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Hybrid Bio-Metallic Nailing For Pathological Fracture With Juxta-Articular Bone Gap in Adolescent Femur-A Case Report

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Case Report

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Abstract

This case report describes the management of a pathological distal femur fracture with a 6 cm bone gap and an active S. aureus infection in a 10-year-old boy. Other reconstructive methods—including distraction osteogenesis, the Masquelet technique, and vascularized bone grafting—were ruled out due to potential soft tissue complications, substantial graft requirements, long immobilization periods, or limited local infrastructure. Instead, sequestrectomy and thorough debridement followed by hybrid bio-metallic nailing was done. This technique utilized an autologous non-vascularized fibular strut graft as a biological scaffold mounted over a flexible titanium elastic nail acting as a stable internal splint. Complete radiological union was achieved at 30 weeks, and the nail was removed at 36 weeks without subsequent complications at the 18-month follow-up. Hybrid bio-metallic nailing offers a low-cost, highly reproducible alternative for treating infected juxta-articular bone loss in resource-limited settings.

Keywords: Pathological Fracture; Bone Gap; Hybrid Nailing

Introduction

A pathological fracture with an associated bone gap and active infection at the distal femur represents one of the most complex scenarios in orthopaedic reconstruction. This condition combines critical structural loss, metabolic vulnerabilities (such as local hypoxia and acidosis), and a compromised biological microenvironment characterized by reduced osteoprogenitor cell counts and local immune suppression. Three major reconstruction options exist for this condition [1]. (1) distraction osteogenesis using an Ilizarov external fixator or a monorail limb reconstruction system (LRS); (2) the two-stage Masquelet induced-membrane technique; and (3) vascularized bone grafting. Each modality carries its own distinct merits and complications.

Case Report

A 10-year-old boy presented with pain, swelling, and a chronic draining wound yielding a watery discharge in the lower third of the thigh. He had been unable to bear weight for the preceding six months. On clinical examination, a discharging sinus tract measuring 1.5 cm in diameter was noted with active serous discharge. The ipsilateral knee was stiff, demonstrating a severely restricted range of motion of approximately 0-10 degrees.

Anteroposterior and lateral radiographs revealed a large sequestrum measuring approximately 6 cm, associated with a pathological fracture in the distal third of the femur (Figure 1). A pus culture isolated Staphylococcus aureus.

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The patient's hemogram was unremarkable except for a haemoglobin level of 9.5 g/dL. The erythrocyte sedimentation rate (ESR) was elevated at 32 mm in the first hour, while the C-reactive protein (CRP) test was negative. All potential treatment modalities were discussed in detail, and written informed consent was obtained from the legal guardian since the patient was a minor.



Figure 1: Large sequestrum in lower end of femur.

Although the Ilizarov method provides excellent biomechanical stability, soft-tissue tolerance is notoriously poor in the thigh. Unlike the subcutaneous borders of the tibia, the femur is enveloped by a thick, dynamic muscle mass. Transfixation wires and half-pins penetrate these moving soft-tissue layers, frequently causing severe pain, irritation, pin-track tethering, pin-site infections, and muscular transfixation. Furthermore, the bulky external frame is heavy, prevents side-sleeping, complicates clothing changes, and imposes a significant psychological burden on paediatric patients. Considering these factors—along with the guardian's explicit refusal after viewing photographs of an Ilizarov frame—external fixation was ruled out.

The two-stage Masquelet technique requires an extended treatment timeline and demands a substantial volume of autologous bone graft to fill large defects. Because the child had already been bedridden for six months, and harvesting a sufficient volume of autologous graft for a 6 cm gap in a 10-year-old patient posed a significant challenge, this option was not selected. Additionally, microsurgical expertise and the specialized infrastructure required for vascularized bone grafting were unavailable at our centre, excluding the third modality.

Ultimately, the surgical plan was tailored to consist of a thorough sequestrectomy, aggressive debridement, and a hybrid bio-metallic internal fixation construct. This construct utilized an autologous non-vascularized fibular strut as the biological component and a flexible titanium elastic nail (TEN) as the metallic component, bridging the bone gap in tandem. The rationale was that the titanium nail would act as a stable internal splint permitting physiological micro-motion while preventing varus/valgus deformities, while the fibula would serve as a biological scaffold possessing high osteogenic potential and providing immediate mechanical structural support.

Following the administration of anaesthesia, the patient was placed in a lateral decubitus position. An 8 cm segment of the ipsilateral fibula was harvested, and its intramedullary canal was sequentially reamed using a 3.5 mm forearm reamer. The distal third of the thigh was accessed via a lateral approach; the sequestrum was excised, and the operative site underwent thorough devitalized tissue debridement. A 3.5 mm flexible titanium nail was passed retrogradely through the femur, crossing the gluteal skin via a small stab incision. The harvested fibular graft was then mounted over the titanium nail (Figure 2), and this combined nail-fibula construct was fitted to bridge the intercalary bone defect (Figure 3). The titanium nail was driven distally into the tibial metaphysis to optimize structural stability and purchase.



Figure 2: Removed & fibular graft mounted over titanium nail.

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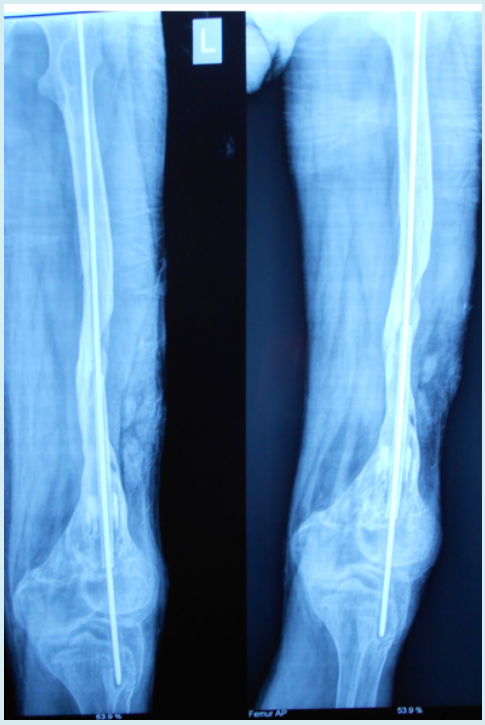


Figure 3: Bone gap bridged with nail-fibula construct.

The wound was closed over a negative-pressure vacuum drain, which was removed after 24 hours. Approximately 400 mL of blood was collected in the drain; to compensate for this loss, two units of packed red blood cells were transfused. A long knee brace was applied for supplementary external protection. Postoperatively, oral linezolid (300 mg) was administered twice daily for 10 days, followed by oral amoxicillin-clavulanate (325 mg) twice daily for the subsequent 15 days. Static quadriceps exercises were initiated immediately.

The surgical wound was completely dry by postoperative day 26. At 3 months, supported weight-bearing with the knee brace was initiated. Structural consolidation at the operative site was monitored using serial radiographs at 6-week intervals. Clear radiological union was evident by week 30 (Figure 4), allowing the patient to progress to unsupported full weight-bearing. The titanium nail was electively removed at 36 weeks, after which dynamic quadriceps exercises were commenced.

The patient was followed for a total of 18 months, during which no deep recurrence of infection or structural failure was observed. The range of knee motion did not improve significantly despite regular physical therapy, likely due to pre-existing articular cartilage damage and arthrofibrosis secondary to the chronic infection. A 1 cm limb-length discrepancy was noted at final follow-up, which was well-tolerated and presented clinically as a mild lurching gait.



Figire 4: United pathological fracture.

Discussion

For the management of infected segmental bone gaps, the Ilizarov method remains a highly effective option, though it carries substantial morbidity. The technique demands a steep learning curve [2] to mitigate an overall complication rate that hovers around 30%. In a study by Bonnard, et al. [3], only 13 out of 26 paediatric patients completed treatment without complications. Similarly, Liu, et al. [4] observed complications in 29 out of 62 patients (46.7%), including persistent pin-track infections, axial deviations, muscle contractures, joint stiffness, and soft-tissue incarceration. Distraction osteogenesis is technically demanding and lengthy, predisposing patients to unique complications [5]. Velazquez, et al. [6] reported 38 major complications requiring unplanned secondary surgeries or resulting in permanent sequelae across 61 treated limb segments in 40 patients. Distracting a bone segment too rapidly can overstretch adjacent neurovascular structures. Furthermore, once the transported segment reaches the target site, it must achieve solid docking. In post-osteomyelitis juxta-articular defects, the remaining regional tissue is often severely scarred, avascular, and sclerotic, culminating in high rates of delayed union or non-union at the docking site. Feng, et al. [7] reported docking site complications in 53% of a 103-patient cohort. Monorail limb reconstruction systems mirror these high complication rates [8]. Lu et al. noted docking site non-union in two out of eight patients managed with this

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approach [9].

The Masquelet technique requires a minimum of two major surgical stages and a prolonged period to achieve definitive union. For expansive defects, harvesting the requisite large volume of autologous bone graft can induce donor-site morbidity and may be exhausted quickly in paediatric cohorts. In a meta-analysis by Morelli, et al. [10], persistent infection or non-union occurred in 18% (77 of 431) of cases. Additionally, the induced-membrane technique mandates robust secondary structural fixation, as morselized graft fragments offer no intrinsic mechanical stability. This contrasts sharply with an intramedullary fibular strut, which provides immediate mechanical advantages alongside intrinsic osteogenic potential.

Vascularized fibular grafting is a technically demanding microvascular procedure that requires prolonged mechanical protection, specialized microvascular training, and carries distinct donor-site morbidity risks. Consequently, its utility is largely restricted to specialized tertiary care institutions.

In contrast, combining a non-vascularized fibular graft with a titanium elastic nail—as demonstrated in this report and supported by historical literature—offers a highly reproducible, cost-effective alternative. It achieves excellent long-term biological bone remodelling without requiring microvascular expertise [11].

Conclusion

Hybrid bio-metallic nailing represents a viable alternative for managing juxta-articular bone loss complicated by active infection, particularly in resource-limited or peripheral healthcare environments. Larger, multicentre prospective studies are warranted to further validate the long-term efficacy, safety profile, and reproducibility of this technique.

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