Ilizarov External Fixator for Length Salvage in Infected Amputated Nonunions

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Abstract

The technique of compression distraction induced osteogenesis via the Ilizarov external fixator system has been used for a variety of traumatic limb pathologies that necessitate boney union and limb preservation. In this case report, we describe an uncommon scenario were an Ilizarov external fixator was used to treat an infected nonunion following a below knee amputation.

The Ilizarov apparatus has been widely used since the 1940s for limb lengthening, filling in boney defects, treatment of nonunions as well as osteomyelitis. 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 used to treat infected tibial nonunions following amputation. To our knowledge, such an application of the Ilizarov external fixation device has yet to be reported. We present in this case report, a patient who underwent a below-knee-amputation (BKA) of a concomitant infected proximal tibial nonunion. The patient described in this report was surgically treated for multiple failed attempts at fixation and fusion of a comminuted segmental fracture that subsequently got infected. Additionally, we highlight the importance of amputation level when deciding to amputate as well as its impact on limb function and the use of the Ilizarov external fixator to preserve length in an un-fused stump.

Case Report

A 38-year-old man sustained a Grade IIIB segmental tibial fracture and massive soft tissue loss of his right leg following a motorcycle accident. This was a two-part fracture that divided the tibial shaft into three segments. The proximal fracture site was at the tibial tubercle and distal site at mid-tibial shaft (Fig. 1). At the time of injury, patient was treated via wound debridement, skin grafts, gastrocnemius free flap, and a spanning external fixator, which was later converted to a hybrid non-spanning external fixator below the knee. One month after treatment, there were no signs of bony union, and the patient went on to develop 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, failed.

Taking into account the chronicity of infection and nonunion, amputation was very likely despite attempts at limb salvage. In order to exhaust all options at limb salvage, a successful free flap transfer needed to be in place. Unfortunately, our flap failed and left a large soft tissue defect over the medial aspect of the tibia. Given the sequela of suboptimal neurovascular status at proximal tibial nonunion sites, there was a high probability of an above-knee-amputation (AKA). Additionally, amputation levels have been shown to have significant impacts on prosthetic fitting and gait. As a result, aggressive management to optimize limb-prosthetic function and overall clinical outcome was instead indicated.

Patient consented to a below-knee-amputation (BKA) at the mid-tibia shaft level. A more proximal level, the site of proximal nonunion, would have left him with a very short BKA 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 will afford him sufficient stump length to optimize limb-prosthetic function. Given his current history of osteomyelitis, it was decided that a circular external fixation

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frame would provide safest methods to fuse nonunion. In addition, we consulted with an infectious disease specialist to implement appropriate intravenous antibiotic regimen to treat the infected nonunion.

The patient subsequently underwent a BKA and fixation of the proximal tibial nonunion site via the Ilizarov external fixator, using bone autografts and Bone Morphogenic Protein (BMP) to augment fusion. The distal two-thirds of the tibia was degloved of overlying skin, dissected using a fillet foot technique, where all muscular and soft tissue components are left behind as one bulk of myocutaneous tissue (Fig. 2). This was accomplished with the assistance of a plastic surgeon. Fine wires were later added to increase stability of the construct, allowing the patient to bare weight for physical therapy (Fig. 3).

Six to 10 weeks following amputation, radiographs showed progressive improvements marked by interval healing of nonunion and adequate callus formation. At 5 months post-amputation, hardware was removed and radiographic films showed bridging bone across fragment ends (Fig. 4). The patient was successfully fitted with a lower-limb prosthetic device one month after hardware removal and continued physical therapy for 4 more months.

Discussion

The Ilizarov external fixator device has been widely used to correct limb length discrepancies, lengthen both limb and amputation stumps, treat a myriad of bony deformities, defects, and nonunions. But to our knowledge, there are no published cases demonstrating its use in the setting of an infected tibial nonunion post-amputation, where the Ilizarov device simultaneously salvages stump length and fuses a nonunion.

In the USA alone, delayed union occurs in an estimated 600,000 patients with fractures each year, and approximately 100,000 of them progress to nonunions. Consequently, tibial nonunion is not an uncommon complication of high-energy traumatic injuries. 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, substandard surgical care, medication, or poor nutritional status. The patient described in this 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 an existing comorbidity or direct vascular injury, significantly predisposes the bone defect to microbial colonization and delayed healing. However, even with clinical evidence of good blood flow, free flaps may still fail, necessitating more interventions and prolonged hospital time. Despite numerous attempts at limb salvage via tissue debridement, vascular reconstruction, and several fixation

Figure 1 A. Coronal T1 magnetic resonance imaging without contrast and B. clinical photo of infected tibial nonunions at the tibial tubercle and midshaft levels, left to right.

Figure 2 Intraoperative photo of a right below knee amputation showing slay of foot with intact myocutaneous tissue flap before envelope closure.
attempts, our patient went on to develop a chronically infected nonunion. Although myocutaneous free flaps and vascular anastomosis have proven to be vital therapeutic requisites for traumatic limb salvage,\textsuperscript{16} they are not always successful.\textsuperscript{17,18} With this in mind, thorough investigation of patient compliance, past medical history, socioeconomic status, clinical judgment, and evidence-based medicine are all essential to implement the best course of therapy.

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 is less

Figure 3 A. Anterior to posterolateral intraoperative radiographs of right tibia status post below knee amputation and placement of Ilizarov external fixator, left to right. B. Intraoperative photo of a right below knee amputation stump following placement of an Ilizarov external fixation frame.

Figure 4 Anterior to posterolateral radiographs of right proximal tibia at 5 months status after below knee amputation and hardware removal.
compared to a more proximal above-knee-amputation.19 After any amputation, there is significant compensation from the residual ipsilateral limb-prosthesis to achieve proper kinematics during gait and strength for propulsion. This, therefore, makes ambulation more difficult and less efficient than the native limb. Studies have shown that metabolic costs of walking following amputation can be up to 200% greater than normal gait.20-22 In terms of BKA versus AKA, Marshall and Stansby reported that walking with a prosthesis compared to normal ambulation requires 25% to 40% more energy expenditure for below-knee prosthesis versus 65% to 100% for above-knee prosthesis.23 Hence, careful and early assessment of indications for a BKA versus AKA is important when considering amputation as a therapeutic option. Aside from lower energy expenditure, a below-knee-amputation employs 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 environment requires adequate blood supply and mechanical stresses across the surface area of fragment ends.5,13 When treating septic nonunions, prophylactic measures have to be taken to prevent widespread infection because it may potentially lead to fulminant sepsis.24 For that reason, an external fixator was used. The type of fixator was a hybrid Ilizarov external fixator comprised of small wires, two 5/8” circular fixator frames, percutaneous pins, and outside rods and screws. In establishing the microenvironment that would promote osteogenesis, the fracture ends were debrided of all necrotic tissue. Fragments were then reduced and mechanically stabilized with pin placement above and below nonunion sites. Bone Morphogenetic Proteins (BMP) and autologous bone grafts were placed in-between fragment ends in a sandwich-like manner to help augment inter-fragmental osteogenesis. At one month, the Ilizarov device was adjusted to promote stress about the nonunion site. The device was loosened, compressed, and then re-tightened. Additionally, this served to avoid unwanted pathomechanical movements about the defect that could impede union. Securing stability after proper alignment not only complements fixation but also prevents delayed or nonunion gap. Such environment requires adequate blood supply and mechanical stresses across the surface area of fragment ends.5,13 For that reason, an external fixator was used. The type of fixator was a hybrid Ilizarov external fixator comprised of small wires, two 5/8” circular fixator frames, percutaneous pins, and outside rods and screws. In establishing the microenvironment that would promote osteogenesis, the fracture ends were debrided of all necrotic tissue. Fragments were then reduced and mechanically stabilized with pin placement above and below nonunion sites. Bone Morphogenetic Proteins (BMP) and autologous bone grafts were placed in-between fragment ends in a sandwich-like manner to help augment inter-fragmental osteogenesis. At one month, the Ilizarov device was adjusted to promote stress about the nonunion site. The device was loosened, compressed, and then re-tightened. Additionally, this served to avoid unwanted pathomechanical movements about the defect that could impede union. Securing stability after proper alignment not only complements fixation but also prevents delayed or nonunion. The patient was subsequently fitted for custom orthotics that would allow him to bear weight on the device as he underwent therapy. At 7 weeks following amputation, a course of physical therapy was instituted. Radiographs at 7 weeks showed abundant callus formation and satisfactory alignment. A single pin at the cephalad end of the Ilizarov frame had to be changed due to loosening and suspicion as a possible source of infection. Wound and overlying skin were clean, non-erythematic, and intact with appropriate signs of healing. The Ilizarov fixator frame was taken off 5 months post-amputation, and the patient was subsequently fitted for below-knee prosthesis one month following removal of hardware.

Patient was left on intravenous antibiotics for several months after removal of hardware but was later switched to oral antibiotics and ultimately weaned off. The patient received routine post-amputee protocols, which included physical therapy, occupational therapy, and prophylactic psychiatric consultation.25 Since then, the patient has been reported to be doing well from a surgical and medical standpoint. Serial follow-up with physical examination and X-rays demonstrated a functional tibial stump with complete bone fusion without signs of infection.

Conclusion

Treatment of Grade IIIB open tibial fractures are possibly some of the most difficult of traumatic injuries to treat. Not only have they been associated with high rates of infection (50%) and amputation (30%), their relative risk of long-term medical and psychological morbidity, pain, and immobility are much higher than the rest of the subpopulation of tibial fractures.25 This case illustrates several factors that could predict a successful outcome when treating a complex nonunion. Three factors we found to be critical for successful outcomes are: 1. timing of soft tissue coverage,26 2. level of amputation, and 3. eradication of infection. This report suggests the use of the Ilizarov hybrid external fixator as an excellent option to treat infected tibial nonunion in an amputated stump. Although we report a successful outcome in this case, it is not to say that the use of the Ilizarov device is without setbacks. The application of the Ilizarov apparatus is highly technical and requires meticulous postoperative care and compliance by both patient and surgeon. Even when compliance and postoperative care are adequately met, the risk of treatment failure and complications are still possible.

Disclosure Statement

None of the authors have a financial or proprietary interest in the subject matter or materials discussed, including, but not limited to, employment, consultancies, stock ownership, honoraria, and paid expert testimony.

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