixator frames, percutaneous pins, and outside rods and screws. In establishing the microenvironment that would promote osteogenesis, fracture ends were debrided of all necrotic tissue until bleeding bone was found. Fragments were then reduced and mechanically stabilized with pin placement above and below the nonunion sites (Figure 3). Bone morphogenic proteins and autologous bone grafts were placed between fragment ends in a sandwich-like manner to help augment inter-fragmental osteogenesis. At 1 month postoperatively, adjustments to induce stressors about the nonunion were made, loosening followed by compressing and retightening of fixator frame. This served to avoid unwanted pathomechanical movements about the defect, which could impede the healing process. Furthermore, proper alignment and secure stability complements fixation and prevents deformity or malunion. The patient was subsequently fitted for custom orthotics that would allow him to bear weight on the Ilizarov device while undergoing physical therapy.

At 7 weeks postoperatively, physical therapy was instituted, with radiographs at 10 weeks showing abundant callus formation and satisfactory alignment. A single pin at the cephalad end of the Ilizarov construct had to be changed due to loosening and suspicion as a possible source of infection. Wound and overlying skin were clean, nonerythematous, and intact, showing appropriate signs of healing. The Ilizarov fixator frame was taken off 5 months after amputation, and the patient was subsequently fitted for a below-knee prosthesis 1 month after hardware removal.

The patient continued intravenous antibiotics for several months after hardware removal because of chronic infection. This route for antibiotic treatment was later switched to oral administration, the patient was weaned off antibiotics once repeated tissue cultures were negative and no clinical signs of infection existed. The patient underwent a routine post-amputation protocol, which included physical therapy, occupational therapy, and prophylactic psychiatric consultation because anxiety and depression are common after amputation, especially in patients with grade IIIB fractures. Serial follow-up with physical examination and limb radiographs demonstrated a functional tibial stump with complete bone fusion and no signs of infection.

**CONCLUSION**

Treatment of grade IIIB open tibial fractures are some of the most difficult traumatic injuries to treat. Not only have they been associated with high rates of infection (50%) and amputation (30%), but their relative risk of long-term medical and psychological morbidity, pain, and immobility are much higher than the remaining subpopulation of tibial fractures. The current case demonstrates several factors that predict a successful outcome when treating a complex tibial fracture: (1) the timing of soft tissue coverage; (2) the level of amputation; and (3) the eradication of infection.

The Ilizarov hybrid external fixator is an excellent option to treat infected tibial nonunion in an amputated stump. Although the current case had a successful outcome, the use of the Ilizarov device is not without drawbacks. The application of the Ilizarov device is highly technical and requires meticulous postoperative care and compliance by the patient and surgeon. Even then, the risk of treatment failure and complications exists.

**REFERENCES**