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Distal femoral resection and reconstruction using a distal femoral tumor megaprosthesis

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1. Introduction

The distal femur, together with the proximal femur, proximal tibia, and proximal humerus, is among the most common anatomical sites of osseous tumors. Depending on the biological behavior and histopathological entity of the lesion, resection of the distal femur with subsequent reconstruction may be required, particularly in cases of primary bone sarcomas, metastatic disease, or recurrent locally aggressive tumors. In this setting, reconstruction using a distal femoral replacement in the form of a fully hinged endoprosthesis is currently regarded as the reconstructive gold standard. Especially in the often young patient population affected by primary bone sarcomas, this limb-salvage approach enables preservation of the extremity while providing acceptable functional outcomes and satisfactory postoperative quality of life.

The following step-by-step guide is intended primarily as a practical reference for junior colleagues with an interest in orthopedic oncology and aims to provide useful technical advice, surgical pearls, and procedural guidance. Although distal femoral replacement may also be employed in other clinical settings, such as revision arthroplasty, the present text focuses specifically on tumor orthopedic indications, with particular emphasis on the surgical management of primary bone sarcomas.

2. Clinical presentation

We present the case of a 17-year-old male patient who reported progressively increasing pain and swelling of the left knee over several weeks. Initial diagnostic workup included plain radiography and contrast-enhanced MRI. Imaging revealed an unclear osteogenic lesion of the distal femur with cortical destruction, raising suspicion of a primary bone sarcoma (**Figure 1**). An indication was made for open biopsy and extended staging by CT of the chest and abdomen. Already at the time of biopsy, the subsequently planned surgical approach should be taken into

consideration. In cases of suspected primary bone sarcoma, treatment at a specialized center is recommended.

Histopathological examination of the biopsy specimen leads to the diagnosis of conventional osteosarcoma. Staging showed no evidence of distant metastases. To exclude potential skip metastases, compartment MRI of the left thigh with contrast enhancement was performed. Neoadjuvant chemotherapy was initiated in the multidisciplinary treatment approach. Following a good response to treatment, tumor resection was planned in accordance with the treatment protocol. Reconstruction was scheduled using a tumor megaendoprosthesis, in this case manufactured by Implantcast (Buxtehude, Germany). The individual surgical steps are outlined below.

3. Treatment strategy

Preoperative resection planning begins already with selection of the biopsy approach, which must remain attached to the resection specimen at the time of definitive tumor resection. Depending on tumor location and the possible presence of a soft-tissue component, we recommend a medial or lateral subvastus approach. Biopsy, and later resection, through an anterior or posterior approach should be strictly avoided in order to prevent contamination of the neurovascular structures and of the extensor mechanism musculature required for function and soft-tissue coverage. In our surgical approach, the osseous extent of resection, and consequently the required reconstruction length, is determined on the basis of pre-treatment MRI, particularly the coronal T1-weighted sequences. Our aim is to achieve a bony safety margin of 3 cm from the intraosseous tumor in order to ensure complete tumor resection. In the presented case, the tumor extension reaches up to 21 cm proximal to the knee joint line. Therefore, based on the aforementioned criteria, we defined the resection level at 24 cm proximal to the tibiofemoral joint space (**Figure 1**).

In addition to defining the planned resection length, preoperative assessment and surgical planning should also include careful consideration of intra-articular versus extra-articular resection. Particular attention should be directed to the integrity of the femoral articular surface and the presence of intra-articular effusion on pre-treatment imaging. The final decision is made intraoperatively based on the intraoperative findings (see below).

4. Surgical steps

After standard preoperative preparation, including general anaesthesia and, if indicated, placement of regional pain catheters, the patient is positioned supine. The

affected limb — in this case the left leg — is disinfected and draped according to institutional standards. For planned megaprosthetic reconstruction, we recommend the use of iodine-impregnated adhesive drapes on the skin.

As a first step, the relevant anatomical landmarks are marked to guide the surgical approach and incision planning. These should include the patellar tendon, the tibial plateau including the tibial tuberosity, and the tibiofemoral joint line. In relation to these landmarks, the planned resection level is then marked accordingly (**Figure 2**). As mentioned above, we recommend either a medial or lateral subvastus approach, depending on the location of the biopsy tract. The incision curves in towards the insertion of the patella ligament at the tibial tubercle.

Dissection can then usually be carried out rapidly to the subfascial level using monopolar cautery. For the further preparation, we aim for early arthrotomy of the knee joint if an intraarticular resection is possible. On the one hand, this allows prompt assessment of whether the usually feasible intra-articular resection is oncologically acceptable. On the other hand, early arthrotomy facilitates rapid mobilization of the specimen and thereby accelerates the dissection.

A. *Medial approach*

For the medial approach, the skin is incised at the level of the planned resection margin. The subcutaneous tissue is divided using electrocautery, and the fascia is opened longitudinally. Dissection is then carried into the deeper layers, preserving the vastus medialis muscle whenever oncologically feasible. The vastus intermedius component of the quadriceps femoris is left on the resection specimen as an oncological boundary layer.

Distally, the sartorius muscle may be released and mobilized for later use in soft tissue coverage of the prosthetic reconstruction. In the mid-to-distal aspect of the approach, the adductor canal is identified. The adductor canal is bordered anteromedially by the sartorius muscle and the subsartorial fascia, laterally by the vastus medialis muscle, and posteriorly by the adductor longus and adductor magnus muscles. Its main contents include the femoral artery and vein, the saphenous nerve, and the nerve to the vastus medialis (**Figure 10, Figure 12**).

The main neurovascular structures are carefully dissected, separated from the specimen, and followed distally toward the popliteal fossa. Dorsomedially, the medial head of the gastrocnemius muscle is released from its origin (**Figure 11**). Subsequently, controlled arthrotomy is prepared stepwise, and the knee joint is opened in a controlled fashion.

B. *Lateral approach*

For the lateral femoral approach, the skin and subcutaneous tissue are incised, followed by longitudinal opening of the fascia lata and iliotibial tract. Depending on the extent and location of any extraosseous soft tissue tumor component, the vastus lateralis muscle is identified. Whenever oncologically appropriate, the muscle is preserved, elevated, and mobilized to allow for subsequent soft tissue coverage during reconstruction (**Figure 3**). The vastus intermedius component of the quadriceps femoris will be left on the resection specimen as an oncological boundary layer.

The biceps femoris muscle is subsequently identified along the posterior aspect of the approach (**Figure 3**). When indicated, particularly in cases with close proximity of the tumor or scar tissue to the posterolateral structures, the common peroneal nerve should be identified, exposed, and protected throughout the procedure to avoid iatrogenic injury.

If required, the biceps femoris muscle may be detached and used for subsequent soft tissue coverage. From a distal posterolateral approach, the major vessels can be identified after their passage through the adductor canal and before their anatomical course within the popliteal fossa (**Figure 5).**

The lateral gastrocnemius head is released from its origin to allow improved mobilization and exposure (**Figure 6**).

As previously mentioned, early and controlled arthrotomy of the knee joint, preferably through the suprapatellar recess (**Figure 4**), is recommended. Provided that there is no evidence of intra-articular tumor extension, this permits direct assessment of the joint and enables the surgeon to proceed with further dissection in a controlled and efficient manner.

Arthrotomy of the knee joint

After opening the knee joint capsule, the anterior, lateral and medial capsular portions are released promptly, to allow adequate exposure of the joint (**Figure 7**). The collateral ligaments and the anterior cruciate ligament are then transected as required for mobilization and further preparation (**Figure 8**). The menisci are subsequently resected as well.

For improved visualization of the intra-articular anatomy, complete resection of the infrapatellar fat pad is recommended. This step is particularly relevant both in adults and in pediatric patients, in whom the infrapatellar fat pad may be relatively prominent and may otherwise limit exposure.

After removal of the infrapatellar fat pad, the patella can be mobilized and dislocated medially or laterally, depending on the chosen surgical approach. During this mobilization, particular care must be taken to avoid excessive traction on the extensor mechanism and to prevent avulsion of the patellar tendon from its insertion at the tibial tuberosity.

Subsequently, the posterior cruciate ligament and the posterior capsular structures can be carefully released (**Figure 9**). Particular attention must be paid to the close anatomical relationship with the popliteal vessels. The individual tissue layers can, for example, be separated by carefully passing an Overholt clamp beneath them and then dissected layer by layer.

Osteotomy preparation

After completion of the arthrotomy, the distal femur can be further mobilized (**Figure 13**). For this step, it is helpful to elevate the distal femur while keeping the lower leg relaxed, with careful protection of the neurovascular structures. This maneuver places the individual tissue layers under gentle tension and thereby facilitates identification and preparation.

Further dissection is then performed stepwise from distal to proximal toward the planned osteotomy level. Initially, preparation must be carried out with particular caution in order to separate the neurovascular bundle from the resection specimen in the distal third of the femur. Especially in high-grade sarcomas, numerous large-caliber tumor-feeding vessels are frequently encountered and must be carefully controlled.

Once the main neurovascular bundle has been safely separated from the specimen, dissection can proceed more efficiently toward the planned osteotomy level using monopolar electrocautery. During this step, attention should be paid to the diaphyseal perforating vessels, which may be numerous and of considerable caliber. The osteotomy is then performed under controlled conditions, with adequate soft tissue protection and stabilization using a Verbrugge bone-holding clamp, followed by transection with an oscillating saw (**Figure 14**).

After removal of the resection specimen, it is inspected to assess the macroscopic resection margins. Following tumor removal, the surgical site is checked for hemostasis and thoroughly irrigated (**Figure 15).**

Implantation of the tumor endoprosthesis

1) *Preparation of the femur* (**Figures 16-18**)

For femoral preparation an olive wire is inserted. Flexible reamers are used for intramedullary drilling. In non-cemented stems, under-reaming by 1.5 mm is performed, whereas in cemented stems, over-reaming by 2 mm is recommended.

Whenever feasible, we aim for cementless press-fit fixation. Stem lengths and diameters are available in different configurations. The shortest standard femoral stem from the manufacturer shown here (Implantcast, Buxtehude, Germany) has a length of 12 cm.

Reaming of the femoral canal, as well as impaction of the rasp and stem, is performed in a standardized manner with protection and stabilization of the bone using a Verbrugge bone-holding clamp. The intramedullary canal at the cut bone end is further prepared using a deepening reamer.

The rasp should correspond to the size of the intended definitive stem. Particular attention must be paid to rotational alignment, as the stems are curved in accordance with the femoral anatomy.

The final femoral stem is implanted after tibial preparation and trial reduction have been completed in case additional femoral shortening should unexpectedly be required.

2) *Preparation of the tibia*

For tibial preparation, the leg should be positioned in flexion. During preparation and reconstruction, it is essential to avoid traction or compression of the main neurovascular structures.

Initially, redundant soft tissue, including the menisci and residual ligamentous insertions, is removed. Preparation can be facilitated by slight anterior translation of the tibia and elevation of the femur. The tibial canal is then opened using an entry drill. The tibial entry point is selected at the insertion of the anterior cruciate ligament and in line with the midline of the patellar tendon (**Figure 19**).

Subsequently, the tibia is reamed using rigid intramedullary reamers until the desired size is achieved (**Figure 20**). The manufacturer-specific tibial cutting block is then attached. Particular attention must be paid to correct alignment and rotational orientation, using the anterior tibial crest as a reference and aligning the tibial component in the direction of the first and second ray of the foot (**Figure 21**).

After tibial resection has been performed, the cutting block is removed. For the manufacturer (Implantcast, Buxtehude, Germany) shown here, the last used reamer is reinserted, and the required size of the tibial plateau, including the offset adapter,

is determined. Correct rotation and alignment of the tibial plateau must be carefully verified (**Figure 22**).

The tibia is then further prepared using the corresponding tibial milling instruments and according to the manufacturer's instructions, in this case using fin chisels (**Figure 22**). Once tibial preparation has been completed, the surgical site is irrigated again and checked for hemostasis. Trial reduction is then performed.

3) *Trial reduction and final implantation of the tumor endoprosthesis* (**Figures 23 - 24**)

We recommend first determining the appropriate tibial plateau size. Offset adapters are helpful for correct alignment and sizing. Care should be taken to avoid any overhang of the metallic plateau; therefore, a slightly smaller plateau should be preferred over an oversized component.

For determining the correct offset position and plateau alignment, the anterior tibial crest and the imaginary extension line between the first and second rays of the foot serve as anterior landmarks.

For the manufacturer presented here, after final determination of the plateau size and offset adapter configuration, the components are connected to the previously selected stem. Following appropriate irrigation of the plateau, the plateau-stem construct is implanted using a thin layer of bone cement on the tibial plateau, resulting in hybrid cementation. Any excess cement is removed.

During implantation and before cement curing, correct rotational alignment must be verified once again.

The overall prosthetic reconstruction length is initially assembled as a trial construct corresponding to the length of the resection specimen and introduced into the surgical site. With the prosthetic system shown here, the reconstruction length can be selected in 20-mm increments, with the shortest reconstruction measuring 100 mm.

During trial reduction, adequate soft tissue tension and coverage should be ensured, as well as restoration of limb length in comparison with the contralateral side. If the trial reduction is satisfactory, the previously selected femoral stem can be inserted, preferably using press-fit fixation whenever feasible, or alternatively cemented, under protection with a Verbrugge bone-holding clamp.

The definitive implant components are then connected to the stem while carefully controlling rotational alignment and limb position. Subsequently, the polyethylene

insert is implanted, and the components are linked using the coupling mechanism. Before wound closure, correct rotational alignment and soft tissue tension are verified once again.

Soft Tissue Management and Wound Closure

In the region of the knee joint, any remaining joint capsule, if preserved, should be used for closure. A multilayered muscular wound closure is recommended. During primary implantation, sufficient soft tissue coverage can often be achieved without additional reconstructive muscle flap coverage (**Figure 25**).

If a tension-free and adequate soft tissue closure cannot be achieved, for example in cases with an extensive extraosseous soft tissue tumor component or insufficient or large biopsy tracts, local rotational flaps may be helpful. These include medial or lateral gastrocnemius rotational flaps, lateral biceps femoris flaps, and medial sartorius or gracilis flaps. Additional meshed split-thickness skin grafts may be used, if necessary, to achieve tension-free wound closure.

Final irrigation of the surgical side is performed using a pulsatile lavage system. We recommend the placement of a Redon drain, usually 10 or 12 Charrière. After completion of muscular coverage, fascial closure is performed whenever feasible. This is followed by inverted subcutaneous suturing and skin closure, usually with staples or non-absorbable sutures. A sterile wound dressing is applied, followed by elastic compression wrapping of the limb. Application of a stabilizing knee brace is not routinely required.

Postoperative Management and Rehabilitation

Due to the extent of resection, the implanted tumor prosthesis, and the immunodeficiency frequently associated with neoadjuvant or adjuvant chemotherapy, postoperative antibiotic prophylaxis with a broad-spectrum antibiotic is administered at our institution, typically cefazolin 2 g intravenously three times daily for five days. In cases of allergy, clindamycin 600 mg orally three times daily may be used as an alternative. The optimal antibiotic regimen remains a matter of considerable debate considering the current literature [1, 2].

Postoperatively, immobilization of the limb is generally not required. In fully cemented prostheses, early mobilization with full weight-bearing is permitted after an initial period of bed rest for hematoma prophylaxis.

In cases of hybrid cementation and press-fit implantation of the femoral stem, we recommend partial weight-bearing limited to 20 kg for 4–6 weeks postoperatively,

depending on the patient's age and bone quality. Thereafter, weight-bearing is gradually increased by 10 kg per week until full weight-bearing is achieved.

To allow soft tissue healing and integration, we recommend limiting knee flexion to approximately 45° during the first postoperative week. Afterward, free range of motion is permitted up to the maximum allowed by the prosthetic design.

Local pain catheters, such as sciatic or femoral nerve catheters, can be helpful in the immediate postoperative period to prevent the development of pain sensitization and to facilitate early mobilization.

Postoperative discharge is usually possible after 7–14 days.

A continuous passive motion device may be used to support further mobilization; however, it does not replace active, independent exercises of the affected limb. After completion of oncological treatment and achievement of full weight-bearing, we recommend either outpatient or inpatient rehabilitation focusing on muscle strengthening and gait training.

In addition, regular physiotherapy, typically two to three times per week, as well as self-directed exercises are recommended, with particular emphasis on strengthening the quadriceps femoris muscle and the periarticular musculature around the knee.

Depending on the oncological follow-up schedule, regular clinical and radiological assessment of the prosthesis is performed in combination with oncological surveillance.

Supplementary Material

- https://worldsurgerytour.tv/programs/recon-surgery-tumor-resection
- https://www.implantcast.de/download

5. Technical Pearls

- If an intra-articular resection is oncologically feasible, early arthrotomy of the knee joint is recommended to allow prompt and controlled tumor resection.
- For reconstruction, we recommend avoiding oversizing of the tibial plateau component; therefore, a slightly smaller component should be selected rather than an oversized one.

6. Avoiding and Managing Complications.

- Particularly in extensive sarcomas associated with substantial soft tissue loss, intraoperative soft tissue management should already be considered during preoperative planning, including potential reconstructive options such as gastrocnemius rotational flaps or MESH-grafting.
- High-grade bone sarcomas often exhibit marked vascularization. Therefore, meticulous hemostasis using clips, ligatures, and transfixion sutures is essential.

7. Comments from the expert

- Based on our assessment and experience, the osseous resection margin is determined using the pretherapeutic MRI, with a safety margin of 3 cm into healthy bone.
- Especially in young growing patients requiring implantation of a tumor endoprosthesis, the subsequent and sometimes considerable limb-length discrepancy must be taken into account. In this context, the use of polished stems in the region of preserved growth plates, such as the proximal tibial physis in cases of distal femoral replacement, or the use of expandable tumor prostheses should be considered during the initial planning phase.
- In cases with extensive osseous involvement, modern tumor endoprosthetic reconstruction may allow the use of custom-made short-stem components in selected patients in order to preserve as much healthy bone as possible and, where feasible, adjacent joints.

8. Infography

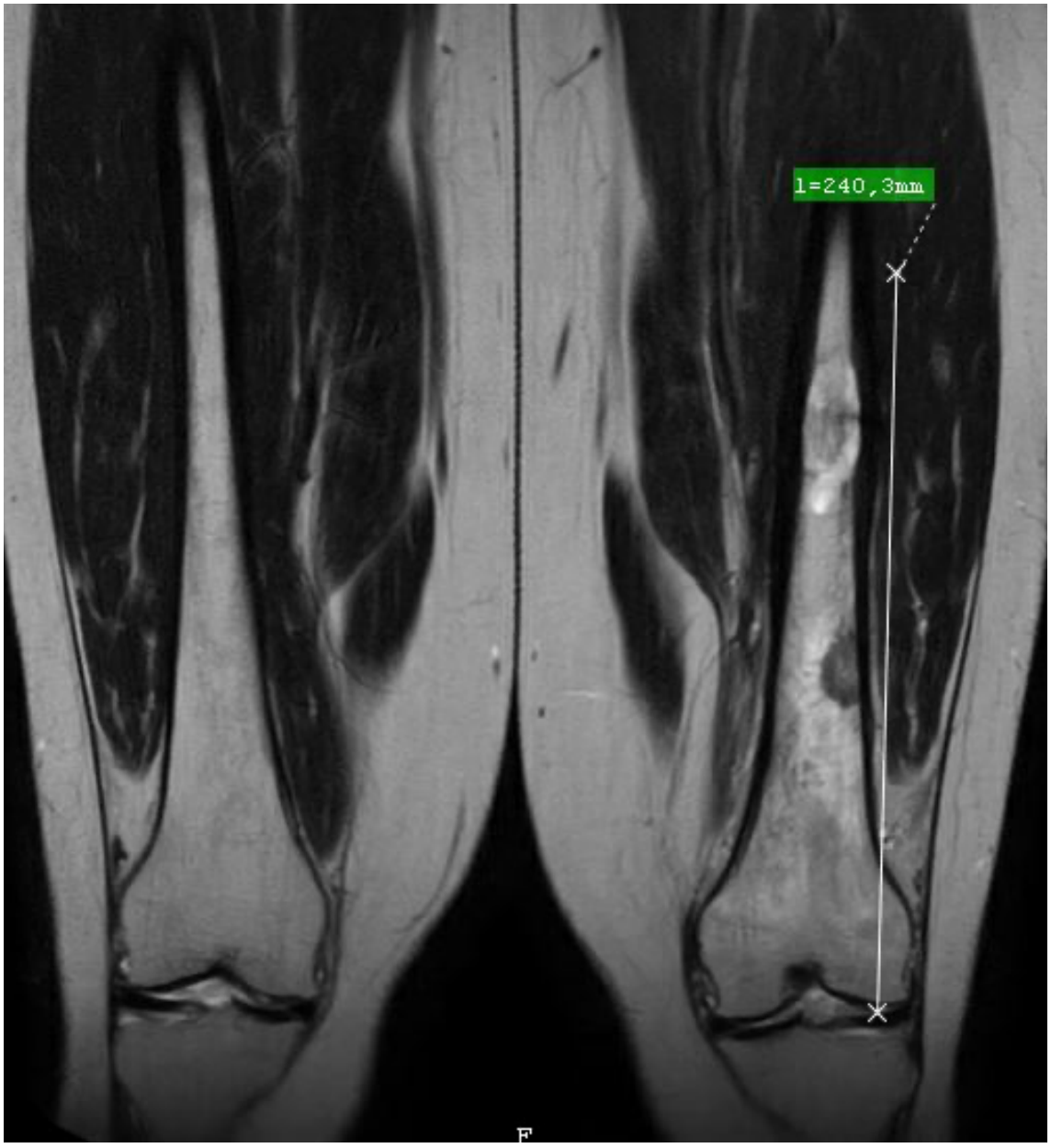


Fig. 1: MRI (T1 coronar) of the left femur (with contrast enhancement).

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Fig. 2: Anatomical landmarks. A lateral subvastus approach is presented.

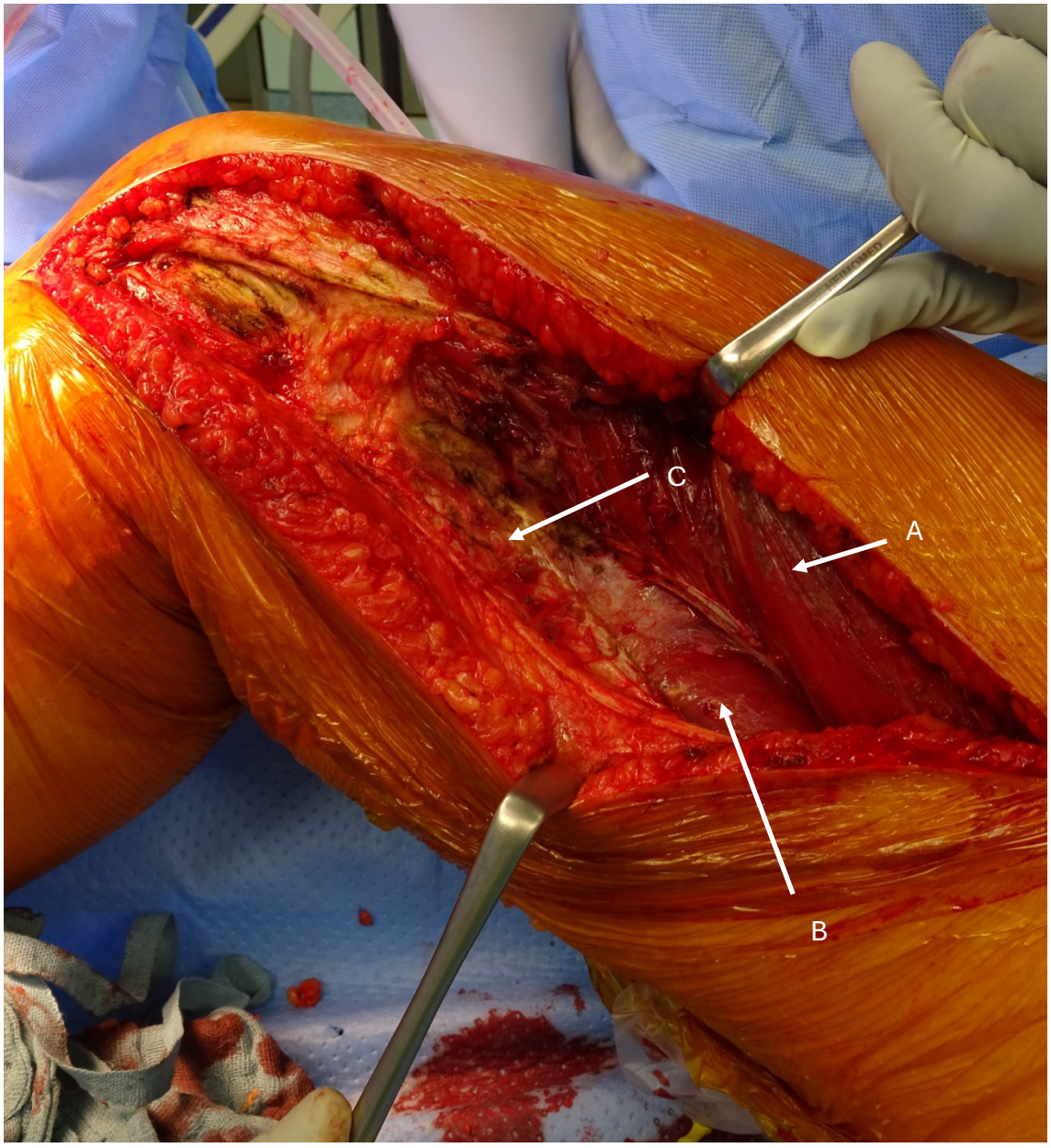


Fig. 3: Lateral subvastus approach. The subcutaneous tissue and iliotibial tract have already been divided. The incision is made laterally, with distal extension toward the patellar ligament, which is preserved. The image shows the partially mobilized vastus lateralis muscle (A), the biceps femoris muscle (B), and the lateral intermuscular septum (C).

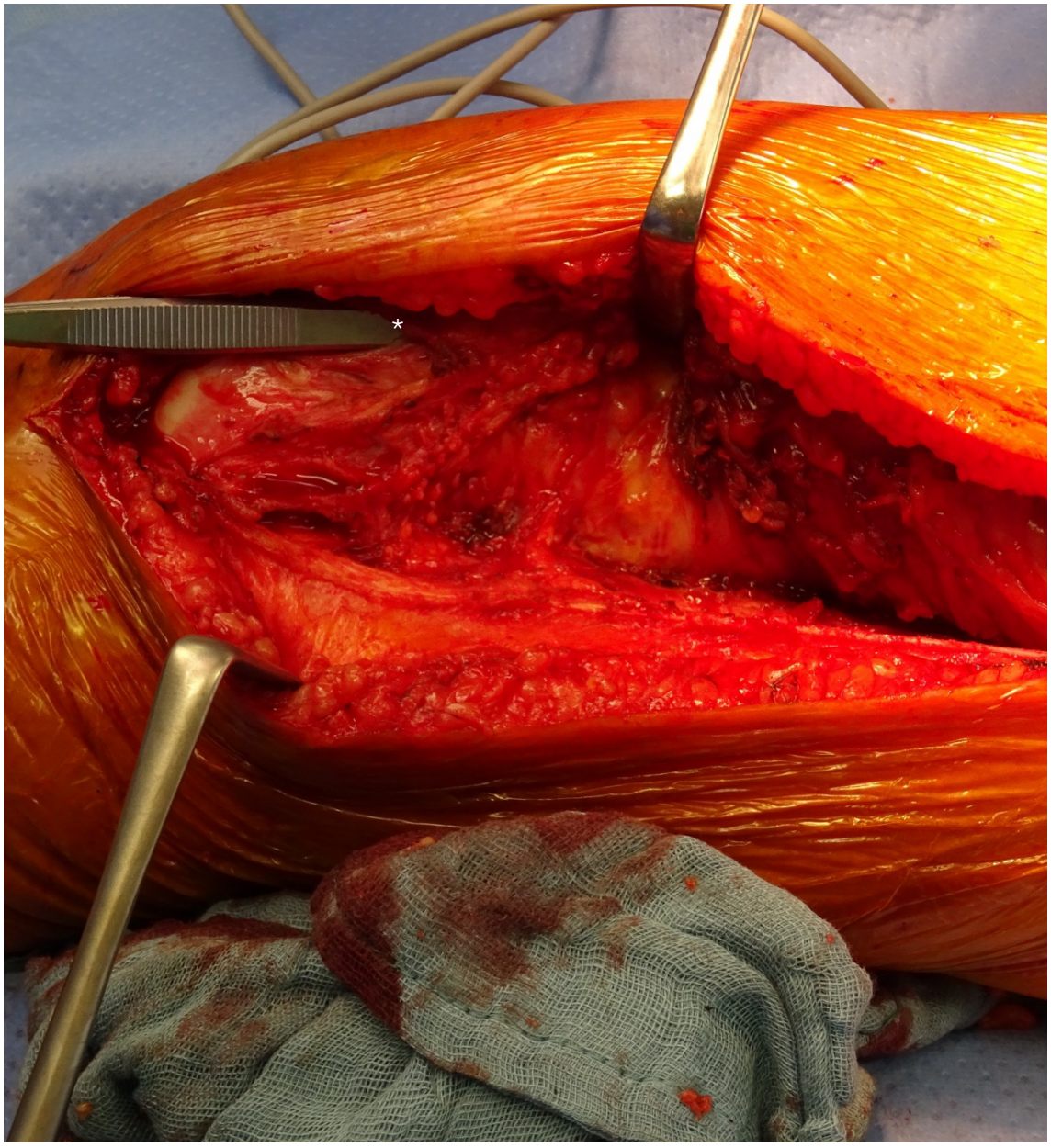


Fig. 4: The suprapatellar recess is opened (*) to further mobilize the knee joint. In addition, this enables prompt intra-articular inspection to determine whether an intra-articular resection can be safely performed from an oncological perspective, if there is no bloody joint effusion or macroscopic tumor involvement within the joint.

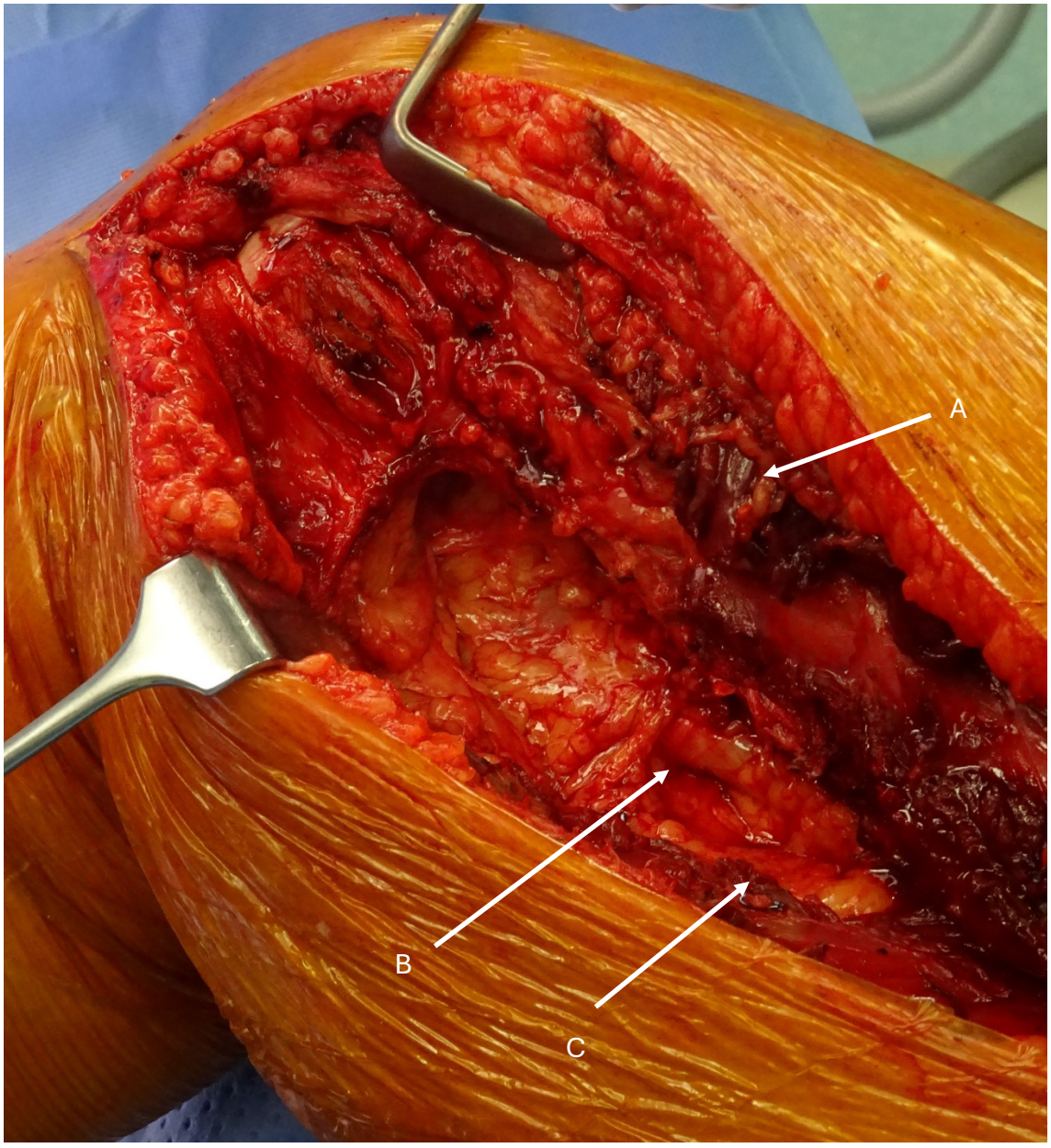


Fig. 5: The biceps femoris muscle was released, and the main vessels were identified and followed toward the popliteal fossa.

A: M. vastus lateralis B: Popliteal vessels C: M. biceps femoris

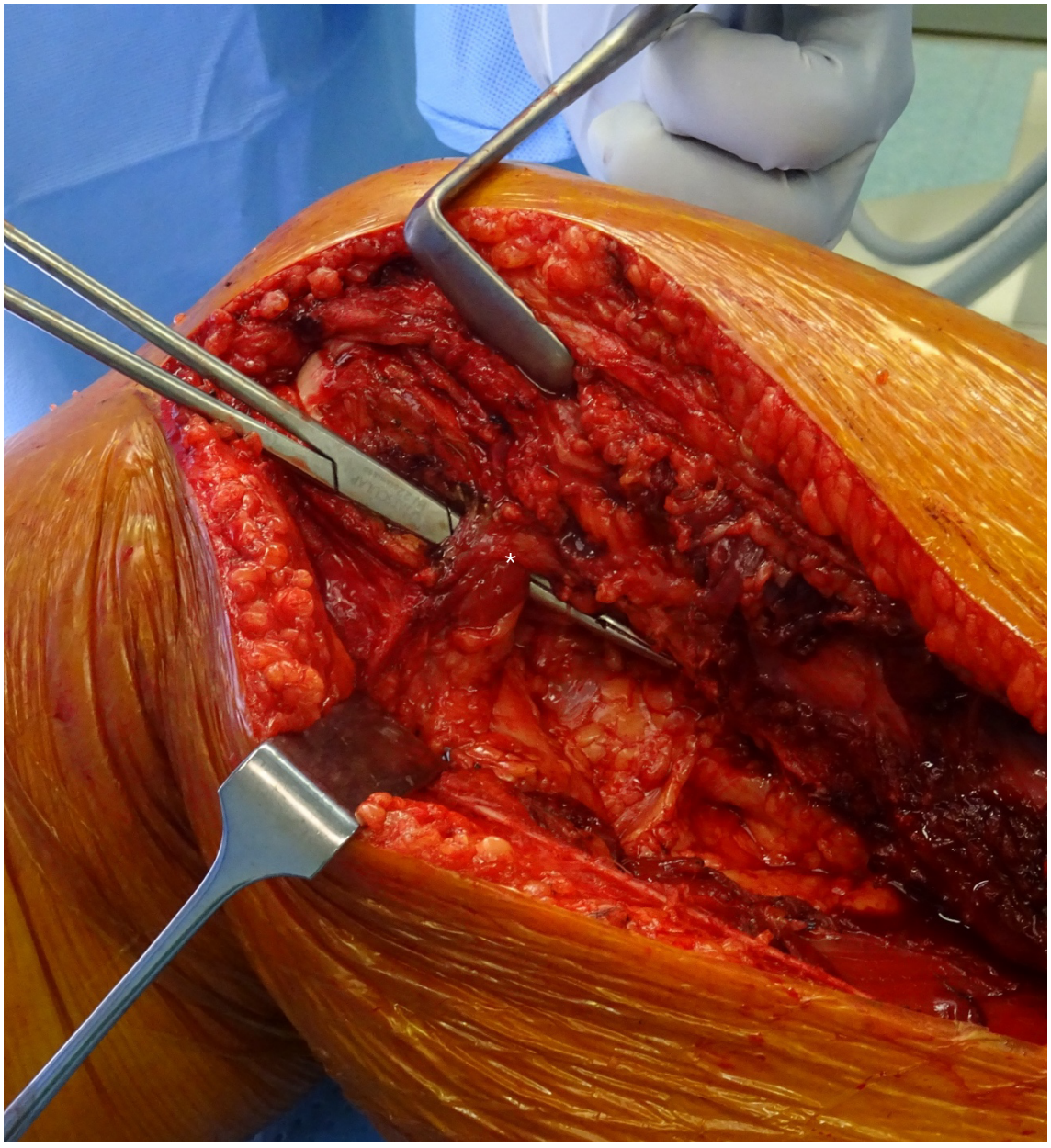


Fig. 6: The lateral head of the gastrocnemius muscle is released close to the resection specimen (*). The lateral collateral ligament is also released, while the main vessels are carefully protected in the deeper dissection plane.

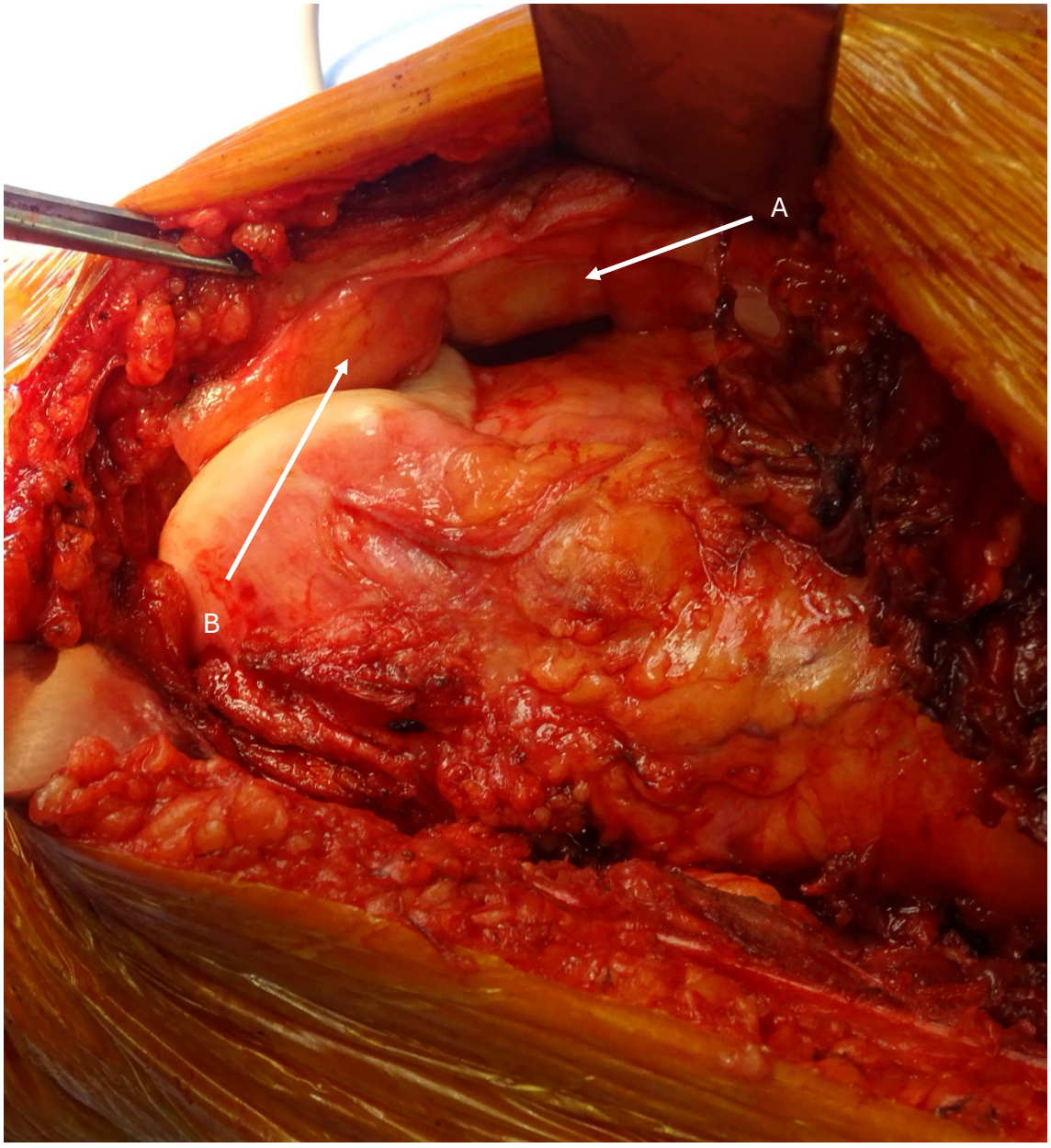


Fig. 7: After lateral arthrotomy, the patella (A) can be rapidly mobilized to the side, in this case medially. The insertion of the patellar ligament must be preserved. The infrapatellar fat pad (B) is completely removed to facilitate mobilization.

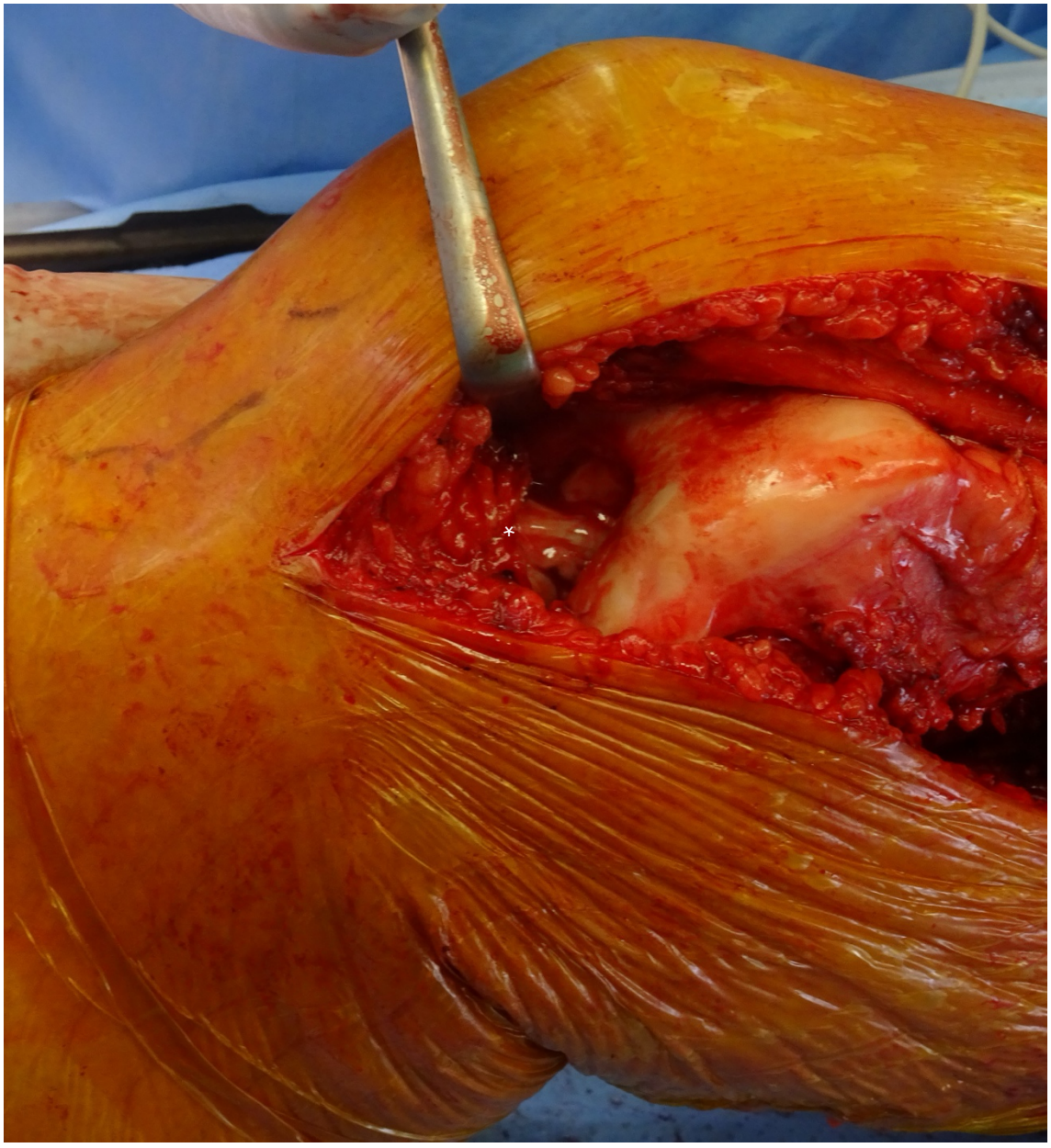


Fig. 8: View of the cruciate ligaments (*). For improved exposure, the knee is flexed and placed in varus. The cruciate ligaments are carefully transected.

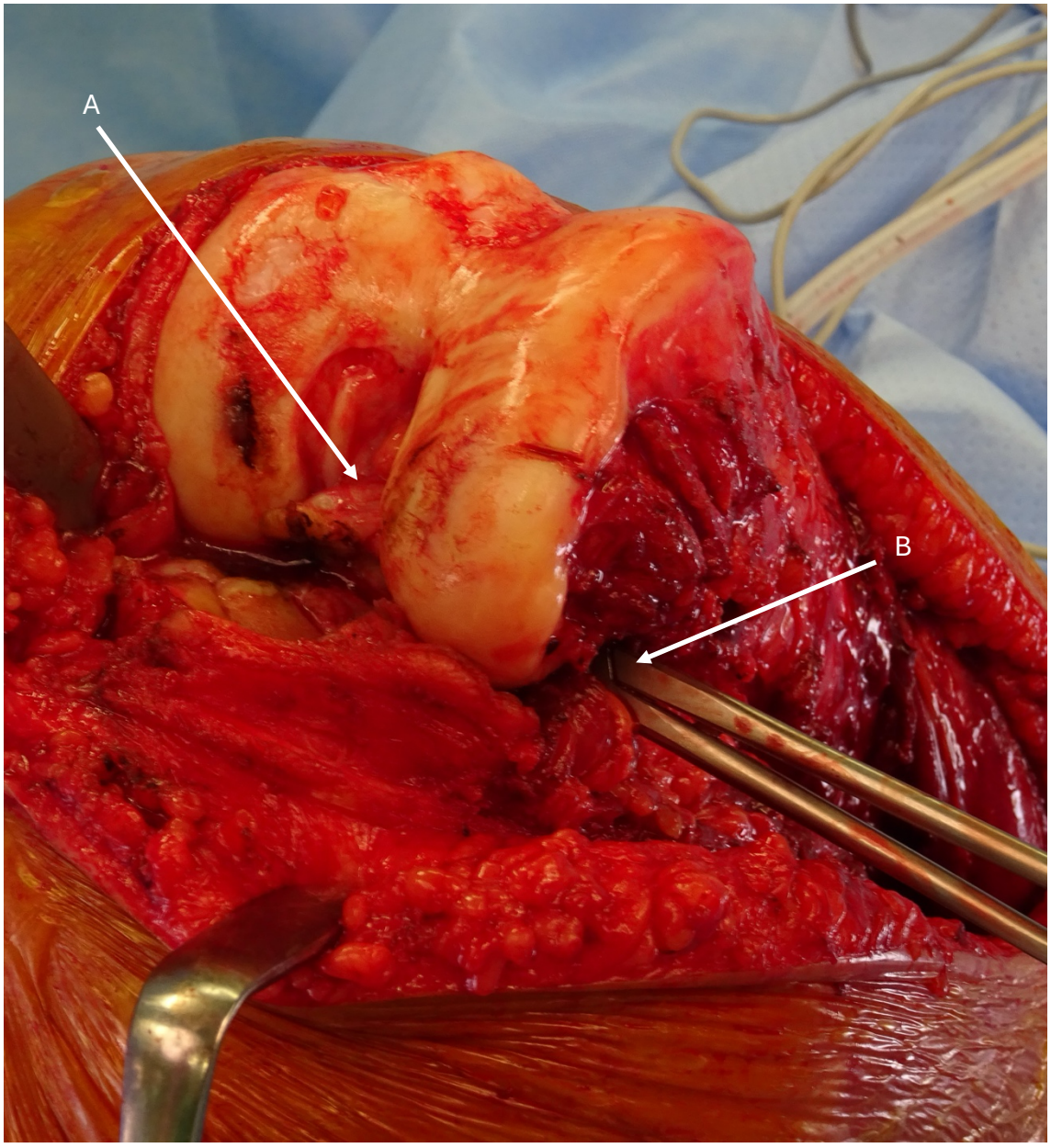


Fig. 9: The posterior arthrotomy is performed after transection of the cruciate ligaments (A). The popliteal vessels are protected, for example, using an Overholt clamp (B). Preparation can be facilitated by slight elevation of the femur and anterior translation of the tibia.



Fig. 10: Medial arthrotomy. The patella is retracted to the side. The medial collateral ligament is released, followed by detachment of the vastus medialis muscle (*) and the adductor magnus muscle (*) from the resection specimen.

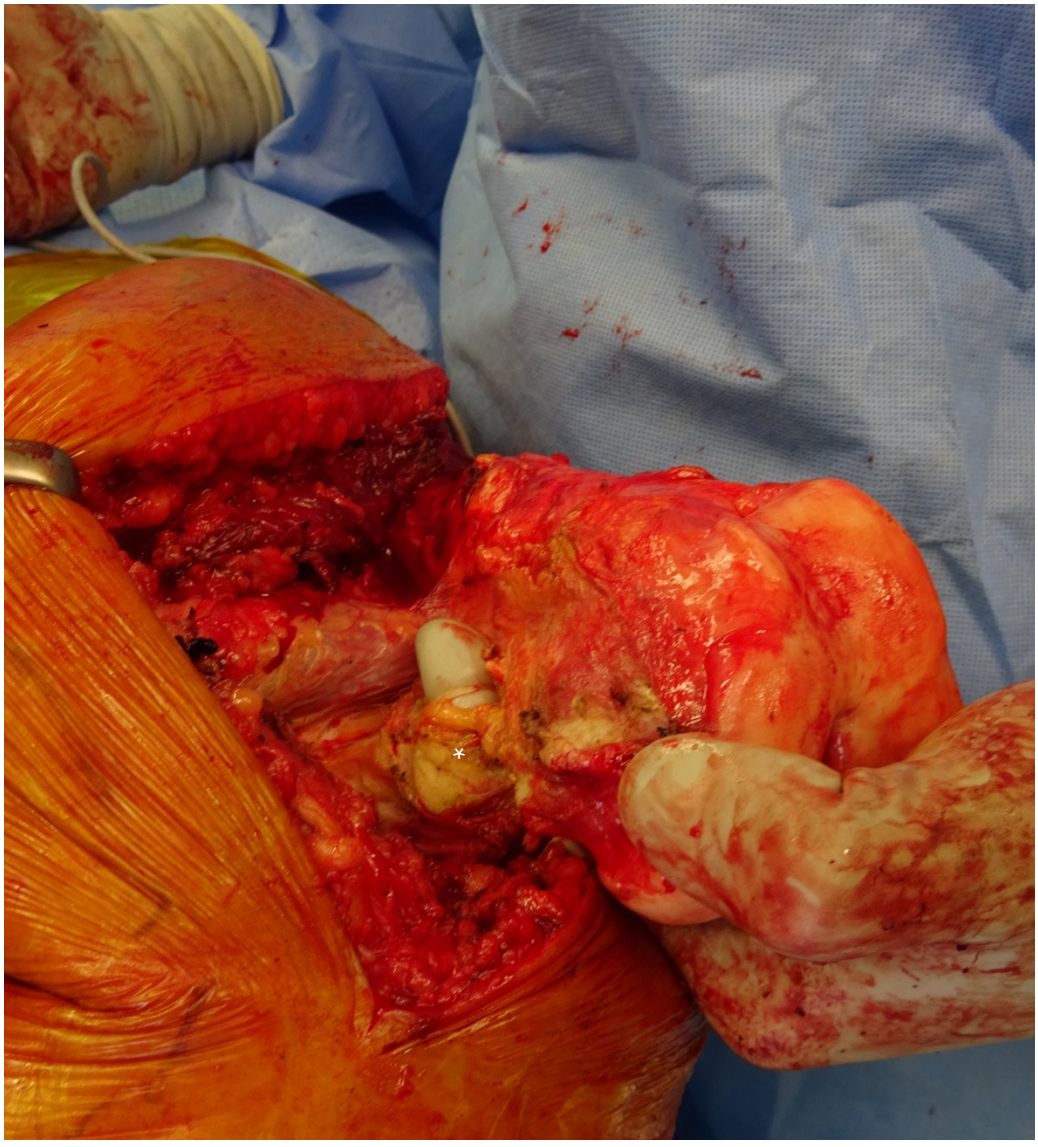


Fig. 11: Further dissection is carried out toward the adductor canal. The medial head of the gastrocnemius muscle (*) is released. The resection specimen can then be progressively mobilized and elevated.

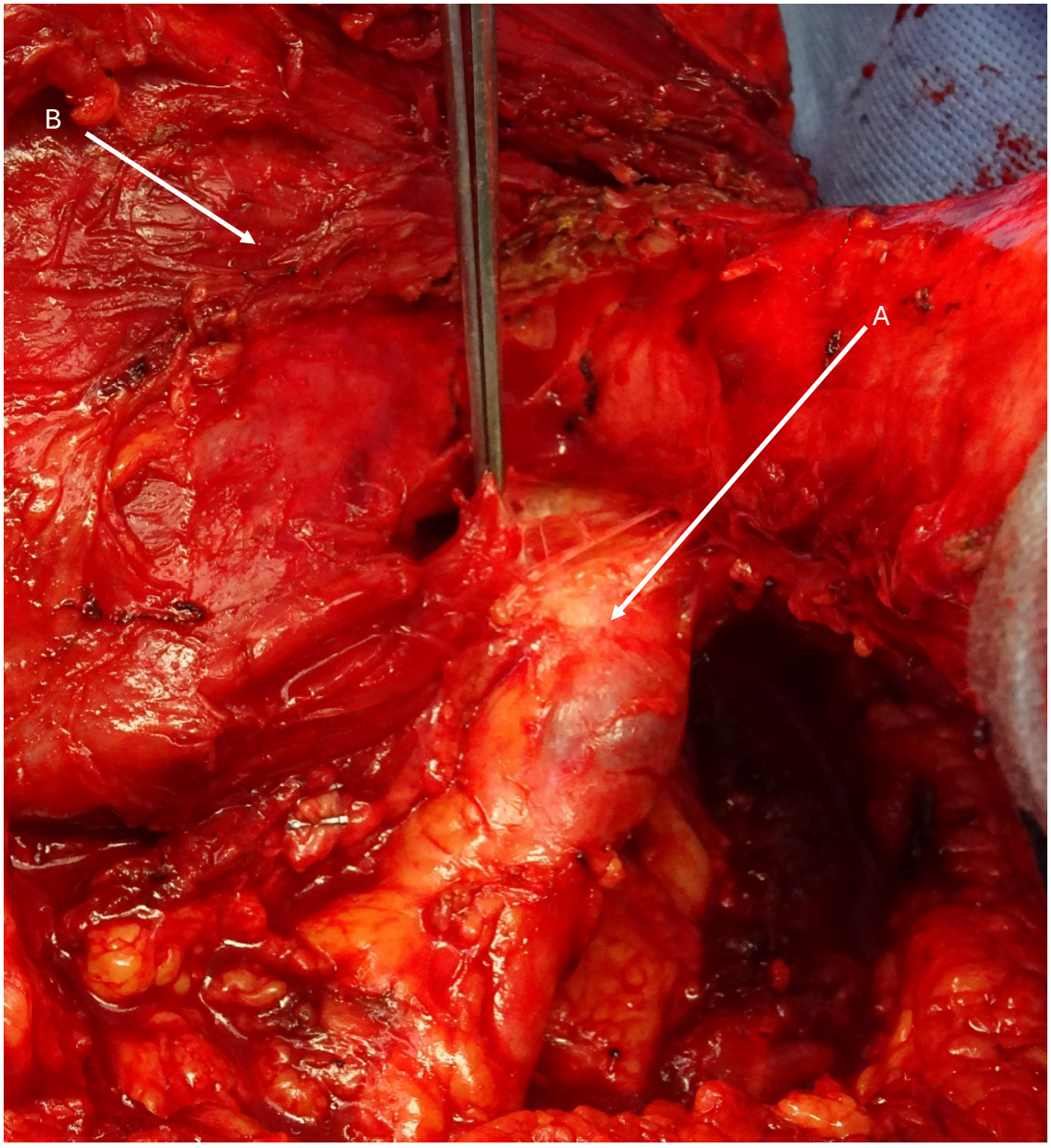


Fig. 12: Intraoperative view of the adductor canal. The femoral vessels (A) are shown exiting the canal. The anteromedial wall of the canal is formed by the sartorius muscle, the posterior wall by the adductor longus and adductor magnus muscles, and the lateral wall by the vastus medialis muscle (B).

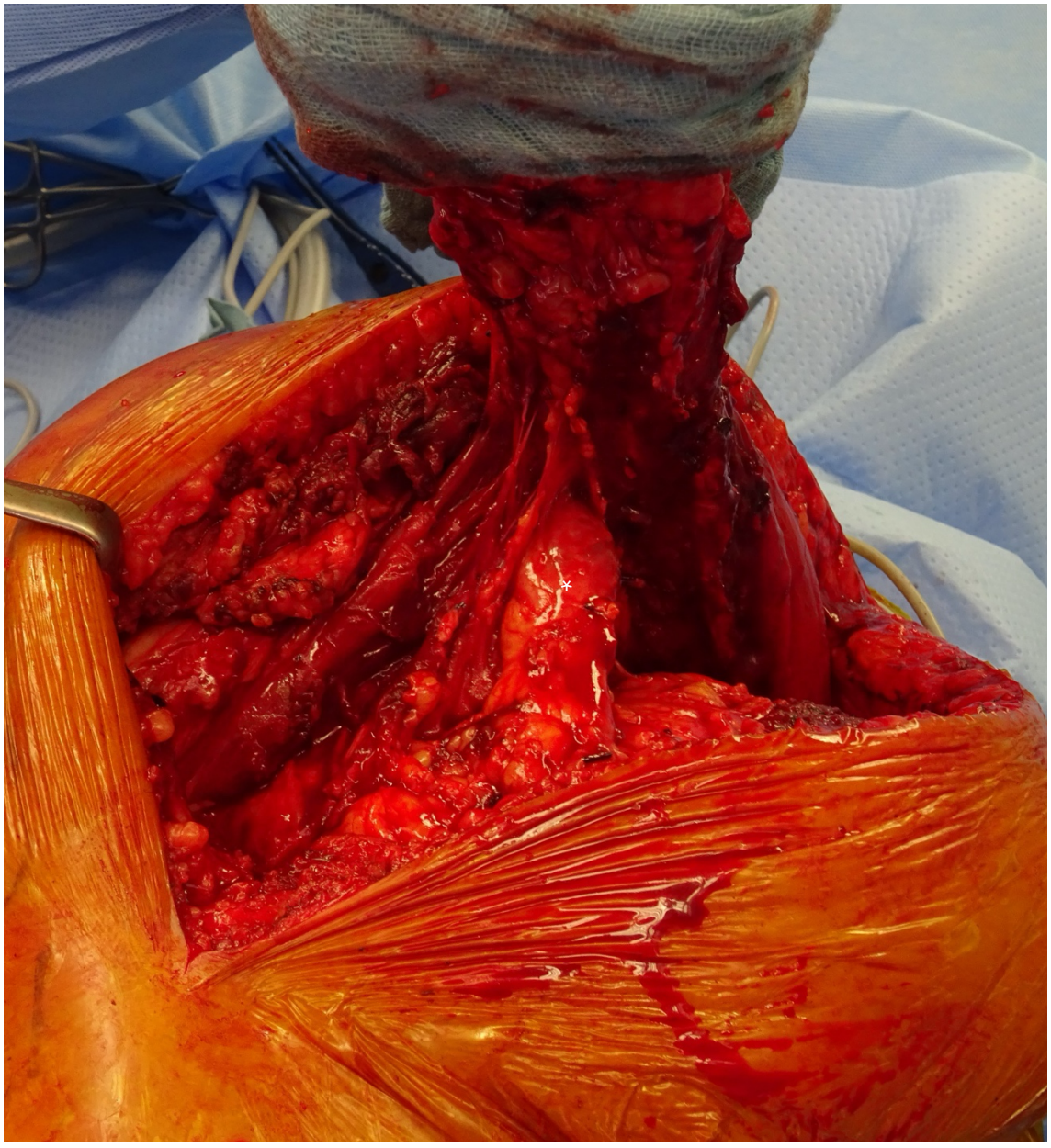


Fig. 13: The distal femur is elevated. The femoral vessels (*) are further exposed and dissected along their course through the adductor canal.

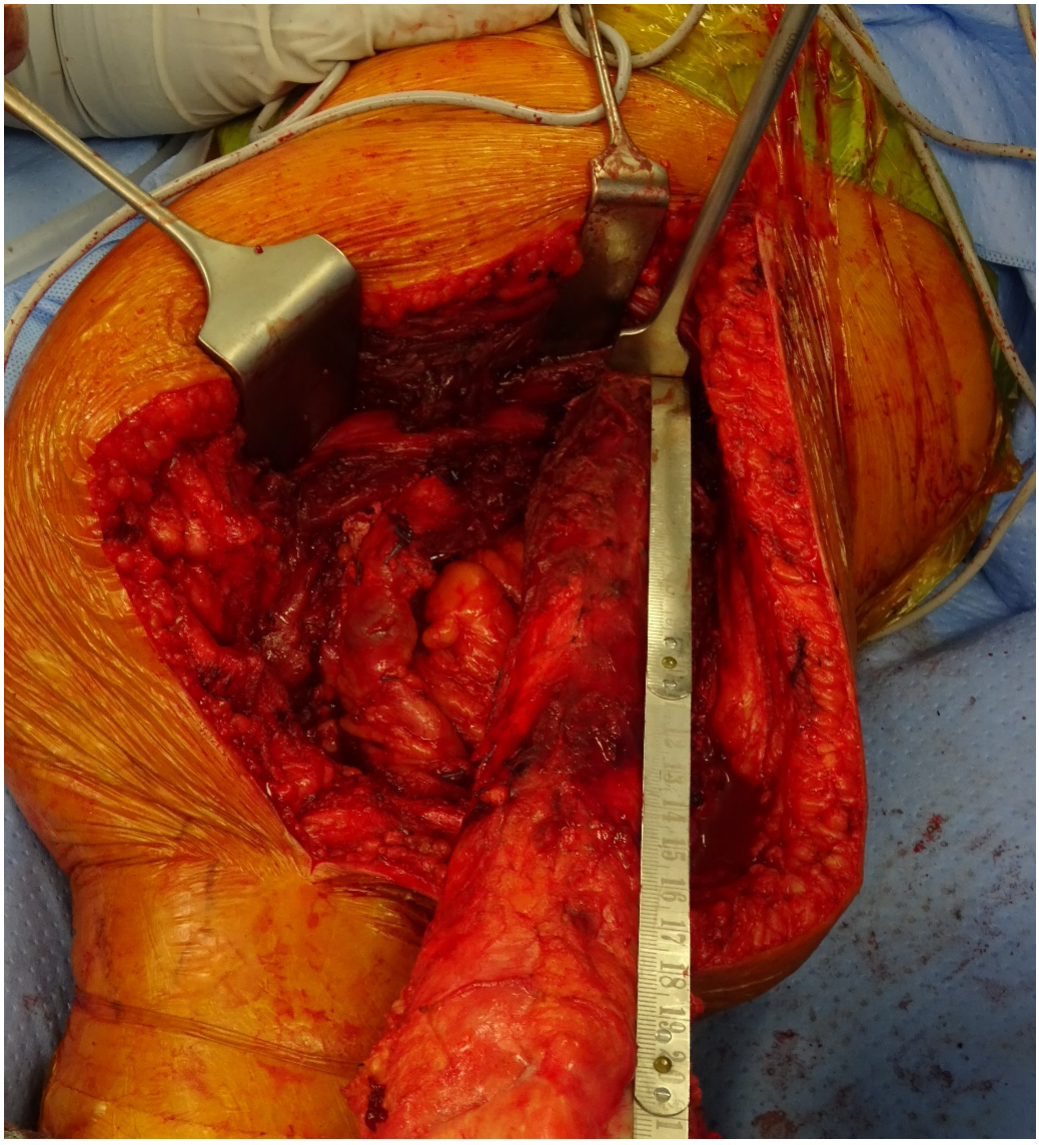


Fig. 14: After the main vessels have been released from the resection specimen, dissection can proceed directly toward the planned osteotomy level, in this case 24 cm. Once the osteotomy level has been reached and the correct resection length has been rechecked using a measuring gauge, a Verbrugge bone-holding clamp is applied. The osteotomy is then performed in a controlled manner using an oscillating saw under adequate soft tissue protection.

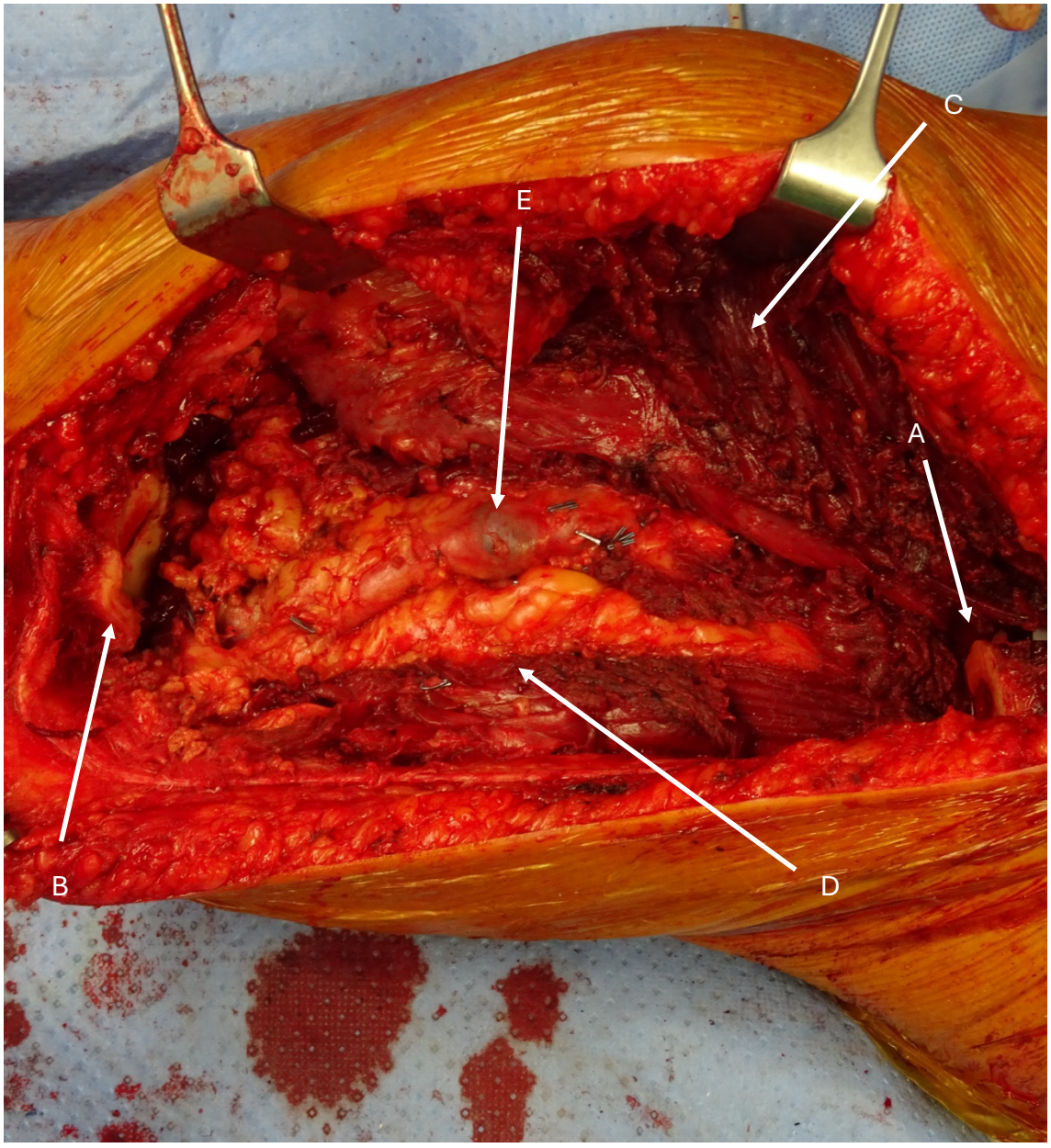


Fig. 15: Intraoperative view of the former tumor bed after tumor resection, showing the femur (A), tibia (B), quadriceps muscle (C), biceps femoris muscle (D), and femoral vessels (E).



Fig. 16: The femur is grasped with a Verbrugge bone-holding clamp, and the intramedullary canal is deepened using a canal reamer. An olive wire is then inserted to guide the flexible reamers.



Fig. 17: Drilling is performed using flexible reamers. In non-cemented stems, under-reaming by 1.5 mm is performed, whereas in cemented stems, over-reaming by 2 mm is recommended.

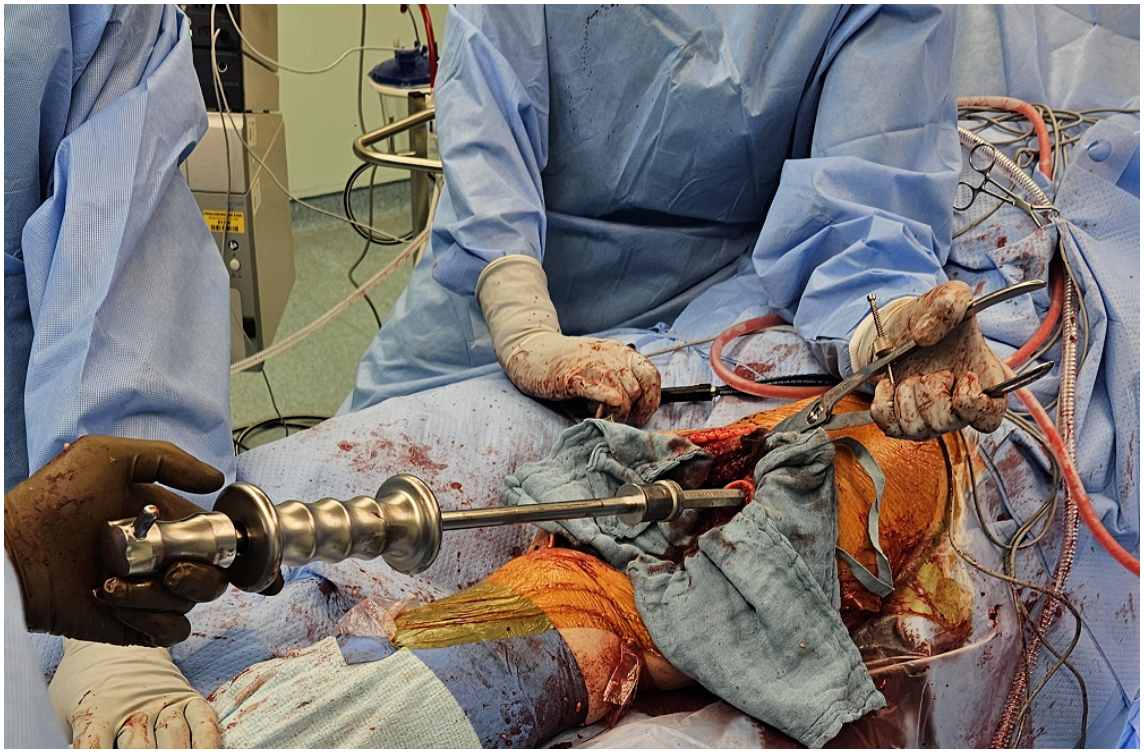


Fig. 18: After the correct reaming depth has been reached, in cases of cementless fixation, the rasp corresponding to the final stem size is carefully impacted under protection with a Verbrugge bone-holding clamp. Particular attention must be paid to rotational alignment by using curved femoral stems.

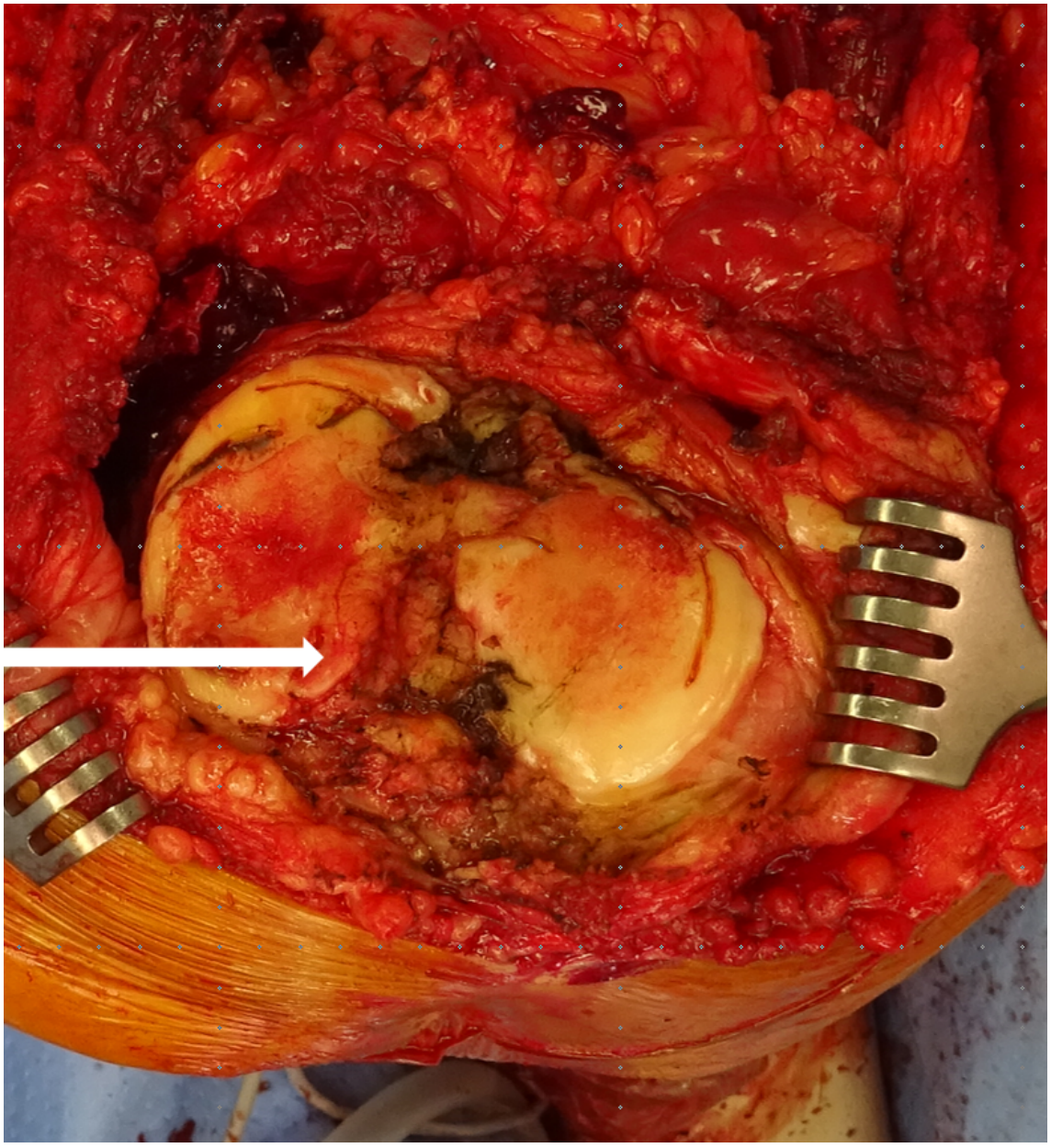


Fig. 19: The lower leg is positioned upright/flexed to proceed with tibial preparation. The tibial entry point (arrow) is located at the insertion of the anterior cruciate ligament and in line with the midline of the patellar tendon.

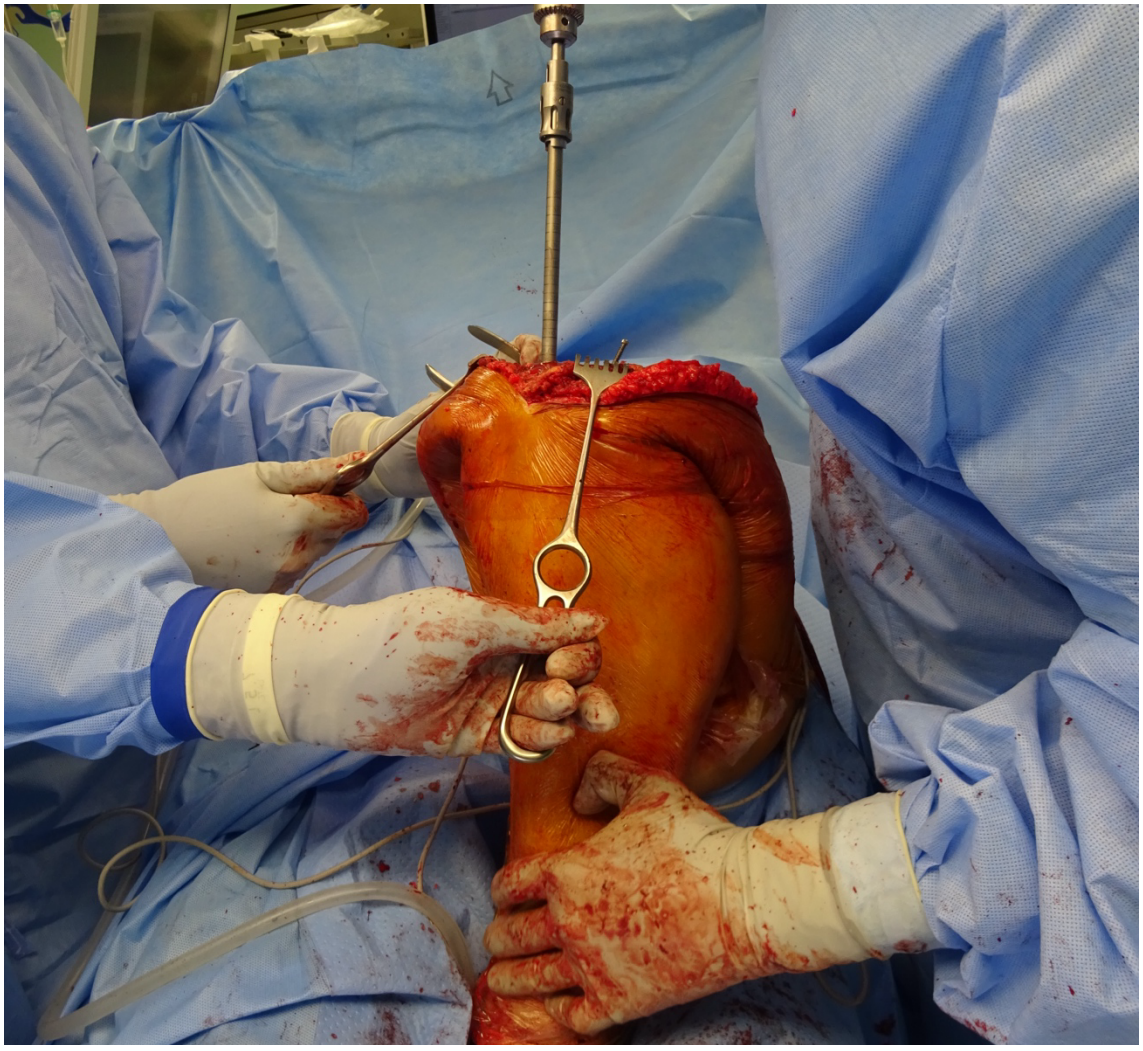


Fig. 20: The tibia is opened using an entry drill and then reamed stepwise with rigid reamers until a satisfactory size is achieved.

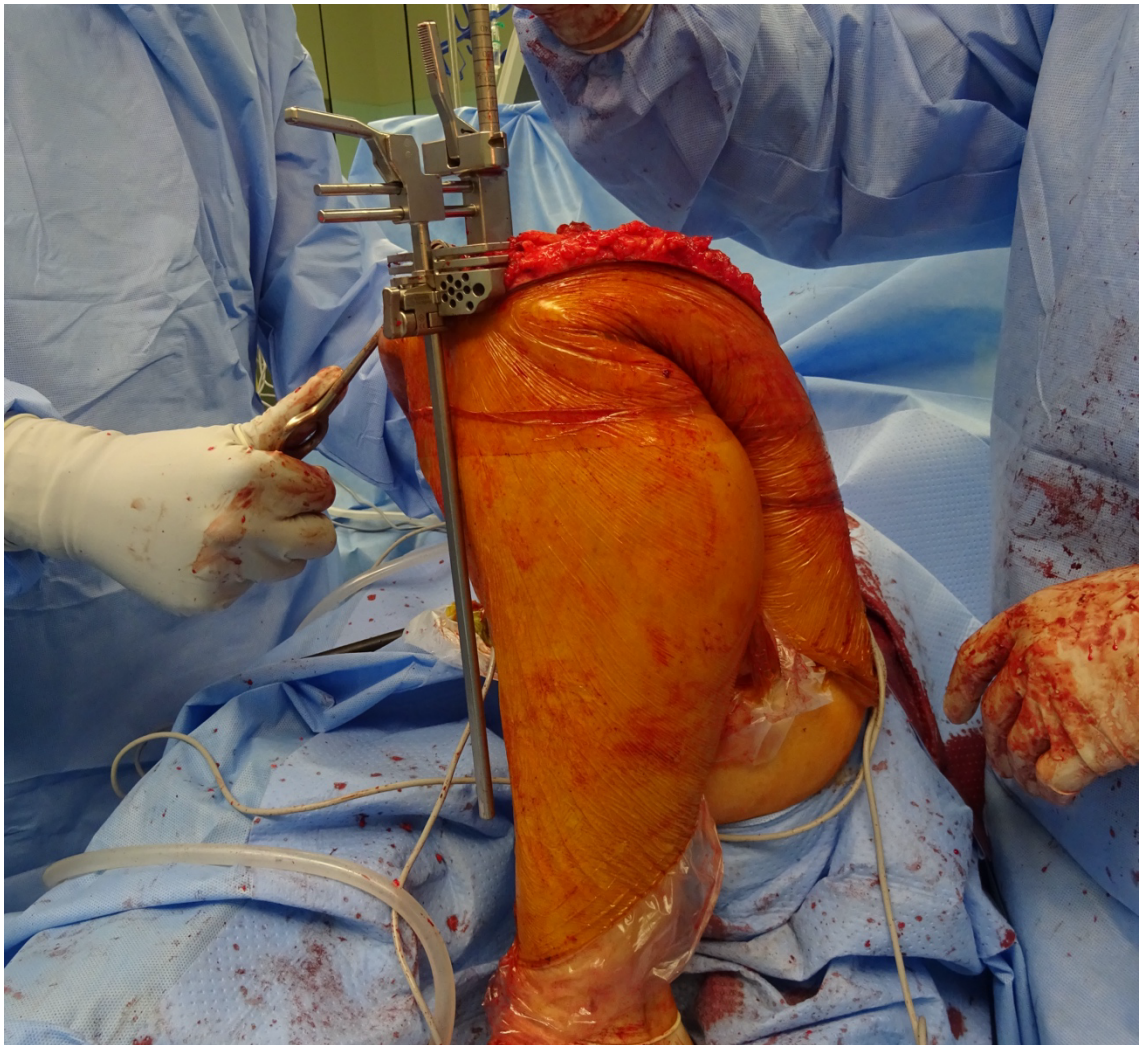


Fig. 21: The last tibial reamer is left in place, and the cutting block is attached. Alignment is performed using the anterior tibial crest as a reference. The correct cutting depth is verified, and the cutting block is fixed with pins. The reamer hat to be removed. Further preparation of the tibial plateau is then performed using an oscillating saw.

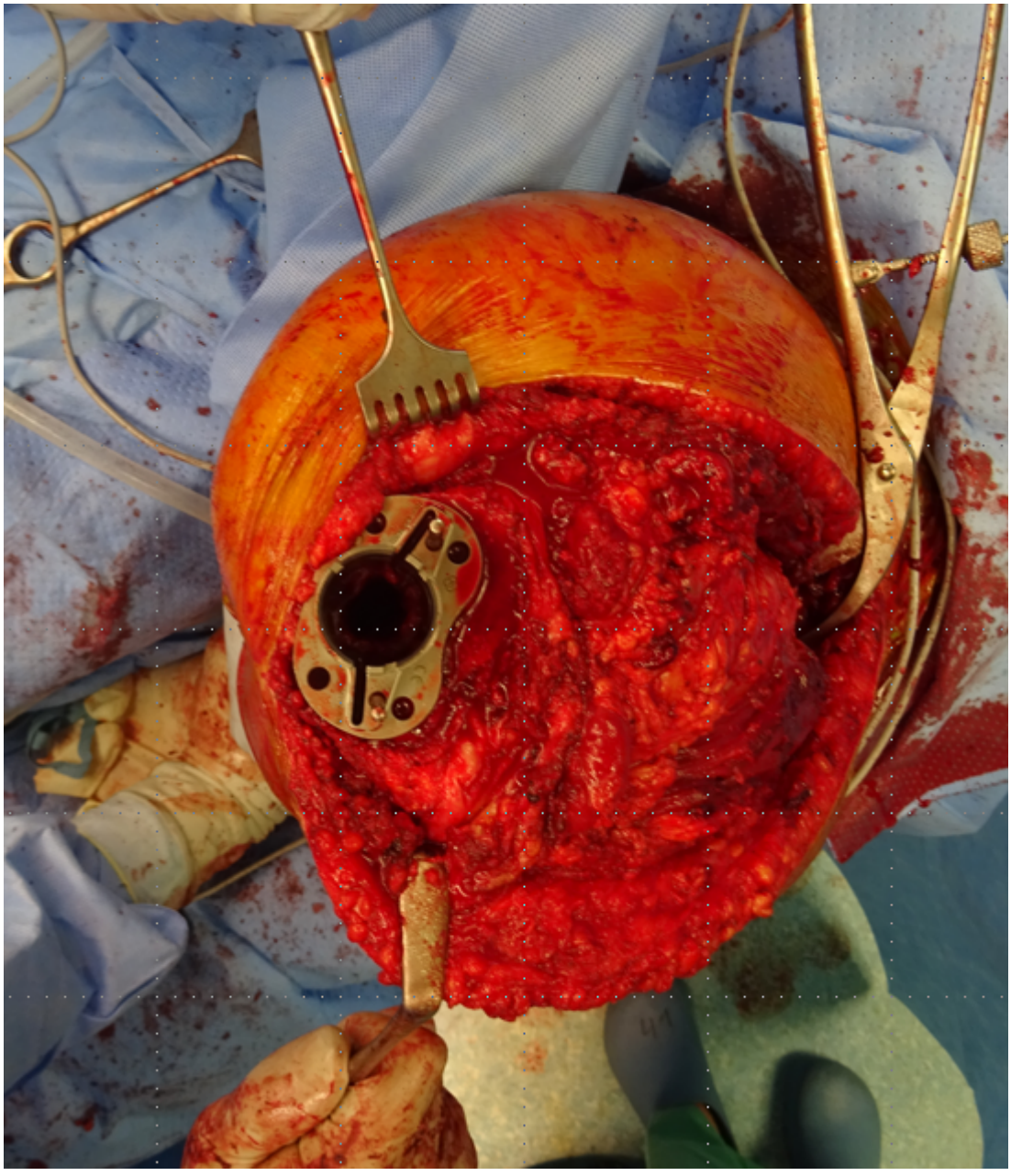


Fig. 22: The cutting block and reamer are removed, and the tibial plateau size is determined. Size adjustment and positioning is performed using an offset adapter, followed by final rotational correction.



Fig. 23: Implantation of the original tibial stem, including the offset adapter and tibial plateau, is performed using hybrid cementation (thin cement layer on the plateau). Final rotational alignment is checked during implantation and before cement curing. Subsequently, trial assembly is performed to assess soft tissue tension and reconstruction length.

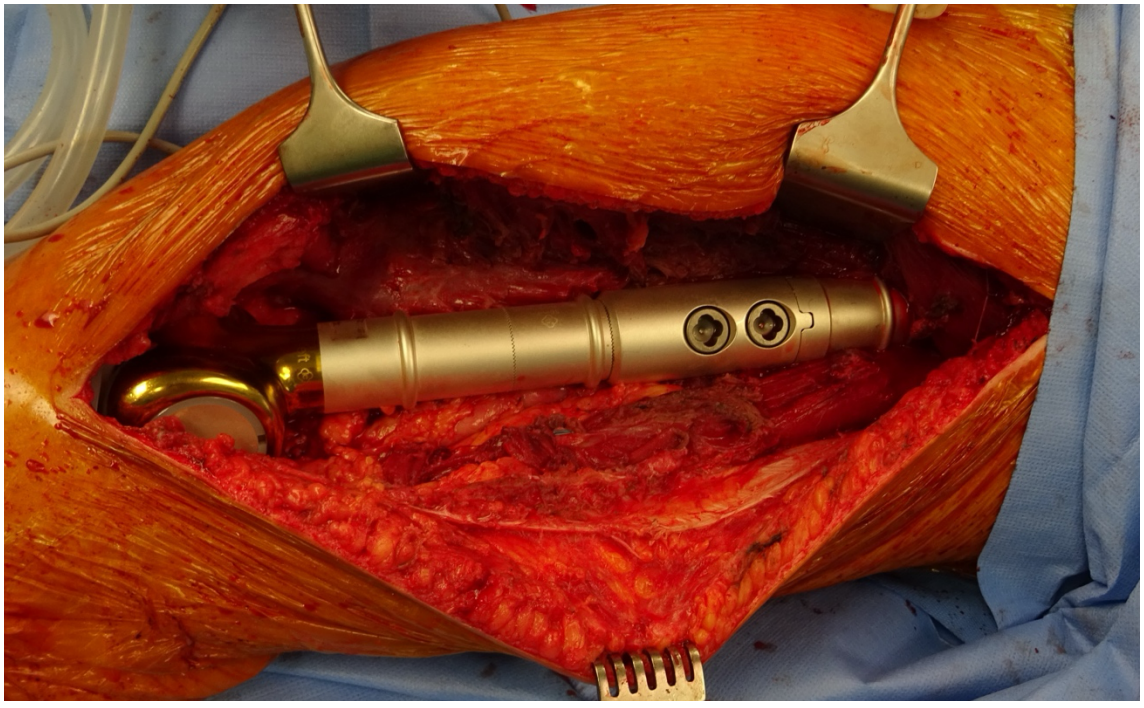


Fig. 24: The definitive implant is implanted, with careful verification of rotational alignment.

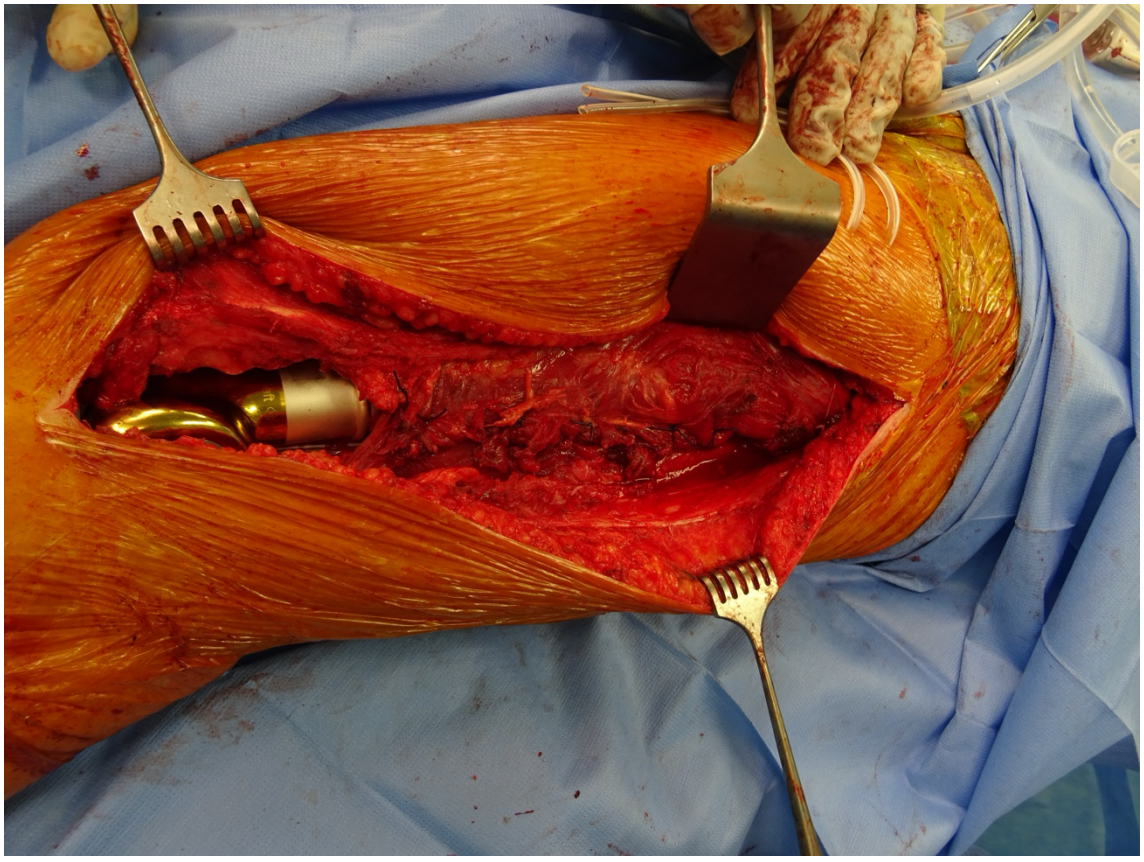


Fig. 25: The entire surgical site is irrigated. Wound closure is performed using a multilayer technique. A 10–12 Charrière drain is placed.

9. Bibliography

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