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Aseptic Tibial Nonunion Following Open Fracture Initially Managed with External Fixation: A Case Series of Three Patients

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Abstract | **Case Report**

Background: Open tibial fractures are associated with a high risk of nonunion, particularly when prolonged external fixation is employed as the primary stabilization method. The pathophysiology involves a combined mechanical and biological failure at the fracture site, including cortical devascularization, axial instability, and impaired osteogenic stimulation. ***Methods:*** We present a series of three patients with aseptic diaphyseal tibial nonunion, all of whom sustained open tibial fractures initially managed with external fixation. Time from initial injury to definitive surgical treatment ranged from 8 to 12 months. All three underwent surgical treatment combining reamed, locked intramedullary nailing with biological stimulation through cortical decortication, medullary preparation, and autologous cancellous bone grafting from the iliac crest. ***Results:*** All three patients achieved complete radiological consolidation with satisfactory functional recovery. No postoperative infectious complications were recorded. The outcomes are consistent with published literature reporting union rates of 76–96% with reamed intramedullary nailing for aseptic tibial nonunion. ***Conclusion:*** This case series reinforces the efficacy of combined biomechanical and biological treatment in aseptic tibial nonunion following open fracture and prolonged external fixation. Reamed, interlocked intramedullary nailing combined with autologous bone grafting represents the gold-standard approach in this setting.

Keywords: Tibial nonunion; Open fracture; External fixation; Intramedullary nailing; Autologous bone graft; Cortical decortication.

1. INTRODUCTION

The tibia is the most common site of long bone nonunion, with a reported nonunion rate of approximately 2.5% following tibial shaft fractures [1]. Aseptic tibial nonunion following open fracture managed with external fixation represents a particularly challenging clinical scenario, given the compounded mechanical and biological insults to the fracture site. Nonunion is defined as the absence of radiological and clinical signs of fracture healing beyond nine months following the initial injury, in the absence of infection, according to criteria established by the U.S. Food and Drug Administration [2].

External fixation remains an essential tool in the emergency management of open tibial fractures, especially in high-energy trauma, owing to its rapid applicability and capacity for wound access. However, when maintained as definitive treatment for extended periods, it introduces several factors detrimental to bone healing: axial instability, absence of controlled interfragmentary micromotion, periosteal devascularization from pin placement, and inadequate cortical contact [3–5]. These conditions collectively disrupt the normal biological cascade of bone repair, predisposing patients to nonunion.

Treatment of tibial nonunion is challenging and must address both the mechanical and biological dimensions of the failure of healing [6]. Reamed, interlocked intramedullary (IM) nailing has emerged as the gold-standard single-stage treatment for aseptic diaphyseal tibial nonunions, with reported union rates ranging from 76% to 96% [7–8]. This technique restores axial alignment, provides rotational stability, transmits physiological axial loads, and permits controlled micromotion at the nonunion site. Reaming of the medullary canal further serves as a biological stimulus by releasing growth factors and multipotent stem cells from the endosteum, enhancing osteogenic activity [9].

We report a series of three patients with aseptic tibial diaphyseal nonunion, all following open fractures initially stabilized with external fixation, who were successfully treated with reamed locked IM nailing supplemented by autologous bone grafting and biological stimulation at the nonunion site.

2. CASE REPORTS

Case 1

A 31-year-old male patient with no significant past medical history was admitted following a high-energy motor vehicle collision (motorcycle versus automobile) that resulted in a Gustilo-Anderson grade IIIA open fracture of the right tibial diaphysis. The fracture was managed acutely with external fixation. One year after the initial injury, the patient presented to our department complaining of persistent pain, progressive valgus deformity, and a fixed equinus contracture of the right foot.

Clinical examination confirmed mechanical instability at the fracture site without signs of local or systemic infection. Standard radiographs revealed an atrophic aseptic tibial nonunion with established valgus malalignment, classified as a mobile atrophic nonunion according to the Weber-Cech system. Preoperative infection workup, including complete blood count, erythrocyte sedimentation rate (ESR), and C-reactive protein (CRP), was within normal limits. No fistulas or draining sinuses were present.

Surgical management consisted of a combined biomechanical and biological approach: debridement and freshening of the nonunion site, cortical decortication, progressive reaming of the medullary canal to 1.5 mm beyond the planned nail diameter, placement of a statically locked reamed intramedullary nail, and autologous iliac crest cancellous bone grafting. The fixed equinus deformity was simultaneously corrected by Achilles tendon lengthening.

The postoperative course was uneventful. Radiological union, defined as bridging callus across three cortices on two orthogonal views, was confirmed at six months postoperatively. At twelve months follow-up, the patient demonstrated complete bone consolidation, satisfactory functional recovery, and restoration of lower limb alignment with full unassisted weight bearing.

Figure 1. Anteroposterior and lateral radiographs demonstrating the initial external fixator in situ (Case 1)

Figure 2. Intraoperative photograph showing preparation of the medullary canal (Case 1)

Figure 3. Pre- and postoperative photographs of the Achilles tendon lengthening procedure (Case 1)

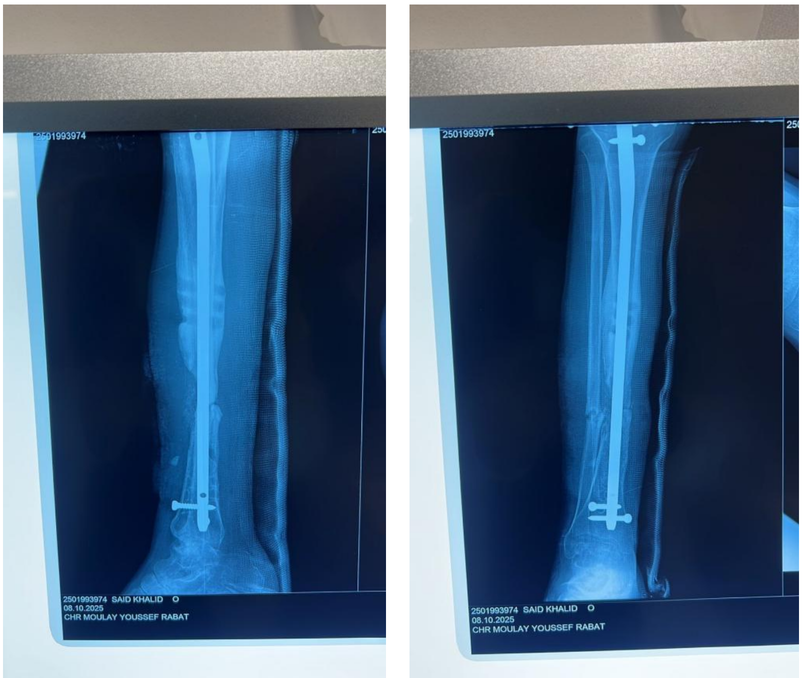

Figure 4. Postoperative anteroposterior and lateral radiographs confirming solid union following reamed locked intramedullary nailing (Case 1)

Case 2

A 42-year-old male patient presented one year after sustaining a Gustilo-Anderson grade II open fracture of the right leg in a road traffic accident, which had been managed with external fixation. He reported persistent pain, inability to bear weight, and functional limitation of the right lower limb.

Radiological evaluation demonstrated an atrophic aseptic tibial nonunion with a consolidated fibula. There was no clinical or biochemical evidence of infection. The Weber-Cech classification identified this as a mobile atrophic (oligotrophic) nonunion.

Treatment was performed in a single surgical stage via an anterolateral approach to the nonunion site. The procedure included excision of fibrous tissue, cortical decortication, progressive medullary reaming, and definitive fixation with a statically locked reamed intramedullary nail. Fibular osteotomy was performed through a separate incision to facilitate axial load transfer to the tibia and allow nail insertion. Early weight bearing was encouraged postoperatively with physiotherapy support.

Radiological union was confirmed at five months postoperatively. At twelve months follow-up, the patient had achieved complete osseous consolidation with restoration of axial alignment and resumed full weight bearing without pain.

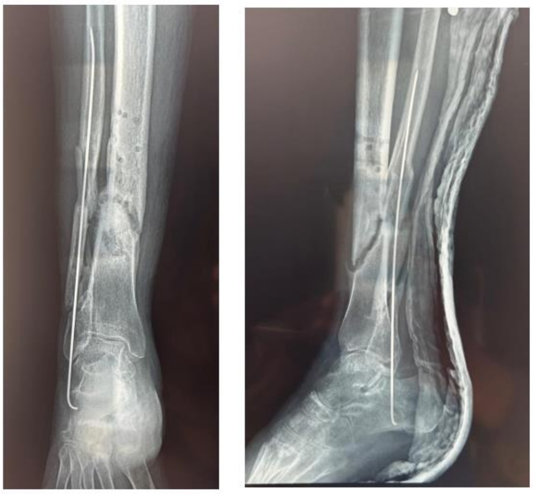

Figure 5. Anteroposterior and lateral radiographs demonstrating atrophic aseptic tibial nonunion with consolidated fibula, prior to surgical intervention (Case 2)

Figure 6. Postoperative radiographs confirming solid union following reamed locked intramedullary nailing (Case 2)

Case 3

A 35-year-old male patient with no significant medical history was referred eight months after sustaining a Gustilo-Anderson grade II open fracture of the tibial diaphysis in a road traffic accident. The initial management consisted solely of external fixation without subsequent conversion to internal fixation.

At presentation, the patient reported persistent pain and complete functional impairment of the affected lower limb. Physical examination revealed abnormal mobility at the fracture site without local or systemic signs of infection. Standard radiographs confirmed an atrophic tibial nonunion, classified as mobile atrophic (oligotrophic) according to the Weber-Cech system. Although the FDA criterion defines nonunion at nine months, the combination of established radiological atrophy, absence of any callus progression over the preceding two months, and complete clinical non-healing justified operative intervention at eight months, consistent with accepted practice for atrophic nonunions. Preoperative biological workup (full blood count, ESR, CRP) and bacteriological cultures from pin-track wounds were negative.

Surgical treatment comprised excision of fibrous tissue at the nonunion site, cortical decortication, medullary preparation with progressive reaming, insertion of a statically locked reamed intramedullary tibial nail, and supplementary autologous cancellous bone grafting harvested from the iliac crest. The periosteal sleeve was carefully preserved and repaired.

Postoperative follow-up was unremarkable. Radiological union was confirmed at seven months postoperatively. At fourteen months follow-up, the patient had achieved complete consolidation with satisfactory functional recovery and full unassisted weight bearing.

Figure 7. Anteroposterior and lateral radiographs demonstrating atrophic tibial nonunion eight months after initial external fixation (Case 3)

Figure 8: Postoperative radiographs (AP and lateral) illustrating solid union following placement of the reamed locked intramedullary nail (Case 3)

3. DISCUSSION

Aseptic tibial nonunion following open fracture managed with external fixation is a well-characterized complication, reflecting both mechanical inadequacy and biological impairment at the fracture site [3,6]. Our series of three cases illustrates the dual-component pathophysiology of this condition and confirms the efficacy of a combined biomechanical and biological treatment strategy.

External fixation, while indispensable in the emergency management of open tibial fractures as part of damage control orthopaedics, carries inherent risks when retained as definitive stabilization. Prolonged external fixation results in axial instability, absence of controlled interfragmentary compression, periosteal vascular compromise secondary to pin placement, and inadequate cortical contact [4,5]. Collectively, these factors inhibit the normal osteogenic cascade and predispose the fracture site to biological quiescence. In the large retrospective series reported by Kostic et al. [7], 82% of patients with aseptic tibial nonunion had been initially managed with external fixation, underscoring the strong epidemiological association between this treatment modality and nonunion.

The cornerstone of treatment in all three of our cases was reamed, interlocked intramedullary nailing. This technique addresses the mechanical component of nonunion by restoring axial alignment, providing rotational control, and facilitating the transmission of physiological axial compressive loads across the fracture site [3,7]. Controlled interfragmentary micromotion, permitted by the elastic properties of the intramedullary construct, stimulates periosteal callus formation and accelerates consolidation [10]. Kostic et al. [7] reported a union rate of 93.9% within eight months using this approach in a cohort of 33 patients, a finding consistent with the broader literature reporting success rates of 76–96% [8,11].

Beyond its mechanical role, reaming of the medullary canal confers a critical biological benefit. The reaming process releases growth factors, bone morphogenetic proteins, and multipotent mesenchymal stem cells from the endosteal surface and intramedullary fat, creating an osteogenic microenvironment at the nonunion site [9,12]. Schemitsch et al. demonstrated in a sheep fracture model that reamed nailing significantly improved perfusion in the surrounding periosteal soft tissues compared to unreamed nailing [13], suggesting that reaming may also enhance the biological milieu through vascular recruitment.

Biological stimulation through cortical decortication and autologous iliac crest cancellous bone grafting was performed in all three of our cases, consistent with the indications for supplementary bone grafting in atrophic nonunions. Autologous cancellous graft provides all three elements required for bone regeneration: osteogenic cells, osteoinductive growth factors (including bone morphogenetic proteins), and an osteoconductive scaffold [6,14]. While Kostic et al. [7] reserved autologous bone grafting only for cases with cortical defects exceeding 50% of the bone circumference, our institutional approach applies bone grafting more broadly in atrophic nonunions given the biological impoverishment of the nonunion site following prolonged external fixation.

Fibular integrity represents an important consideration in tibial nonunion management. In Case 2, the fibula was already consolidated at the time of surgery, and fibular osteotomy was performed to allow axial load transfer to the tibia and facilitate intramedullary nail insertion. Kostic et al. [7] performed fibular osteotomy or partial fibulectomy in 78.8% of their cases, citing its role in correcting malalignment and redistributing loads to the tibia [15].

The rigorous preoperative exclusion of infection is paramount before proceeding with single-stage intramedullary nailing. In all three of our cases, infection was systematically excluded by clinical evaluation, standard inflammatory markers (ESR, CRP, white blood cell count), bacteriological swab cultures from pin-track wounds, and intraoperative Gram staining and culture of reaming material. This protocol is aligned with the approach described by Kostic et al. [7], who reported a deep infection rate of only 3.3% attributable to strict adherence to preoperative infection screening.

Case 1 presented the additional complexity of a fixed equinus deformity secondary to Achilles tendon contracture, managed concurrently with tendon lengthening. This illustrates that tibial nonunion following open fracture may be compounded by soft tissue sequelae, necessitating a comprehensive surgical plan beyond the osseous reconstruction.

The limitations of this report include the small case series design without a control group, retrospective data collection, and the absence of validated radiological union criteria (Radiographic Union Score for Tibial fractures, RUST) and functional outcome scores (Lower Extremity Functional Scale, LEFS; or AOFAS ankle-hindfoot score). Prospective comparative studies with standardized outcome measures are required to further define optimal surgical protocols.

4. CONCLUSION

Aseptic tibial nonunion following open fracture initially managed with external fixation is a severe but treatable complication. The results of this case series, consistent with the evidence base including the series reported by Kostic et al. [7], confirm that a combined biomechanical and biological approach is effective. Reamed, statically locked intramedullary nailing restores the mechanical environment necessary for bone repair, while cortical decortication and autologous iliac crest bone grafting provide the biological substrate for osteogenesis. This combined strategy achieves reliable consolidation and satisfactory functional recovery, and should be considered the standard of care for this indication.

Patient Consent

Written informed consent was obtained from all patients for publication of this case series and any accompanying images. A copy of the written consents is available for review by the Editor-in-Chief of this journal.

Conflicts of Interest

The authors declare no conflicts of interest.

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