Reconstruction of Massive Femoral Bone Loss Following Malignant Tumor Resection Using the Masquelet Technique Combined with Distraction Osteogenesis and a Modified AO External Fixator: A Case Report

Imad Al Hariri, MD

Orthopedic Surgeon

Former Head of Orthopedic Surgery, Tishreen Military Hospital (2019–2024)

President, Syrian Society of Orthopedic Surgery (2023–2025)

Damascus, Syria

Email: imadhariri65@gmail.com

Abstract:

The management of massive bone loss following surgical resection of malignant bone tumors remains a significant challenge for orthopedic surgeons.

We report a successful case of a young man with a 20 cm femoral bone defect following wide resection of an osteosarcoma. Reconstruction was performed using a multi-stage approach combining the Masquelet induced membrane technique, distraction osteogenesis with a locally modified AO external fixator, and a retrograde intramedullary nail.

Bone transport was initiated after a latency period at a rate of approximately 1 mm/day. A total of 17.5 cm of bone was reconstructed over 6.5 months, followed by iliac crest bone grafting for the remaining 2.5 cm.

Complete bone consolidation was achieved within 15 months. At 4-year follow-up, no local recurrence or metastasis was observed. The patient regained independent ambulation despite residual knee stiffness.

This case demonstrates that this combined biological approach represents a viable and cost-effective option for reconstructing extensive bone defects, particularly in resource-limited settings.

Background

Osteosarcoma is the most common primary bone malignancy in children and adolescents [1], typically derived from primitive bone-forming mesenchymal cells. It has a bimodal age distribution, with a primary peak occurring in individuals aged 10 to 14 years, corresponding to the pubertal growth spurt. This highly heterogeneous tumor can be classified into various subtypes based on location, differentiation, and histological characteristics. In recent years, significant advancements in medical and surgical treatments have markedly improved patient survival rates.

Before the 1970s, amputation was the standard treatment for malignant bone tumors of the lower extremities. However, due to continuous progress in chemotherapy, medical imaging, and implant technology, more than 90% of osteosarcoma cases are now managed with limb-sparing surgery [1]. Reconstruction options after wide resection include osteoarticular allografts, allograft–prosthetic composites, recycled autografts, and modular or custom-made endoprostheses. Although these techniques allow earlier restoration of limb function, they are associated with complications such as infection, nonunion, and graft resorption [11,13], and often involve significant financial cost.

In response to these limitations, biological reconstruction methods have gained increasing attention. The two-stage induced membrane technique [2,8,9], also known as Masquelet's technique, has shown promising results in the management of critical-sized bone defects, including those exceeding 15 cm. While it was initially believed that the optimal interval between stages was approximately one-month, recent studies have demonstrated that the induced membrane maintains its osteogenic properties even when the second stage is delayed [3], with successful outcomes reported after delays of up to six months.

Distraction osteogenesis [4,5] using external fixation is another well-established technique for the treatment of limb length discrepancies and reconstruction of large bone defects. Its combination with intramedullary nailing has been widely adopted to guide bone transport, improve alignment, and enhance stability [6,7]. Several studies have demonstrated the effectiveness of this combined approach in reconstructing bone defects resulting from infection or tumor resection.

In this case report, we present a combined approach utilizing the Masquelet technique, distraction osteogenesis, and retrograde intramedullary nailing for the reconstruction of a massive 20 cm femoral bone defect following tumor resection. In addition, a locally modified AO external fixator was used to facilitate controlled long-distance bone transport. This modification, developed in our institution under resource-limited conditions, enabled successful reconstruction of approximately 17.5 cm, which is difficult to achieve using conventional external fixation systems.

To the best of our knowledge, this represents one of the largest femoral reconstructions performed using this combined biological approach.

Clinical Findings and Diagnostic Assessment

Clinical Presentation:

A 23-year-old male athlete presented with a history of progressive pain in the right femur over several weeks. The pain initially worsened with physical activity and improved with rest, but later became constant and was not relieved by rest or analgesics. The patient had no history of trauma, medication use, prior medical conditions, or family history of similar diseases.

Physical Examination:

On examination, there was no visible swelling, erythema, or local warmth in the thigh. The patient demonstrated a slight limp while walking and reported localized tenderness on deep

palpation of the distal third of the right femur. Hip and knee joint movements were normal and unrestricted. Neurovascular examination of the lower limb was unremarkable, with no palpable lymphadenopathy in the inguinal or popliteal regions.

Laboratory Findings:

Initial laboratory investigations were within normal limits, except for a mild elevation in lactate dehydrogenase (LDH) at 401 U/L.

Radiological Assessment:

Plain radiography of the right femur (Fig. 1) revealed a heterogeneous lesion with ill-defined borders located at the junction of the middle and distal thirds of the femur, associated with cortical destruction and extension of approximately 7 cm toward the femoral condyles.

Magnetic resonance imaging (MRI) (Fig. 2) demonstrated a destructive intramedullary lesion measuring approximately 14 cm, with an associated soft tissue mass showing heterogeneous contrast enhancement and surrounding edema. There was no evidence of direct involvement of the neurovascular bundle.

Computed tomography (CT) scan of the chest, abdomen, pelvis, and limbs confirmed that no distant metastases**. CT angiography (CTA)** (Fig. 3) confirmed that the lesion had no direct relationship with the major femoral vessels.

Histopathological Findings:

A needle-guided biopsy (Fig. 4) revealed proliferation of malignant spindle-shaped cells with osteoid formation and atypical mitotic activity, consistent with high-grade fibroblastic osteosarcoma.

Diagnosis:

Based on clinical, radiological, and histopathological findings, the final diagnosis was **high-grade fibroblastic osteosarcoma of the right femur.**

Therapeutic Interventions

A multidisciplinary team (MDT) meeting was conducted to discuss the patient's management. Due to local resource limitations and concerns regarding the availability and efficacy of chemotherapy agents, a decision was made to proceed with surgical management first, followed by adjuvant chemotherapy. This approach represented a deviation from standard treatment protocols.

Surgical Planning and First Stage

Based on three-dimensional CT and MRI findings, a staged surgical reconstruction strategy was planned (Fig. 5).

1. **First Stage Surgical Technique (Fig. 6):**

Wide tumor resection was performed, including approximately 20 cm of the femoral diaphysis along with surrounding soft tissues. The femoral neurovascular structures were carefully exposed and preserved. The femur was stabilized using a retrograde interlocking intramedullary nail inserted through the distal femur.

The resulting bone defect was filled with polymethylmethacrylate (PMMA) cement to act as a spacer and to induce the formation of a biological membrane, representing the first stage of the Masquelet technique.

First Stage Follow-up (Fig. 7):

Postoperatively, the patient received antibiotics and thromboprophylaxis. Mobilization with crutches without weight bearing was initiated after three days. A postoperative radiograph was obtained, and the resected specimen was sent for histopathological examination (Fig. 8), confirming the diagnosis of high-grade fibroblastic osteosarcoma.

Following wound healing, the patient was referred to the oncology department and received a 6-month chemotherapy protocol based on the National Comprehensive Cancer Network (NCCN) 2020 guidelines.

2. **Second Stage of Surgery**

After completion of chemotherapy, the patient was re-evaluated and reconstruction was planned, taking into account the limited availability of advanced reconstructive implants. Distraction osteogenesis using a locally modified monolateral AO external fixator was selected to achieve bone transport (Fig. 9).

Second Stage Surgical Technique:

The previous intramedullary nail was exchanged for a longer nail to allow guidance of bone transport. The cement spacer was removed while carefully preserving the induced membrane to maintain its biological properties.

Multiple biopsies were obtained from the resection margins and surrounding tissues and were sent for histopathological and microbiological analysis to exclude tumor recurrence and infection. All results were negative.

A monolateral external fixation system (AO type) was applied; however, the device was modified intraoperatively to allow controlled long-distance bone transport while maintaining mechanical stability over the large defect.

Bone transport was initiated after a latency period of approximately two weeks (Fig.10) at a rate of 1 mm per day.

Second Stage Follow-up (Figs. 11 and 12):

Bone transport was continued for approximately 6.5 months, achieving 17.5 cm of newly formed bone. The procedure was discontinued due to patient discomfort and the presence of mild serous discharge, leaving a residual bone defect of approximately 2.5 cm. *(Fig. 11: Follow-up X-rays at 2 and 4 Months Post-Second Surgery). (Fig. 12: X-ray 6.5 Months Post-Second Surgery)*

3. **Third Stage Surgery**

A third surgical procedure was performed to address the remaining defect. An autologous bone graft harvested from the iliac crest was used to fill the residual 2.5 cm gap and was stabilized using an intercondylar plate following partial retraction of the intramedullary nail (Fig. 13).

Additional bone and soft tissue biopsies were obtained intraoperatively, and all findings were negative for tumor recurrence or infection.

Follow-up:

Postoperatively, the patient was closely monitored by the oncology department with regular clinical and radiological evaluations. All follow-up assessments showed no evidence of local tumor recurrence or distant metastasis.

Two months after the final bone grafting procedure, the patient was able to discontinue the use of crutches and progressed to full weight-bearing ambulation.

A residual limb length discrepancy of approximately 2.5 cm was observed. Despite these limitations, the overall functional outcome was considered satisfactory, and the patient was able to return to daily activities.

At 4-year follow-up, the patient remained free of local recurrence and distant metastasis and was able to walk independently without assistive devices. Despite successful bone reconstruction, some long-term functional limitations were observed. The patient demonstrated a noticeable limp during ambulation and severe knee stiffness, with almost complete limitation of joint motion.

These limitations were attributed to several factors, including prolonged interruption of physiotherapy during the distraction phase, the presence of the external fixator around the knee joint, extensive bone and soft tissue resection, and surgical exposure of the knee.

Nevertheless, limb preservation was achieved, and the patient was able to ambulate with full weight bearing and return to daily life activities (Fig. 14).

The functional outcome was evaluated using the Musculoskeletal Tumor Society (MSTS) scoring system, with a total score of 21/30, corresponding to approximately 70%. (Table.1).

Table 1. Functional outcome assessment using MSTS score

Parameter	Score (0–5)
Pain	4
Function	3
Emotional acceptance	4
Supports	5
Walking ability	3

Gait	2

Total	21/30 (70%)

Discussion

Reconstruction of massive femoral bone defects following malignant tumor resection remains one of the most challenging problems in orthopedic oncology [1]. While limb-sparing surgery has become the standard of care in more than 90% of osteosarcoma cases, achieving durable biological reconstruction and satisfactory functional outcomes in large defects remains difficult.

Several reconstruction options have been described in the literature, including endoprosthetic reconstruction, allografts, and vascularized fibular grafts. Although these techniques allow early restoration of limb function, they are associated with significant limitations, such as infection, nonunion, graft resorption [11,13], mechanical failure, and high financial cost, particularly in resource-limited settings.

The Masquelet induced membrane technique has gained increasing attention as a reliable biological method for the treatment of critical-sized bone defects [2,8,9]. Previous studies have demonstrated that the induced membrane provides a favorable environment for bone regeneration and maintains its osteogenic properties even when the second stage is delayed up to several months [3]. This supports the strategy used in our case, where the second stage was performed after six months without compromising bone healing.

Distraction osteogenesis using external fixation is another well-established technique for managing large bone defects [4]. Several studies have reported successful reconstruction of femoral defects ranging from 6 to 17 cm using monolateral external fixation, with acceptable functional outcomes [5]. However, complications such as pin tract infection, joint stiffness, and prolonged treatment duration remain common.

The combination of distraction osteogenesis with intramedullary nailing has been shown to improve mechanical stability, maintain alignment during bone transport, and reduce complications associated with external fixation alone. Reported external fixation indices range between 13.5 and 18 days/cm, with consolidation indices ranging from 30 to 35 days/cm in most series [6,7]. Systematic reviews also support its effectiveness [11].

In the present case, bone transport was performed at a rate of 1 mm/day. The external fixation index was approximately 11.1 days/cm, and the consolidation index was approximately 26 days/cm. These values are favorable when compared to previously reported series (Table.2).

A key factor contributing to the success of this case was the use of a locally modified AO external fixation device. This modification allowed controlled long-distance bone transport of approximately 17.5 cm, which exceeds most reported cases in the literature and is difficult to achieve using conventional external fixation systems.

These favorable indices may be attributed to the mechanical stability provided by the intramedullary nail and the efficiency of the modified external fixation system.

Another important aspect of this technique is its applicability in resource-limited settings. In many environments, access to advanced reconstructive implants is limited due to economic constraints. The combined use of the Masquelet technique and distraction osteogenesis provides a cost-effective and biologically sound alternative.

Despite the successful reconstruction, some limitations were observed. The patient developed significant knee stiffness, which can be attributed to prolonged immobilization, the presence of the external fixator around the joint, and the extensive soft tissue resection. This highlights the importance of early and aggressive rehabilitation protocols when feasible.

Nevertheless, the ability to reconstruct a massive 20 cm femoral defect with complete bone consolidation and without tumor recurrence represents a significant achievement.

To the best of our knowledge, this case represents one of the largest femoral reconstructions performed using a combination of the Masquelet technique, distraction osteogenesis, and a modified AO external fixation system.

.

Table 2. Comparison of bone transport indices with published literature

Parameter	Present Case	Reported Range
Distraction rate	1 mm/day	1 mm/day
External fixation index	11.1 days/cm	13–18 days/cm
Consolidation index	26 days/cm	30–35 days/cm

Conclusion

This case demonstrates that a combined biological approach using the Masquelet induced membrane technique, distraction osteogenesis, and a locally modified AO external fixation system with intramedullary nail guidance is an effective method for reconstructing massive femoral bone defects.

In this case, approximately 17.5 cm of bone was successfully regenerated, with complete consolidation achieved within 15 months and without major complications such as infection or nonunion.

This technique represents a cost-effective and viable alternative to other reconstruction methods, particularly in resource-limited settings.

To the best of our knowledge, this represents one of the largest femoral reconstructions achieved using this combined approach.

Ethical Approval:

This study was conducted in accordance with the ethical standards of the institutional and national research committee and with the principles of the Declaration of Helsinki.

Informed Consent:

Written informed consent was obtained from the patient for publication of this case report and accompanying images.

Conflict of Interest:

The authors declare that they have no conflict of interest.

Funding:

This research received no external funding.

References

1. Prater S, McKeon B. Osteosarcoma. StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2023.

2. Masquelet AC. Masquelet's induced membrane technique: Review of current concepts and future directions. J Orthop Res. 2021;39(4):707–718.

3. Gindraux F, Loisel F, Bourgeois M, et al. Induced membrane maintains its osteogenic properties even when the second stage of Masquelet's technique is performed later. Eur J Trauma Emerg Surg. 2020;46(2):313–315.

4. Lenze U, Baumgart R. The use of distraction osteogenesis for the reconstruction of bone defects following resection of malignant bone tumours. Unfallchirurg. 2023;52(9):729–737.

5. Zhang Q, Zhang W, Zhang Z, et al. Femoral nonunion with segmental bone defect treated by distraction osteogenesis with monolateral external fixation. J Orthop Surg Res. 2017;12(1):183.

6. Kocaoglu M, Eralp L, Rashid HU, et al. Reconstruction of segmental bone defects due to chronic osteomyelitis with use of an external fixator and an intramedullary nail. J Bone Joint Surg Am. 2006;88(10):2137–2145.

7. Li Z, Zhang X, Duan L, et al. Distraction osteogenesis using an intramedullary nail and a monolateral external fixator in reconstruction of massive femoral defects. Can J Surg. 2009;52(2):103–111.

8. Pelissier P, et al. The induced membrane technique for the treatment of massive bone defects: a review. J Orthop Sci. 2013;18(5):690–698.

9. Masquelet AC, Begue T. The Masquelet technique: A new method for bone reconstruction. Orthop Traumatol Surg Res. 2010;1(1):10–18.

10. Paley D. Principles of deformity correction. Berlin: Springer; 2002.

11. Mainardi L, et al. Distraction osteogenesis for the reconstruction of large bone defects: A systematic review and meta-analysis. Injury. 2022;53(6):2038–2046.

12. Bono CM, et al. Use of a modified Ilizarov external fixator for treatment of a femoral bone defect. Case Rep Orthop. 2012.

13. Dhar SA, et al. The Masquelet technique and bone transport in reconstruction of post-traumatic tibial bone defects. Bone Joint J. 2016;98-B(7):979–985.

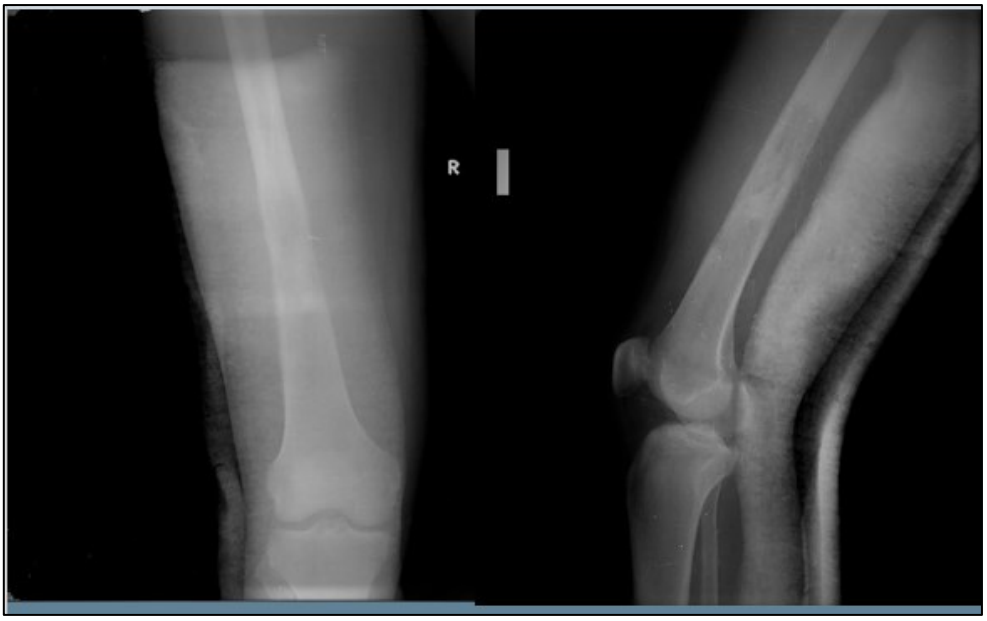

Figure 1: Preoperative anteroposterior radiograph of the right femur showing a heterogeneous destructive lesion with ill-defined margins at the junction of the middle and distal thirds, associated with cortical erosion and extension into the surrounding soft tissues.

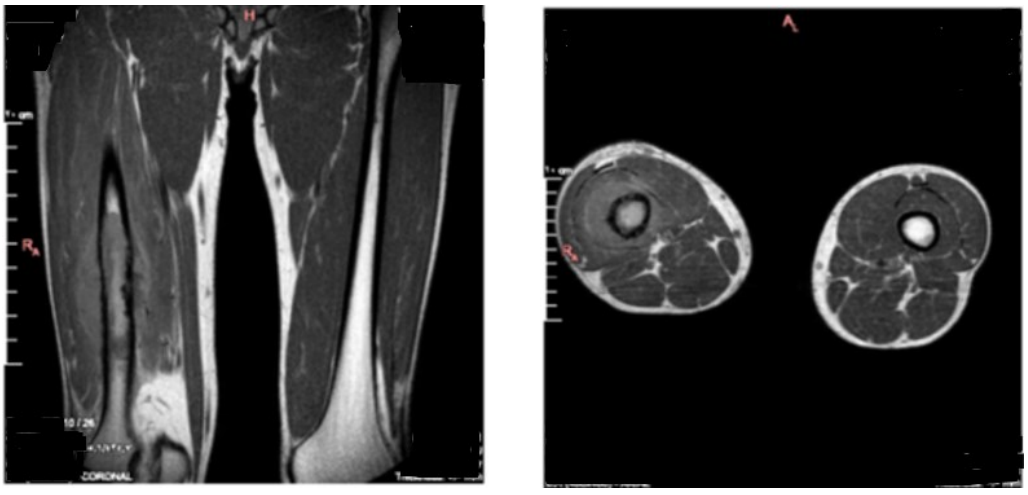

Figure 2: Preoperative MRI of the right femur.

Preoperative magnetic resonance imaging (MRI) of the right femur demonstrating a destructive intramedullary lesion measuring approximately 14 cm, associated with a large soft tissue mass and heterogeneous contrast enhancement, without involvement of the neurovascular bundle

---

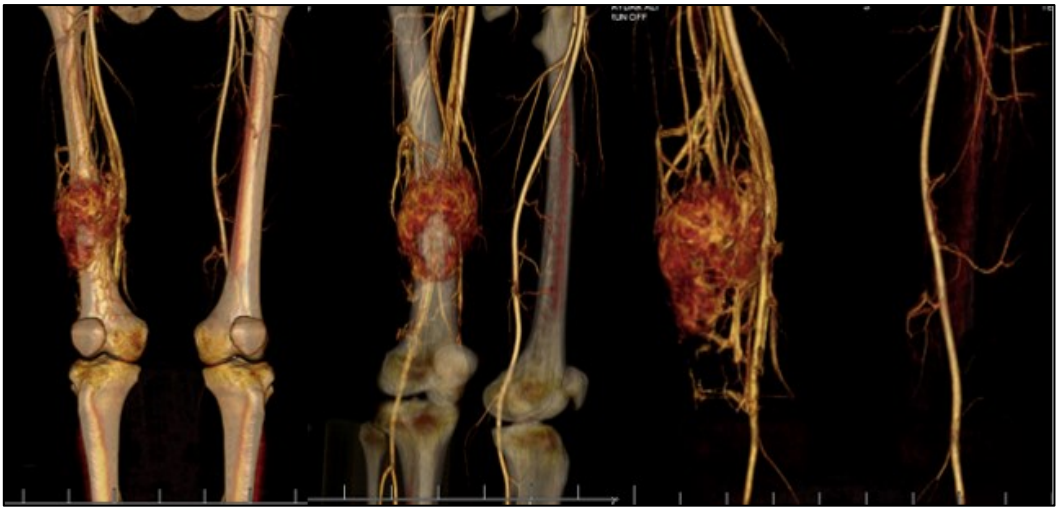

Figure 3: Preoperative (CT-3D) Angiography

Preoperative computed tomography (CT) angiography showing no involvement or displacement of the major femoral vessels by the tumor mass.

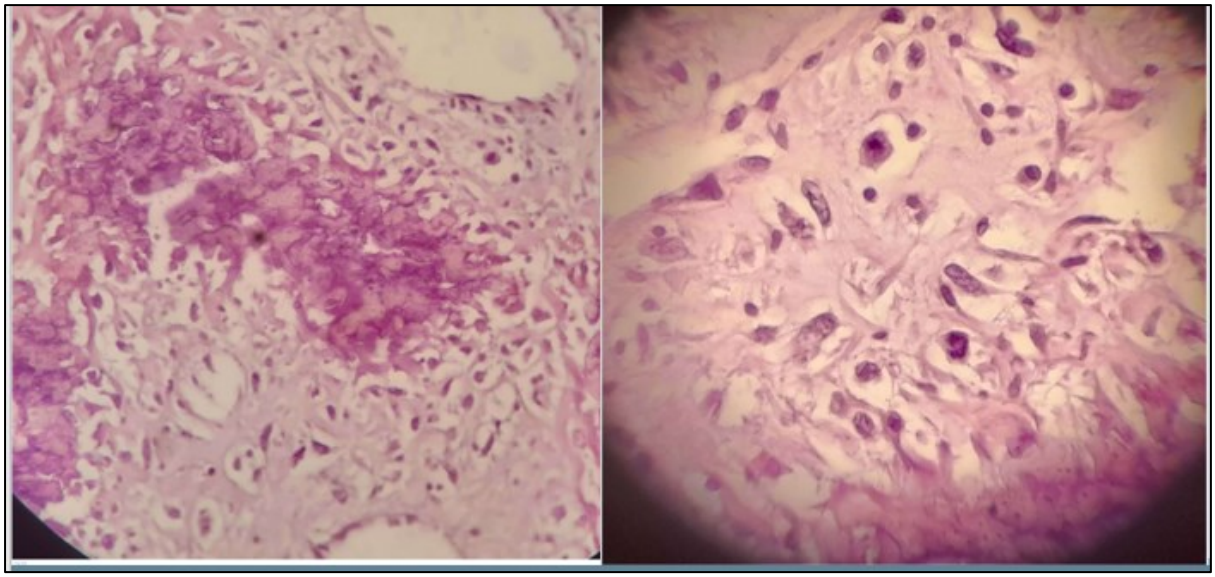

Figure 4: Post-Biopsy Histopathology Report

Histopathological examination of the biopsy specimen showing malignant spindle cells with osteoid formation and atypical mitotic activity, consistent with **high-grade fibroblastic osteosarcoma**

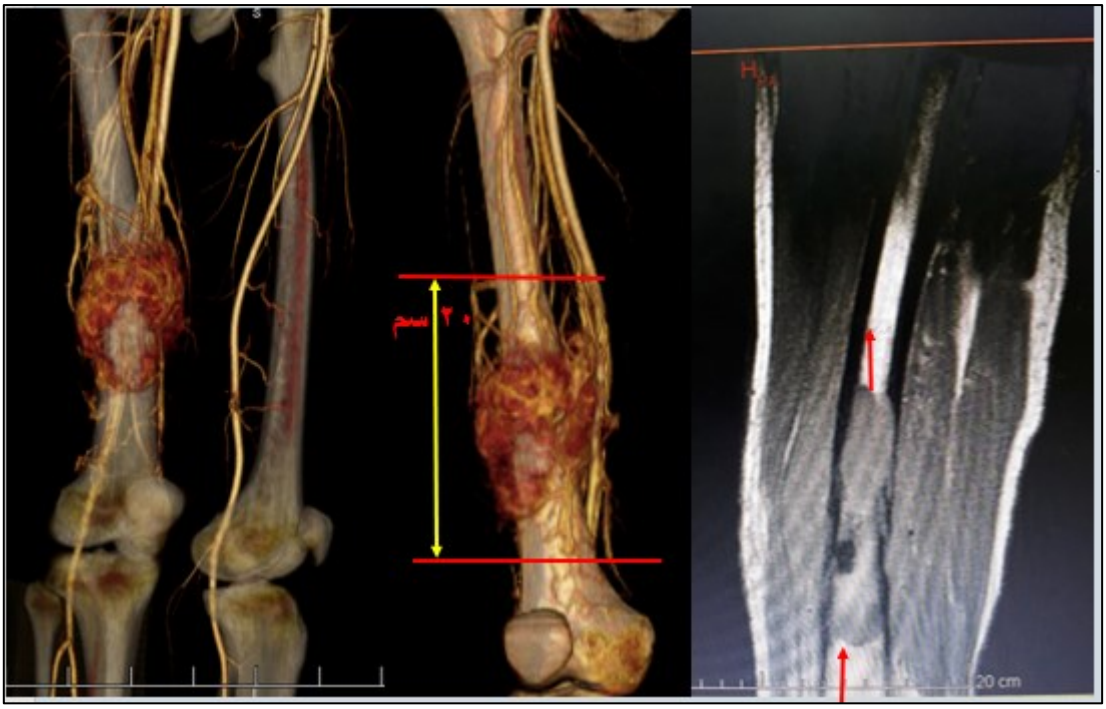

Figure 5: The First Surgical Plan

Preoperative surgical planning illustrating the extent of tumor resection, planned margins, and positioning of the retrograde intramedullary nail and cement spacer.

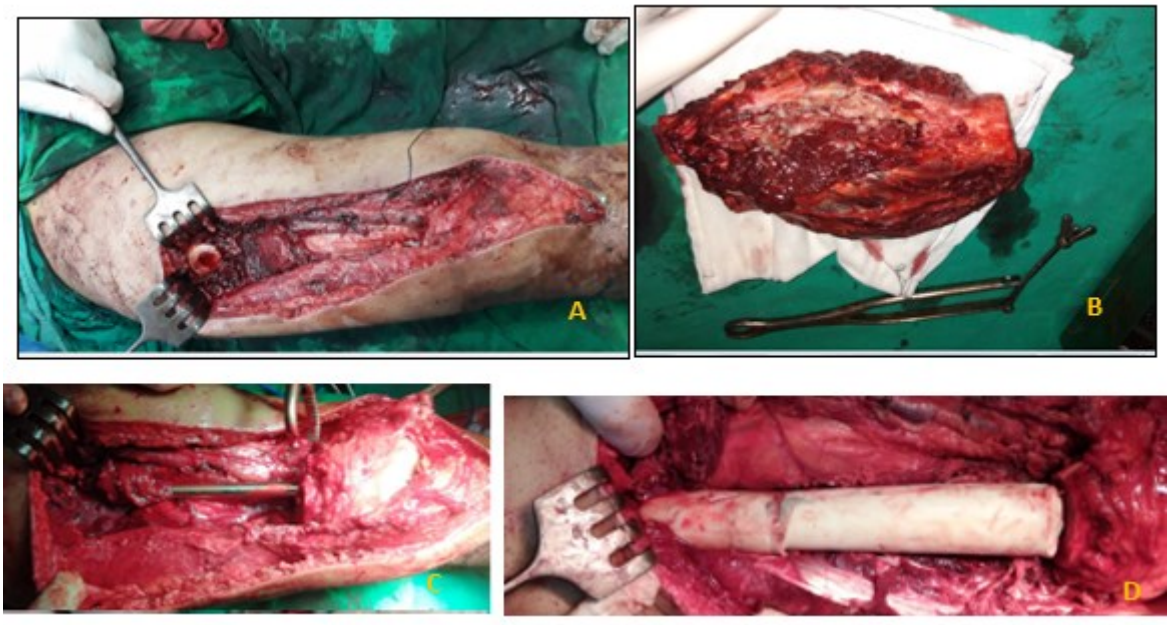

Figure 6: First Stage of the Surgical Technique

- Intraoperative images of the first surgical stage:
  (A) Bone resection margins after tumor excision & preservation of the femoral

neurovascular bundle
(B) Resected tumor specimen
(C) Insertion of retrograde intramedullary nail
(D) Placement of polymethylmethacrylate (PMMA) cement spacer

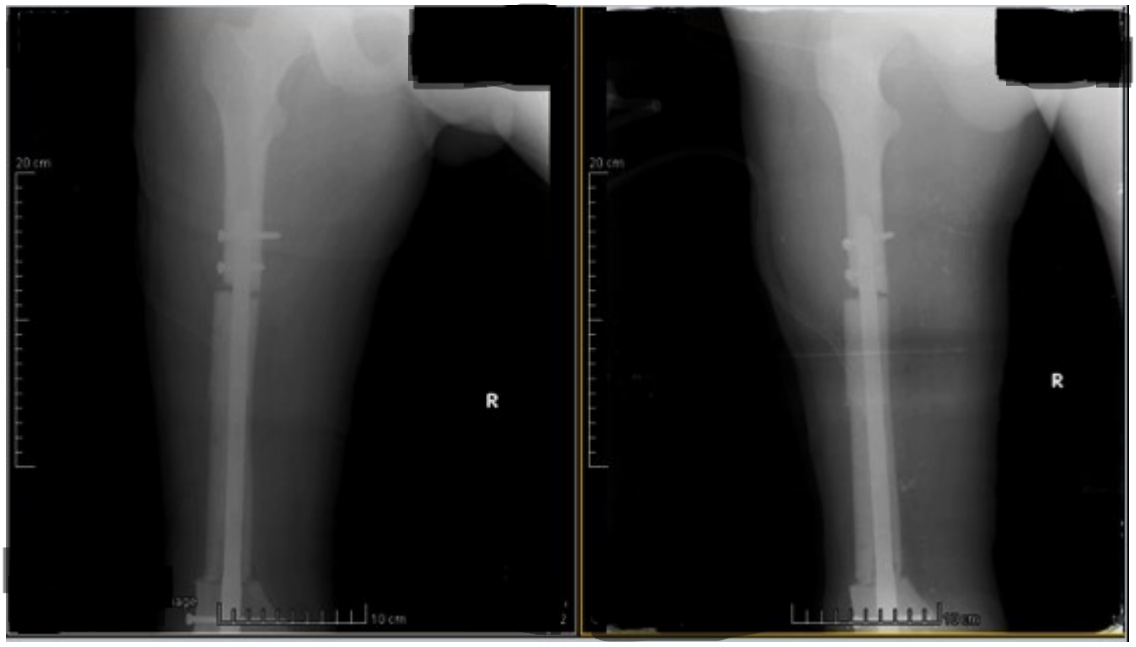

Figure 7: Postoperative X-ray after the First Surgery

Postoperative radiograph following the first surgical stage showing intramedullary nail fixation and cement spacer occupying the bone defect (Masquelet technique).

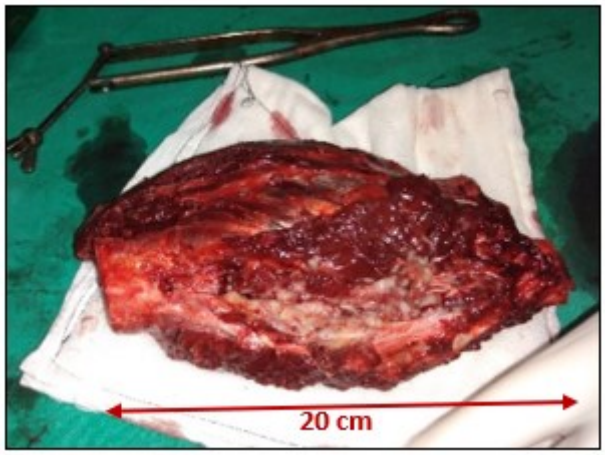

Figure 8: Postoperative Histopathological Examination

Histopathological analysis of the resected specimen confirming high-grade fibroblastic osteosarcoma.

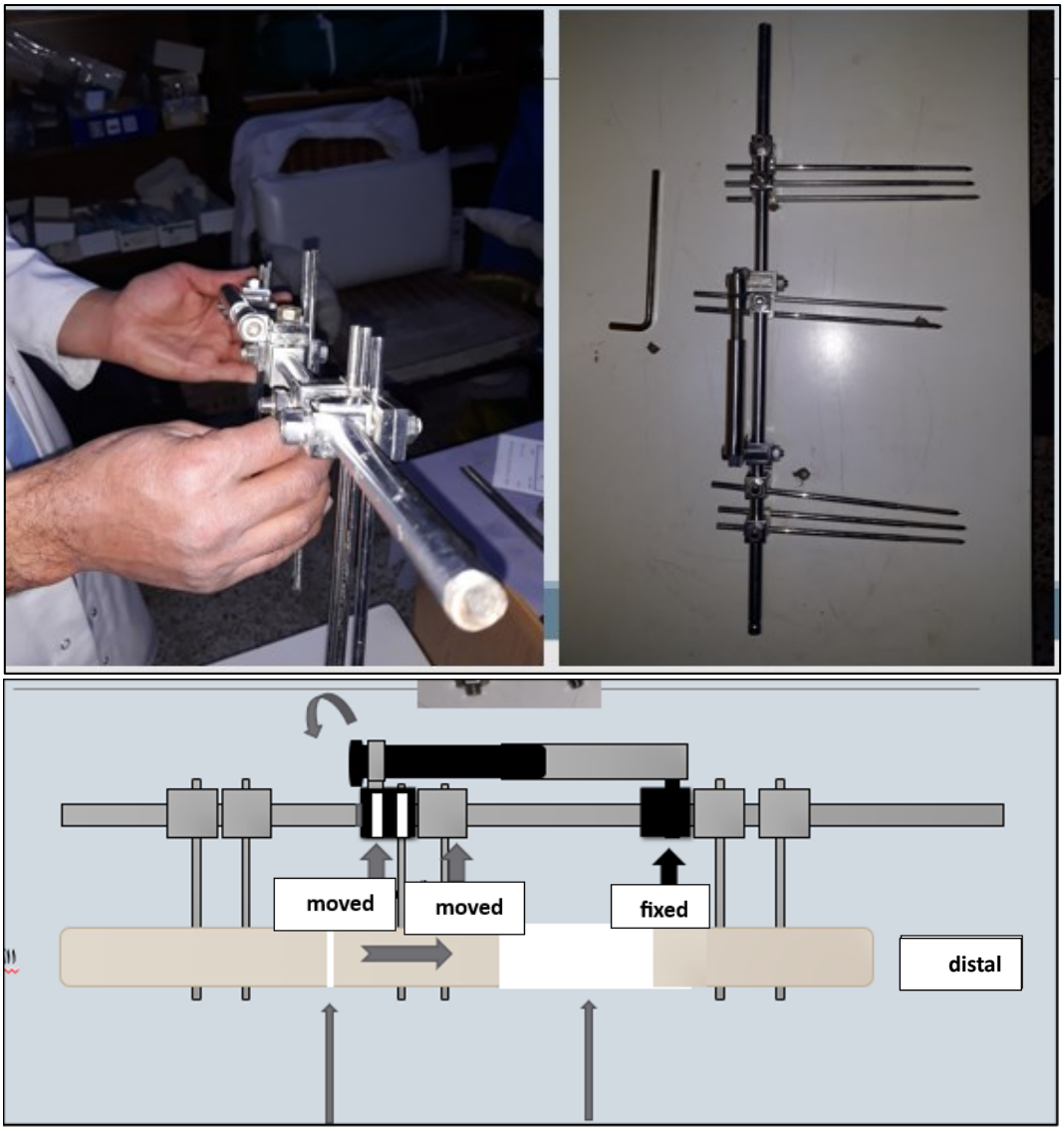

Figure 9: Locally Modified Monolateral External Fixation Device (AO)

Locally modified monolateral AO external fixation device used for distraction osteogenesis, demonstrating the additional component allowing long-distance bone transport.

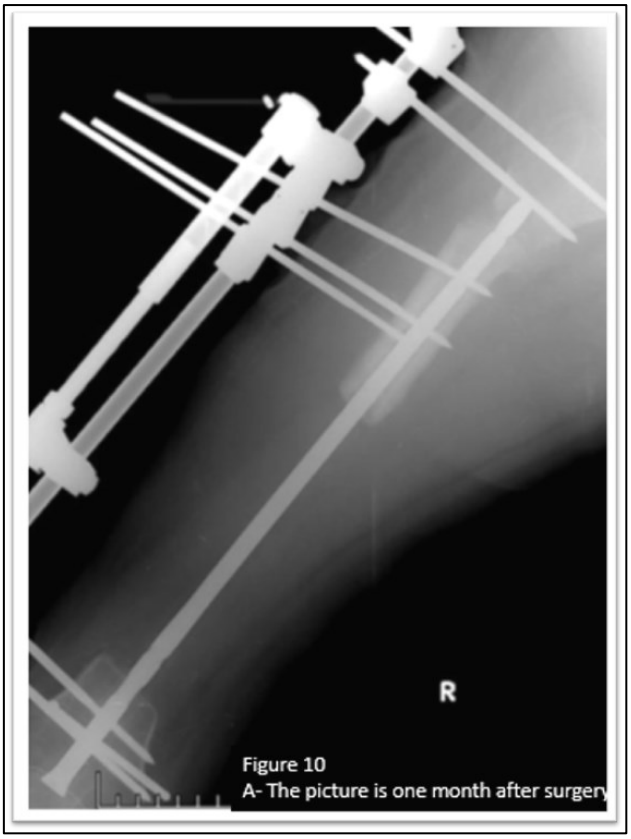

Figure 10: X-ray One Month Post-Second Surgery

Radiograph one month after the second surgery showing initiation of bone transport with early regenerate formation.

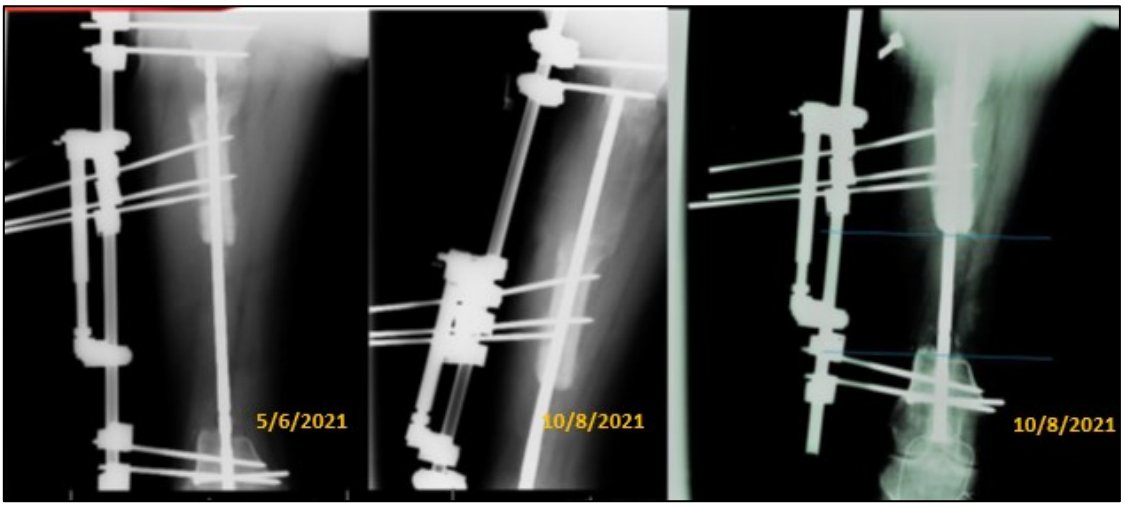

Figure 11: Follow-up X-rays at 2 and 4 Months Post-Second Surgery

Follow-up radiographs at 2 and 4 months demonstrating progressive bone transport and callus formation within the distraction gap.

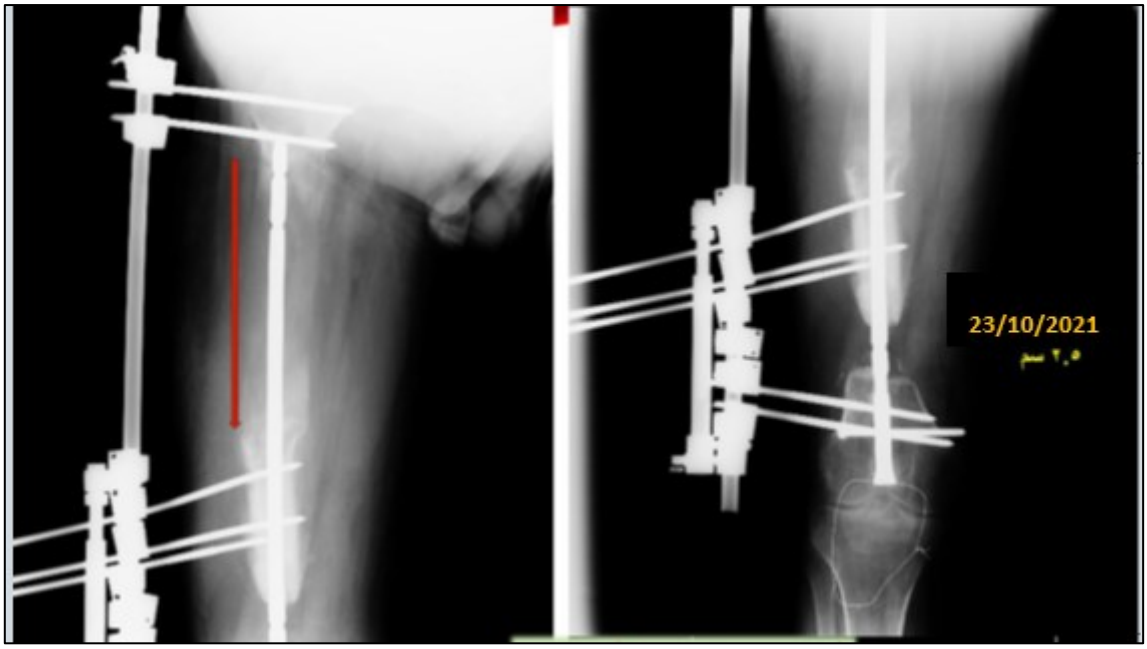

Figure 12: X-ray 6.5 Months Post-Second Surgery

Radiograph at 6.5 months showing approximately 17.5 cm of regenerated bone, with a residual defect of approximately 2.5 cm.

Figure 13: X-ray Five Months After the Third Surgery

Radiograph after the third surgical stage showing iliac crest bone grafting of the residual defect with plate fixation and progressive consolidation.

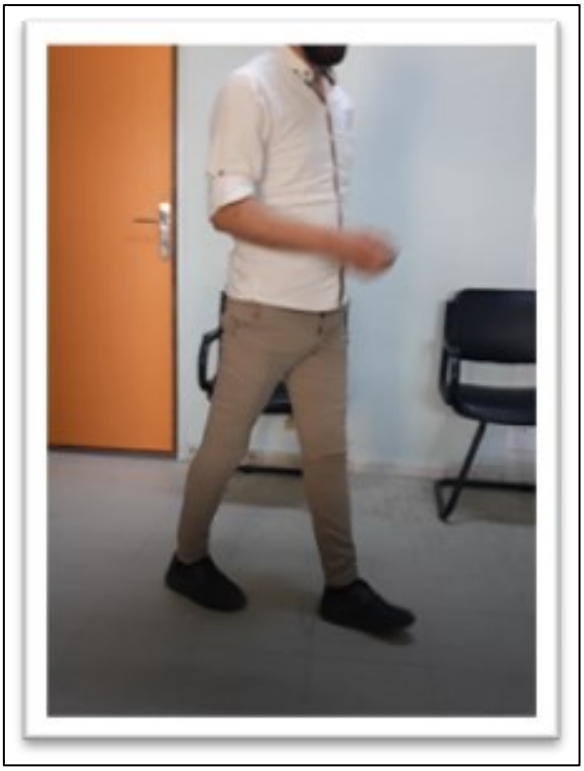

Figure 14: Clinical Outcome after 4-Year Follow-up

Clinical photograph at 4-year follow-up demonstrating independent ambulation with full weight bearing despite residual knee stiffness.