

Trifocal Ilizarov Bone Transport for a 21-cm Tibial Defect in a Chronic Smoker with Longstanding Osteomyelitis: A Complex Limb Salvage Case

Umar Hayat¹, Abdulaziz A Abdulaziz², Faisal A Alghamdi³, Khalid Ahmad Alnofeay¹, Hassan Ghazi Ashry¹, Atif Ahmed Labban¹

¹Orthopedic Department, King Faisal Hospital, Makkah, Saudi Arabia; ²Orthopedic Department, King Faisal Medical Complex Taif, Taif, Saudi Arabia; ³College of Medicine, Umm Al-Qura University, Makkah, Saudi Arabia

Correspondence: Faisal A Alghamdi, College of Medicine, Umm Al-Qura University, Makkah, Saudi Arabia, Email iigamde707@gmail.com

Abstract: This case study presents the successful management of a 21-cm tibial defect in a 38-year-old man smoker with longstanding osteomyelitis using trifocal Ilizarov bone transport. Despite the complexities posed by chronic infection and extensive bone loss, a meticulously planned staged reconstructive protocol involving aggressive debridement, targeted antimicrobial therapy, and advanced bone transport techniques culminated in remarkable limb salvage and functional recovery. Integration of low-intensity pulsed ultrasound (LIPUS) further optimized bone healing in this intricate scenario. This case report addresses these gaps by detailing a successful trifocal Ilizarov strategy augmented with LIPUS in a chronic smoker with an exceptionally large tibial defect.

Keywords: ilizarov, reconstruction, bone regeneration, bone loss tibial defect

Introduction

Chronic osteomyelitis of the tibia remains one of the most formidable complications following both intra- and extra-medullary fixation of leg fractures. Its incidence can be as high as 22.4% in certain series, particularly in the context of open fractures, contaminated wounds, and inadequate initial stabilization or soft tissue management.^{1–3} Once established, chronic osteomyelitis presents a complex therapeutic dilemma, often requiring a multidisciplinary approach involving aggressive debridement, targeted antimicrobial therapy, and definitive skeletal reconstruction.

Among the modifiable risk factors, smoking has been consistently identified as a significant contributor to the pathogenesis and persistence of chronic osteomyelitis. Beyond its systemic effects, smoking impairs local vascularity, suppresses osteoblastic activity, and adversely affects both primary bone healing and regenerate formation in distraction osteogenesis.⁴

The management of large segmental tibial defects resulting from infection-related debridement poses an additional challenge. Various reconstructive options exist, including the Masquelet induced membrane technique, vascularized or non-vascularized autologous bone grafting, and bone transport using distraction osteogenesis.^{5–7} However, in Cierny–Mader type IV chronic osteomyelitis—with extensive segmental bone loss and compromised host status—traditional methods such as sequestrectomy, antibiotic therapy, and repeated internal fixation often yield suboptimal outcomes and high failure rates.^{8–10}

In this context, the Ilizarov method of bone transport has emerged as the gold standard for limb salvage in cases of extensive diaphyseal bone loss, particularly when accompanied by active infection and soft tissue compromise. First described by Professor Gavril Ilizarov, the technique allows for simultaneous infection control, segmental bone regeneration, and correction of deformity without the need for massive bone grafting.^{11–14}

Existing literature suggests that bifocal Ilizarov bone transport is effective, but it is associated with long external-fixation times and regenerate problems; trifocal transport may shorten treatment but remains under-reported and

controversial.¹⁵ There is also limited evidence regarding the use of low-intensity pulsed ultrasound (LIPUS) during distraction osteogenesis, especially in smokers.¹⁶

This report presents a rare and particularly challenging case of chronic post-traumatic osteomyelitis in a 38-year-old male with a 22-year history of infection, heavy smoking, and a resultant 21-cm tibial defect. The successful management of this case using staged debridement and trifocal Ilizarov bone transport augmented by LIPUS offers insight into the application of advanced limb reconstruction strategies in high-risk, multiply operated patients.

Case Presentation

A 38-year-old man, previously healthy but a chronic smoker, presented to our tertiary limb reconstruction clinic with a long-standing, draining sinus over the anterior aspect of his right leg (**Figure 1**). His clinical history was striking: 22 years prior, he had sustained a high-energy road traffic accident resulting in a Gustilo-Anderson grade IIIB open fracture of the right tibial shaft. At the time, the injury was managed with a monolateral external fixator and coverage using a split-thickness skin graft. Despite undergoing six separate procedures over several years—addressing both bony stabilization and soft tissue reconstruction—he had never fully recovered. Since the initial injury, he had lived with



Figure 1 Clinical picture of the leg on the first visit of the patient showing sequestrum protruding through the sinus.

intermittent purulent discharge and the occasional extrusion of bone fragments through the sinus. His leg had become not just a source of pain but a visible reminder of trauma, infection, and limitation.

At presentation, the patient reported escalating pain, foul-smelling discharge, and a large bone fragment visibly protruding through the sinus tract. He described significant functional limitations and expressed emotional fatigue from years of living with a non-healing wound. (Figure 2) Radiographs and computed tomography revealed dense cortical sclerosis, periosteal hyperplasia, and a large sequestrum involving the mid-diaphysis of the tibia. Laboratory investigations were consistent with chronic osteomyelitis.

After extensive counseling, including discussions around the relative benefits of amputation versus limb salvage, the patient expressed a strong preference to retain his limb. A two-stage reconstructive strategy was planned. The first stage focused on eradicating infection. Under general anesthesia, approximately 21 cm of infected mid-tibial diaphysis was excised (Figure 3), followed by the application of an Ilizarov circular external fixator (Figure 4). Antibiotic-loaded polymethyl methacrylate (PMMA) cement was inserted to maintain space and deliver local antimicrobial therapy



Figure 2 X-ray of the right leg on the day of admission showing sequestra and sclerosis of the middle segment of the tibia.

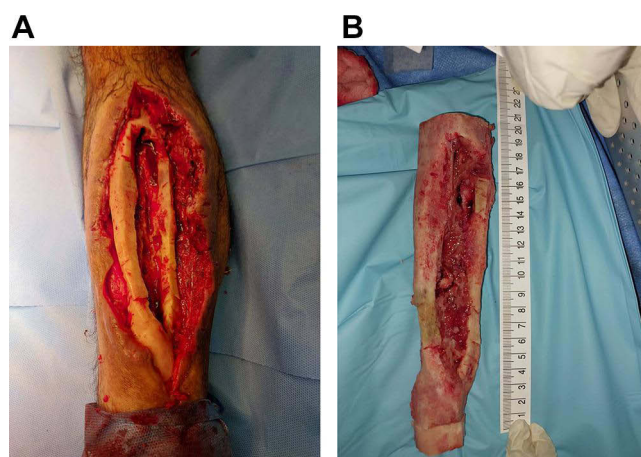


Figure 3 (A) Per-op clinical picture of the wound after the second debridement, showing extensive sclerosis with no bleeding bone. (B) Length of tibia excised after radical debridement till bleeding bone.



Figure 4 Clinical picture of the leg with the Ilizarov frame in place.

(Figure 5). Multiple intraoperative samples were obtained for microbiological and histopathological analysis. Postoperatively, he was treated with six weeks of culture-directed intravenous antibiotics. Wound culture and sensitivity showed *Proteus Mirabilis* ESBL sensitive to bactrim started on meropenem while admitted then discharged on bactrim for six weeks till labs return to normal range as advised by infectious disease department.

The second stage of reconstruction began six weeks later. After confirming local infection control, the cement spacer was removed and a proximal tibial corticotomy was performed (Figure 6). Bone transport was initiated 10 days postoperatively at a rate of 1 mm/day. However, after three months, regenerate formation at the proximal site was suboptimal. In response, a second corticotomy was performed distally (Figure 7), converting the strategy to trifocal bone transport to reduce total time in the frame and improve regenerate quality.

During the distraction phase, the patient required two additional surgeries: one for exchange of infected wires and another for realignment and frame adjustment. Despite these challenges, he remained compliant and motivated. Supportive measures were introduced to optimize osteogenesis. Nutritional counseling, oral supplements, and an individualized physiotherapy regimen were initiated. The patient successfully stopped smoking six months after frame application. The accordion technique—alternating compression and distraction—was employed twice to stimulate regeneration at the proximal site. In addition, two courses of low-intensity pulsed ultrasound (LIPUS) were administered, both of which resulted in qualitative improvement in callus density and morphology on radiographs (Figure 8).



Figure 5 Immediate post-op x-ray showing remaining tibia, fibular osteotomy, and bone cement in situ.

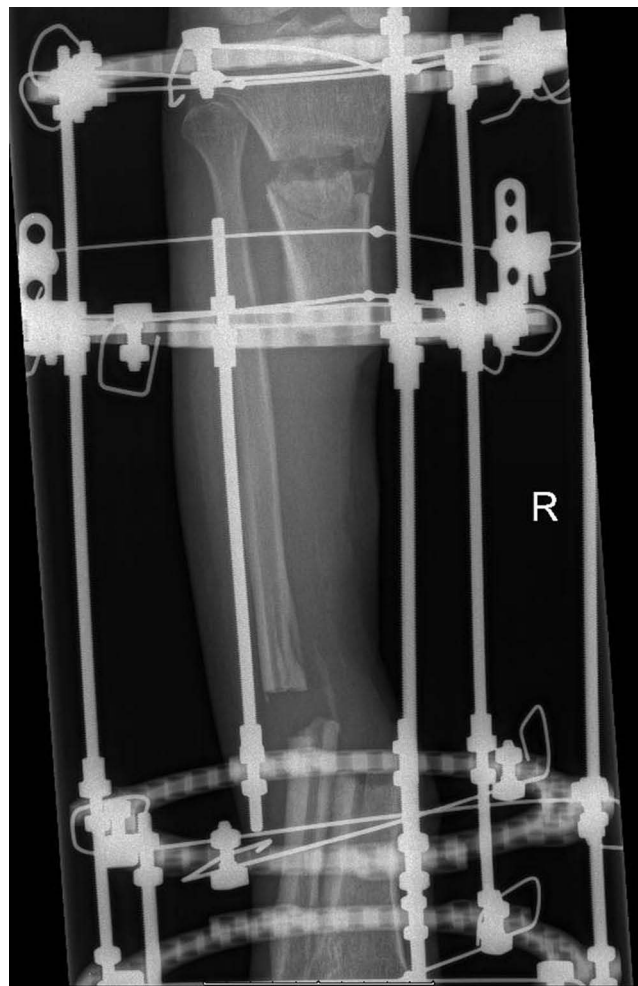


Figure 6 X-ray taken during follow-up showing bone transport at proximal.

Given the magnitude of the defect and delayed regenerate formation, a residual limb shortening of 4 cm was accepted. Ultimately, 17 cm of new bone was successfully transported and consolidated. At the 18-month follow-up, radiographs confirmed union at the docking site and mature regenerate formation (Figure 9). The external fixator was dynamized prior to removal to promote load-sharing.

At the final assessment (Figure 10), three months after removal of ilizarov fixator the patient had achieved a full range of motion at the knee with only mild ankle stiffness. Functional outcomes were satisfactory: the Knee Society Score was 95/100, and the functional score was 60/100. According to the ASAMI criteria, both bone and functional results were graded as “good.” The bone healing index was calculated at 1.1 cm/month, consistent with literature benchmarks for trifocal transport in complex tibial defects.¹⁷

Discussion

The primary objective in this case was to restore equal limb length to regain optimal function. Several reconstructive options were considered to address the extensive tibial bone defect. Autologous bone grafting, while biologically favorable, is limited in cases of large defects due to the need for multiple donor sites, which introduces significant morbidity and donor site complications.¹⁸

Free vascularized fibular grafts from the contralateral limb are a suitable option for large defects but are best reserved for cases where the donor limb is not under high functional demand, which was not applicable in our patient. Allograft reconstruction presents its own challenges, including complex preparation, preservation requirements, and risk of



Figure 7 Distal osteotomy sites in progress.

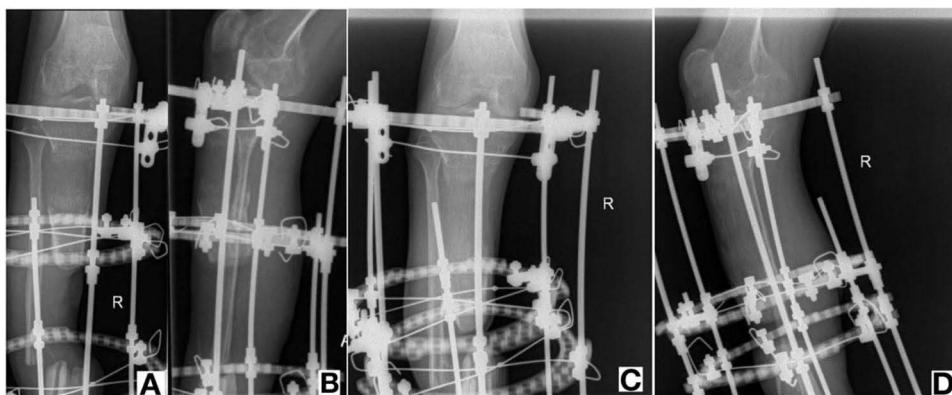


Figure 8 (A and B) Radiographs obtained in April 2024 demonstrating delayed regenerate maturation 6 months after fixator application. (C and D) Radiographs obtained in August 2024, four months after initiation of LIPUS, showing improved regenerate quality.

immunologic rejection or infection.^{18,19} Furthermore, the presence of soft tissue involvement and the extent of the defect precluded these traditional approaches, as adequate soft tissue coverage must be established first—an inherently time-consuming step. While amputation offers rapid functional rehabilitation and can be a viable option in selected cases, the irreversible loss of the limb makes it an unfavorable first-line solution for most patients.

After a comprehensive evaluation, multilevel bone transport was selected as the most suitable reconstructive approach. This technique is particularly advantageous in managing extensive bone loss, as it reduces total treatment time and addresses segmental defects effectively. For instance, Lerner in his research has successfully employed bifocal transport to bridge a 22 cm tibial gap.²⁰ Similarly, Alkenani in his study demonstrated successful unifocal transport in a large defect (14.5 cm) without the need for an intramedullary nail, achieving full bone regeneration.²¹ However, it is important to note that multilevel transport requires a complex external fixator system and may be associated with delayed regenerate consolidation.²²



Figure 9 X-ray after removal of the frame showing (A) completely united bone (B) mechanical alignment maintained.

To optimize healing in our case, low-intensity pulsed ultrasound (LIPUS) was integrated into the management protocol. In a retrospective cohort study by Song et al involving 30 patients, LIPUS significantly improved consolidation, particularly in the anterior and medial cortices ($p < 0.001$ and $p = 0.002$, respectively). It was associated with denser, more uniform callus formation, potentially translating into stronger bone regeneration.²³

In our case, a trifocal lengthening strategy combined with LIPUS allowed for full restoration of a 17 cm tibial defect. The adjunctive use of LIPUS was especially valuable given the complicating factors of chronic osteomyelitis and a history of smoking, both of which negatively impact bone healing. This approach achieved successful limb salvage. Equalization of limb length and restoration of function.

Conclusion

This case emphasizes the feasibility of trifocal Ilizarov reconstruction for large 21 cm tibial bone defect complicated by Osteomyelitis and smoking. The integration of LIPUS may augment regenerate maturation in compromised bone, representing a potential adjunct to modern distraction osteogenesis protocols.

Ethical Approval

Institutional approval was not required for publishing the case details according to our institution's policies.

Informed Consent for Publication

Written informed consent was obtained from the patient's for publication of this case report and accompanying images.



Figure 10 Clinical picture of the patient 2 months after the removal of the frame.

Acknowledgments

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Author Contributions

All authors contributed to the data analysis, drafting or revising the article, have agreed on the journal to which the article will be submitted, gave final approval or the version to be published, and agree to be accountable for all aspects of the work.

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Disclosure

The authors report no conflicts of interest in this work.

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