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Reconstruction of massive bone loss with the combination between Masquelet technique, and distraction osteogenesis method by using a locally modified AO tubular device, guided with an interlocking nail for reconstructing bone loss 20 cm due to a malignant bone tumor in the femur (case report)

Orthopedic Surgery Department, Oncology Department, Tichreen Military Hospital, Dmascus ,Syria

By: Dr.Imad Al Hariri, head of the orthopedic surgery department at Tichreen Hospital

Dr.Jihad Mando ,head of the Oncology department, at Tichreen Hospital

.Tel: 00963-938550183-Email: imadhariri65@gmail.com

***Keys words**: (external fixation,* . Masquelet technique*, distraction osteogenesis, reconstruction bone, osteosarcoma),*

Abstract:

- The massive bone loss after treatment surgical of the bone tumor pose big challenge to the orthopedists, this were depending on the site of the tumor in the bone. We were successfully treated bone loss in the femurs of a young man have about 20 cm of bone loss caused by wide resection of osteosarcoma in the femur. We had used three techniques :. Masquelet method and progressive induction method using external fixator(monolateral) and retrograde femoral nail. By two surgical stages. 6 months interval and follow up 15 months to achieve bone consolidation. And we findthis is the first case in the literatures were utilized for it this combination in the treatment.
- Masquelet's induced membrane technique (MIMT) is a relatively new, two-stage surgical procedure to reconstruct segmental bone defects, First performed by Dr. Masquelet in the mid-1980s, MIMT has shown great promise to revolutionize critical-sized bone defect repair and has several advantages over its alternative, distraction osteogenesis (DO). Also, its success in extremely challenging cases (defects > 15 cm). The delay of the second stage of this method for more than six months keeper the induced membrane preserving its biological properties
- External fixation has been widely used for the treatment of limb length discrepancy, deformity correction, and bone defect using distraction osteogenesis. We can use this technique for the treatment of reconstruction after malignant bone tumor resection. The advantages of external fixation for the treatment include a possibility of reconstructing the bone loss more than 6 cm.
- The used of interlocking nail with the combination of the external fixation can guide the bone segment pendent the transporting of the bone, becoming a widely used technique for the treatment of the bone deficiency by using distraction osteogenesis.
- We have used these techniques to reconstruct about 20 cm of bone loss caused by wide resection of osteosarcoma in the femur. Masquelet method and progressive induction method using external fixator and retrograde femoral nail. And this is making our case the first case in the literatures were utilized for it this combination in the treatment.
- The Ao external fixation is designs to fix the bone segments in open fractures. In this case, we used an external AO tubular fixation device by adding a piece to transform the bone. It achieved a transformation of about 17.5 cm of bone. This is difficult to achieve with any other external fixing device.

methods:

- A 23-year-old man, admitted to the hospital with a diagnosis: High grade fibroblasts osteosarcoma in his right femur at the junction of middle and third parts, a distance of the tumor is 14 cm in the femoral diaphysis, proximally to the line of the knee joint is about 7 cm. Treated surgically in two stages. The first stage: wide resection of the tumor (about 20 cm of bone with a safety margin of bone and surrounding soft tissues). With temporary reconstruction by cement (Masquelet's) and fixing the femur by a retrograde intermedullary nail from the knee joint. And after 6 months we have been elevated the cement from the femur and we are using an external AO tubular fixation monolateral to transfer the bone from subtrochanteric area to the distal part with guiding by intermedullary nail. Lengthening was monitored for a period of about 15 months.

Results:

The bone was transferred about 17.5 cm. And finally, we were continuing the treatment by filling an iliac graft to continuing treating the rest bone loss 2.5 cm and then fixed with a anatomic plate, the tumor was recovered without any localized relapse or metastasis. After 15 months of monitoring the consolidations was achieved in the femur. The hole massive losing bone was fully consolidated and the patient restoring their activities without metastases and local recurrence of the tumor site.

Conclusion:

- These three combination techniques have very useful procedures in reconstruction large bone defect in the treatment of different cases in orthopedic and traumatic surgeries. And the bone which was induced by this technic is natural and has the main properties of the original bone. And has less complications comparing with the others reconstructions technics like allografts, allograft prosthetic

composites, recycled autograft, and modular or custom-made endoprostheses. This will be added another useful technique and less costing for reconstructions massive bone losing in the lower or upper extremities.

Background:

- Osteosarcoma is the most common primary pediatric bone malignancy, derived from primitive bone-forming (osteoid producing) mesenchymal cells. It occurs in primary (no underlying bone pathology) and secondary forms (underlying pathology which has undergone malignant degeneration/conversion), accounting for approximately 20% of all primary bone tumors. Osteosarcoma is highly heterogeneous in its manifestation, which permits division into several subtypes according to the degree of differentiation, location within the bone, and histological variation. These subtypes vary in imaging appearance, demographics, and biological behavior. With the ceaseless work of numerous medical, surgical, and scientific professionals, treatment options and survivability have vastly improved in recent years,{1},

- Osteosarcoma has a bimodal age distribution. The initial peak is in the 10-to-14-year age group, corresponding to the pubertal growth spurt. This group represents the vast majority of primary osteosarcomas. In the 0-to-14-year age range, the incidence rate of osteosarcoma in all races and genders is four cases per year per million people (3.5 to 4.6, 95% confidence interval). This number rises to five cases per year per million people (4.6 to 5.6, 95% confidence interval) for the range 0-to-19-year age range

- Prior to the 1970s, amputation or joint disarticulations were standard and the only choice of treatment for the malignant bone tumors in lower extremities. However, now >90% of osteosarcoma resections are limb-sparing surgeries due to advancements in chemotherapy, medical imaging, and implant technology Options for limb salvage reconstruction after wide resection include osteoarticular allografts, allograft prosthetic composites, recycled autograft, and modular or custom-made endoprostheses. These reconstructions enable to recover to maximum their limb function more quickly. However, these limb functions often remain limited and deteriorate over time. Complications such as infections, nonunion of grafts, and bone resorption could eventually lead to amputation. Therefore, the aim of biological reconstruction is to achieve better limbs and almost normal limb function and reduce complications. On the other hand, some of these techniques carry a significant financial cost in our society.

- Previous clinical studies have shown the effectiveness of bone repair using two-stage surgery called the induced membrane (IM) or Masquelet's technique. The optimal wait before the second surgery is said to be 1 month. But now we can wait more than 1 month for doing the second stage in Masquelet's technique. In a one study was published on pubmed {Trauma Emerg Surg. 2020 Apr;46(2):313-315. doi: 10.1007/s00068-019-01242-x. PMID: 31667537 },{3}, it is successfully performing the IM technique while waiting an average of 6 months to carry out the second stage. the hypothesis that the IM maintains its beneficial capabilities, even at a later second stage, and that there is no relation between the speed of bone union and the wait between the first and second stage.

- External fixation has been widely used for the treatment of limb length discrepancy, deformity correction, and bone defect using distraction osteogenesis. Several studies in literature described the benefit of using momolateral external fixation for remonstration the bone by distraction osteogenesis.

- In the review published on Aug September 2023{4} in Germany has noted that the use of distraction osteogenesis represents an excellent method for defect reconstruction and treatment of secondary limb length discrepancies following bone tumor resection

- In study was published on 2017 Nov 25,{5}, to investigate the outcomes of segmental femoral defects treated with monolateral external fixation using the distraction osteogenesis. were retrospectively analyzed patients with femoral nonunion with segmental bone defects (> 6 cm) between January 2010 and January 2014 in one single trauma center. All patients were treated by distraction osteogenesis with monolateral external fixation. All surgeries were performed by the same surgeon. The Results: Forty-one patients were enrolled in this study for analysis. The length of the bone defect ranged from 6 to 17 cm. All patients eventually achieved healing, and no patient experienced recurrence of infection or newly developed infection. The average time needed for healing was 13 months. In terms of the incidence of complications, 3 cases axial deviations, 5 cases docking site nonunion, 23 cases pin-tract infection, 14 cases knee joint stiffness or their joint mobility declined, 2 cases osteogenesis insufficient in the distraction area,1 case refracture, and 2 cases loose external fixation pins. In terms of the evaluations of fracture healing and function, 30 patients excellent, 6 patients good, 5 patients fair, and 0 patient poor. In terms of postoperative function evaluations, 21 patients excellent, 9 patients good, 7 patients fair, and 4 patients poor. In the Conclusion in this study: For patients with femoral nonunion with large segmental bone defects, the monolateral external fixation can provide effective stability, improve compliance, and reduce complications.

- Callus distraction over an intramedullary nail is a nowadays widely used this technique for the reconstruction of intercalary defects of the femur and tibia after radical debridement of chronic osteomyelitis foci or bone tumors. In the earlier study published in J Bone Joint Surg Am. 2006 Oct,{6}; Thirteen patients who ranged in age from eighteen to sixty-three years underwent radical debridement to treat a nonunion associated with chronic osteomyelitis of the tibia (seven patients) and femur (six patients) The resulting segmental defects and any limb-length discrepancy were then reconstructed with use of distraction osteogenesis over an intramedullary nail. The mean size of the defect was 10 cm (range, 6 to 13 cm) in the femur and 7 cm (range, 5 to 10 cm) in the tibia. The mean external fixator index was 13.5 days per centimeter, the consolidation index was 31.7 days/cm, and the mean time to union at the docking site was nine months (range, five to sixteen months). At a mean follow-up of 47.3 months, eleven of the thirteen patients had an excellent result in terms of both bone and functional assessment.

- Other study published in 2009 {7}: Between January 1998 and October 2004, 17 patients with massive postosteomyelitis skeletal defects of the femur (11 men and

6 women), underwent the reconstruction procedure. After osteotomy of diaphysis of the femur, were inserted an intramedullary nail into the femur, and placed a monolateral external fixator with half-pins lateral to the nail. Lengthening was started on the seventh postoperative day at a rate of 1 mm/d. Once were achieved solid bone union, the monolateral external fixator were removed; the intramedullary nail remained for bone consolidation until reconstruction was complete. The assessment of the outcomes clinically and radiographically at a mean of 70.3 months postoperatively. The result: At follow-up (mean 70.3, range 14.0-96.0 mo), all the skeletal defects were filled, bone union at docking sites was achieved without bone graft and leg length discrepancies were less than 2.5 cm in all patients. The mean gain in length was 12.9 (range 10.2-18.4) cm. According to Paley and Maar's evaluation criteria, they graded the bone results as excellent for 10 patients, good for 5, fair for 1 and poor for 1. they graded the functional results as excellent for 12 patients, good for 4 and fair for 1. The mean external fixator index was 18.1 d/cm; the consolidation index was 35.7 d/cm. Ten patients experienced pin infection, and 1 patient experienced a recurrence of deep infection. There were no neurologic or vascular injuries.

- in our case we were used three techniques: the induced membrane, tubular external fixation and retrograde femoral nail techniques for treatment of large bone defect after the resection total of malignant bone tumor from the femur about 20 cm. in this combination of the treatment we achieved bone consolidation in the femur within 15 months. And this is the first case in the literatures were utilized this combination in the treatment.
- We were used the induced membrane (IM) technique in the first stage of surgery after the tumor resection then replaced the bone loss with cement (Methyl acolytate), in the second stage of the surgery after 6 months we were used external fixation to begin the distraction osteogenesis. And we were fixed the femur by retrograde intramedullary nail to guide the transferred bone segment.
- In this case, we used an external AO tubular fixation device. Normally this device was designed to fix the bone externally in open bone fractures. But in this case, we were adding an external piece to the bar of the external fixation to help the bone to transfer. By this modification of the AO external fixation was achieved a transformation of about 17.5 cm of bone. This is difficult to achieve with any other external fixing device. The using of this modified Ao external fixation was developed in our hospital during the Syrian War, by me. Because there were big numbers of cases we had ,and I found this is easily to used and is quickly procedure.

Clinical Findings and Diagnostic Assessment

Clinical presentation:

A 23-year-old undergoes an intensive sports course, he is **presenting with** the story of pain in the right femur several weeks ago, the pain increases with effort and hides with rest, without a trauma story. The pain becomes worsen and becomes permanent not relieved at rest or to sedatives,

Patient's antecedents: nonsmoking – nonalcoholic, No family history, no history of medication, no surgical or illness history.

on clinical examination: no swelling, no redness, or no warmth localized in the thigh, and he has only some tenderness in deep palpation in the distal third of the right femur. With little limping while walking. Without any limitation of movement in the hip or the knee joints. Neurovascular examination of the lower extremity was normal, no nodular hyperplasia was palpated in the groin or popliteal fossa.

Laboratory tests: They were normal., only had a slight rise in LDH (401)

Laboratory tests

WBC	Neut	Lym	Hb	Plt	Na^+	K^+
12000	63%	30%	14	386	141	3.8

ALP	ALT	LDH	ALB	CA	TB
115	47	401	47	2.5	5

Radiological study: *(Figure 1*)

X-ray of the right thigh: showed a heterogeneous lesion with unclear borders at the junction of the middle and distal third of the thigh, with destruction of the external bony cortex, extending for a distance of more than 7 cm distally towards the femoral condyles.

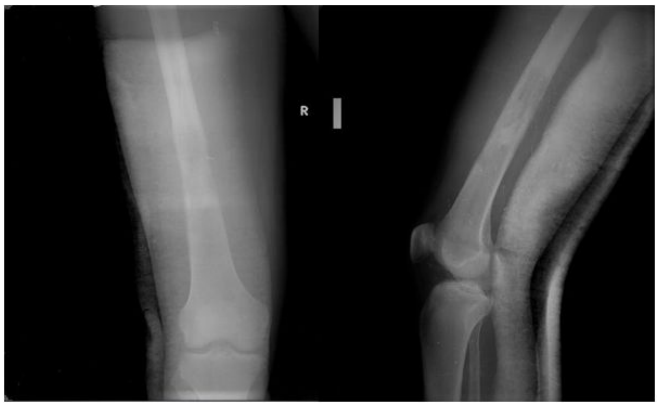


Figure 1)
XRy: of the right thigh showed a heterogeneous lesion with unclear borders at the junction of the middle and distal third of the thigh, without destruction of the external bony cortex, extending for a distance of more than 7 cm distally towards the femoral condyles..

Figure(1): X-ray of the femur

MRI, CT scan study, and needle-guided biopsy was undertaken for patient in the second step.

MRI: (*Figure 2*)

Was presented a Destructive injury in the femur bone with an accompanying soft tissue mass between the distal two-thirds of the right femur measuring 14 cm. Measures in cross sections 4.5-7 cm. Equal sign at the first time (T1). With heterogeneous enhancement after injection. With the appearance of edematous changes in the surrounding tissues, it has no relationship with the neurovascular bundle. No other findings abnormal.

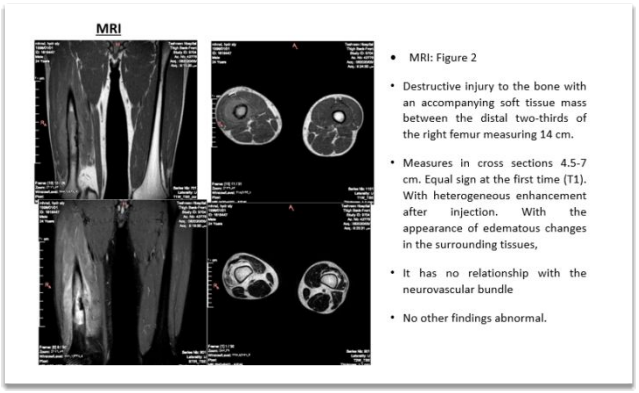


Figure (2): MRI of the femur

Axial tomography scan: CT cap CT Scanner: for the chest, abdomen, pelvis and limbs was performed There are no metastasizes have been showed.

MCT angiography: *(Figure 3)* There is no relationship between the tumor mass and the vessels

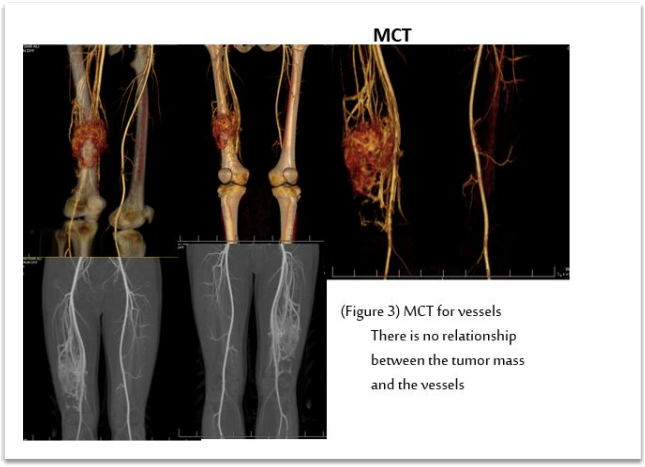


Figure (3): MCT angio-scan

Needle-guided biopsy:(*Figure 4*)

Was showed proliferation of abnormal spindle cells with abnormal divisions with foci of new bone formation consistent with: High grade fibroblastic osteosarcoma

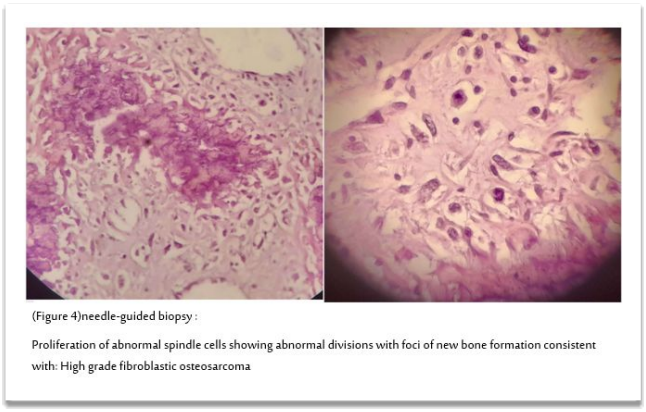


Figure 4: the result of needle guided biopsy

Diagnosis:

High grade fibroblastic osteosarcoma in the right femur

Therapeutic interventions

According to the local system in the treatment of bone tumors in our hospital, a multidisciplinary meeting M D T was held to discuss the diagnosis and the treatment methods. The decision was toked place during M D T is to perform surgery first, then after three weeks of the surgery will begin chemotherapy. contravention the therapeutic guideline in the treatment of this tumor. (The reason will be explained later).

Planning to surgery:

At the orthopedic department in the hospital,the surgery was planned based on three-dimensional CTs and the magnetic resonance imaging. The decision was: to perform the surgery in two stages. *(Figure 5)*

In the first stage: Wide excision of the affected bone and surrounding soft tissue. With a margin of safety in the bone and soft tissues, and putting the cement (methyl acrylate) in place of the removed bone and then fixing the femur with a retrograde nail from the knee joint.

In the second stage, remove the cement and sliding the bone from a subtrochanteric region to a distally by using the locally modified monoliteral external fixation device (AO).

The patient's approval of the surgical plan was taken in writing, after explaining the technique of surgery and the complications associated with it.

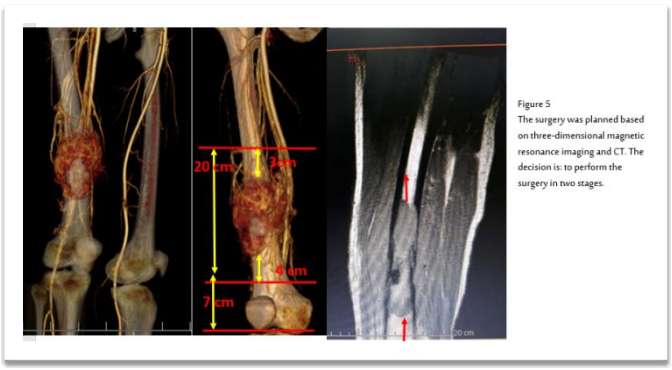


Figure (5): the 1st surgical planning

Surgical technique (first stage): *(Figure 6)*

The upper and lower bony boundaries of the tumor and the soft tissues surrounding the tumor were exposed. The bone is cut at a distance of 3 cm from the upper tumor border, 4 cm from the lower tumor border and 7 cm from the knee joint line. Femoral vessels (artery and vein) were exposed and preserved. Then we were Fixed the femur by Interlocking Retrograde Nail. Then we were putting in the place of bone loss with a Cement (methyl acrylate) as the first step of the in Masquelet's method for membrane induction. *(Figure 6)*

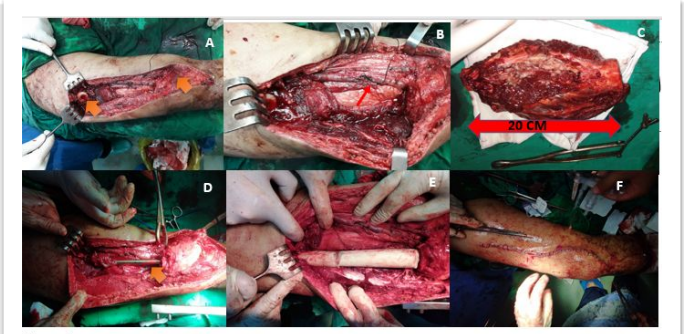


Figure 6
A- Severed bone boundaries after total tumor removal (broad arrows)
B- The femoral vascular bundle is preserved (small arrow)
C-the Femoral nail retrograde inserted from the knee joint
D- Bone cement around the Nile and fills the places of bone loss
E- Incision and closure

Figure(6): *A- severed bone boundaries after total tumor removal(broad arrows}.B- the femoral vascular bundle(small arrow).C- the tumor resected. D- the femoral retrograde Nail inserted from the Knee joint (broad arrow). E- the cement methyl acolyte filling the place of the bone resected around the Nail. F- skin closer.*

Follow-up after the first surgery:

After surgery, the patient was placed on antithrombotic treat: Clexan 40 mg for 20 days. Antibiotic treatment: cefazoline 1 g 3 daily for 3 days.
The patient was allowed to move after 3 days and walk with the help of crutches without weight bearing. Then, after the wound healed, the patient was transferred to the Oncology department to beginning chemotherapy.

X-ray image after the first surgery: *Figure (7)*

Figure (7)X-ray image after the first surgery

Figure (7): X-ray image after the first surgery

The entire bone fragment was sent to the pathological anatomy laboratory for histological study .The result of the pathological autopsy of the excised tumor is : High grade fibroblastic osteosarcoma. *Figure (8).*

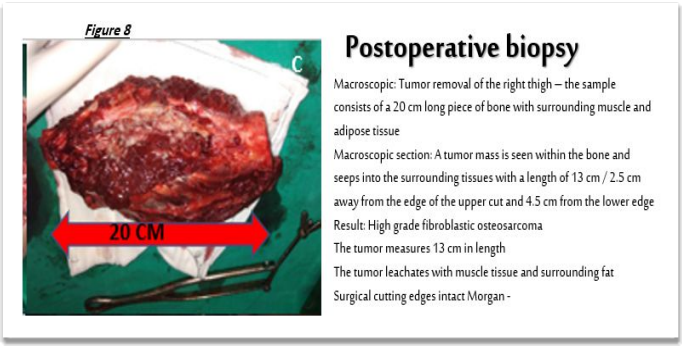


Figure (8): the postoperative bone resected biopsy

Treatment in the Department of Oncology:
The decision during the multidisciplinary meeting (MDT) was: to start surgical treatment first and then chemotherapy after the surgery. The reason, from the point of view of the oncologist, is that he conducted studies on the non-use of chemotherapy before surgery, so he had encouraging results in this tumor, as he noticed an increase in tumor growth during chemotherapy, which takes 5-6 months, in the period before the tumor removal, because he suggested the drugs which used in his department is not effective (bad medical synthesis) so he believed that the surgical treatment on first step of the treatment will prevents the opportunity for growth and increase in the size of the tumor. And he was studying 8 cases and this case of them.

Therefore, after surgery, the chemotherapy protocol was applied according to the oncology counselor. National Comprehensive Cancer Network's 2020 Guidelines.

During his stay in the oncology department, he was undergone to the necessary radiographic, CT and MRI, follow-ups to monitor for local relapse and for tumor metastases, all the results were normal. After the end of the chemotherapy, which lasted a period of 6 months, he was transferred to the Orthopedic department to complete the reconstruction surgical treatment.

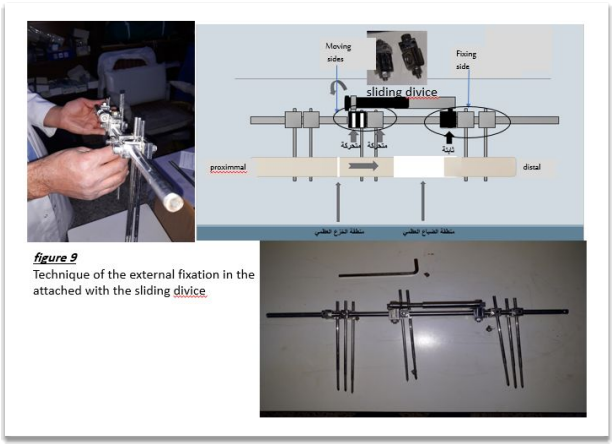
Second stage of surgery:

The patient's condition was rediscussed in our staff. That the bone to be reconstruct is about twenty centimeters. There was no grand choose methods in the treatment available in our country like protheses or artificial metallics osteo-conductions, due to the economic blockade imposed on Syria. We must use local methods available and not expensive. So that we were choose the simple methods available to us. The distraction osteogenesis method was chosen by used momolateral external fixation (AO) with a local modification by adding a distracting device to the external bar(Figure 9). And with helping by Interlocking Retrograde Nail will guiding the transferred bone.

Surgical Technique:

In the second stage of surgery, we were replaced the retrograde nail with another one more long, then the cement was removed, and the locally modified external fixation device was installed to perform the

transformation of the bone from the subtrochanteric area to the distal of the femur. Several biopsies were taken from the soft tissue , from the bone edges surrounding the cement and sending to the histological studies for searching the local recurrence.



(Figure 9): (the technique of the monoliteral external fixation which modified by myself by adding extractor dives to the long bar of the external fixation)

Immediately after surgery, the patient was given antibiotics and an anticoagulant according to local treatment protocols.

The results of anatomopathological studies were normal

(Figure 9) (the technique of the external fixation)

The bone lengthening began two weeks after surgery***. Figure 10***

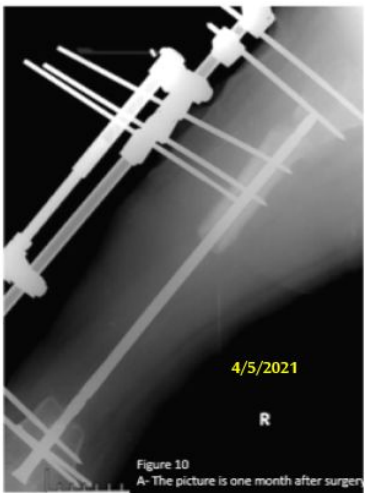


Figure (10): X-ry one momth post operation of the 2nd surgery (4/5/2021)

Follow-up:
transferring the bone was monitored for a period of about 6.5 months. The bone was transferred about 17.5 cm , and the patient was not allowed to walk with weightbearing on his limb in this period.*(figure 11.12)* The bone lengthening was stopped due to the presence of serous perfusion and the patient's discomfort from the pins of the device. About 2.5 cm left of the missing bone. *(figure 12)*

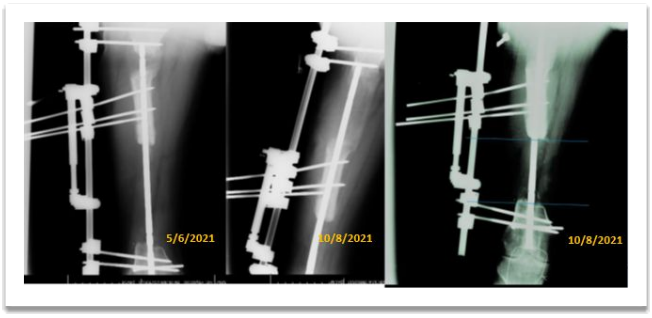


Figure (11): follow up after (2.and 4 months) of the 2nd surgery

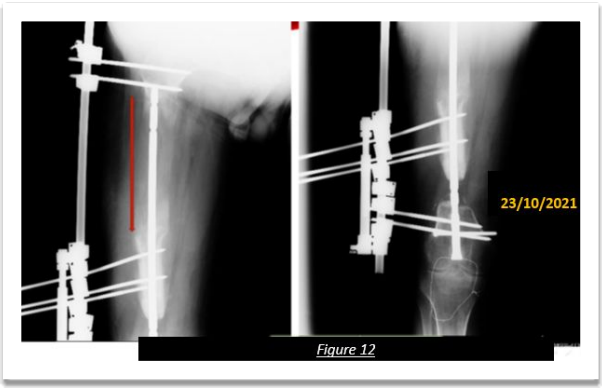


figure (12): post 6.5 months of the 2nd surgery .About 2.5 cm left of the missing bone

Third surgery

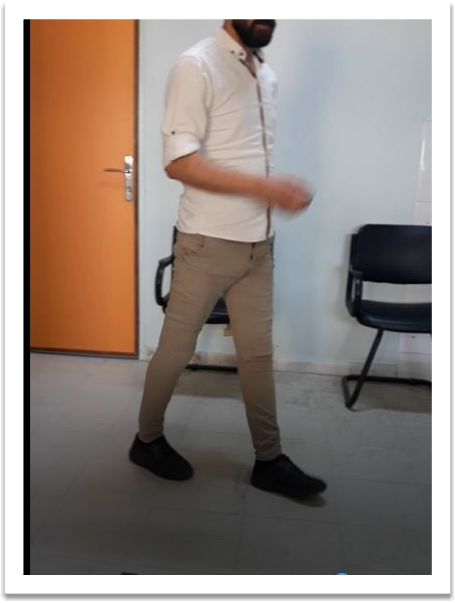
Bone graft was taken from the iliac crest to fill the remaining bone loss, and fixed with a short plate *figure (13),* several bone and tissue biopsies were taken from the area during the surgery, to the pathological anatomy lab for testing. (The results were normal).

Figure (13): 5 months post the 3rd surgery

Follow-up

In the Department of Oncology: Several radiological monitoring was conducted to the patient according to the monitoring protocols of the Oncology Department. All results were intact without localized relapse or metastases.

Two months after the bone graft, the patient was allowed to leave the crutches, walk full bearing on their lower limbs, and continue his life.



Sequels

Significant limp while walking. complete limitation in the movement at the knee joint, because:

- physical therapy cannot be performed during the lengthening period,
- And also, because there is an external fixator that extends far around the knee
- And also, because of the amount of losing in the bone and surrounding muscles in the tumoral area resected.
- In addition to the surgical exposure at the knee joint.

Conclusion:

In the using these three techniques in reconstruction about 20 cm of bone loss. we were achieved normal bone induced in 15 months without any major complications like infection or losing in the materials utilized or non-union in the bone. We founded it's better combination methods and less effectiveness for our patients in my country.

Treatment of massive bone loss in our region poses a big problem in treatment, due to the financial weakness of patients and the high costs of treatment, so that, we resort to lighter methods. It may be the longest in rehabilitation. In this case, I did not deviate from the traditional methods in the treating of mass bone loss, because the device that I modified myself, help to restore bone length of 17.5 cm. This distance in lengthening is difficult to achieve with the other approved lengthening device.

In this case, I did not deviate from the traditional methods in the treating of mass bone loss, these techniques is widely used in orthopedic surgery, but this time I found it's the first combination to treatment the large bone defect in medical literatures.

This patient **Currently**: is grateful for his results after surgery and he was thanked of all the medical staff to the grand care of him. And for giving him the opportunity to live by healing from the tumor and not needed to amputating his lower limb, he is now walking and moving freely and satisfied with his condition and continuing his work normally, and now he is free from tumor after 3 years.

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24-12-2023

Reconstruction of massive bone loss with the combination between Masquelet technique, and distraction osteogenesis method by using a locally modified AO tubular device, guided with an interlocking nail for reconstructing bone loss 20 cm due to a malignant bone tumor in the femur (case report)

Orthopedic Surgery Department, Oncology Department, Tichreen Military Hospital, Dmascus ,Syria

By: Dr.Imad Al Hariri, head of the orthopedic surgery department at Tichreen Hospital

Dr.Jihad Mando ,head of the Oncology department, at Tichreen Hospital

.Tel: 00963-938550183-Email: imadhariri65@gmail.com

***Keys words**: (external fixation,* . Masquelet technique*, distraction osteogenesis, reconstruction bone, osteosarcoma),*

Abstract:

- The massive bone loss after treatment surgical of the bone tumor pose big challenge to the orthopedists, this were depending on the site of the tumor in the bone. We were successfully treated bone loss in the femurs of a young man have about 20 cm of bone loss caused by wide resection of osteosarcoma in the femur. We had used three techniques :. Masquelet method and progressive induction method using external fixator(monolateral) and retrograde femoral nail. By two surgical stages. 6 months interval and follow up 15 months to achieve bone consolidation. And we findthis is the first case in the literatures were utilized for it this combination in the treatment.
- Masquelet's induced membrane technique (MIMT) is a relatively new, two-stage surgical procedure to reconstruct segmental bone defects, First performed by Dr. Masquelet in the mid-1980s, MIMT has shown great promise to revolutionize critical-sized bone defect repair and has several advantages over its alternative, distraction osteogenesis (DO). Also, its success in extremely challenging cases (defects > 15 cm). The delay of the second stage of this method for more than six months keeper the induced membrane preserving its biological properties
- External fixation has been widely used for the treatment of limb length discrepancy, deformity correction, and bone defect using distraction osteogenesis. We can use this technique for the treatment of reconstruction after malignant bone tumor resection. The advantages of external fixation for the treatment include a possibility of reconstructing the bone loss more than 6 cm.
- The used of interlocking nail with the combination of the external fixation can guide the bone segment pendent the transporting of the bone, becoming a widely used technique for the treatment of the bone deficiency by using distraction osteogenesis.
- We have used these techniques to reconstruct about 20 cm of bone loss caused by wide resection of osteosarcoma in the femur. Masquelet method and progressive induction method using external fixator and retrograde femoral nail. And this is making our case the first case in the literatures were utilized for it this combination in the treatment.
- The Ao external fixation is designs to fix the bone segments in open fractures. In this case, we used an external AO tubular fixation device by adding a piece to transform the bone. It achieved a transformation of about 17.5 cm of bone. This is difficult to achieve with any other external fixing device.

methods:

- A 23-year-old man, admitted to the hospital with a diagnosis: High grade fibroblasts osteosarcoma in his right femur at the junction of middle and third parts, a distance of the tumor is 14 cm in the femoral diaphysis, proximally to the line of the knee joint is about 7 cm. Treated surgically in two stages. The first stage: wide resection of the tumor (about 20 cm of bone with a safety margin of bone and surrounding soft tissues). With temporary reconstruction by cement (Masquelet's) and fixing the femur by a retrograde intermedullary nail from the knee joint. And after 6 months we have been elevated the cement from the femur and we are using an external AO tubular fixation monolateral to transfer the bone from subtrochanteric area to the distal part with guiding by intermedullary nail. Lengthening was monitored for a period of about 15 months.

Results:

The bone was transferred about 17.5 cm. And finally, we were continuing the treatment by filling an iliac graft to continuing treating the rest bone loss 2.5 cm and then fixed with a anatomic plate, the tumor was recovered without any localized relapse or metastasis. After 15 months of monitoring the consolidations was achieved in the femur. The hole massive losing bone was fully consolidated and the patient restoring their activities without metastases and local recurrence of the tumor site.

Conclusion:

- These three combination techniques have very useful procedures in reconstruction large bone defect in the treatment of different cases in orthopedic and traumatic surgeries. And the bone which was induced by this technic is natural and has the main properties of

the original bone. And has less complications comparing with the others reconstructions technics like allografts, allograft prosthetic composites, recycled autograft, and modular or custom-made endoprostheses. This will be added another useful technique and less costing for reconstructions massive bone losing in the lower or upper extremities.

Background:

- Osteosarcoma is the most common primary pediatric bone malignancy, derived from primitive bone-forming (osteoid producing) mesenchymal cells. It occurs in primary (no underlying bone pathology) and secondary forms (underlying pathology which has undergone malignant degeneration/conversion), accounting for approximately 20% of all primary bone tumors. Osteosarcoma is highly heterogeneous in its manifestation, which permits division into several subtypes according to the degree of differentiation, location within the bone, and histological variation. These subtypes vary in imaging appearance, demographics, and biological behavior. With the ceaseless work of numerous medical, surgical, and scientific professionals, treatment options and survivability have vastly improved in recent years,{1},

- Osteosarcoma has a bimodal age distribution. The initial peak is in the 10-to-14-year age group, corresponding to the pubertal growth spurt. This group represents the vast majority of primary osteosarcomas. In the 0-to-14-year age range, the incidence rate of osteosarcoma in all races and genders is four cases per year per million people (3.5 to 4.6, 95% confidence interval). This number rises to five cases per year per million people (4.6 to 5.6, 95% confidence interval) for the range 0-to-19-year age range

- Prior to the 1970s, amputation or joint disarticulations were standard and the only choice of treatment for the malignant bone tumors in lower extremities. However, now >90% of osteosarcoma resections are limb-sparing surgeries due to advancements in chemotherapy, medical imaging, and implant technology Options for limb salvage reconstruction after wide resection include osteoarticular allografts, allograft prosthetic composites, recycled autograft, and modular or custom-made endoprostheses. These reconstructions enable to recover to maximum their limb function more quickly. However, these limb functions often remain limited and deteriorate over time. Complications such as infections, nonunion of grafts, and bone resorption could eventually lead to amputation. Therefore, the aim of biological reconstruction is to achieve better limbs and almost normal limb function and reduce complications. On the other hand, some of these techniques carry a significant financial cost in our society.

- Previous clinical studies have shown the effectiveness of bone repair using two-stage surgery called the induced membrane (IM) or Masquelet's technique. The optimal wait before the second surgery is said to be 1 month. But now we can wait more than 1 month for doing the second stage in Masquelet's technique. In a one study was published on pubmed {Trauma Emerg Surg. 2020 Apr;46(2):313-315. doi: 10.1007/s00068-019-01242-x. PMID: 31667537 },{3}, it is successfully performing the IM technique while waiting an average of 6 months to carry out the second stage. the hypothesis that the IM maintains its beneficial capabilities, even at a later second stage, and that there is no relation between the speed of bone union and the wait between the first and second stage.

- External fixation has been widely used for the treatment of limb length discrepancy, deformity correction, and bone defect using distraction osteogenesis. Several studies in literature described the benefit of using momolateral external fixation for remonstration the bone by distraction osteogenesis.

- In the review published on Aug September 2023{4} in Germany has noted that the use of distraction osteogenesis represents an excellent method for defect reconstruction and treatment of secondary limb length discrepancies following bone tumor resection

- In study was published on 2017 Nov 25,{5}, to investigate the outcomes of segmental femoral defects treated with monolateral external fixation using the distraction osteogenesis. were retrospectively analyzed patients with femoral nonunion with segmental bone defects (> 6 cm) between January 2010 and January 2014 in one single trauma center. All patients were treated by distraction osteogenesis with monolateral external fixation. All surgeries were performed by the same surgeon. The Results: Forty-one patients were enrolled in this study for analysis. The length of the bone defect ranged from 6 to 17 cm. All patients eventually achieved healing, and no patient experienced recurrence of infection or newly developed infection. The average time needed for healing was 13 months. In terms of the incidence of complications, 3 cases axial deviations, 5 cases docking site nonunion, 23 cases pin-tract infection, 14 cases knee joint stiffness or their joint mobility declined, 2 cases osteogenesis insufficient in the distraction area,1 case refracture, and 2 cases loose external fixation pins. In terms of the evaluations of fracture healing and function, 30 patients excellent, 6 patients good, 5 patients fair, and 0 patient poor. In terms of postoperative function evaluations, 21 patients excellent, 9 patients good, 7 patients fair, and 4 patients poor. In the Conclusion in this study: For patients with femoral nonunion with large segmental bone defects, the monolateral external fixation can provide effective stability, improve compliance, and reduce complications.

- Callus distraction over an intramedullary nail is a nowadays widely used this technique for the reconstruction of intercalary defects of the femur and tibia after radical debridement of chronic osteomyelitis foci or bone tumors. In the earlier study published in J Bone Joint Surg Am. 2006 Oct,{6}; Thirteen patients who ranged in age from eighteen to sixty-three years underwent radical debridement to treat a nonunion associated with chronic osteomyelitis of the tibia (seven patients) and femur (six patients) The resulting segmental defects and any limb-length discrepancy were then reconstructed with use of distraction osteogenesis over an intramedullary nail. The mean size of the defect was 10 cm (range, 6 to 13 cm) in the femur and 7 cm (range, 5 to 10 cm) in the tibia. The mean external fixator index was 13.5 days per centimeter, the consolidation index was 31.7 days/cm, and the mean time to union at the docking site was nine months (range, five to sixteen months). At a mean follow-up of 47.3 months, eleven of the thirteen patients had an excellent result in terms of both bone and functional assessment.

- Other study published in 2009 {7}: Between January 1998 and October 2004, 17 patients with massive postosteomyelitis skeletal defects of the femur (11 men and

6 women), underwent the reconstruction procedure. After osteotomy of diaphysis of the femur, were inserted an intramedullary nail into the femur, and placed a monolateral external fixator with half-pins lateral to the nail. Lengthening was started on the seventh postoperative day at a rate of 1 mm/d. Once were achieved solid bone union, the monolateral external fixator were removed; the intramedullary nail remained for bone consolidation until reconstruction was complete. The assessment of the outcomes clinically and radiographically at a mean of 70.3 months postoperatively. The result: At follow-up (mean 70.3, range 14.0-96.0 mo), all the skeletal defects were filled, bone union at docking sites was achieved without bone graft and leg length discrepancies were less than 2.5 cm in all patients. The mean gain in length was 12.9 (range 10.2-18.4) cm. According to Paley and Maar's evaluation criteria, they graded the bone results as excellent for 10 patients, good for 5, fair for 1 and poor for 1. they graded the functional results as excellent for 12 patients, good for 4 and fair for 1. The mean external fixator index was 18.1 d/cm; the consolidation index was 35.7 d/cm. Ten patients experienced pin infection, and 1 patient experienced a recurrence of deep infection. There were no neurologic or vascular injuries.

- in our case we were used three techniques: the induced membrane, tubular external fixation and retrograde femoral nail techniques for treatment of large bone defect after the resection total of malignant bone tumor from the femur about 20 cm. in this combination of the treatment we achieved bone consolidation in the femur within 15 months. And this is the first case in the literatures were utilized this combination in the treatment.
- We were used the induced membrane (IM) technique in the first stage of surgery after the tumor resection then replaced the bone loss with cement (Methyl acolytate), in the second stage of the surgery after 6 months we were used external fixation to begin the distraction osteogenesis. And we were fixed the femur by retrograde intramedullary nail to guide the transferred bone segment.
- In this case, we used an external AO tubular fixation device. Normally this device was designed to fix the bone externally in open bone fractures. But in this case, we were adding an external piece to the bar of the external fixation to help the bone to transfer. By this modification of the AO external fixation was achieved a transformation of about 17.5 cm of bone. This is difficult to achieve with any other external fixing device. The using of this modified Ao external fixation was developed in our hospital during the Syrian War, by me. Because there were big numbers of cases we had ,and I found this is easily to used and is quickly procedure.

Clinical Findings and Diagnostic Assessment

Clinical presentation:

A 23-year-old undergoes an intensive sports course, he is **presenting with** the story of pain in the right femur several weeks ago, the pain increases with effort and hides with rest, without a trauma story. The pain becomes worsen and becomes permanent not relieved at rest or to sedatives,

Patient's antecedents: nonsmoking – nonalcoholic, No family history, no history of medication, no surgical or illness history.

on clinical examination: no swelling, no redness, or no warmth localized in the thigh, and he has only some tenderness in deep palpation in the distal third of the right femur. With little limping while walking. Without any limitation of movement in the hip or the knee joints. Neurovascular examination of the lower extremity was normal, no nodular hyperplasia was palpated in the groin or popliteal fossa.

Laboratory tests: They were normal., only had a slight rise in LDH (401)

Laboratory tests

WBC	Neut	Lym	Hb	Plt	Na^+	K^+
12000	63%	30%	14	386	141	3.8

ALP	ALT	LDH	ALB	CA	TB
115	47	401	47	2:5	5

Radiological study: *(Figure 1*)

X-ray of the right thigh: showed a heterogeneous lesion with unclear borders at the junction of the middle and distal third of the thigh, with destruction of the external bony cortex, extending for a distance of more than 7 cm distally towards the femoral condyles.

Figure 1)
XRy: of the right thigh showed a heterogeneous lesion with unclear borders at the junction of the middle and distal third of the thigh, without destruction of the external bony cortex, extending for a distance of more than 7 cm distally towards the femoral condyles..

Figure(1): X-ray of the femur

MRI, CT scan study, and needle-guided biopsy was undertaken for patient in the second step.

MRI: (*Figure 2*)

Was presented a Destructive injury in the femur bone with an accompanying soft tissue mass between the distal two-thirds of the right femur measuring 14 cm. Measures in cross sections 4.5-7 cm. Equal sign at the first time (T1). With heterogeneous enhancement after injection. With the appearance of edematous changes in the surrounding tissues, it has no relationship with the neurovascular bundle. No other findings abnormal.

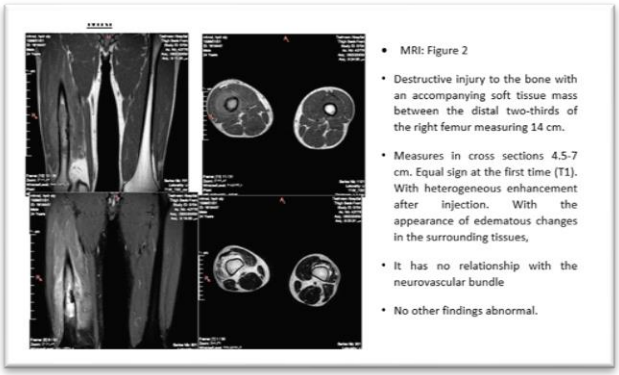


Figure (2): MRI of the femur

Axial tomography scan: CT cap CT Scanner: for the chest, abdomen, pelvis and limbs was performed There are no metastasizes have been showed.

MCT angiography: *(Figure 3)* There is no relationship between the tumor mass and the vessels

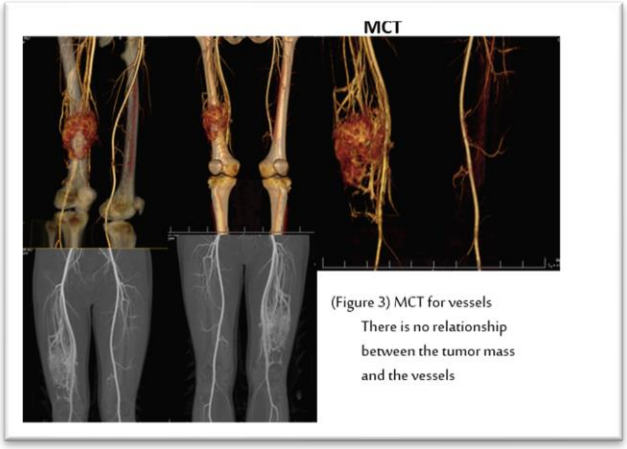


Figure (3): MCT angio-scan

Needle-guided biopsy:(*Figure 4*)

Was showed proliferation of abnormal spindle cells with abnormal divisions with foci of new bone formation consistent with: High grade fibroblastic osteosarcoma

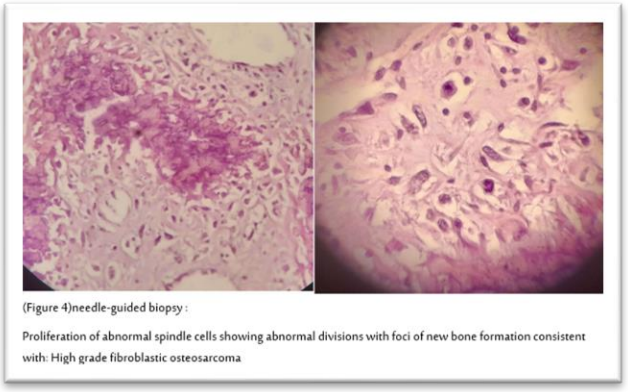


Figure 4: the result of needle guided biopsy

Diagnosis:

High grade fibroblastic osteosarcoma in the right femur

Therapeutic interventions

According to the local system in the treatment of bone tumors in our hospital, a multidisciplinary meeting M D T was held to discuss the diagnosis and the treatment methods. The decision was toked place during M D T is to perform surgery first, then after three weeks of the surgery will begin chemotherapy. contravention the therapeutic guideline in the treatment of this tumor. (The reason will be explained later).

Planning to surgery:

At the orthopedic department in the hospital,the surgery was planned based on three-dimensional CTs and the magnetic resonance imaging. The decision was: to perform the surgery in two stages. *(Figure 5)*

In the first stage: Wide excision of the affected bone and surrounding soft tissue. With a margin of safety in the bone and soft tissues, and putting the cement (methyl acrylate) in place of the removed bone and then fixing the femur with a retrograde nail from the knee joint.

In the second stage, remove the cement and sliding the bone from a subtrochanteric region to a distally by using the locally modified monoliteral external fixation device (AO).

The patient's approval of the surgical plan was taken in writing, after explaining the technique of surgery and the complications associated with it.

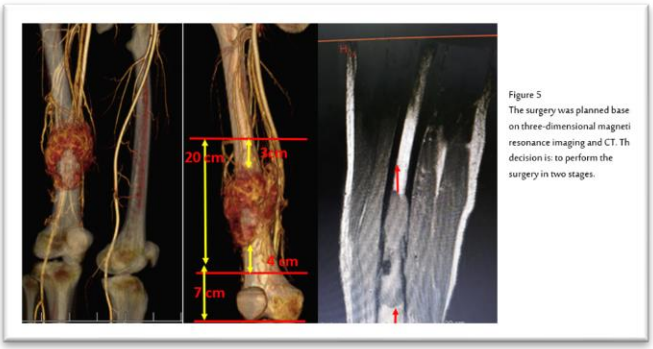
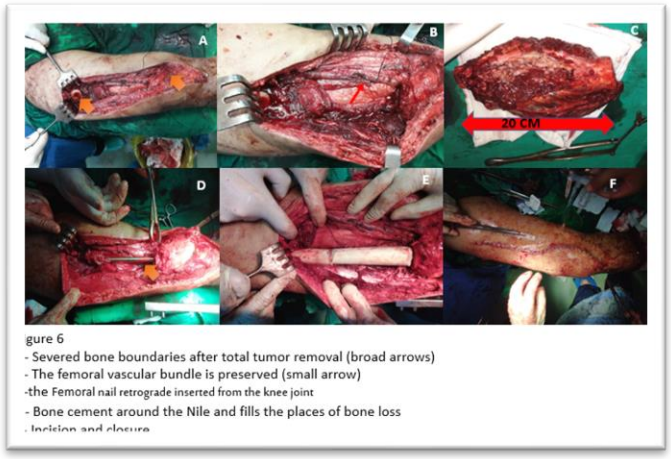


Figure (5): the 1st surgical planning

Surgical technique (first stage): *(Figure 6)*

The upper and lower bony boundaries of the tumor and the soft tissues surrounding the tumor were exposed. The bone is cut at a distance of 3 cm from the upper tumor border, 4 cm from the lower tumor border and 7 cm from the knee joint line. Femoral vessels (artery and vein) were exposed and preserved. Then we were Fixed the femur by Interlocking Retrograde Nail. Then we were putting in the place of bone loss with a Cement (methyl acrylate) as the first step of the in Masquelet's method for membrane induction. *(Figure 6)*



Figure(6): *A- severed bone boundaries after total tumor removal(broad arrows}.B- the femoral vascular bundle(small arrow).C- the tumor resected. D- the femoral retrograde Nail inserted from the Knee joint (broad arrow). E- the cement methyl acolyte filling the place of the bone resected around the Nail. F- skin closer.*

Follow-up after the first surgery:

After surgery, the patient was placed on antithrombotic treat: Clexan 40 mg for 20 days. Antibiotic treatment: cefazoline 1 g 3 daily for 3 days.
The patient was allowed to move after 3 days and walk with the help of crutches without weight bearing. Then, after the wound healed, the patient was transferred to the Oncology department to beginning chemotherapy.

X-ray image after the first surgery: *Figure (7)*

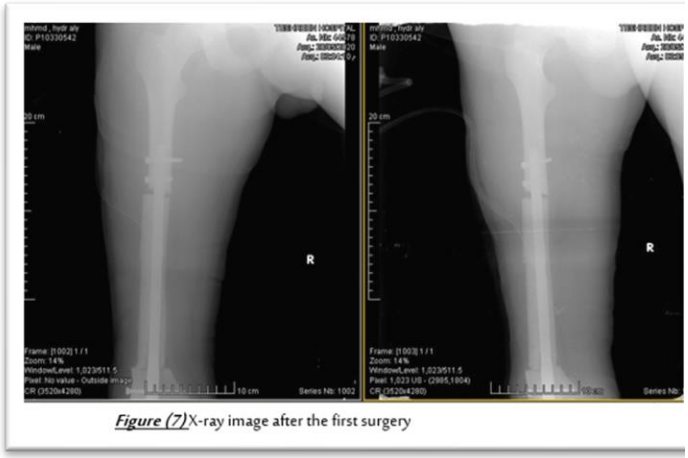


Figure (7): X-ray image after the first surgery

The entire bone fragment was sent to the pathological anatomy laboratory for histological study .The result of the pathological autopsy of the excised tumor is : High grade fibroblastic osteosarcoma. *Figure (8).*

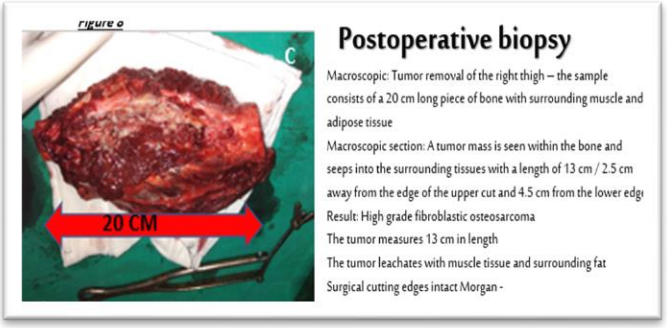


Figure (8): the postoperative bone resected biopsy

Treatment in the Department of Oncology:
The decision during the multidisciplinary meeting (MDT) was: to start surgical treatment first and then chemotherapy after the surgery. The reason, from the point of view of the oncologist, is that he conducted studies on the non-use of chemotherapy before surgery, so he had encouraging results in this tumor, as he noticed an increase in tumor growth during chemotherapy, which takes 5-6 months, in the period before the tumor removal, because he suggested the drugs which used in his department is not effective (bad medical synthesis) so he believed that the surgical treatment on first step of the treatment will prevents the opportunity for growth and increase in the size of the tumor. And he was studying 8 cases and this case of them.

Therefore, after surgery, the chemotherapy protocol was applied according to the oncology counselor. National Comprehensive Cancer Network's 2020 Guidelines.

During his stay in the oncology department, he was undergone to the necessary radiographic, CT and MRI, follow-ups to monitor for local relapse and for tumor metastases, all the results were normal. After the end of the chemotherapy, which lasted a period of 6 months, he was transferred to the Orthopedic department to complete the reconstruction surgical treatment.

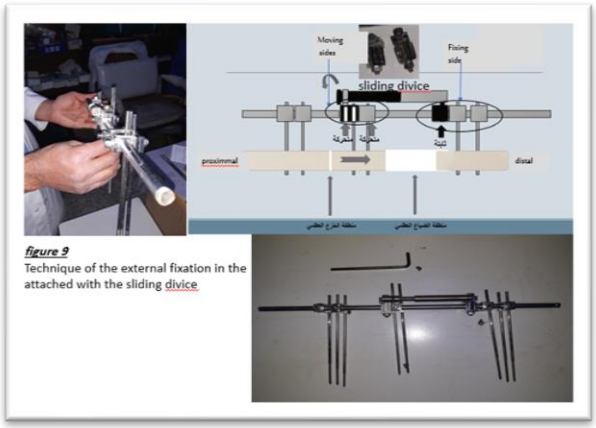
Second stage of surgery:

The patient's condition was rediscussed in our staff. That the bone to be reconstruct is about twenty centimeters. There was no grand choose methods in the treatment available in our country like protheses or artificial metallics osteo-conductions, due to the economic blockade imposed on Syria. We must use local methods available and not expensive. So that we were choose the simple methods available to us. The distraction osteogenesis method was chosen by used momolateral external fixation (AO) with a local modification by adding a distracting device to the external bar(Figure 9). And with helping by Interlocking Retrograde Nail will guiding the transferred bone.

Surgical Technique:

In the second stage of surgery, we were replaced the retrograde nail with another one more long, then the cement was removed, and the locally modified external fixation device was installed to perform the transformation of the bone from the subtrochanteric area to the distal

of the femur. Several biopsies were taken from the soft tissue , from the bone edges surrounding the cement and sending to the histological studies for searching the local recurrence.



(Figure 9): (the technique of the monoliteral external fixation which modified by myself by adding extractor dives to the long bar of the external fixation)

Immediately after surgery, the patient was given antibiotics and an anticoagulant according to local treatment protocols.

The results of anatomopathological studies were normal

(Figure 9) (the technique of the external fixation)

The bone lengthening began two weeks after surgery**. *Figure 10***

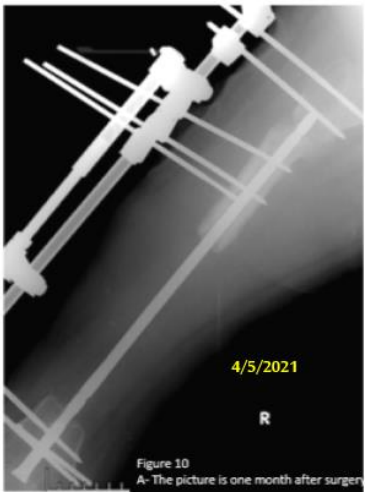


Figure (10): X-ry one momth post operation of the 2nd surgery (4/5/2021)

Follow-up:
transferring the bone was monitored for a period of about 6.5 months. The bone was transferred about 17.5 cm , and the patient was not allowed to walk with weightbearing on his limb in this period.*(figure 11.12)* The bone lengthening was stopped due to the presence of serous perfusion and the patient's discomfort from the pins of the device. About 2.5 cm left of the missing bone. *(figure 12)*

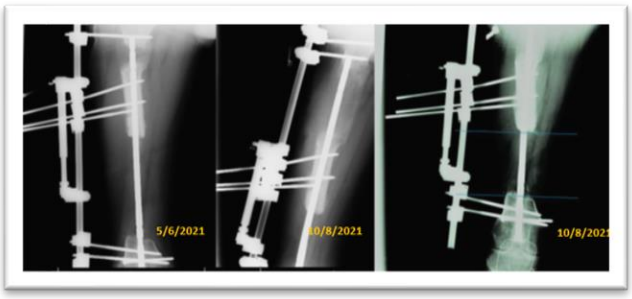


Figure (11): follow up after (2.and 4 months) of the 2nd surgery

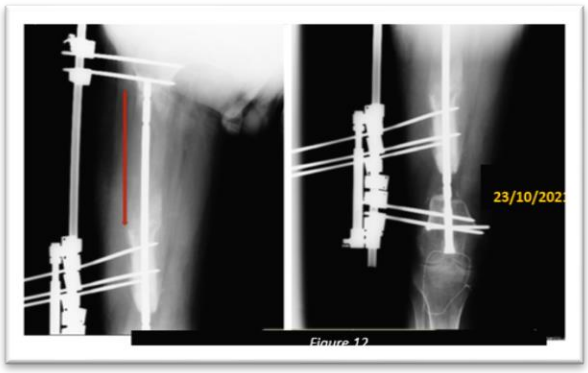


figure (12): post 6.5 months of the 2nd surgery .About 2.5 cm left of the missing bone

Third surgery

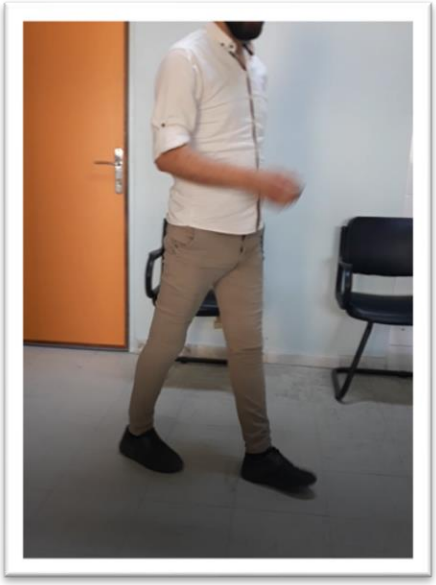
Bone graft was taken from the iliac crest to fill the remaining bone loss, and fixed with a short plate *figure (13),* several bone and tissue biopsies were taken from the area during the surgery, to the pathological anatomy lab for testing. (The results were normal).

Figure (13): 5 months post the 3rd surgery

Follow-up

In the Department of Oncology: Several radiological monitoring was conducted to the patient according to the monitoring protocols of the Oncology Department. All results were intact without localized relapse or metastases.

Two months after the bone graft, the patient was allowed to leave the crutches, walk full bearing on their lower limbs, and continue his life.



Sequels

Significant limp while walking. complete limitation in the movement at the knee joint, because:

- physical therapy cannot be performed during the lengthening period,
- And also, because there is an external fixator that extends far around the knee
- And also, because of the amount of losing in the bone and surrounding muscles in the tumoral area resected.
- In addition to the surgical exposure at the knee joint.

Conclusion:

In the using these three techniques in reconstruction about 20 cm of bone loss. we were achieved normal bone induced in 15 months without any major complications like infection or losing in the materials utilized or non-union in the bone. We founded it's better combination methods and less effectiveness for our patients in my country.

Treatment of massive bone loss in our region poses a big problem in treatment, due to the financial weakness of patients and the high costs of treatment, so that, we resort to lighter methods. It may be the longest in rehabilitation. In this case, I did not deviate from the traditional methods in the treating of mass bone loss, because the device that I modified myself, help to restore bone length of 17.5 cm. This distance in lengthening is difficult to achieve with the other approved lengthening device.

In this case, I did not deviate from the traditional methods in the treating of mass bone loss, these techniques is widely used in orthopedic surgery, but this time I found it's the first combination to treatment the large bone defect in medical literatures.

This patient **Currently**: is grateful for his results after surgery and he was thanked of all the medical staff to the grand care of him. And for giving him the opportunity to live by healing from the tumor and not needed to amputating his lower limb, he is now walking and moving freely and satisfied with his condition and continuing his work normally, and now he is free from tumor after 3 years.

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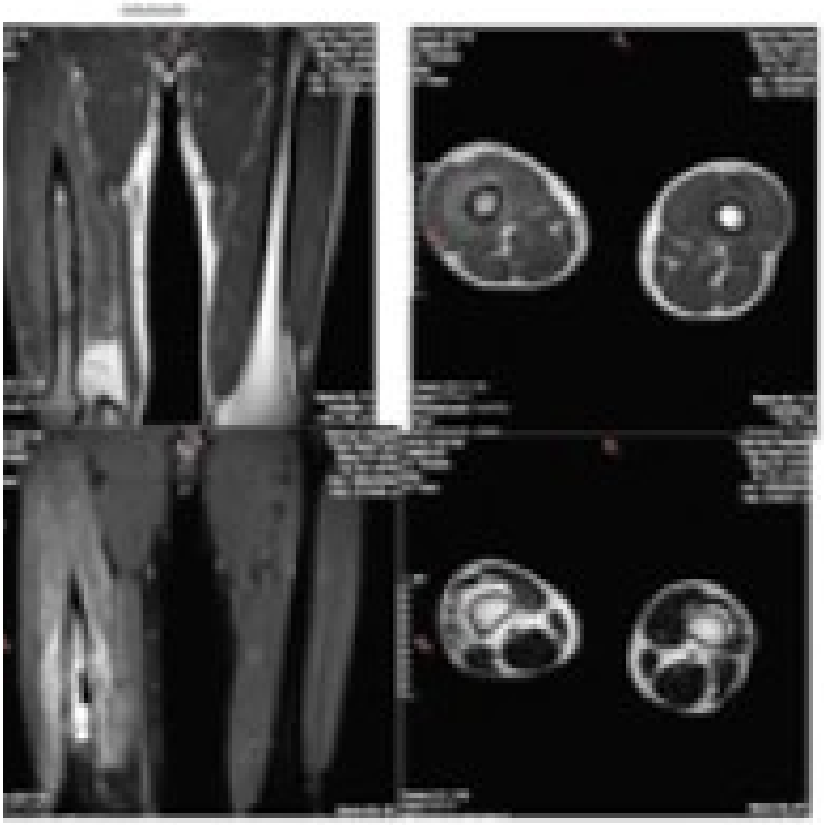
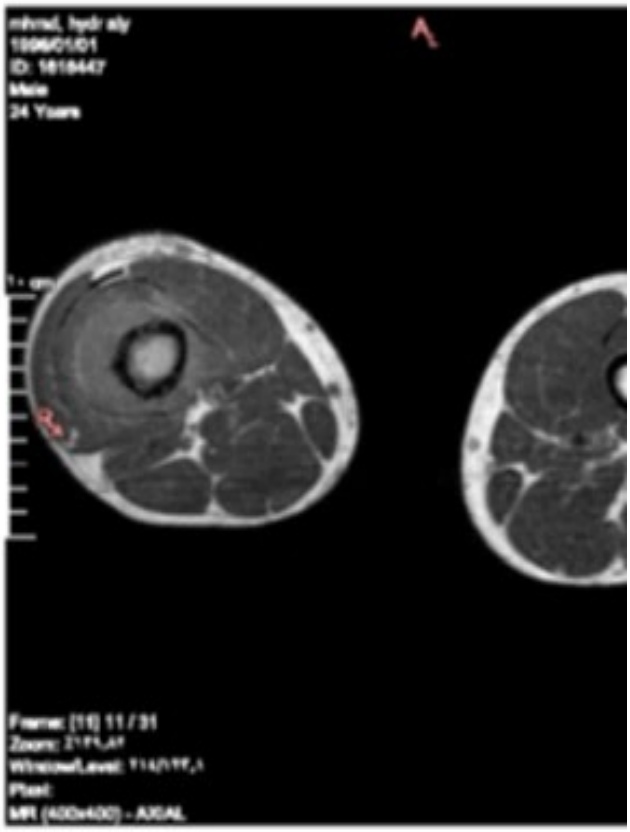
6. *J Bone Joint Surg Am ٢٠٠٦ Oct;88(10):2137-45 .doi: 10.2106/JBJS.E.01152. Reconstruction of segmental bone defects due to chronic osteomyelitis with use of an external fixator and an intramedullary nail Mehmet Kocaoglu 1, Levent Eralp, Haroon Ur Rashid, Cengiz Sen, Kerem Bilsel Affiliations expand PMID: 17015589 DOI: 10.2106/JBJS.E.01152*
7. *Can J Surg ٢٠٠٩ . Apr;52(2):103-11 Distraction osteogenesis technique using an intramedullary nail and a monolateral external fixator in the reconstruction of massive postosteomyelitis skeletal defects of the femur Zhihong Li 1, Xiangsheng Zhang, Liqun Duan, Xiaoming Chen Affiliations expand PMID: 19399204 PMCID: PMC2663497 Free PMC article*
8.

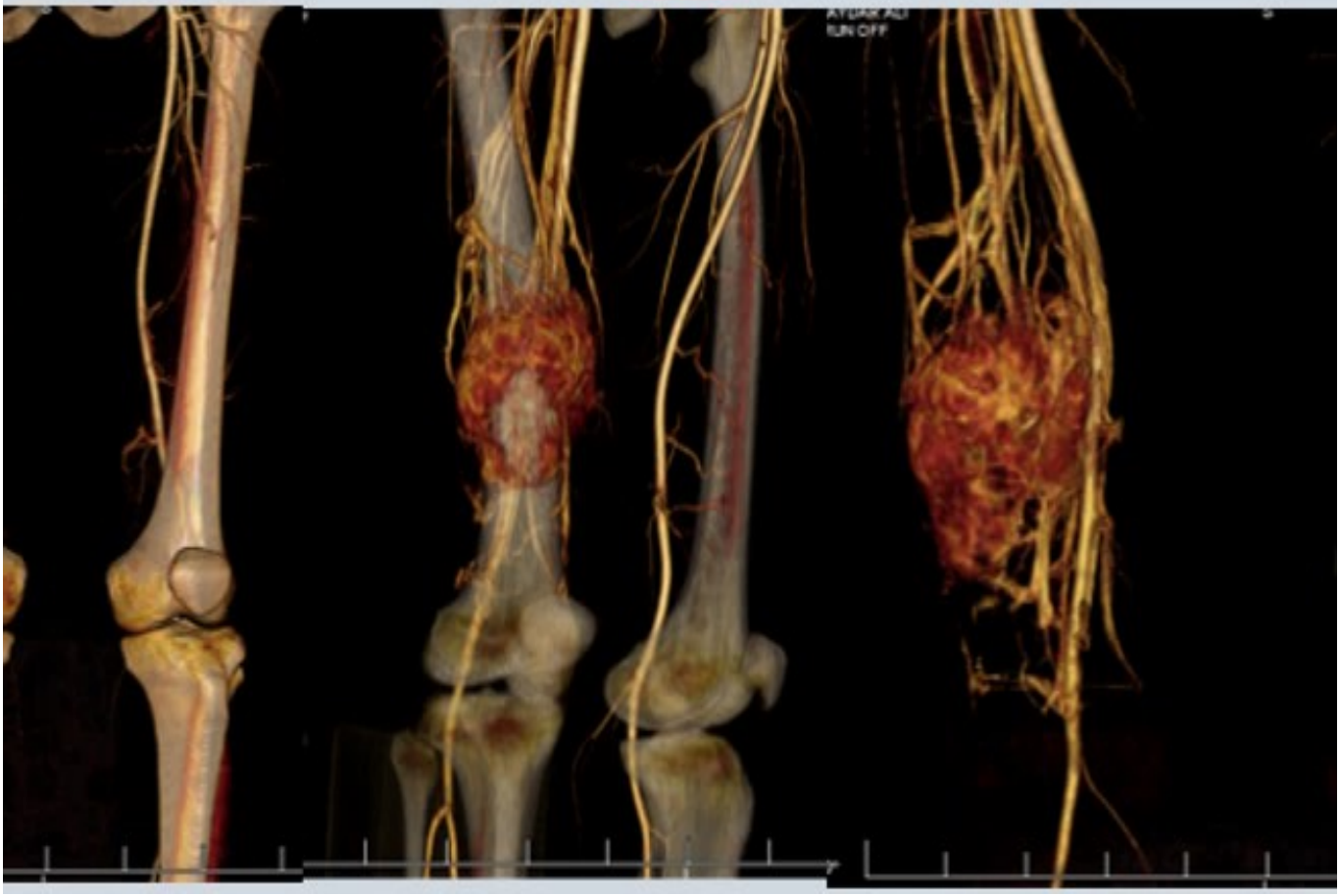


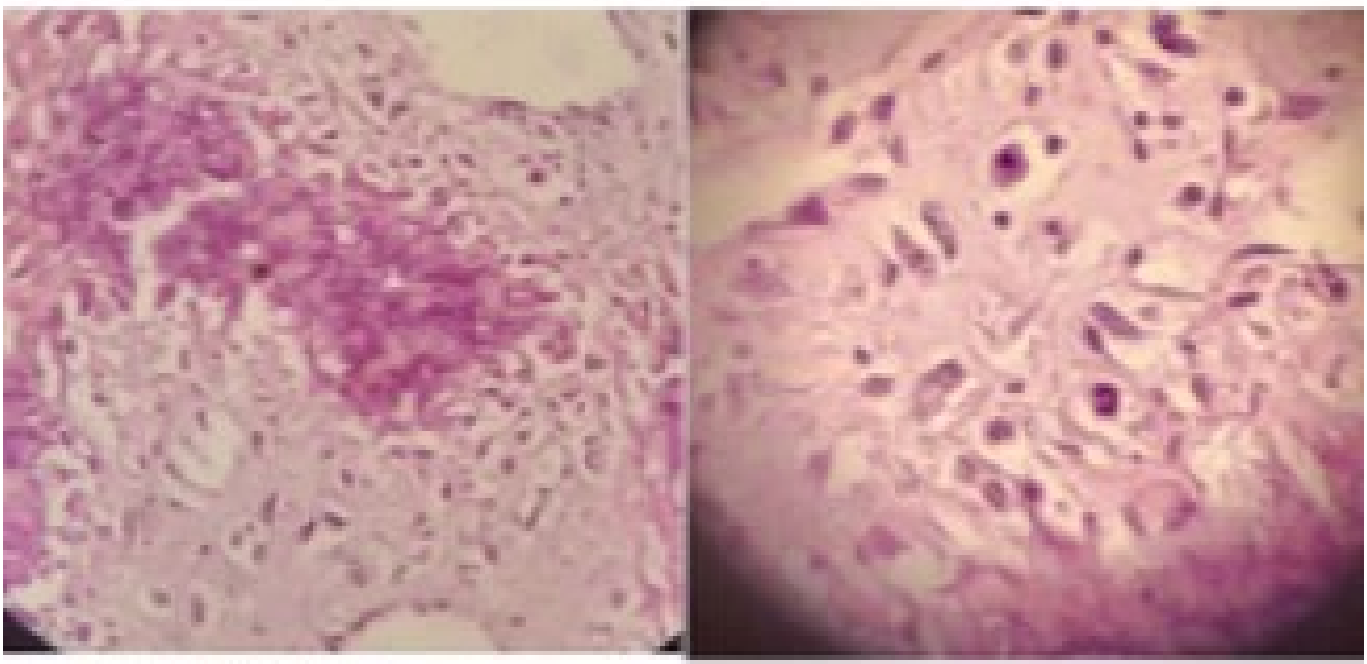
- MRI: Figure 2
- Destructive injury to the bone with an accompanying soft tissue mass between the distal two-thirds of the right femur measuring 14 cm.
- Measures in cross sections 4.5-7 cm. Equal sign at the first time (T1). With heterogeneous enhancement after injection. With the appearance of edematous changes in the surrounding tissues.
- It has no relationship with the neurovascular bundle
- No other findings abnormal.

MRI



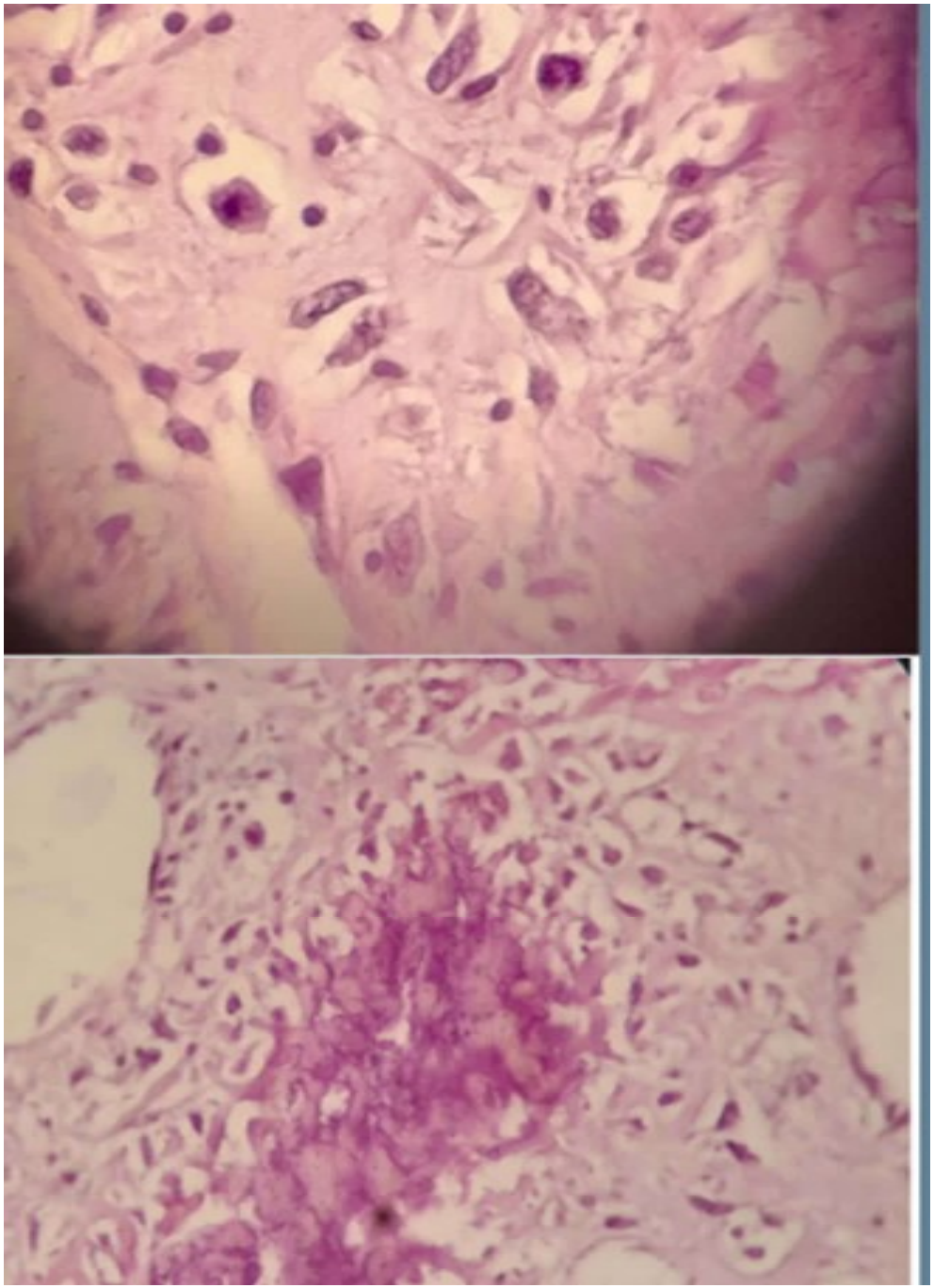
MCT angio

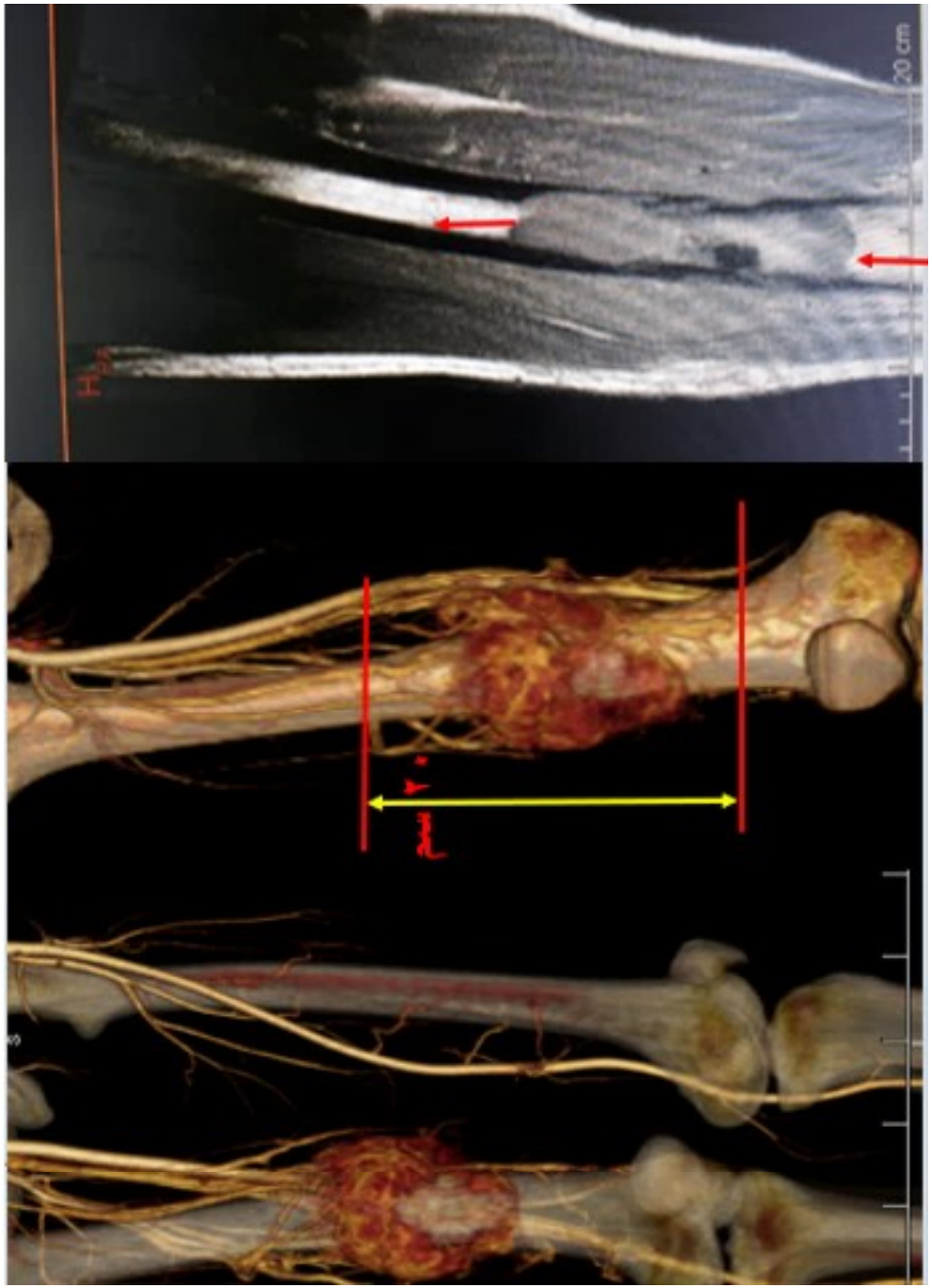




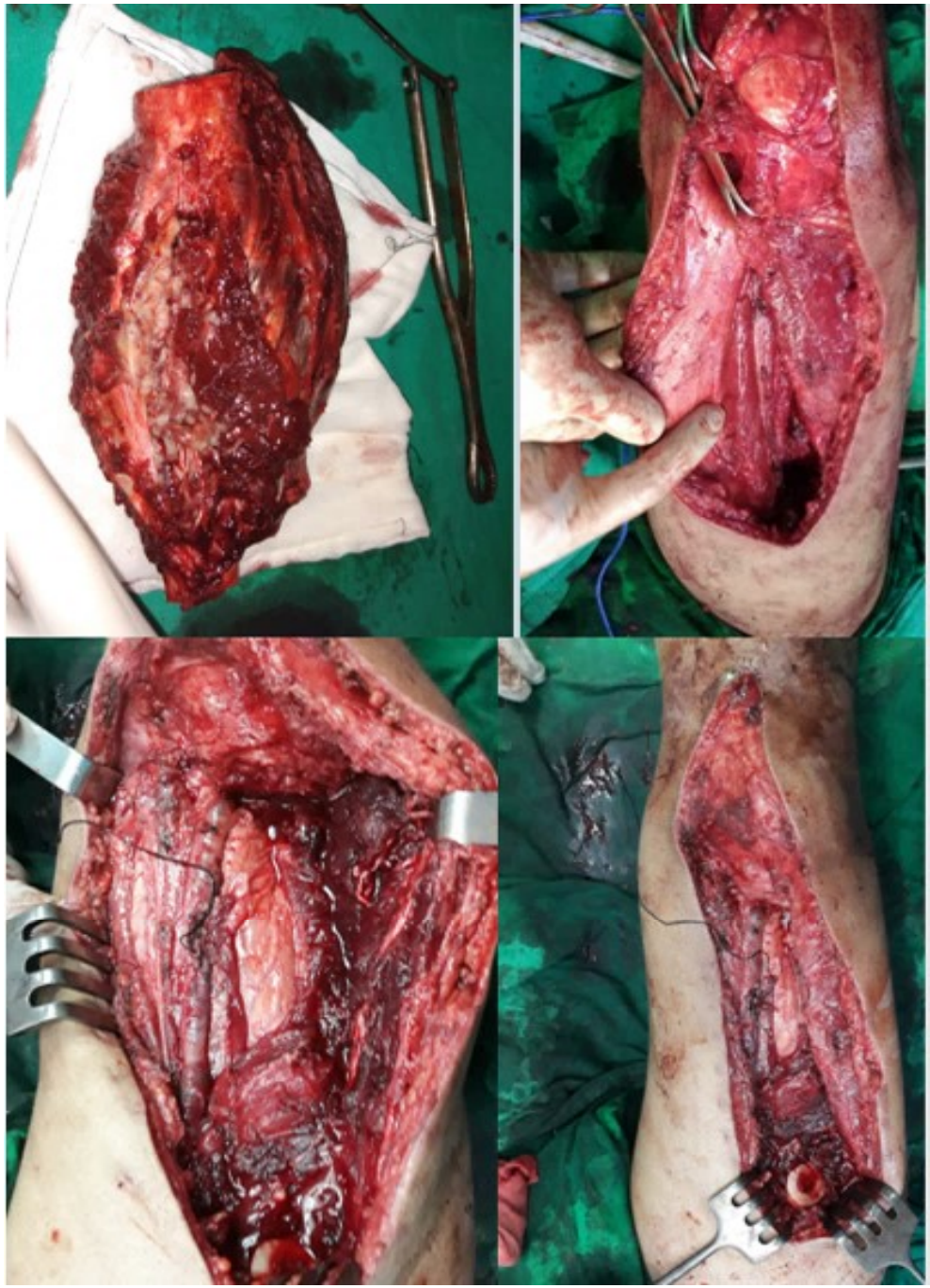
igure 4:(needle-guided biopsy:

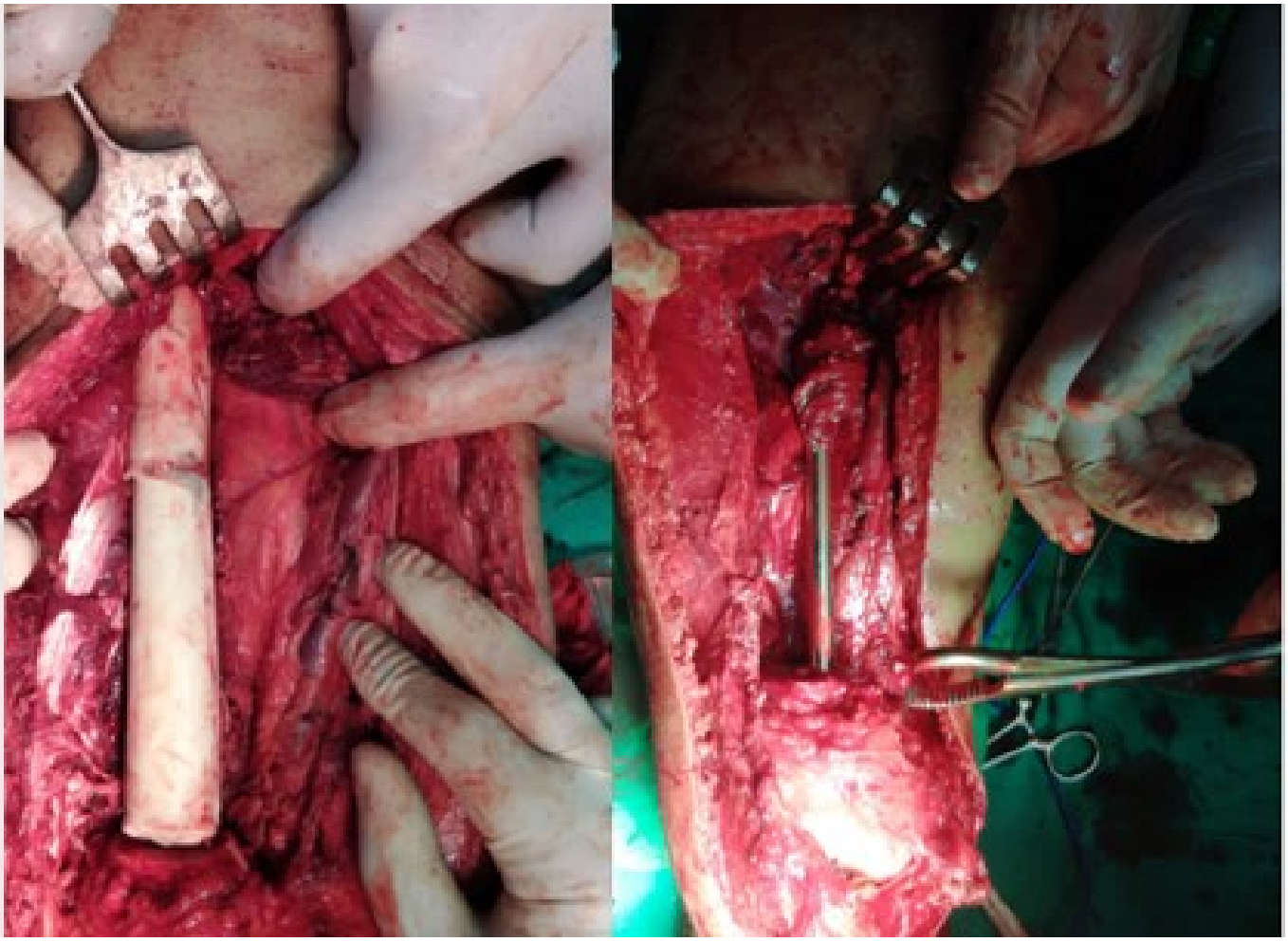
roliferation of abnormal spindle cells showing abnormal divisions with foci of new bone formation consistent ith High grade fibroblastic osteosarcoma

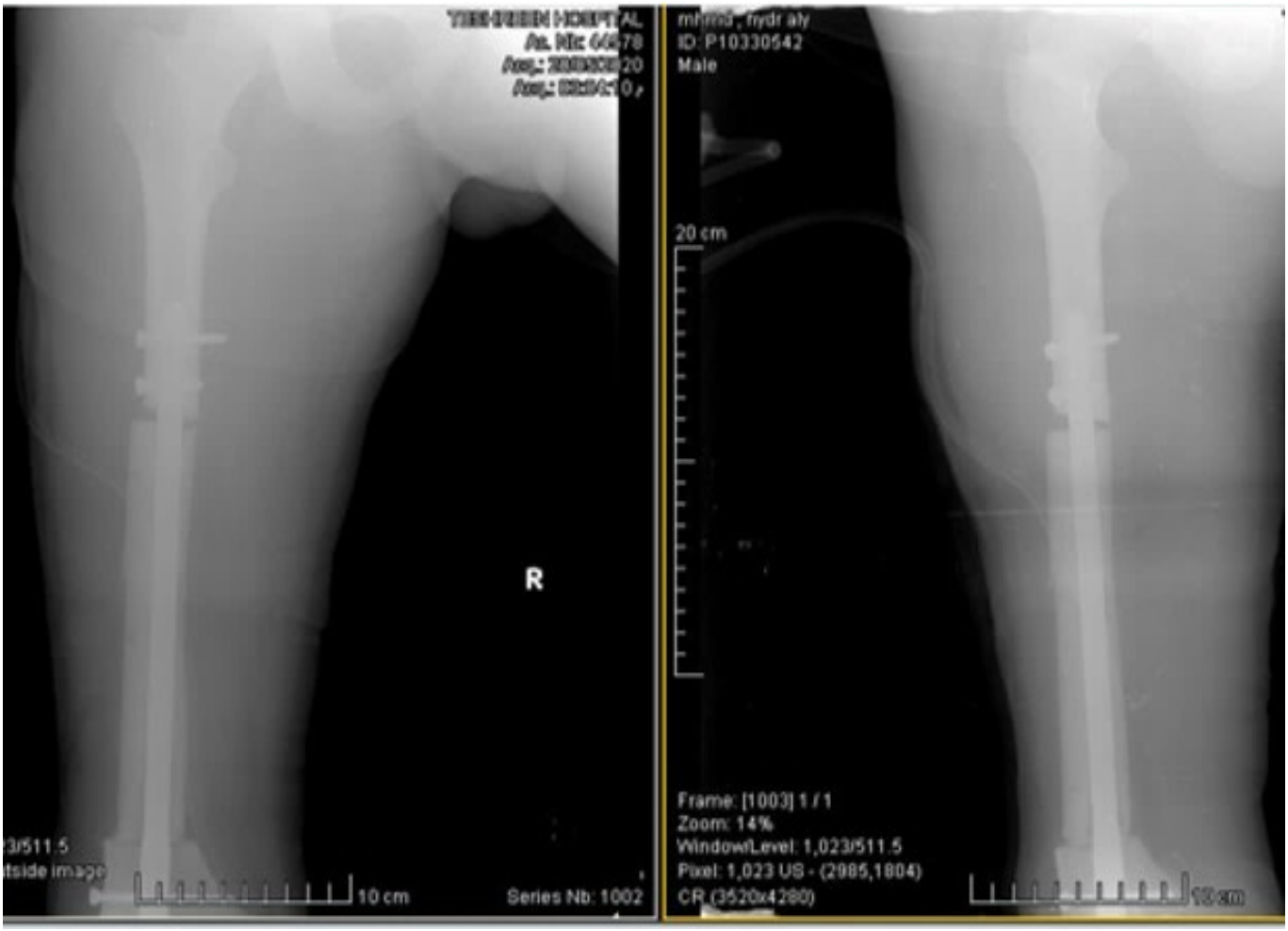


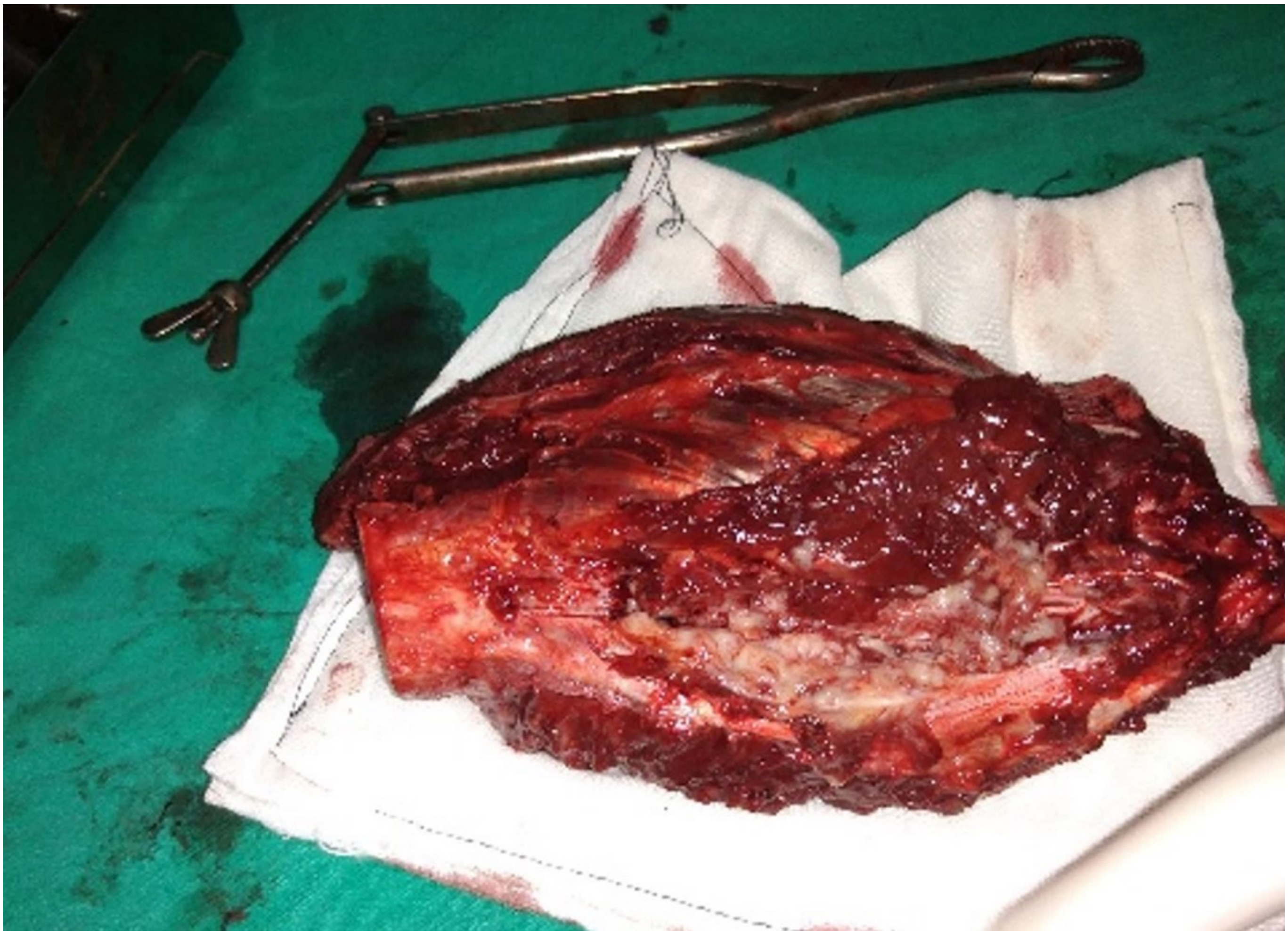


- Severed bone boundaries after total tumor removal (broad arrow)
- The femoral vascular bundle is preserved (small arrow)
- the femoral nail nonspirale inserted from the knee joint
- Bone cement around the Nile and fills the places of bone loss

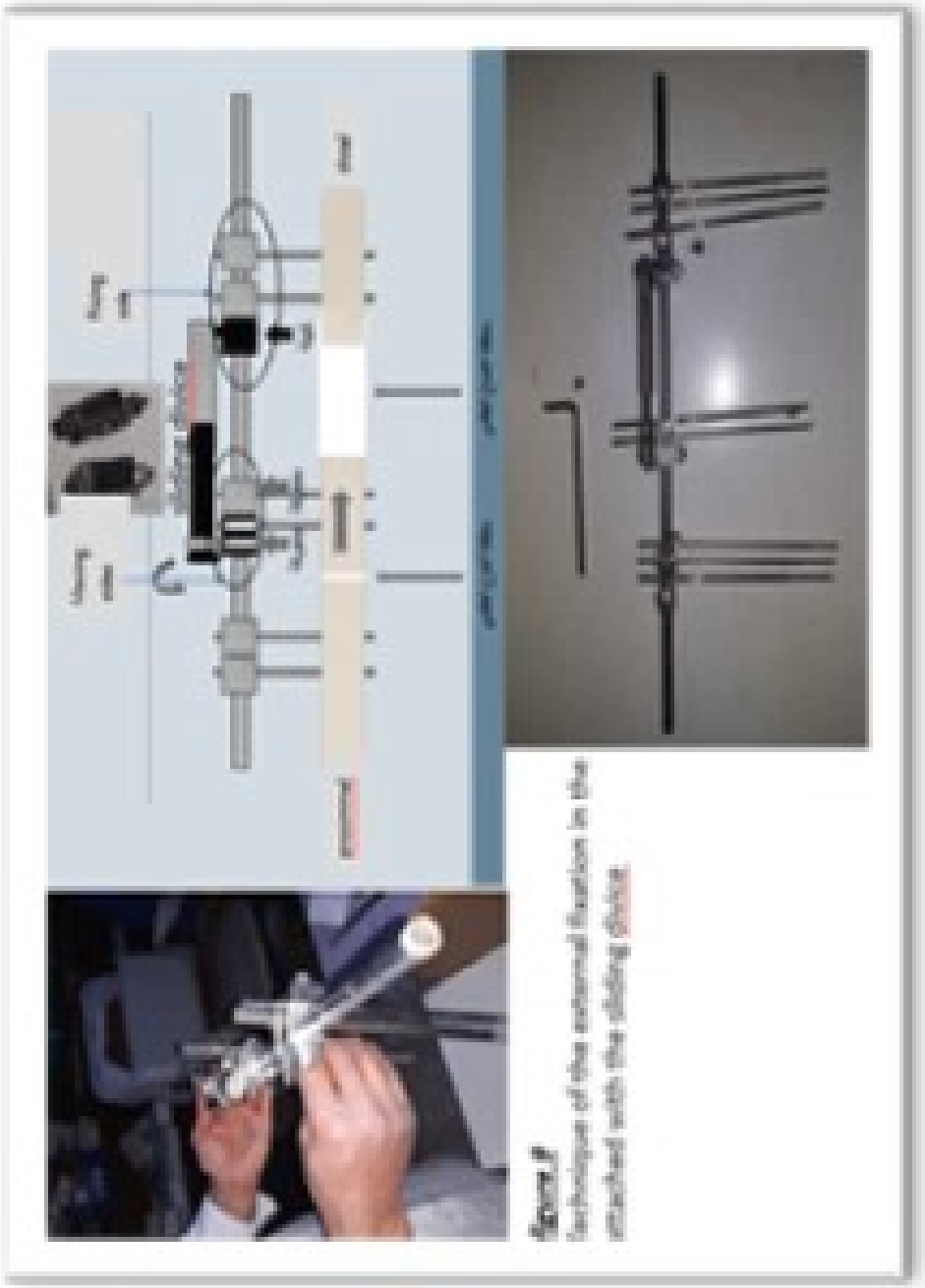




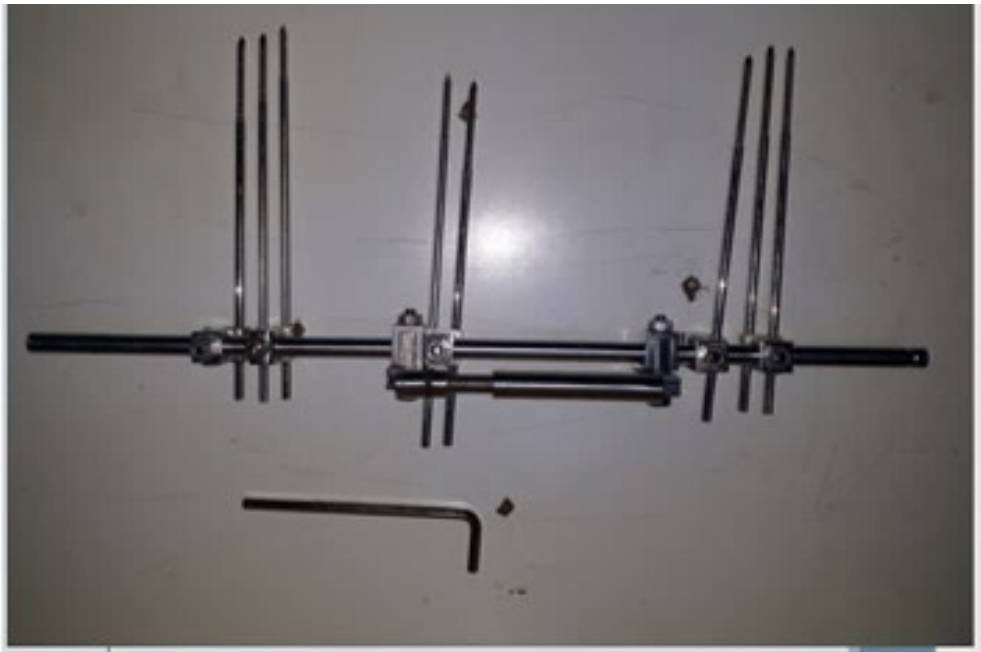

ID: P10330542
Male
20 cm
R
10 cm
Series Nb: 1002
Frame: [1003] 1 / 1
Zoom: 14%
Window\Level: 1,023\511.5
Pixel: 1,023 US - (2985,1804)
CR (3520x4280)

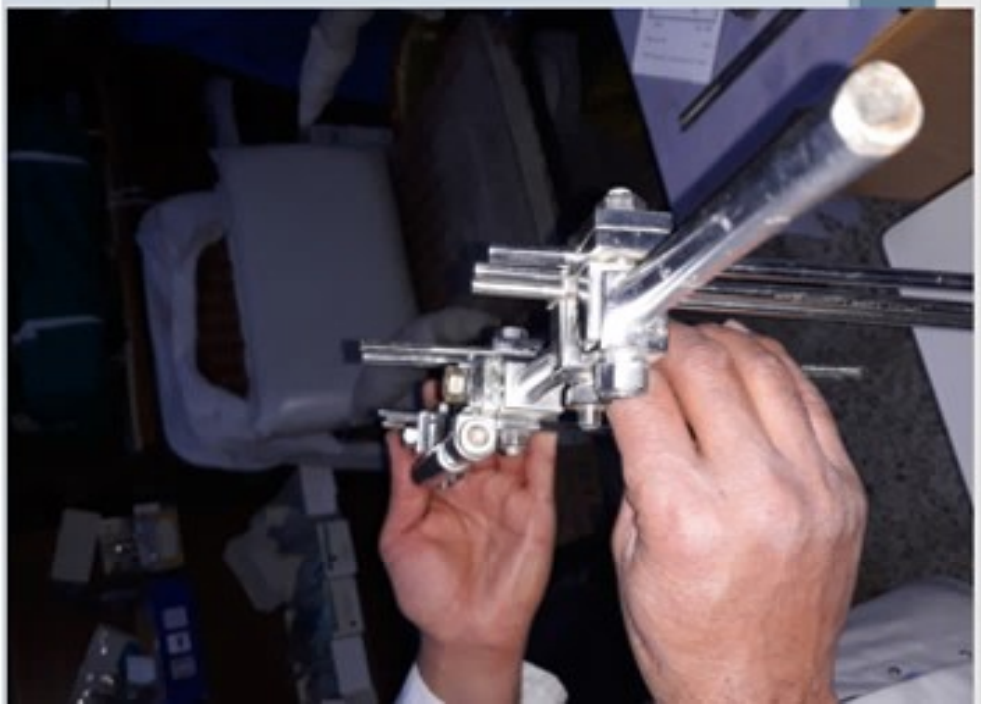


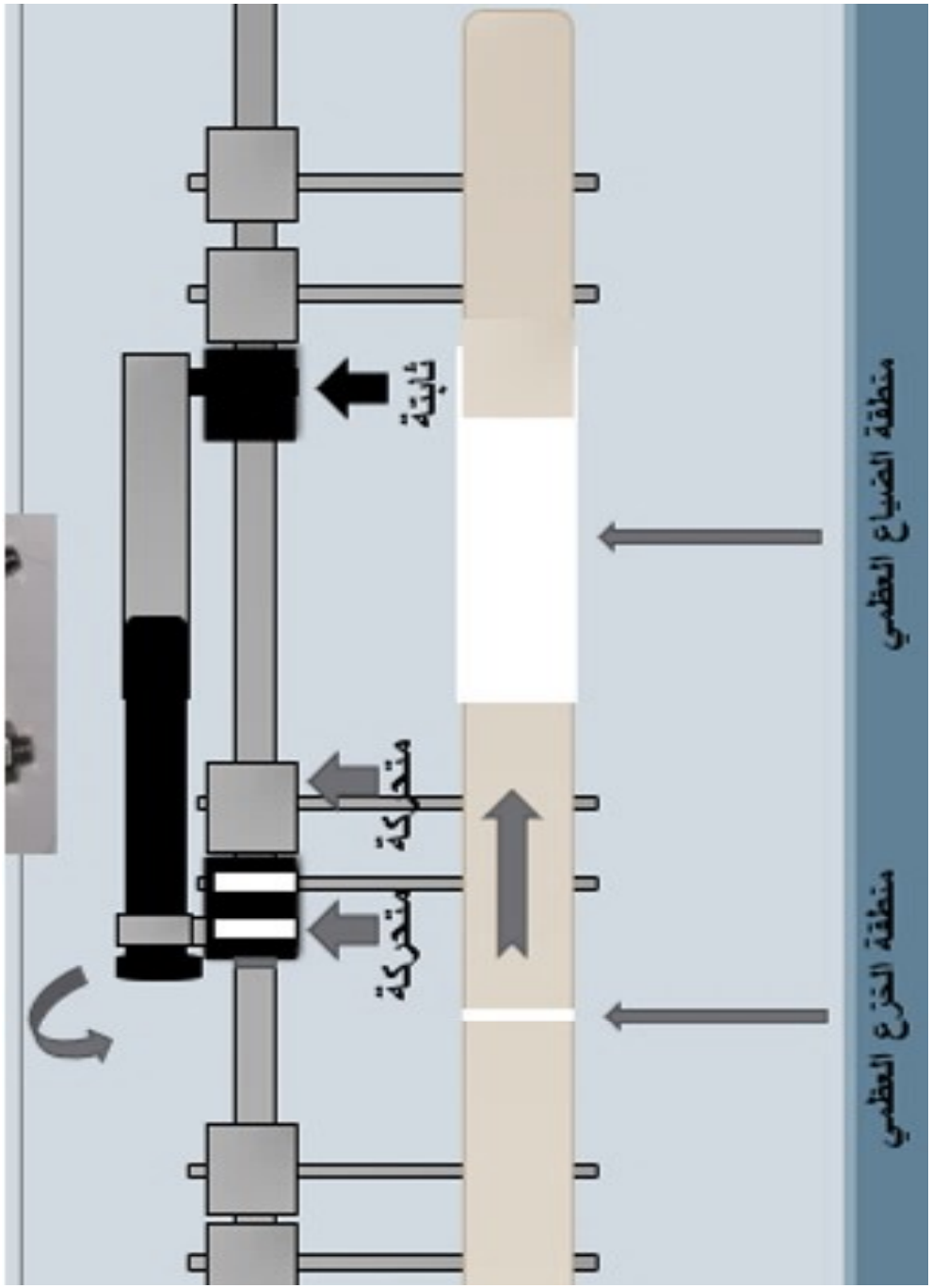

Postoperative biopsy
Macroscopic: Tumor removal of the right thigh – the
consists of a 20 cm long piece of bone with surroundi
adipose tissue
Macroscopic section: A tumor mass is seen within the
seeps into the surrounding tissues with a length of 13
away from the edge of the upper cut and 4.5 cm from
Result: High grade fibroblastic osteosarcoma
The tumor measures 13 cm in length
The tumor leachates with muscle tissue and surround
Surgical cutting edges intact Morgan -
20 CM



technique of the external fixation in the
attached with the sliding clicks







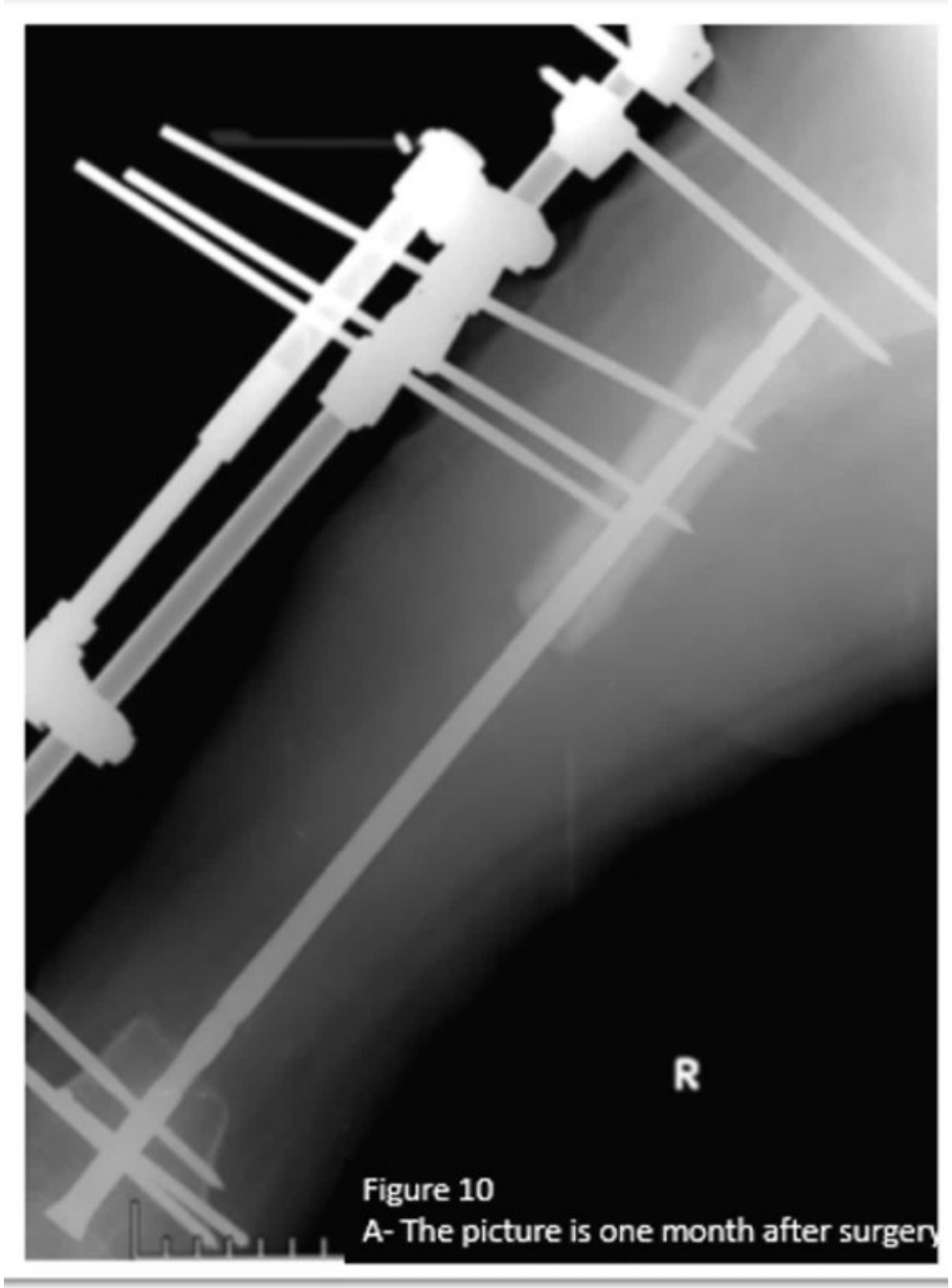
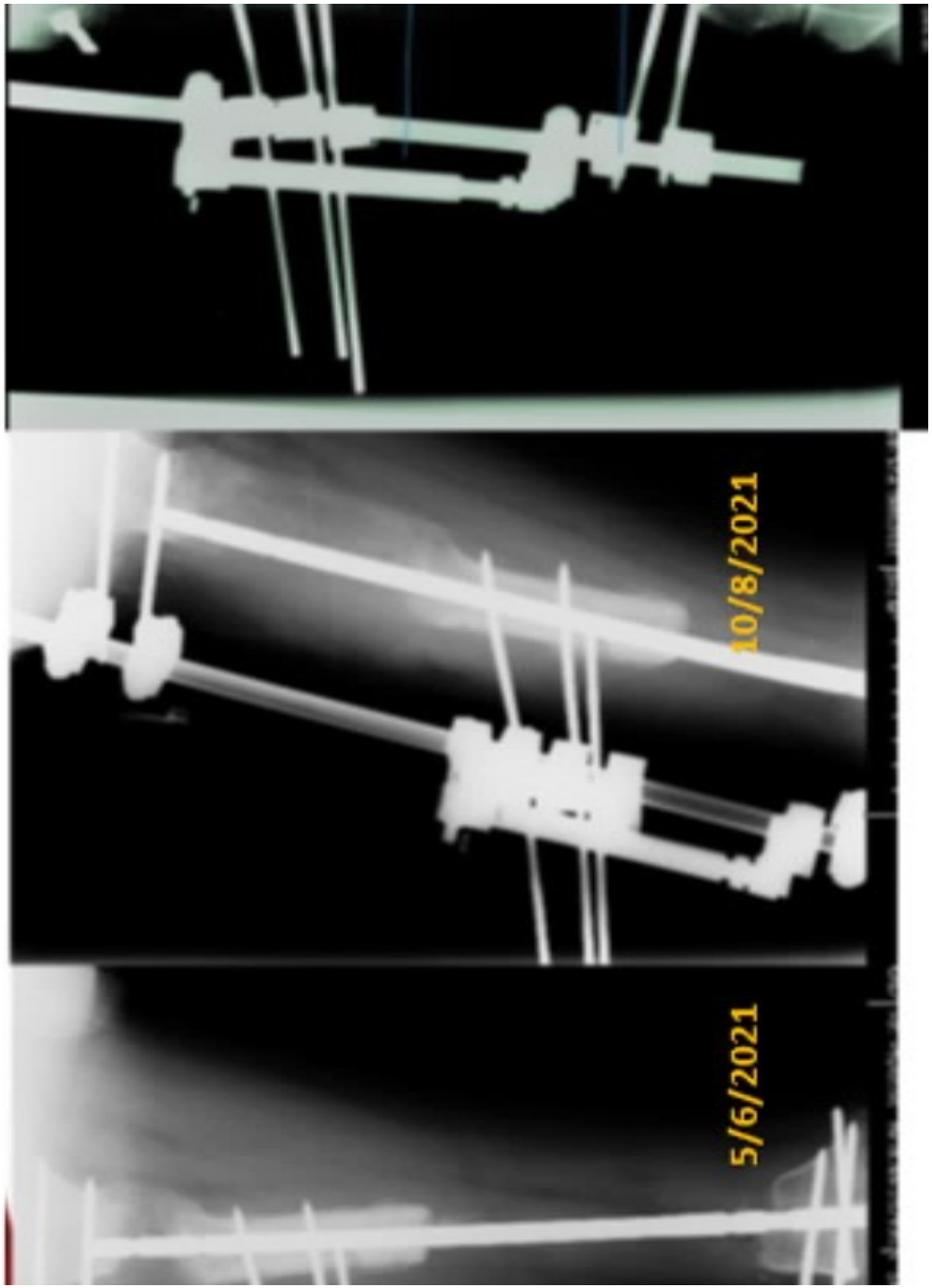


Figure 10
A- The picture is one month after surgery


10/8/2021
5/6/2021

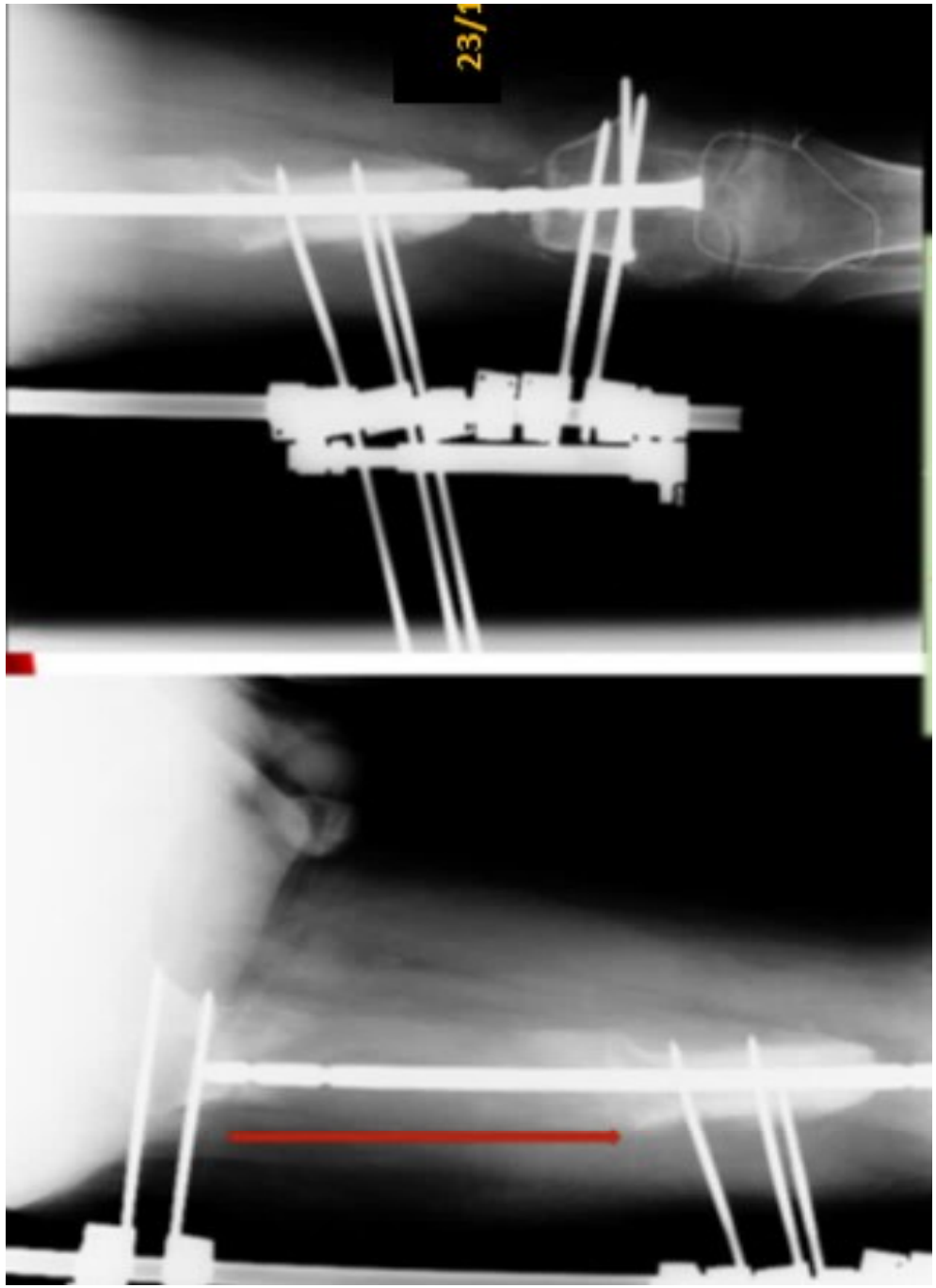


Figure 13

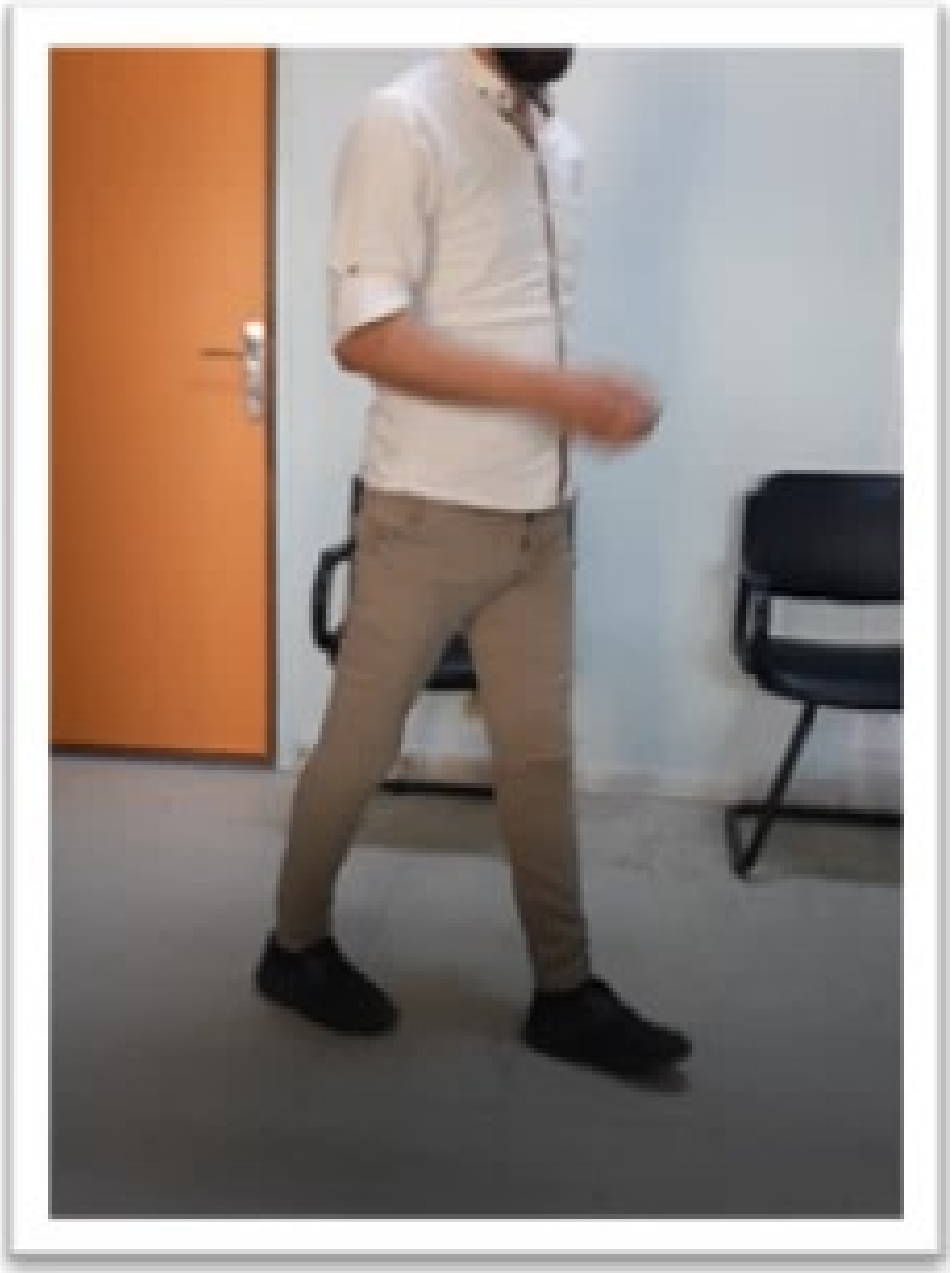


Figure 1)
XRy: of the right thigh showed a heterogeneous lesion with unclear borders at the junction of the middle and distal third of the thigh, without destruction of the external bony cortex, extending for a distance of more than 7 cm distally towards the femoral condyles