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Case Report

Biological Reconstruction of Massive Post-Traumatic Femoral Bone Defects: A Three Case Series

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Abstract

Massive post-traumatic osseous loss of the femur represents a complex reconstructive challenge in orthopaedic trauma surgery. Segmental defects greater than 15 cm are rarely reported and often require advanced biological reconstruction techniques. This case series describes surgical strategies and outcomes in three patients presenting with Gustilo-Anderson grade III open femoral fractures associated with extensive segmental bone loss following high-energy road traffic accidents. Bone defects ranged from approximately 14.5 cm to 23.6 cm. Initial treatment included aggressive debridement and temporary stabilisation using an external fixator with or without a bone cement spacer. Definitive reconstruction was performed using vascularized fibular grafting in all three patients, with the additional induced membrane technique described by Alain-Charles Masquelet in one patient. At a mean follow-up of 2 years, all patients demonstrated radiological union and satisfactory limb alignment. Functional outcomes were favourable, with restoration of acceptable knee range of motion and absence of implant failure or deep infection in all three patients. This case series corroborates the successful reconstruction of massive femoral bone defects using biological techniques such as vascularized fibular grafting and the induced membrane technique, enabling limb salvage and functional recovery even in patients with extreme bone loss.

Keywords: Femoral Bone Defect; Vascularized Fibular Graft; Induced Membrane Technique; Limb Salvage; Open Fracture

Introduction

High-energy road traffic accidents frequently cause extensive bone and soft-tissue damage, wound contamination and vascular compromise [1]. Fractures of the femur resulting from such events are one of the most challenging injuries encountered in orthopaedic trauma. The management aims to restore acceptable limb alignment and length, prevent infection and achieve fracture union while preserving function. The different bone recovery techniques include distraction osteogenesis using circular external fixation, structural bone grafting, vascularized bone transfer and the induced membrane technique [2,3].

Structural autograft is extensively used in fracture reconstruction and it continues to be regarded as the gold standard, attributable to its inherent osteogenic, osteoinductive and osteoconductive potential. However, its application is constrained by donor-site morbidity, including postoperative pain and complications associated with graft harvesting. In contrast, allogeneic grafts obviate donor-site concerns while providing substantial structural support conducive to fracture stabilization and healing but has higher cost implications and the theoretical risk of disease transmission [1].

The fibula, being a tubular bone with suitable length, wide geometry and remarkable mechanical strength is considered as the best donor bone for long bone defects [3,4]. The fibular pedicle provides an optimal vessel caliber and length, facilitating effective microsurgical anastomoses. Upto 26 cm of the fibula may be harvested, either as a single-tissue flap or as a composite flap incorporating skin, fascia and muscle enabling reconstruction of extensive soft tissue defects and bone loss exceeding 6 cm [3].

A Vascularized Fibular Graft (VFG) in which a segment of fibula is transferred along with its intact vascular pedicle is the gold standard surgical technique in cases of large and complex osseous defects or established non-unions [3,4]. In situations where anatomical reconstruction of the joint is not possible because of severe comminution or articular bone loss, arthroplasty utilizing a tumor reconstruction prosthesis may be employed. Allograft-Prosthesis Composites (APCs) represent a valuable reconstructive option in younger patients with sufficient osteogenic potential to facilitate reliable union at the host–graft interface [5,6]. The use of APC constructs is accompanied by a heightened risk profile, including graft resorption, deep infection, periprosthetic fracture and non-union [7–9]. Allograft assisted arthrodesis is another plan for revision scenarios, infections [10]. The present series reports three patients with massive femoral bone defects ranging from approximately 14.5 cm to 23.6 cm managed using different biological reconstruction techniques.

Case Series

Case 1-Patient A

A 21-year-old male presented with a Gustilo-Anderson grade IIIB distal femur fracture with intercondylar extension of left lower limb (AO/OTA – 33-C3), vertical fracture of the patella with bipolar avulsion of the patellar tendon and traumatic arthrotomy of the left knee. Radiological evaluation demonstrated approximately 14.5 cm of bone loss. Initial management included emergency systematic wound debridement, stabilization using a knee-spanning external fixator combined with the first stage of induced membrane technique. After a satisfactory relook debridement, definitive reconstruction was performed 4 weeks later with the second stage of the induced membrane technique utilizing autologous corticocancellous bone graft, fixation of the fracture with the distal femoral locking plate augmenting the construct with a vascularized fibular graft from the opposite leg (Fig. 1,2).

Follow-up: At 2 years follow-up, he had satisfactory limb length alignment and functional knee range of motion with no evidence of infection or implant failure.

Case 2- Patient B

A 47-year-old male patient sustained a Gustilo-Anderson grade IIIB open distal femur fracture with intercondylar extension (AO/OTA – 33-C3) and comminuted tibial plateau fracture (Schatzker – Type 1) of left lower limb, a fracture of base of the second and third metatarsals, an avulsion fracture of the base of the fifth metatarsal, a degloving injury of the right hand and a deep lacerated wound of the fourth interdigital cleft of the right foot. Radiological evaluation demonstrated femoral bone loss of approximately 18.77 cm. Emergency wound debridement and external fixator application were done, followed by re-look debridement and definitive fixation with a distal femoral locking plate. In addition to this, the plastic surgery team managed the soft tissue injuries. Reconstruction was performed using a vascularized fibular graft from the contralateral leg and autologous corticocancellous bone grafting from both iliac crests to the right distal femur (Fig. 3).

Follow-up: Radiological evaluation at 2-year follow-up demonstrated graft incorporation and union. Clinically, the patient achieved 110 degrees of flexion with no extension lag and was able to ambulate independently without complications.

Case 3-Patient C

A 31-year-old male presented with a Gustilo-Anderson grade III B open comminuted femoral shaft fracture with intercondylar extension of the right lower limb (AO/OTA – 33-C3) without neurovascular deficit following a road traffic accident. Radiographic evaluation demonstrated significant segmental bone loss of 23.6 cm. Initial management included a systematic wound debridement and temporary stabilization with external fixation. Definitive fixation was performed following a satisfactory second look debridement using a Distal Femoral Locking Plate (Depuy-Synthes DFLP). Reconstruction of the bone defect was achieved using combined vascularized and non-vascularized fibular strut grafts (Fig. 4,5).

Follow-up: At 1.5-year follow-up, radiographs demonstrated satisfactory union and restoration of limb alignment and length. The patient achieved 140 degrees of flexion with no extension lag, without evidence of implant failure or deep infection.

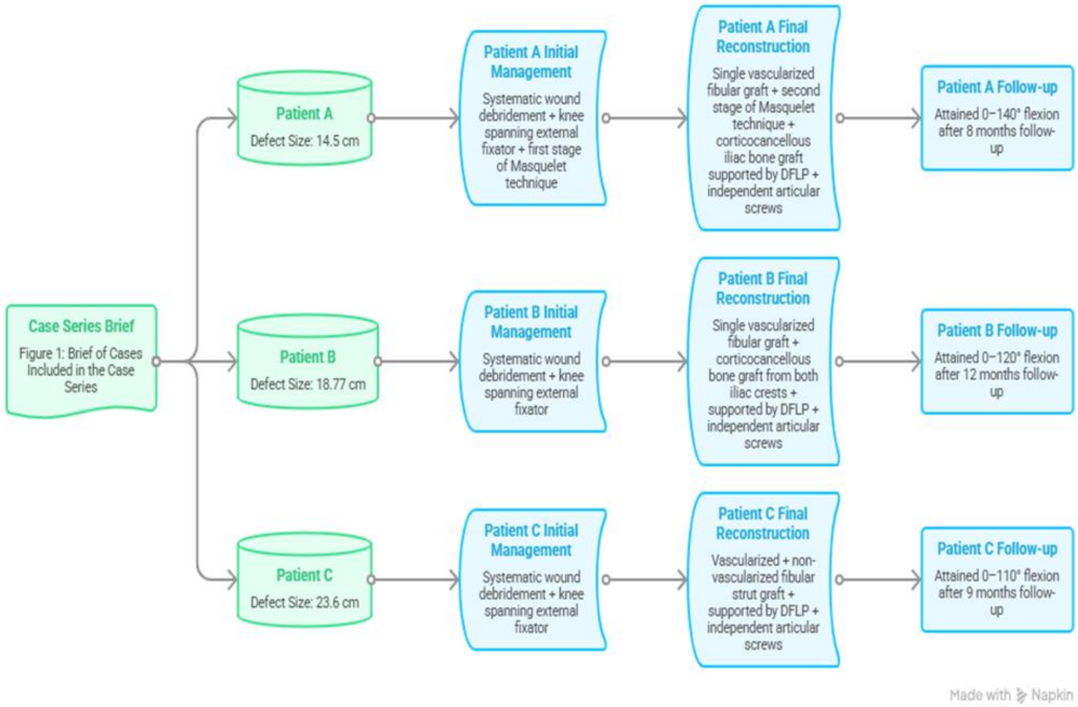

Figure 1: Brief of cases included in the case series.

Figure 2: Pre-operative X-ray images of patient A– 2(A), patient B- 2(B) and patient C - 2(C) showing large femoral bone defects.

Figure 3: Intra-operative images of vascularized fibular graft harvest.

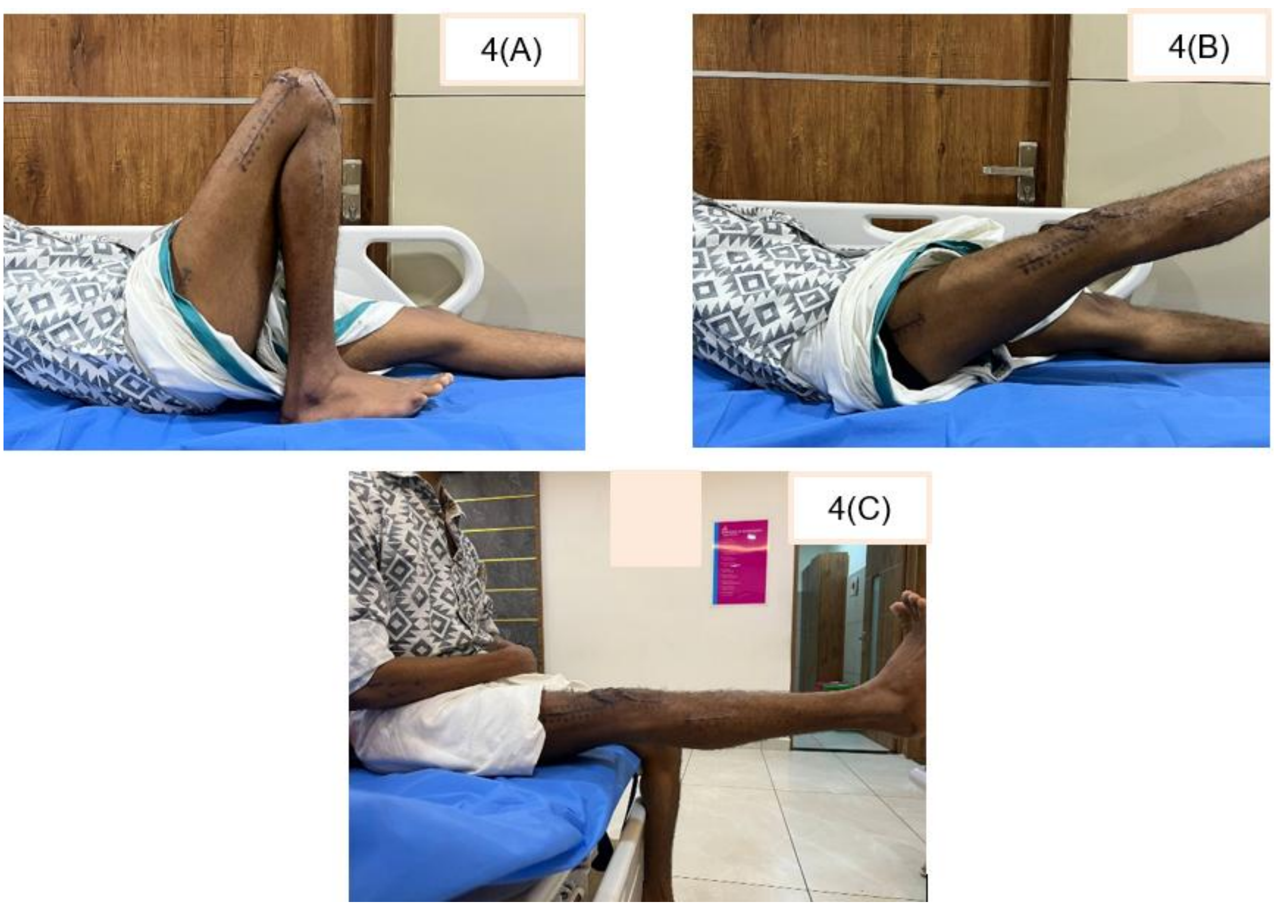

Figure 4: Clinical images of patient C showing the range of movements at 1.5 years follow-up.

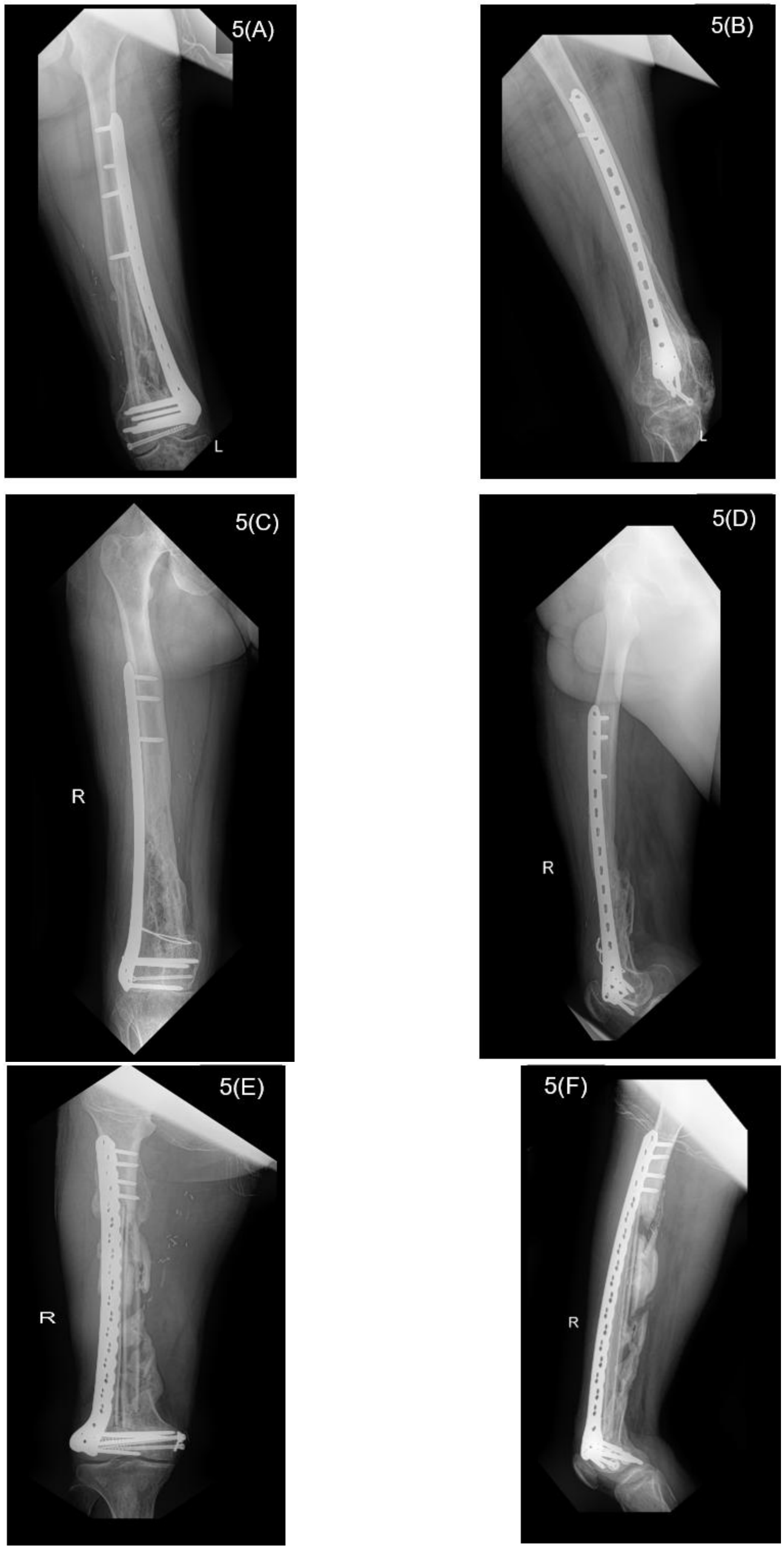

Figure 5: Follow-up images of patient A (5A and 5B), patient B (5C and 5D) and patient C (5E and 5F) showing good graft uptake, fibular hypertrophy and union at fracture site.

Surgical Technique

Initial Management

Initial management of these patients was carried out in the emergency room (ER) in line with the standard ATLS protocol by a multidisciplinary polytrauma management team. Broad-spectrum antibiotics and judicial transfusion of blood products were done in all three patients. All patients were medically optimised before proceeding to emergency orthopaedic management. Repeated secondary surveys ruled out injuries other than those diagnosed at initial presentation. Initial orthopaedic management included emergency wound irrigation and systematic surgical debridements. Further management included a staged approach which comprised of fracture stabilisation using a knee-spanning external fixator in all patients (Patients A, B and C), multiple relook debridements, articular fixation and bone loss reconstruction.

Systematic Debridement and External Fixation

All the patients in our series underwent aggressive surgical debridement with removal of all devitalized bone and soft tissue protecting the vital neurovascular structures. The quality of the initial debridement and decontamination has a greater effect on the outcome in these subset of patients. Articular comminution was thoroughly assessed and displaced articular fragments were provisionally reduced. Knee spanning unilateral, modular external fixator was applied in all three patients for initial stabilization of the fracture, making way for relook debridement. An external fixator frame applied in the first surgery provides enough stability to the fracture so that satisfactory length and alignment of the limb can be restored until definitive fixation. It also allows the surgeon to have multiple wound checks, dressing changes and even multiple repeated debridements all the while maintaining stability at the fracture site avoiding farther injury to the soft tissue including the neurovascular bundle. It also bundles for safe transportation of the patient for further imaging.

Relook Debridement

Multiple relook debridements are necessary to completely decontaminate the open wounds and remove residual necrotic tissue before a definitive fixation is undertaken. Tissue samples from representative areas of the wound and bone ends are typically sent during relook debridements. After a satisfactory second look debridement, anatomical reduction and stable fixation of the articular surface was achieved by means of partially threaded cancellous screws, all the while keeping the limb in external fixator. At approximately 48 hours after the first surgery, a non-contrast computer tomography (NCCT) with 3D reconstruction was done in all patients for planning definitive fixation. Multiple relook debridements are necessary to completely decontaminate the open wounds and revive residual necrotic tissue before a definitive fractions undertaken. Tissue samples from representative areas of the wound and bare ends are typically sent during relook debridements.

Definitive Stabilization with Wound Coverage

After multiple relook debridements and achieving a healthy vascular bed, all patients were prepared for definitive stabilization and wound coverage at approximately 5-7 days from injury. All patients underwent definitive fixation of the fracture using distal femoral locking plates applied with minimally invasive techniques whenever feasible. This approach facilitated restoration of limb alignment and length. Patient A additionally received the Masquelet technique since the wound was grossly contaminated at initial presentation.

Osseous Reconstruction Techniques

a. Vascularized Fibular Graft

Free VFGs in comparison with non-VFGs retain their intrinsic blood supply, which helps with accelerated bone healing, hypertrophy and higher union rates [3-5]. Two patients (Patients A and B) with extensive segmental bone loss underwent reconstruction using vascularized fibular graft transfer. The key steps included:

1. Harvest of fibular graft with vascular pedicle from contralateral leg
2. Preparation of proximal and distal femoral bone ends
3. Insertion of fibular graft into the femoral canal to bridge the defect
4. Microsurgical anastomosis of graft vessels to recipient vessels by plastic surgery team
5. Supplementary cancellous bone grafting where required

This technique provides both mechanical support and biological osteogenic potential.

b. Double Fibular Graft Technique

When the bone defects are large and the bone size is big enough to accommodate two fibular grafts, a combination of vascularised and a non-vascularised fibular strut grafts can be used. Two vascularised fibular grafts are typically avoided as two adjacent end to side anastomoses to major limb vessels can potentially cause distal limb ischemia [4,5].

In Patient C, a double fibular technique was utilised by additionally harvesting a non-vascularised fibular graft and placing it in between the fracture gap parallel to a vascularized fibula. All the fibular grafts placed in the fracture gap were impacted into the cancellous bone bed of distal metaphysis and proximally docked into the medullary canal of the shaft for at least 3 cm by reshaping the bone ends. At the completion of the procedure, appropriate wound coverage technique using local tissue flap mobilization and split thickness skin grafting was employed by plastic surgery team. The donor site leg from which the fibular graft was harvested was immobilized in a below knee plaster cast for allowing musculotendinous scarring in functional ankle position allowing a tenodesis effect.

c. Induced Membrane Technique (Masquelet Technique)

Patient A was treated initially using induced membrane technique which essentially included a staged procedure.

Stage 1- Thorough debridement was performed, followed by placement of an antibiotic-impregnated polymethylmethacrylate (PMMA) cement spacer and stabilization with locking plate fixation.

Stage 2- After adequate membrane maturation at 4 weeks, the cement spacer was removed and the defect was filled with cancellous autograft within the induced membrane preserving the membrane bag. This membrane facilitates vascularization and enhances growth factor activity, thereby promoting bone regeneration.

Soft Tissue Coverage

Adequate soft tissue coverage of the defect utilizing locally mobilized tissue flaps, independent split thickness skin graft on mobilized muscle tissue was carried out by the plastic surgery team at the end of each osseous reconstruction.

Post-operative Rehabilitation

Passive and active assisted ROM exercises of knee and hip were started in the immediate post-op period for all three patients and were mobilized using a walker frame on a strict non-weight bearing protocol. All patients were discharged at appropriate times based on the management of their initial injury. At discharge, all patients showed clean wounds, no signs of infection and were comfortably mobilizing.

Patients (A, B and C) were followed-up at 6 weeks interval for first 6 months and thereafter at 3 months interval. Serial X-rays at follow-up showed progressive bone healing with gradual increase in girth of transferred fibula with no evidence of implant loosening or breakage. None of the patients showed evidence of deep infection. All patients achieved progressive improvement in knee ROM and finally achieved independent ambulatory status with good alignment of the limbs, without evidence of any limb-length discrepancy.

Discussion

Reconstruction of massive femoral bone defects remains a significant challenge due to the combined problems of bone loss, soft-tissue damage and infection risk. Vascularized fibular grafting has been widely used for reconstruction of long bone defects because the graft maintains its intrinsic blood supply, promoting rapid incorporation and remodeling. Studies have demonstrated successful outcomes for defects ranging between 6 cm and 15 cm [3,4]. The induced membrane technique described by Alain-Charles Masquelet has also emerged as an effective method for the reconstruction of critical bone defects. The membrane formed around the cement spacer secretes growth factors that support graft integration and osteogenesis [11].

In the present series, defects ranged from approximately 14.5 cm to 23.6 cm, representing extremely large femoral bone losses. Successful limb salvage in all patients highlights the potential of biological reconstruction techniques when combined with meticulous debridement, stable fixation and multidisciplinary care.

Compared with previously reported cases describing reconstruction of a 21 cm distal femoral defect, the current series demonstrates comparable outcomes using both vascularized fibular grafting and the induced membrane technique [5,6,9,11].

Limitations

Limitations of this study include a relatively small sample size. However, the series provides valuable insight into management strategies for extreme femoral bone defects.

Conclusion

Massive post-traumatic femoral bone defects can be successfully reconstructed using biological techniques such as vascularized fibular grafting and the induced membrane technique. Careful surgical planning, staged management and stable fixation can achieve limb salvage with satisfactory functional outcomes.

Conflict of Interest

The authors declared no potential conflicts of interest with respect to the research, authorship and/or publication of this article.

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Data Availability Statement

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

Ethical Statement

The project did not meet the definition of human subject research under the purview of the IRB according to federal regulations and therefore was exempt.

Informed Consent Statement

Informed consent was obtained from all participants included in the study.

Authors' Contributions

All authors contributed equally to this paper.

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