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Single-Stage Reconstruction of Tibial Nonunion with Segmental Bone Loss Using Combined Non-Vascularized Fibular and Iliac Crest Grafting in a War Setting: A Case Series from Gaza

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Abstract

Reconstruction of tibial shaft nonunion with segmental bone loss remains a major challenge in war-related trauma, particularly in settings with delayed presentation, extensive soft tissue damage, and limited access to advanced reconstructive techniques. This case series describes five patients with high-energy blast and gunshot injuries treated at the Jordanian Field Hospital in Gaza between June and September 2024. All patients presented with established nonunion following initial external fixation, with segmental bone defects ranging from 4 to 11 cm.

All cases were managed using a single-stage reconstructive approach that included thorough debridement, preparation of the medullary canal, and reconstruction with non-vascularized fibular grafts combined with autologous iliac crest bone grafting, stabilized with locking compression plates. Patients were followed clinically and radiologically for 16–20 months. Union was achieved in all five patients within 8–14 months; however, two patients required revision surgery due to implant failure and delayed union before successful consolidation was achieved.

This case series may support the use of combined non-vascularized fibular and iliac crest bone grafting as a practical, effective, and reproducible single-stage technique for managing large tibial defects in resource-limited conflict settings, provided that adequate debridement, stable fixation, and appropriate postoperative care are ensured.

Keywords: Tibia nonunion; Segmental bone loss; Non-vascularized fibular graft; Iliac crest bone graft; War-related trauma

Introduction

War-related injuries in Gaza over the past two years have resulted in a substantial burden of complex trauma and placed extreme strain on an already limited healthcare system. In a retrospective analysis of 362 orthopedic trauma patients treated at the Jordanian Military Field Hospital in Southern Gaza, blast injuries and gunshot wounds accounted for the majority of cases, with lower-extremity injuries representing a significant proportion of the orthopedic workload [1], These injuries frequently involve multisystem trauma with severe orthopedic damage, including open comminuted fractures, extensive soft tissue loss, neurovascular compromise, and contaminated wounds. Lower limb injuries, particularly tibial fractures associated with contamination and segmental bone loss, remain especially challenging due to impaired biological healing, increased risk of infection, and high rates

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of delayed union and nonunion [2], Fracture nonunion is a common consequence of high-energy tibial trauma, largely due to compromised vascularity, periosteal stripping, and infection risk. Management is further complicated when associated with segmental bone defects, often requiring complex reconstructive strategies and staged procedures [3].

Reconstruction of segmental tibial defects remains one of the most demanding challenges in orthopedic trauma surgery, particularly in conflict settings where delayed presentation, limited resources, and restricted access to advanced microsurgical reconstruction may constrain available treatment options.

Several surgical options have been described for managing tibial nonunion with bone loss, including autologous bone grafting, distraction osteogenesis, vascularized fibular transfer, allografts, and titanium spacers, while amputation remains a last resort in non-reconstructable cases [4-6]. The induced membrane (Masquelet) technique has become an important two-stage reconstructive method, in which a cement spacer induces a vascularized membrane that enhances graft incorporation and limits resorption [7].

Autologous bone grafting remains the gold standard due to its osteogenic, osteoinductive, and osteoconductive properties. However, large defects are limited by donor-site morbidity and insufficient graft volume. The combination of iliac crest graft with structural fibular grafting can help overcome these limitations in extensive defects [8-10].

In resource-limited conflict settings where staged reconstruction and microsurgical options may not be feasible, simpler and reliable alternatives are required. This case series presents five patients with tibial nonunion and segmental bone loss managed using a single-stage approach combining non-vascularized fibular grafts with autologous iliac crest bone graft.

Case Presentation

We report five cases of segmental tibial shaft fractures with large bone defects that presented to the Jordanian Field Hospital in southern Gaza, Khan Younes, and were managed between June and September 2024. Patients presented with established nonunion and were treated with single-stage fibular grafting combined with iliac crest bone grafting, followed prospectively for a variable duration ranging from 16-20 months. Informed consent was obtained for case presentation using first names to facilitate a narrative approach. Follow-up assessments were conducted using both clinical and radiological evaluations.

Case 1:

Issam is a 48-year-old male who sustained a blast injury in December 2023, resulting in a left open tibial fracture (Gustilo type IIIC) with an associated posterior tibial artery injury. Initial management included vascular repair using a tibial artery bypass and fracture stabilization with an external fixator. Ten months later, he presented to the Jordanian Field Hospital with an established nonunion (Figure 1). Initial management involved removal of the external fixator to allow pin-site healing. The patient was also supplemented with vitamin D and calcium for two weeks prior to definitive surgery.

The nonunion site was approached through an anterolateral incision. Thorough debridement was performed, with complete excision of necrotic and fibrous tissue, resulting in an 11 cm bone defect. A 15 cm non-vascularized fibular graft was harvested from the contralateral leg because the ipsilateral fibula was broken and can't fill the gap, using a minimally invasive percutaneous technique through three small proximal, middle and distal incisions (Figure 2). The medullary canal was recanalized and widened using a dynamic hip screw reamer to accommodate the graft. Limb length and defect size were assessed by comparison with the contralateral side to guide graft length. The fibular graft was combined with autologous iliac crest bone graft. Stabilization was achieved using a proximal tibial lateral locking compression plate applied in an inverted orientation due to the unavailability of an appropriately long distal tibial plate (Figure 3).

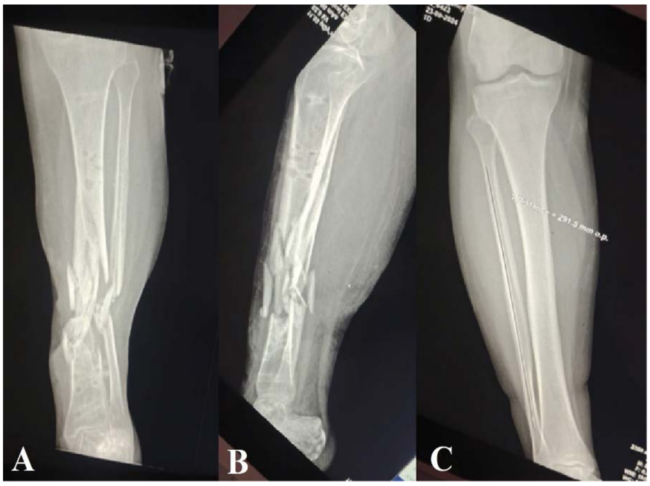

Figure 1: (A, B) Preoperative anteroposterior (AP) and lateral radiographs demonstrating established tibial nonunion. (C) Anteroposterior radiograph of the contralateral leg obtained for preoperative assessment of the fibula as a donor site for non-vascularized fibular graft harvesting.

Radiological union was achieved at 10 months, with complete fracture consolidation (Figure 4). At the final follow-up at 20 months, the patient was ambulating independently without assistive devices, with preserved knee and ankle range of motion comparable to the contralateral side, and no evidence of donor site morbidity.

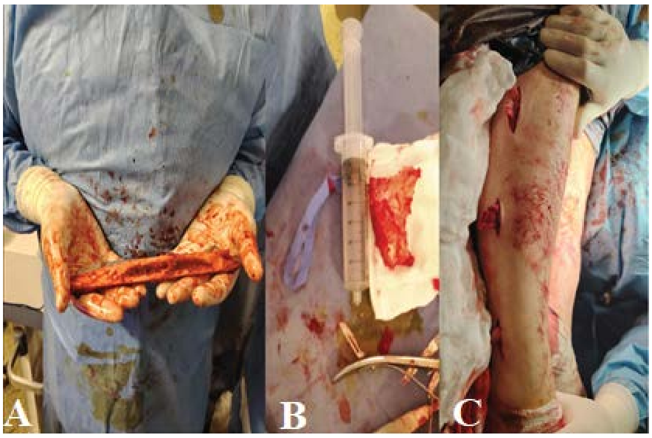

Figure 2: Intraoperative clinical photographs demonstrating (A) the harvested non-vascularized fibular graft (NVFG), (B) harvested iliac crest bone graft, and (C) the donor leg showing three small incisions used for the percutaneous NVFG harvesting technique.

Figure 3: (A, B) Postoperative anteroposterior (AP) and lateral radiographs demonstrating reconstruction of the tibial defect using a non-vascularized fibular graft (NVFG) and iliac crest graft. Fixation was achieved using an inverted proximal tibial lateral locking compression plate (LCP) in combination with two screws securing the distal tibia to the fibular graft. (C) Clinical photograph of the donor site following percutaneous harvesting of the NVFG.

Case 2:

Omar is a 34-year-old male who sustained a gunshot injury in February 2024, resulting in an open fracture of the right tibia (Gustilo type IIIA). Initial management included thorough debridement and stabilization with an external fixator. Six months later, he presented to the Jordanian Field Hospital with no clinical or radiological signs of union (Figure 5). Initial management followed the same protocol applied to all patients in this series, including removal of the external fixator and supplementation with vitamin D and calcium prior to definitive surgery.

Figure 4: Twenty-four-month follow-up radiographs demonstrating complete fracture healing with tibialization and incorporation of the fibular graft. Clinical photographs show the posteromedial soft tissue injury resulting from the initial trauma, with restoration of limb alignment and length.

Intraoperatively, thorough debridement with excision of necrotic bone resulted in an 8 cm segmental defect. Reconstruction was performed using a 12 cm non-vascularized fibular graft harvested from the ipsilateral leg, combined with autologous iliac crest bone graft. Stabilization was achieved using a distal tibial medial locking compression plate (LCP) (Figure 5). Manipulation under anesthesia (MUA) was also performed to address associated knee stiffness and improve range of motion.

Figure 5: (A, B) Preoperative anteroposterior (AP) and lateral radiographs demonstrating tibial shaft nonunion. (C, D) Postoperative AP and lateral radiographs demonstrating reconstruction of an 8-cm tibial defect following excision of devitalized bone, using an intramedullary non-vascularized fibular graft (NVFG) stabilized with a medial distal tibial locking compression plate (LCP).

Early follow-up demonstrated favorable clinical and radiological signs of healing, and the patient was able to ambulate without assistive devices at 4 months. However, he developed a progressive valgus deformity during follow-up. Despite this, the fracture achieved union at 16 months, with only mild residual pain (Figure 6). The patient was satisfied with the outcome, and no further intervention was required.

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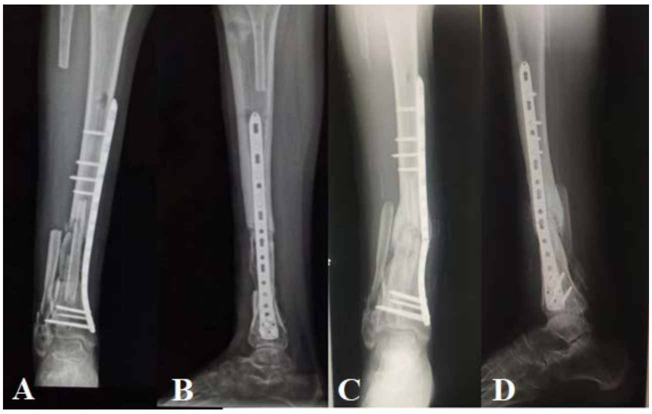

Figure 6: (A, B) Four-month follow-up anteroposterior (AP) and lateral radiographs demonstrating early callus formation. (C, D) Sixteen-month follow-up radiographs showing valgus deformity and implant failure; however, the nonunion site ultimately achieved bony union.

Case 3:

Mo'men is a 26-year-old male who sustained a gunshot injury in November 2023, resulting in an open fracture of the left tibia (Gustilo type IIIC) with associated posterior tibial artery injury. Initial management included thorough debridement, vascular reconstruction with a posterior tibial artery graft, soft tissue coverage, and fracture stabilization using an external fixator.

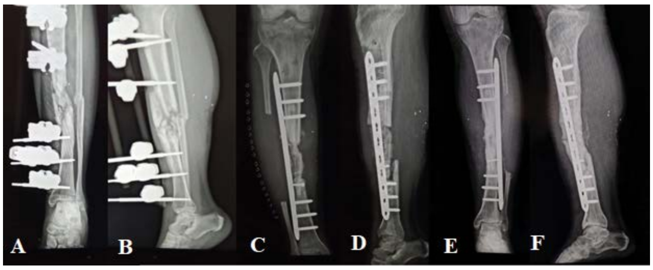

Figure 7: (A, B) Initial presentation anteroposterior (AP) and lateral radiographs demonstrating tibial shaft nonunion. (C, D) Immediate postoperative AP and lateral radiographs showing reconstruction of a 6-cm defect following excision of necrotic bone using an intramedullary non-vascularized fibular graft (NVFG) combined with iliac crest bone graft, with satisfactory alignment, reduction, and fixation of the nonunion site, as well as the ipsilateral fibular donor site. (E, F) Eight-month follow-up AP and lateral radiographs demonstrating progressive healing and consolidation at the nonunion site.

Ten months later, he presented to the Jordanian Field Hospital with no clinical or radiological signs of union (Figure 7), Initial management followed the same protocol applied to all patients. Surgical management involved reconstruction with ipsilateral 13 cm non-vascularized fibular graft to address a 6 cm segmental defect, combined with autologous iliac crest bone grafting. Stabilization was achieved using a straight locking compression plate (LCP) (Figure 7). Manipulation under anesthesia (MUA) of both the knee and ankle joints was performed intraoperatively to improve range of motion.

Fracture union was achieved by 8 months postoperatively. At the final follow-up, 18 months after surgery, the patient was ambulating independently without assistive devices, demonstrating good knee range of motion and no evidence of donor site morbidity.

Case 4:

Bara' is a 42-year-old male who sustained a blast injury in February 2024, resulting in bilateral open tibial fractures (Gustilo type IIIA). Initial management involved stabilization with external fixators. At six months post-injury, there were no clinical or radiological signs of union (Figure 8A). Definitive reconstruction was performed in a single operative session for both lower limbs. After thorough debridement of non-viable bone and soft tissue, segmental defects measuring 4 cm in the right tibia and 8 cm in the left tibia were identified. The left fibula was used as the donor site for non-vascularized fibular graft harvesting for both limbs, with graft lengths of 8 cm for the right tibia and 17 cm for the left tibia, combined with autologous iliac crest bone graft. Stabilization was achieved using medial distal tibial locking compression plates (LCPs) on both sides (Figure 8B).

Figure 8: (A) Preoperative anteroposterior (AP) radiograph demonstrating bilateral tibial shaft nonunion. (B, C) Postoperative AP and lateral radiographs of the right leg showing reconstruction of a 4-cm defect filled with bone graft and stabilized with a medial distal tibial locking compression plate (LCP); the fibular graft was harvested from the left leg for both nonunion sites. (D, E) Postoperative AP and lateral radiographs of the right leg demonstrating reconstruction of an 8-cm defect using an intramedullary non-vascularized fibular graft (NVFG) combined with iliac crest bone graft, fixed with a medial distal tibial LCP.

The patient was started on protected weight-bearing at three months postoperatively. However, he reported persistent left leg pain, particularly during weight-bearing, and radiological evaluation demonstrated delayed progression toward union with no clear signs of healing (Figure 9). Therefore, he underwent revision surgery at eight months, which included debridement of the nonunion site, augmentation with

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autologous iliac crest bone graft, and addition of an anterior locking compression plate (LCP). Clinical and radiological union was achieved by 14 months (Figure 10). At the final follow-up, 18 months postoperatively, the patient was ambulating independently without assistive devices, with good knee range of motion and no evidence of donor-site morbidity.

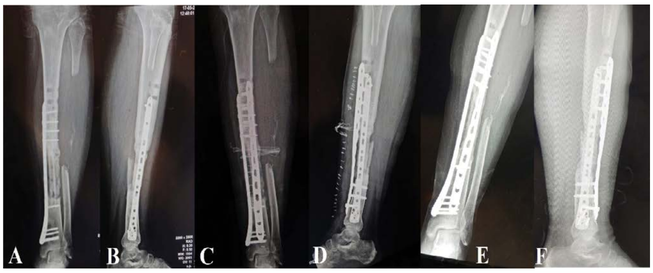

Figure 9: (A, B) Eighteen-week follow-up anteroposterior (AP) and lateral radiographs of the left leg demonstrating delayed progression toward union with no clear radiographic evidence of healing. (C, D) Immediate postoperative AP and lateral radiographs following second revision, showing revised fixation using an anterior straight locking compression plate (LCP). (E, F) Fourteen-month follow-up AP and lateral radiographs demonstrating complete union and consolidation of the nonunion site.

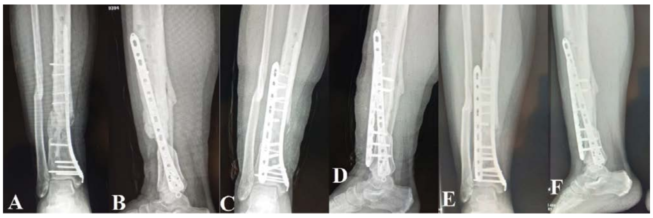

Figure 10: (A, B) Ten-month follow-up anteroposterior (AP) and lateral radiographs of the right leg demonstrating delayed progression toward union. (C, D) Immediate postoperative AP and lateral radiographs following second revision, showing revised fixation with an anterior straight locking compression plate (LCP). (E, F) Fourteen-month follow-up AP and lateral radiographs of the right leg demonstrating complete fracture healing and consolidation of the nonunion site.

Case 5:

Warda is a 23-year-old female who sustained a blast injury in January 2024, resulting in bilateral open tibial fractures (Gustilo type IIIA). Initial management included stabilization with bilateral external fixators. She presented eight months later; the right tibia had achieved union, whereas the left tibia demonstrated nonunion, with persistent pain and abnormal motion at the fracture site on stress examination (Figure 11A and B).

Definitive reconstruction of the left tibia was performed nine months post-injury. Debridement of necrotic bone resulted in an 11 cm defect (Figure 11C), which was reconstructed using ipsilateral 15 cm non-vascularized fibular graft combined with autologous iliac crest bone grafting (Figure 11D). Stabilization was achieved using a lateral proximal tibial locking compression plate (LCP) (Figure 12B and C).

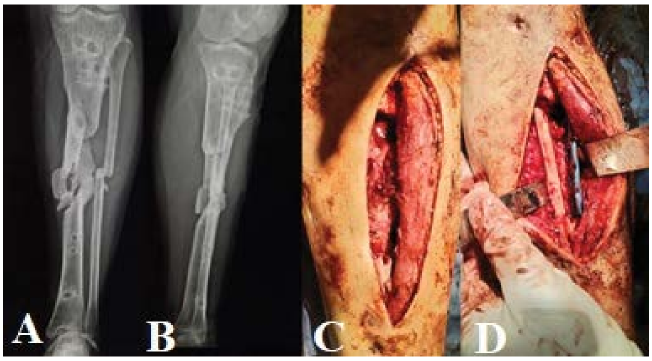

Figure 11: (A, B) Preoperative anteroposterior (AP) and lateral radiographs demonstrating tibial shaft nonunion. (C) Intraoperative clinical photograph showing the tibial defect following excision of necrotic bone. (D) Intraoperative photograph demonstrating placement of a non-vascularized fibular graft (NVFG) with stabilization of the nonunion site using a proximal tibial locking compression plate (LCP).

Union was achieved by eight months postoperatively (Figure 12D and Figure 13). At the final follow-up, 18 months after surgery, the patient was ambulating independently without assistive devices, with good knee range of motion and no evidence of donor-site morbidity.

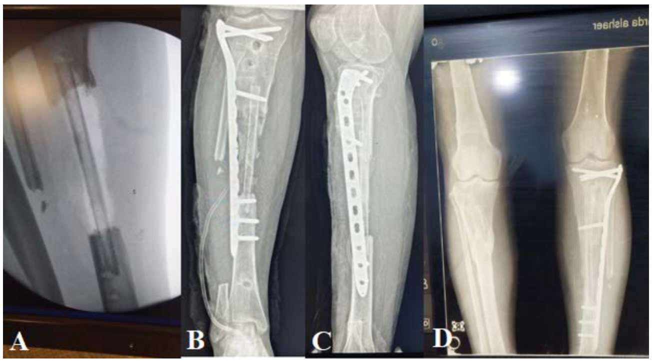

Figure 12: (A) Intraoperative fluoroscopic image demonstrating insertion of the non-vascularized fibular graft (NVFG) into the prepared tibial intramedullary canal. (B, C) Immediate postoperative anteroposterior (AP) and lateral radiographs showing reconstruction of an 11-cm segmental tibial defect using an intramedullary NVFG combined with autologous iliac crest bone graft, stabilized with a lateral proximal tibial locking compression plate (LCP). (D) Eight-month follow-up radiograph demonstrating complete consolidation and tibialization of the fibular graft.

Table 1 summarizes the demographic and clinical characteristics of all patients.

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Figure 13: Computed tomography (CT) of the left leg. (A) CT scout image demonstrating restoration of limb alignment and length following revision of tibial nonunion. (B) Coronal CT images showing complete consolidation at the nonunion site. (C) Axial CT images demonstrating progressive osseous healing around the non-vascularized fibular graft (NVFG). (D) Coronal CT images confirming complete consolidation and remodeling of the reconstructed tibia.

Table 1: Patients' summary.

Case	Case 1	Case 2	Case 3	Case 4	Case 5
Age	48	34	26	42	23
Sex	Male	Male	Male	Male	Female
Mechanism	Blast injury	Bullet injury	Bullet injury	Blast injury	Blast injury
Gustilo classification	IIIC	IIIA	IIIC	IIIA	IIIA
Extremity	Left	Right	Left	Bilateral	Left
Defect size (cm)	11	8	6	R:4 / L:8	11
Union	Yes	Yes	Yes	Yes	Yes
Time to Union (months)	10	11	8	14	8
Complications	None	Metal failure, Valgus deformity	None	Left leg nonunion	None
R: Right; L: left.					

Discussion

Blast and gunshot injuries are commonly associated with extensive contamination, devitalized tissue, and severe soft tissue destruction. Effective management requires early and repeated debridement, as inadequate removal of nonviable tissue significantly increases the risk of infection, osteomyelitis, nonunion, and limb loss [11].

In Gaza, management of complex orthopedic trauma is constrained by limited resources, delayed access to definitive care, and ongoing conflict-related disruptions. Initial treatment is often restricted to basic debridement and external fixation, while advanced reconstructive procedures are frequently delayed or unavailable. These factors contribute to high rates of infection, stiffness, and nonunion, often transforming potentially salvageable injuries into complex reconstructive problems [2,12].

Tibial segmental defects remain particularly difficult to treat due to limited soft tissue coverage and compromised vascularity, especially in high-energy trauma. Successful reconstruction depends on achieving both biological viability and mechanical stability, as failure in either domain may result in persistent nonunion [12,13].

Multiple reconstructive techniques exist for segmental bone loss. Distraction osteogenesis (Ilizarov technique) provides reliable biological reconstruction but requires prolonged treatment and high patient tolerance. Vascularized fibular grafts offer strong biological potential in poorly vascularized environments but require microsurgical expertise and are associated with donor-site morbidity [14,15].

The Masquelet technique provides a two-stage alternative that enhances graft incorporation through formation of a biologically active induced membrane. Its success depends on stable fixation, infection control, and adequate soft tissue conditions. While reported outcomes are generally favorable, variability exists depending on infection status and host factors [16,17].

Autologous bone grafting remains central to reconstruction. The iliac crest provides excellent biological properties but is limited by donor-site morbidity and graft volume constraints. Combining cancellous iliac crest graft with structural fibular grafting may improve stability and reduce graft failure in large defects [18,19]. Non-vascularized fibular grafts offer a simpler, cost-effective structural option that can achieve satisfactory outcomes when combined with stable fixation and adequate biological augmentation, particularly in resource-limited settings (20).

In this series, segmental bone loss resulted from either the initial trauma or necessary debridement of non-viable bone. Given the limitations of the setting—including restricted access to staged reconstruction, inconsistent follow-up, and limited availability of advanced implants—a single-stage strategy was adopted using combined non-vascularized fibular and iliac crest bone grafting.

All patients ultimately achieved bony union and functional ambulation, although healing was delayed (8–14 months). Complications included implant failure with deformity in one case and delayed union requiring revision grafting in another, yet both eventually progressed to union. These results suggest that combined structural and cancellous autografting can provide a reliable reconstructive option in complex tibial defects when stable fixation and adequate debridement are achieved. However, mechanical complications highlight the importance of rigid fixation, careful postoperative monitoring, and structured rehabilitation, particularly in low-resource conflict environments.

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Conclusion

Reconstruction of tibial shaft nonunion with segmental bone loss in conflict settings remains highly challenging due to delayed presentation, soft tissue compromise, and limited resources. This case series demonstrates that a single-stage approach combining non-vascularized fibular grafting with autologous iliac crest bone grafting can achieve satisfactory union and functional outcomes in most patients, even in the presence of large defects. While the biological effectiveness of this technique is reliable, success is strongly dependent on adequate debridement, stable fixation, and careful postoperative management. In resource-constrained war environments where advanced reconstructive options are not feasible, this method may represent a practical, reproducible, and effective treatment strategy.

Conflict of interest statement:

No conflict of interest exists.

Ethical approval:

Ethical approval was obtained from the Jordanian Royal medical services institutional Ethics Committee Amman-Jordan 31/7/2026. Prior to study initiation. Written informed consent for publication, including all images, was obtained from the patient's parents.

Statement of the location where the work was performed:

This study was performed in the Royal medical services.

Patient consent:

Written informed consent was obtained from the patient for publication of this case series and accompanying images. Written consent is available for review by the Editor-in Chief of this journal on request.

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