International Journal of Orthopaedics and Traumatology

ISSN Print: 2664-8318
ISSN Online: 2664-8326
Impact Factor (RJIF): 6.07
IJOT 2025; 7(2): 173-177
www.orthopedicsjournal.in
Received: 11-08-2025
Accepted: 14-09-2025

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Biological reconstruction of post-traumatic femoral shaft defect using non-vascularized fibular graft with auto graft and allograft augmentation

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DOI: https://www.doi.org/10.33545/26648318.2025.v7.i2c.105

Abstract
A 40-year-old male presented to the emergency department following a high-velocity roadside accident. He sustained multiple injuries, including an open wound over the left thigh and a comminuted fracture of the right femoral shaft with significant segmental bone loss. Additionally, there was an associated injury to the right forearm with midshaft fractures of both the radius and ulna. Initial management involved a staged surgical approach. In the first stage, thorough wound debridement, intramedullary nailing of the femur, and application of controlled distraction were performed to stabilize the limb and preserve length. After a two-month interval, definitive reconstruction was undertaken using a large non-vascularized free fibular graft, combined with autologous cancellous graft harvested from the right iliac crest and cadaveric allograft to bridge the femoral defect. At six months postoperatively, radiographic evaluation confirmed solid bony union with good graft incorporation and no evidence of limb length discrepancy. The patient achieved satisfactory functional recovery. This case demonstrates that, in selected post-traumatic scenarios with major femoral bone loss, a non-vascularized fibular graft augmented with auto graft and allograft can serve as an effective and biologically favourable reconstruction strategy.

Keywords: Open femur bone loss, debridement, primary femur distraction nailing, free fibular graft

Introduction

Long bone fractures associated with open injuries and segmental bone loss pose a significant challenge due to delayed union, high risk of non-union, potential limb shortening, and an increased risk of infection. In such complex cases, bone grafting whether autograft or allograft plays a pivotal role in enhancing bone regeneration and structural stability.

The process of bone healing is governed by a delicate balance between bone formation and resorption, orchestrated by osteoblasts, osteoclasts, and osteocytes under the influence of intricate bone-signaling pathways. However, in certain clinical scenarios, this biological cycle is inadequate and requires external assistance through bone grafts or graft substitutes. The essential properties of an ideal bone graft include osteoconduction, osteoinduction, osteogenesis, and mechanical support. Grafting options include autologous bone, allograft, and various synthetic or composite substitutes composed of inorganic materials [1].

Bone grafts are broadly classified into vascularized and non-vascularized types. Non-vascularized bone grafts are increasingly preferred due to their ease of harvest, good osteogenic potential, resistance to infection, and capacity to undergo hypertrophy over time [2]. For small bone defects (<3 cm), cancellous grafts offer rapid revascularization and incorporation [3]. Corticocancellous grafts are ideal for medium-sized defects (3-6 cm), providing a balance of mechanical support and biological activity. In large defects (>6 cm), non-vascularized fibular grafts, often augmented with autograft or allograft, are considered a reliable option for limb length preservation and structural reconstruction. Harvesting the fibula at least 6 cm above the ankle joint does not typically compromise ankle stability [4].

Non-vascularized fibular grafting is technically simpler than vascularized grafting and offers promising union rates with reduced surgical morbidity in carefully selected cases.

Case Report

A 40-year-old male presented with an alleged history of road traffic accident, complaining of pain and swelling in the right forearm, along with severe pain and an open wound over the right thigh. Clinical examination revealed a visible segmental bone loss in the right femur. The patient was alert and hemodynamically stable at presentation.

On physical examination, the neurovascular status of the right lower limb was intact, with palpable dorsalis pedis artery. Similarly, the right upper limb demonstrated preserved neurovascular function.

Radiographic evaluation revealed: Fractures of both the radius and ulna at the midshaft in the right forearm, Comminuted fracture with segmental bone loss in the right femoral shaft, Fracture of the proximal tibia, Fracture of the proximal one-third of the right fibular shaft. A CT angiography of the right lower limb confirmed intact vascular flow up to the foot.

The patient received initial wound care, limb stabilization, and pain management. Surgical intervention was planned for the following day.

Fig 1&2: Showing open wound in thigh and piece of femur lost.

Fig 3: Both bone fracture of forearm

Fig 4: Showing shaft of femur fracture with bone loss.

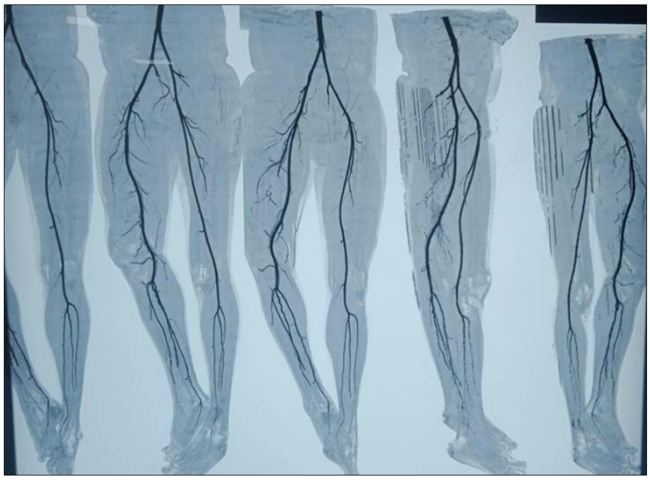

Fig 5: Showing CT angiography picture of both lower limb having bilateral lower Limb good vascularity up to feet.

Initial Surgical Management

The patient was taken to the operation theatre for staged surgical intervention. The midshaft fractures of the right radius and ulna were stabilized using open reduction and internal fixation with plating. The proximal tibial fracture was fixed with intercondylar screws to restore articular congruity and stability.

Thorough debridement of the open wound over the right thigh was performed, followed by copious irrigation with antibiotic solution to minimize infection risk. An intramedullary nail was inserted into the right femur to maintain limb alignment and facilitate gradual distraction, with the aim of preserving limb length and preparing for future definitive reconstruction of the segmental bone loss. Postoperative radiographs were obtained to assess the alignment and fixation.

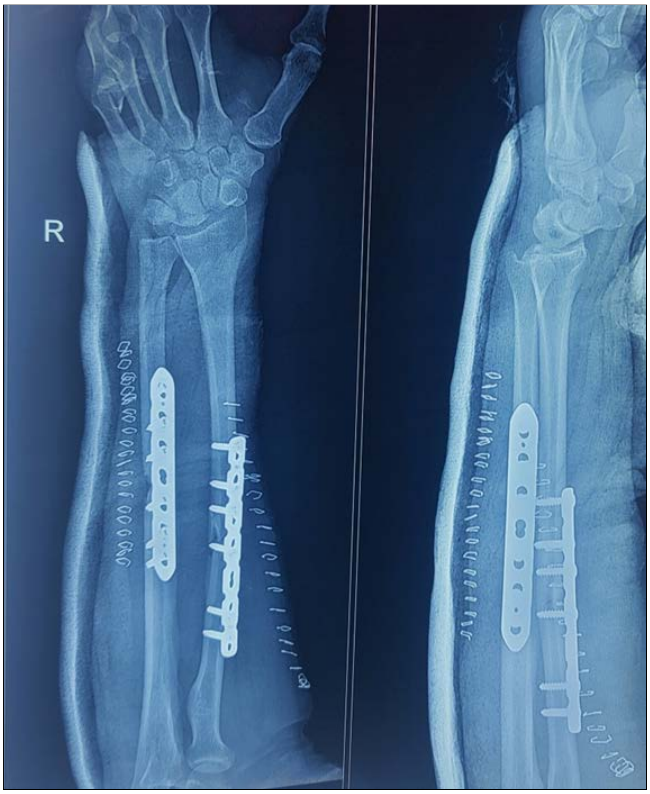

Fig 6: Showing immediate post op x-ray of radius ulna plating.

Figure 7. Immediate post op x-ray of femur with distraction nailing.

Second Stage Surgical Management

The patient received postoperative care with intravenous antibiotics, analgesics, and routine wound dressings in the ward for a few days. After one week, he was discharged and advised to follow up after two months. At the two-month review, he was scheduled for the second-stage surgery to address the femoral bone defect. A non-vascularized fibular autograft measuring 15 cm was harvested and divided into two segments (10 cm and 5 cm, as illustrated in the figure below). Additionally, a tricortical graft was harvested from the iliac crest, and supplemental allograft material was used. The edges of the femoral defect were refreshed, and the grafts were positioned to adequately fill the anterior, posterior, medial, and lateral aspects of the bone gap. Fixation was achieved with lateral femoral plating and tension band wiring at two points to ensure stable graft anchorage. Intraoperative and postoperative images are shown below.

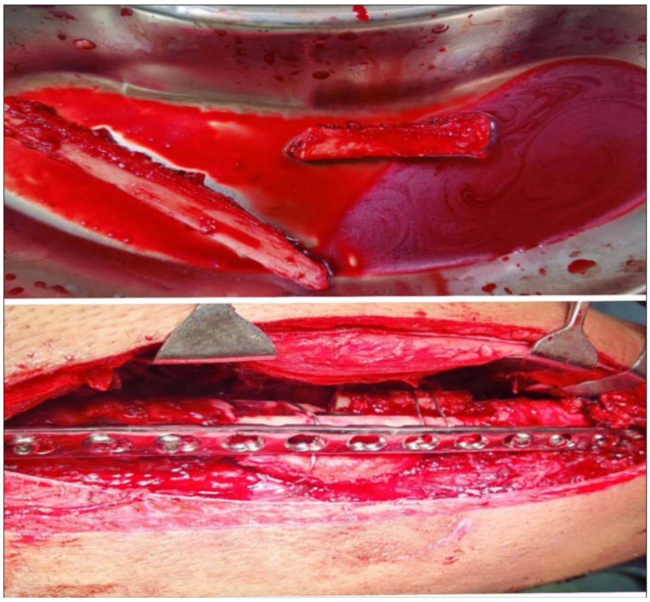

Fig 8: Showing intraoperative pictures of second surgery, two pieces of fibula graft and picture of thigh with fibula graft, tri cortical graft and allograft, fixed with lateral plating and tension band wiring.

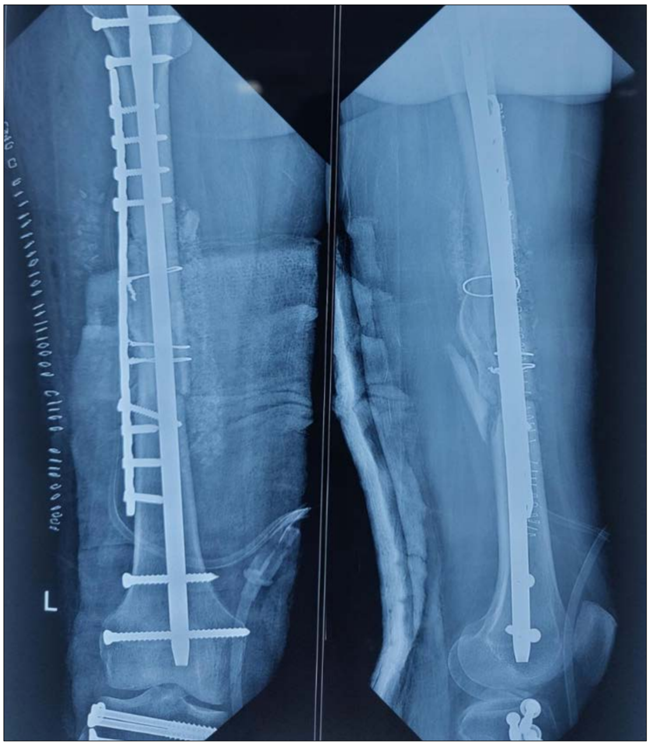

Fig 9: Showing immediate post op x-ray after second surgery with lateral plating.

The patient received postoperative care with intravenous antibiotics, analgesics, and regular wound dressings for several days. There were no signs of infection, the surgical wound appeared healthy, and the neurovascular status of the lower limb remained intact. The patient was subsequently planned for discharge.

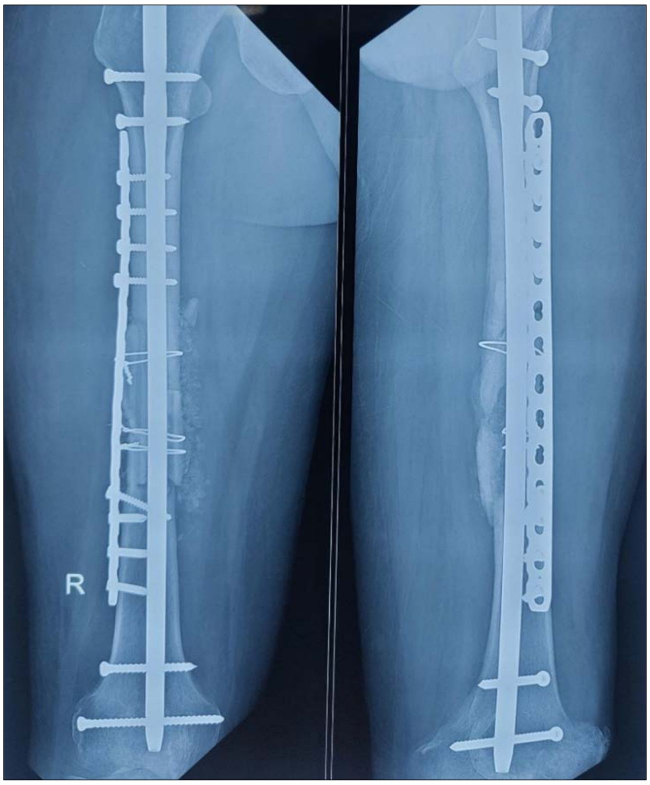

Fig 10: 3 months post op x-ray of femur showing signs of union

Fig 11: 12 months post op x-ray of femur showing signs of union and graft incorporation

After one year of surgery, there were good signs of union both clinically and radiologically. The patient had already begun gradual weight-bearing, initially with the help of a walker, progressing to a stick, and eventually achieving free weight-bearing. The knee range of motion had improved from 5° to 90° of flexion. There was no varus or valgus instability on examination, and the distal neurovascular status was intact with no evidence of digital or vascular injury. The patient was further advised to continue assisted, active, and passive range-of-motion exercises of the lower limb. He demonstrated good functional outcomes and showed steady improvement in performing activities of daily living.

Discussion

Segmental fractures of long bones accompanied by bone loss present a significant surgical challenge, particularly with regard to preventing infection, restoring limb length, and achieving stable reconstruction of the bone defect. Among the available options, a free non-vascularized fibular graft emerges as a favorable solution due to its lower risk of infection, reduced donor site morbidity, shorter healing time, and overall better clinical outcomes. It is a technically straightforward and reliable method for bridging large bone defects resulting from open fractures and infections. This technique has also shown success even in pediatric populations and in anatomically complex regions such as the elbow [5].

A previous study involving 15 cases managed with non-vascularized fibular grafts reported successful union in all but two cases after the second stage of reconstruction, without the need for additional procedures. The union time ranged from 4 to 13 months, with an average duration of 7 months [6].

In a prospective descriptive study conducted between June 1994 and June 2005, the role of free non-vascularized fibular grafts was evaluated in 19 patients with non-united long bone fractures due to trauma, post-tumor or cyst resection, and post-osteomyelitis bone defects. Union was achieved in 89.5% of cases. Complications included stress fractures in two patients (10.5%) and infection or graft resorption in three cases (15.8%) [7].

Although vascularized free fibular grafts are considered a viable option particularly for bone defects exceeding 6 cm, scarred recipient sites, or cases with combined bone and soft-tissue loss they require microsurgical expertise. The outcomes are most favorable when the reconstruction is performed within one week of trauma [8].

Despite their biological advantages, vascularized fibular grafts are technically demanding and resource-intensive. A systematic review and meta-analysis have reported good long-term results in both upper and lower limb reconstructions [9]. However, the complexity of the procedure, potential requirement for secondary surgeries, prolonged rehabilitation, increased healthcare costs, and risk of donor-site morbidity including permanent ankle dysfunction are important limitations to consider [10].

With advancements in bone biology and grafting techniques, non-vascularized fibular grafts are increasingly being recognized as a practical alternative in resource-limited settings. Careful case selection and staged reconstruction remain key to optimizing outcomes.

Conclusion

In complex lower limb injuries, such as femoral shaft fractures associated with bone loss and open wounds, initial management should focus on meticulous debridement to eliminate any source of infection and to create a biologically clean environment conducive to healing. Once infection control is ensured, the next critical step involves reconstruction of the bone defect while maintaining proper limb length and alignment.

Non-vascularized fibular grafts can be an effective and practical solution in such scenarios, especially when resources or surgical expertise for vascularized grafting are limited. Although vascularized fibular grafts are generally considered biologically superior due to their intrinsic blood supply and higher union potential, they are technically complex, time-consuming, and resource-intensive procedures.

Non-vascularized grafts, when carefully selected and combined with corticocancellous auto graft from the iliac crest and supplementary allograft, provide mechanical stability, enhance osteogenic activity, and significantly improve the rate of union. This composite grafting approach offers a cost-effective, technically simpler, and functionally satisfactory alternative for managing large segmental bone loss in the lower limb, particularly in post-traumatic cases.

Funding

No funding sources.

Conflict of interest

None declared.

Ethical approval

Not required.

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How to Cite This Article

Bisht C, Nahar K, Jha Y, Tomar A, Patel T. Biological reconstruction of post-traumatic femoral shaft defect using non-vascularized fibular graft with auto graft and allograft augmentation. International Journal of Orthopaedics and Traumatology 2025; 7(2): 173-177.