



Megaprosthesis in post-traumatic and periprosthetic large bone defects: Issues to consider



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ABSTRACT

Introduction: The recent evolution of prosthesis technology has enabled the surgeon to replace entire limbs. These special prostheses, or megaprotheses, were developed for the treatment of severe oncological bone loss; however, the indications and applications of these devices have expanded to other orthopaedic and trauma situations. For some years, surgeons have been implanting megaprotheses in non-oncological conditions, such as acute trauma in severe bone loss and poor bone quality; post-traumatic failures, both aseptic and septic (represented by complex non-unions and critical size bone defects); major bone loss in prosthetic revision, both aseptic and septic; periprosthetic fractures with component mobilisation and poor bone stock condition. The purpose of this study was to evaluate retrospectively the complications during and after the implantation of megaprosthesis of the lower limb in post-traumatic and prosthetic bone loss, and to propose tips about how to avoid and manage such complications.

Materials and methods: All the complications and difficulties we have encountered during or after the implantation of megaprosthesis in non-oncology patients were evaluated retrospectively. A total of 72 patients were treated with large resection mono- and bi-articular prostheses between January 2008 and January 2014.

Results: The main critical problems found in the study were: restoration of the correct length and rotation of the limb; reconstruction of the knee extensor mechanism; trochanteric reconstruction; stability/dislocation of the implant; mobility/range of motion (ROM) of the implant; skin cover; sepsis, and bone quality.

Conclusion: Megaprosthesis in severe bone loss can be considered as an available solution for the orthopaedic surgeon in extreme, appropriately selected cases. This type of complex surgery must be performed in specialised centres where knowledge and technologies are present. Patients with severe bone loss should not be treated in the same way as oncology patients because life expectancy is definitely longer; therefore, the surgical technique and the system implantation must be extremely rigorous to ensure longevity of the prosthesis. The characteristics of the bone and soft tissue conditions in these patients are very different from those presented by oncology patients, which creates critical problems that the surgeon should be able to manage to avoid serious complications.

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Introduction

The recent evolution of prosthesis technology has enabled the surgeon to replace entire limbs. Regarding the lower limb, particularly, prosthesis can be used to replace the whole femur and part of the tibia. These special prostheses, or megaprotheses, were developed for the treatment of severe bone loss, with the first

and most widespread applications in oncological orthopaedic surgery [1,2]; however, the indications and applications of these devices have expanded to other orthopaedic and trauma situations [3–10]. For some years, surgeons have been implanting megaprotheses in non-oncological conditions, such as acute trauma in severe bone loss and poor bone quality; post-traumatic failures, both aseptic and septic (represented by complex non-unions and critical size bone defects); major bone loss in prosthetic revision, both aseptic and septic; periprosthetic fractures with component mobilisation and poor bone stock condition [11].

The choice of treatment for patients affected by post-traumatic non-union and bone defect is based on the Non-Union Scoring System (NUSS) [12]. This classification system measures the

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complexity and severity of the condition of the patient, taking into account not only the radiological situation and the bone quality, but also the risk factors [13], the general health of the patient and the soft tissue status. The system provides a score from 0 to 100 points and identifies four groups of patients who have increasing complexity. For patients in the range from 0 to 75 points it is possible to perform a reconstructive treatment; in more complex cases (50–75 points) autologous and/or heterologous bone grafting are very useful and often biotechnologies (mesenchymal stem cells, growth factors and scaffolds) are utilised in “polytherapy” [14,15] following the “diamond/pentagon” concept [16,17] and the “Biological Chamber” principle [18]. If, however, the final score for a patient is over 75 points and the possibilities of regeneration are too limited, a more definitive treatment is indicated, such as amputation, arthrodesis or replacement with megaprosthesis.

Post-traumatic, infective and periprosthetic conditions have peculiar characteristics that are very different to those of oncology patients. The patient’s general condition, soft tissue status, lesion characteristics, muscle depletion, previous surgeries, presence of adhesions and any previous sepsis complicate the treatment and are associated with typical problems about which the surgeon should be aware before performing such a complex surgery.

After facing many of these special cases, we were able to understand some critical issues related to the implantation of megaprosthesis in such conditions. The purpose of this study was to evaluate retrospectively the complications during and after the implantation of megaprosthesis of the lower limb in post-traumatic and prosthetic bone loss, and to propose tips about how to avoid and manage such complications.

Materials and methods

All the complications and difficulties we encountered during or after the implantation of megaprosthesis in non-oncology patients were evaluated retrospectively. A total of 72 patients were treated with large resection mono- and bi-articular prostheses between January 2008 and January 2014. These patients were subdivided as follows: 21 proximal femur, 31 distal femur, three proximal tibia, four distal femur and proximal tibia, and 13 total femur. The surgical reconstructions were performed by one surgeon during this period.

The mean follow-up of patients was 18 months (range 6 months to 6 years), during which there were clinical and serial radiographic evaluations with standard methods (X-ray at 45 days, 3, 6, 12, 18 and 24 months after surgery) and monitoring of blood parameters of inflammation for at least 2 months after surgery. A total of 43 of the 72 patients were female and 29 were male. The mean age of the patients was 68 years (range 30–89 years).

The pathologies treated were as follows: 34 non-unions; 22 periprosthetic bone defects with loosening of the components; 11 periprosthetic fractures with poor bone quality and/or loss of bone substance; and five acute fractures in patients with poor bone quality. There was a current or past history of sepsis in 33 of the 72 cases treated in the study. All difficulties and problems encountered during surgery (intraoperative) were recorded, and postoperative complications were registered until the final follow-up.

Results

The main critical problems found in the study were: restoration of the correct length and rotation of the limb; reconstruction of the knee extensor mechanism; trochanteric reconstruction; stability/dislocation of the implant; mobility/range of motion (ROM) of the implant; skin cover; sepsis, and bone quality.

Restoration of the correct length and rotation of the limb

The modularity of megaprosthesis devices enables good management of limb length. The choice of the size and length of the prosthetic elements is critical to find the right balance between correction of limb length, restoration of joint function (a prosthesis that is too long often impedes full extension of the knee) and stability (a prosthesis that is too short can lead to instability), while avoiding iatrogenic injuries related to the stretching of major neurovascular structures. This type of prosthesis also enables better correction than other reconstructive solutions for axial and/or torsional deformities that can afflict the long bone after a large number of failures. In the current series, it was possible to correct the length of the lower limbs in 79.1% of cases.

Reconstruction of the knee extensor mechanism

The quality of the knee extensor mechanism is very often in a critical condition in post-traumatic-prosthetic patients who have undergone multiple surgeries. Common complications include partial tear or complete rupture of the patellar tendon and anterior tibial apophysis avulsion. In our series, 51 of 72 patients were treated at the knee. Many treatment options were used in 36 of these cases, as follows: reinforcement of the anterior tibial apophysis with screws in four cases (Fig. 1a); reinforcement or complete reconstruction of the patellar tendon using synthetic tendon graft substitutes in nine cases (Fig. 1b); tendon-plasty of the quadriceps and/or patellar tendons to stretch the tendon fibres and enable functional reconstruction in 15 cases (Fig. 1c); anchoring the tendon directly to the prosthetic element (in cases of proximal tibial megaprosthesis) using an appropriate plate built for this purpose in seven cases (Fig. 1d); and reinforcement of the patella through peripheral cerclage with non-absorbable metal core wire in one case (Fig. 1e). In the remaining 15 (of 51) patients, the quality of the extensor was good, so it was not necessary to perform any special procedures.

Trochanteric reconstruction

Trochanteric reconstruction is possible using megaprosthesis devices. Preservation of the great and small trochanter is very important during the preparation phase and the removal of the segment. By applying appropriate osteotomy, it is possible to preserve the two apophyses with their muscle insertions. After implantation of the definitive prosthesis, the great trochanter can be anchored to the proximal region of the prosthesis where three dedicated holes are present (Fig. 2a). The small trochanter can be anchored around the prosthesis using special loops made with resistant non-absorbable wire (Fig. 2b). Postoperative scar healing incorporates the tuberosity over time making it adhere to the prosthesis and enabling good muscle function. Reconstruction of the trochanters was performed in all 34 of the proximal femur/total femur megaprotheses implanted in the study. Notably, in all three cases of hip dislocation in this series the muscle insertion at the prosthesis was preserved despite the dislocation, which highlights the resistance of these systems (Fig. 2c). A positive Trendelenburg’s sign was observed in 11 of the 34 patients who underwent proximal femur/total femur megaprosthesis implant.

Stability – dislocation

Dislocation at the hip is one of the most common complications in patients treated using megaprosthesis for proximal bone defects. According to the literature, the incidence of hip dislocation in these patients ranges between 6% [19] and 42% [20]. In the current study of 72 patients, 34 had proximal and total femur

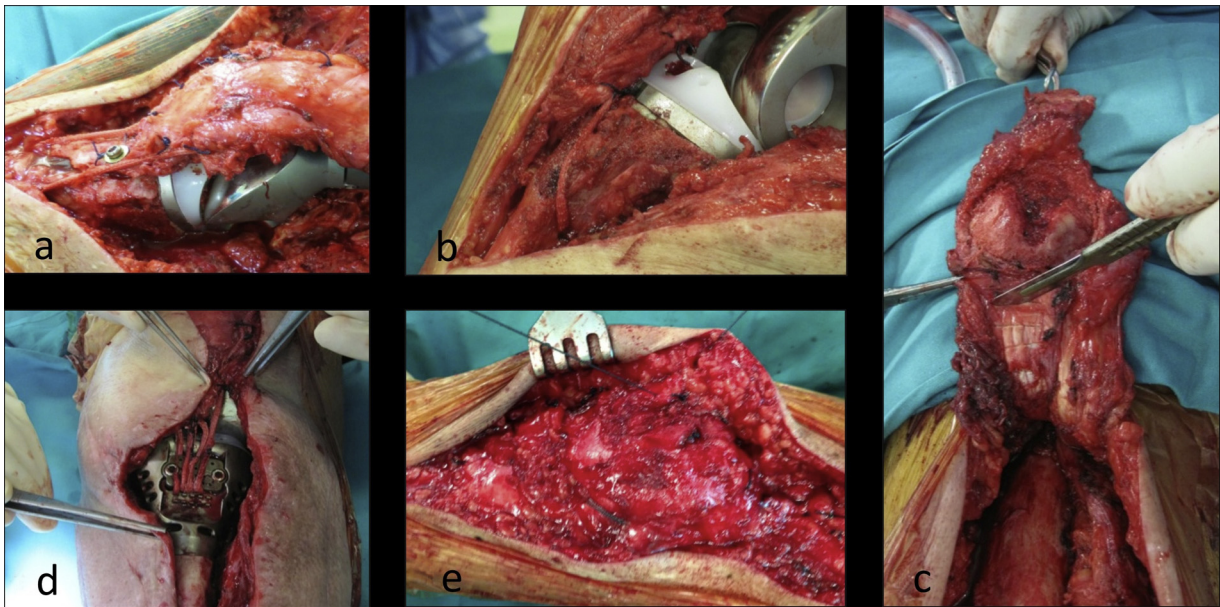


Fig. 1. Different techniques for management of the knee extensor mechanism: reinforcement of the anterior tibial apophysis with screws (a), reinforcement of the patellar tendon using synthetic tendon graft substitutes (b), tendon-plasty of the quadriceps (c), tendon anchoring at the prosthetic component using dedicated plate (d), reinforcement of the patella through peripheral cerclage with non-absorbable metal core wire (e).

megaprosthesis implanted and of these, three patients (8.8%) had a dislocation of the prosthesis at the hip.

The first of these three cases was an active young man who had a traumatic dislocation after a fall. The patient was treated using closed reduction, but after a few days a second dislocation occurred. Surgery was performed and soft tissue was found interposed between the prosthetic head and the acetabulum. Removal of this impingement solved the case.

The second case was a female aged 41 years who had a history of four operations after subtrochanteric fracture of the right femur failed to heal. This patient had modest congenital hip dysplasia. An

accurate intraoperative test was conducted to verify the correct version of the prosthesis neck and the stability of the implant during the prosthetic implantation. As the patient was young, an endoprosthesis was implanted as a bicentric system to safeguard the acetabulum and give good stability. This was not the case, however, because the patient had a non-traumatic dislocation one month later. The acetabular component was therefore implanted. After another month, the patient had a second dislocation. The situation was solved by conducting a second closed reduction. Analysis of the case revealed that the centre of rotation was placed higher than the contralateral, and there was a shortening of the

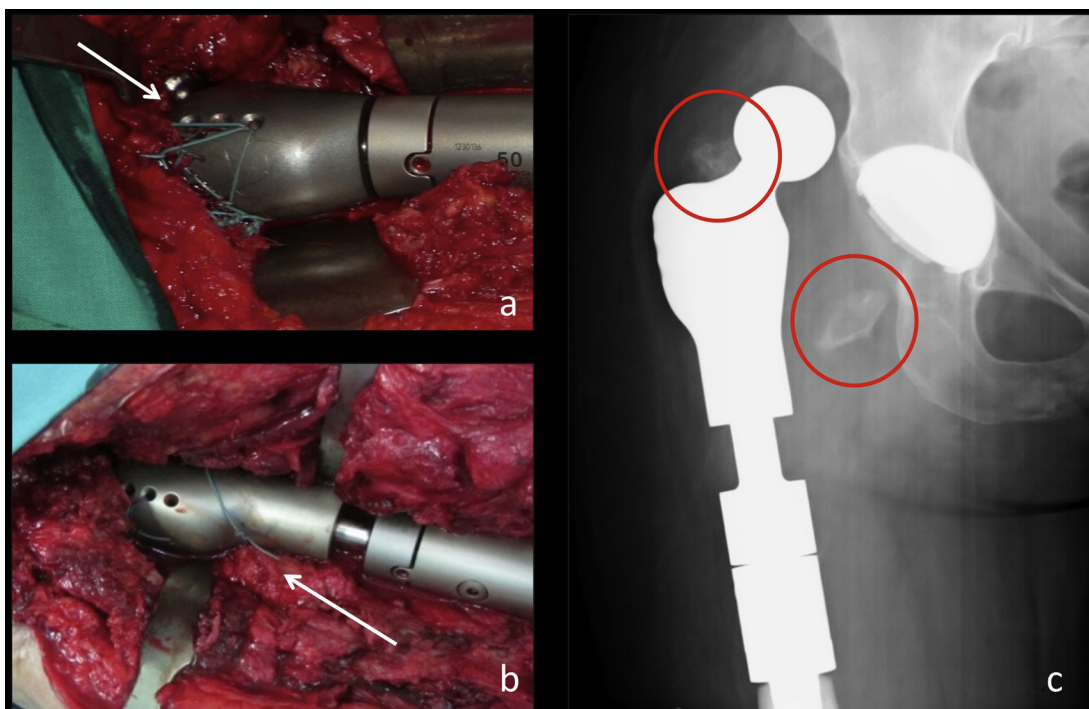


Fig. 2. Reconstructive techniques for the repositioning of great (a) and small (b) trochanter to the prosthesis component. X-ray after dislocation (c): the muscle insertions are still anchored to the prosthesis component.



Fig. 3. X-ray after closed reduction of the second dislocation at the hip. The centre of rotation is placed higher than the contralateral with shortening of the offset (a). Acetabular component with internal augmentation and special antiluxation insert (b).

offset (Fig. 3a). No further dislocation in this patient has occurred during 2 years following the second closed reduction.

The third case was a female aged 89 years with severe and compromised general and soft tissue conditions. A total femur implantation was performed to treat a complete bone loss of the femur with a total knee prosthesis mobilisation. Although a custom-made longer necked prosthesis was used, a dislocation occurred one month after surgery. After two closed reductions without success, a revision of the acetabular component was performed and a dual mobility insert was implanted with satisfactory results.

After critical analysis of these cases, it is clear that there are two major associated problems: the decreased offset and the muscle impairment of these complicated patients. Nowadays, the problem of decreased offset is solved by implanting a new acetabular component that can permit an internal augmentation (improving the offset) and that can, with special antiluxation inserts, increase the head cover (Fig. 3b).

This kind of solution is preferred because a constrained acetabulum could transmit strong forces to the pelvis, which could be a risk for pelvis fracture in patients with poor bone quality. A dual mobility acetabulum is a good solution, but it does not resolve the decreased offset. Application of a device able to extend the length of the prosthetic neck and change varus/valgus could increase the offset; however, this solution adds modularity to the implant and therefore is not recommended.

In conclusion, we suggest performing a perfect primary implantation with a good position of the acetabulum and with the correct anti-retro-version of the prosthetic neck, because this kind of prosthesis permits the surgeon to rotate the neck and choose the more stable condition. Also, good soft tissue reconstruction and trochanteric repositioning are very important to avoid this severe complication.

Mobility – ROM

The recovery of good joint function, particularly of the knee, is a major challenge in patients undergoing megaprosthesis implantation. Scar adhesions related to past failures, joint stiffness due to pre-existing axial or torsional deformities and joint degeneration, and muscle retraction with relative depletion of contractile function and muscle mass are all present in these conditions and need to be treated.

A wide liberation of soft tissues and a lysis of scar adhesions are essential to achieve the maximum possible ROM; usually some transverse sections of the subquadriceps fasciae (pie crusting) are

necessary to stretch the fibres and increase the ROM (Fig. 4). The choice of the length and the size of the prosthesis is another important factor; devices that are too large do not enable a large ROM as they interfere with soft tissue and hinder the sliding of tissues.

Skin cover

The quality of the superficial soft tissues (skin and subcutaneous tissue) can be seriously compromised in post-traumatic patients with previous or current sepsis who have undergone many surgeries. The coverage of the prosthesis is often difficult and ancillary plastic surgery operations may be required, particularly at the level of the distal femur and proximal tibia. Preoperative planning and careful evaluation of the skin may enable the surgeon to plan multidisciplinary surgery with a plastic surgeon. In the current series, 17 out of 72 patients required plastic surgery.

Sepsis

The septic cases are the most complicated. The quality of tissues is extremely poor: necrotic and infected bone requires extensive resection and soft tissues are destroyed by the infection. Debridement should always be conducted carefully and radically. In cases of post-traumatic septic non-union or periprosthetic infection, surgical treatment should be conducted in two steps.

The first step comprises cleaning, removal of fixation devices or prosthetic elements, large debridement of infected tissues, abundant antiseptic washing and implantation of antibiotic-loaded spacer (custom made or performed in the operating room using bi-antibiotic-loaded cement). Both the spacer and the cement should contain groups of antibiotics with efficacy against the bacteria causing the infection.

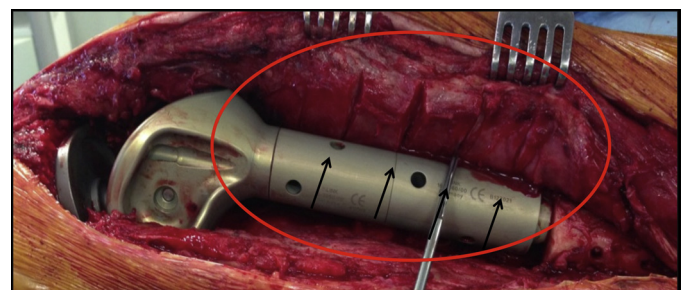


Fig. 4. Transverse sections of the subquadriceps fasciae (pie crusting).

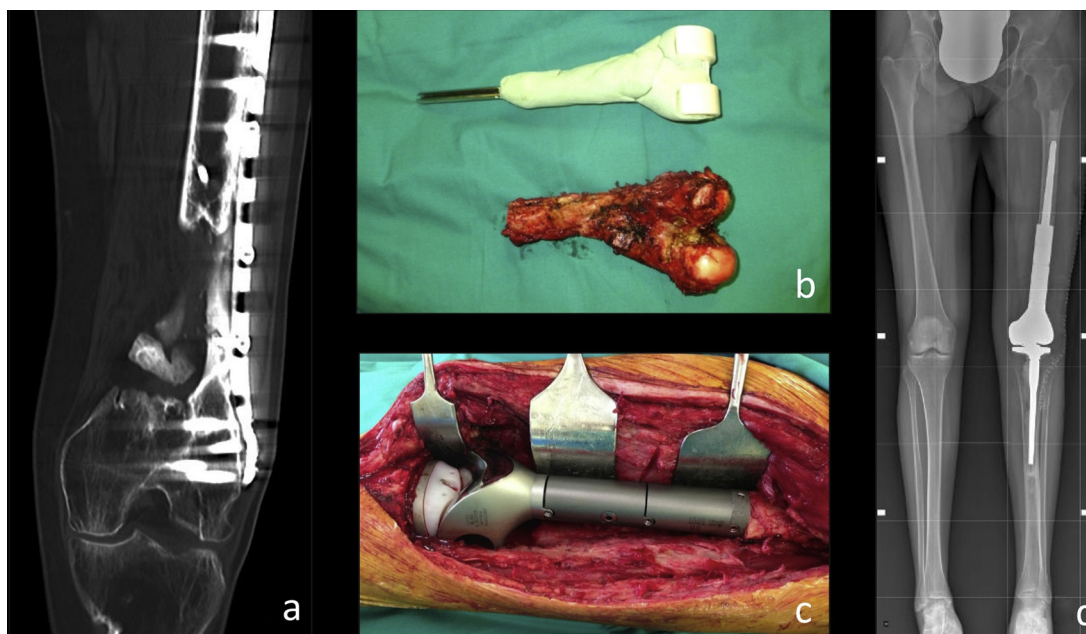


Fig. 5. Severe septic non-union of the distal femur with critical bone loss in a female aged 43 years with three previous surgeries. Pre-op CT scan (a). First step: surgical resection of the distal femur and implantation of antibiotic spacer (b). Second step: removal of the spacer and implantation of megaprosthesis (c). X-ray after 1 year (d).

The second step comprises implantation of a megaprosthesis covered in silver and should be performed no sooner than 2 months after the first step, and only after normalisation of inflammatory markers (C-reactive protein [CRP]) and signs of infection [21]. The removal of the spacer should reveal the creation of a pseudosynovial membrane that can host the prosthesis components in a sterile and protected environment.

In the current series, a two-step surgical treatment was performed in 31 of 72 cases (Fig. 5). Treatment in one surgical step can be reserved for those septic patients in whom it is expected that the complete removal of the affected segment (the whole femur) will be required. If the debridement is radical and the entire infected bone is removed, a megaprosthesis can be implanted in one surgical step. A one-step surgical treatment was performed in two patients in the study: these patients were treated in a unique time with a silver-coated total femur megaprosthesis. There was no recurrence of infection in either patient.

Bone quality

Bone quality in the area in which the prosthesis is to be implanted is often poor and there is a high risk of iatrogenic intraoperative fractures or periprosthetic postoperative fractures. Some measures, such as bone reinforcement using metal cerclages (Fig. 6), good cementation, correct choice of the length and diameter of the intramedullary stems and specific anabolic or anti-catabolic drug therapies, may help the surgeon to avoid complications.

In our series, a patient who had undergone a distal femur megaprosthesis sustained a proximal femur periprosthetic fracture in an accidental fall during rehabilitation. The distal femur megaprosthesis was converted into a total femur megaprosthesis to restore the patient's situation.

Conclusion

In cases of traumatic, post-traumatic and periprosthetic critical bone defects, the life situation of the patient and their level of compliance must be taken into account. The NUSS is suitable for critically assessing whether bone preservation or rapid restoration of biomechanical function is the appropriate treatment strategy. Megaprosthesis in severe bone loss can be considered as an available solution for the orthopaedic surgeon in extreme, appropriately selected cases. This type of complex surgery must be performed in specialised centres where knowledge and technologies are present. Patients with severe bone loss should not be treated in the same way as oncology patients because life expectancy is definitely longer; therefore, the surgical technique and the system implantation must be extremely rigorous to ensure longevity of the prosthesis. The characteristics of the bone and soft tissue conditions in these patients are very different from those presented by oncology patients, which creates critical problems that the surgeon should be able to manage to avoid serious complications.

Conflict of interest

The authors have no conflicts of interest to declare. No financial support has been received by the authors for the preparation of this manuscript.

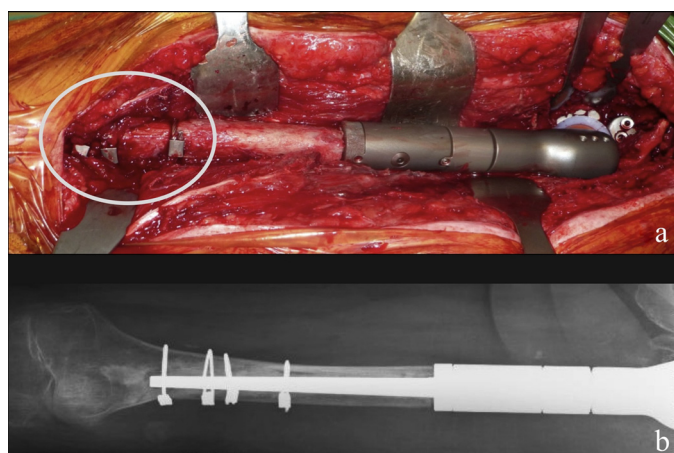


Fig. 6. Reinforcement of the distal femur using metal cerclages (a). Post-op X-ray (b).

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