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Post-traumatic severe femoral bone defect managed with masquelet technique: Case report and review of the literature

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Abstract
Management of large bone defects remains a complex situation, with multiple treatment options but with a persistent lack of reliable models or best practice evidence. In severe bone defects, options are bone transport technique, free vascularized autograft and Masquelet technique. These have all shown advantages and drawbacks and are required to be tailored to the patient's individual situation, including the local situation with size and location of the bone defect, soft tissues condition, local vascularization and risk of infection. Potential complications and duration of treatment should be part of the patient's information when limb reconstruction is considered, to optimize patient compliance in an already life-changing situation. The case reported here describes the management of a 47-year-old man with an Gustilo 3B open distal femoral fracture, with a large circumferential bone defect, treated with the induced membrane technique during 9 months before acquiring bone consolidation.

Keywords: Large segmental bone defects, femur, trauma, repair and reconstruction, masquelet technique

1. Introduction

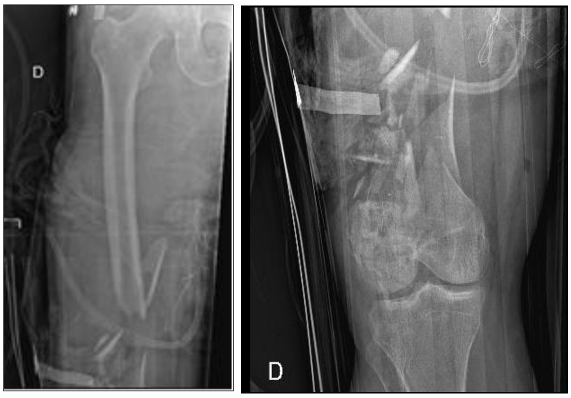
The surgical management of significant post-traumatic bone defects remains a challenge in the 21st century, both in terms of the initial management and of the subsequent potential complications. Several techniques have emerged over the past decades, among these, the Masquelet technique, proposed and developed by the French surgeon AC. This procedure is quite accessible from a technical point of view and affordable, for an appreciable success rate in the management of a complex clinical case. Here is presented the clinical case of a patient admitted to our Trauma Center with an open fracture and post-traumatic large femoral bone defect. Treatment options are exposed, followed by the pro and con's of the Masquelet technique. Future possibilities end the discussion.

2. Case report

A 47-year-old man was brought to emergency after a high-energy motorcycle accident. Clinical examination revealed an open fracture of the right distal femur and tibia as well as close fractures of the right foot. He presented a cold right foot without arterial bleeding, open wounds were not macroscopically soiled and were defined as Gustilo 3B on the femur and tibia. Coloration and pulse of dorsalis pedis and posterior tibial artery recovered when the lower limb was correctly immobilized. Nerve examination was not achievable at that time due to sedation. Imaging assessment with antero-posterior X-ray of the femur showed a diaphyso-metaphyseal bone defect with metaphyso-epiphyseal irradiation of fracture site, described as a 33C3 fracture according to the AO classification (Fig. 1a and 1b).
Imaging of the rest of the right lower limb revealed a fracture of the distal third of the tibia and fibula shaft, a transverse patella fracture and tarso-metatarsal fractures.
After a clinical and imaging assessment and hemodynamic stabilization, the patient was brought to the operating room. Due to multiple severe lesions, a damage control surgery was performed involving a thorough debridement and initial skeletal stabilization with external fixation. Soft tissue coverage was achieved for femur but not for tibia so a vacuum therapy was started until definitive internal stabilization and free flap coverage was realized height days later, along with stabilization of the foot and the patella. Following the fixation the right foot remain neurovascular intact. A significant bone loss remained at the distal femur, and after discussion within the orthopaedic team and with the patient's consent, decision to

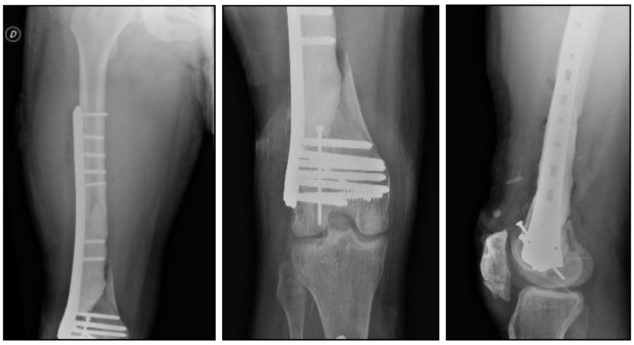
perform Masquelet technique (induced membrane technique) to allow bone healing was retained.

The first stage of the Masquelet technique was performed two days after the patient's arrival. By a lateral approach, external fixation was turned in an internal plating to fix intra articular fracture, avoid pin infection, get better stability and potentially increase range of movement. During internal fixation, attention was paid to restore length, axis both in coronal and sagittal plane and also avoid rotational malreduction. Bone defect was distal, diaphyso-metaphyseal, circumferential and extra articular with a maximal length of 15cm. It was filled in by antibiotic cement spacer: polymethyl methacrylate (PMMA) with refobacin (Fig. 2a and 2b).



(a) (b)

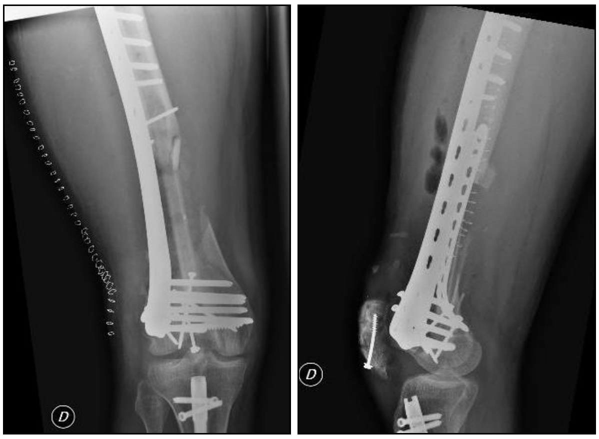
Fig 1(a, b): Initial radiologic assessment of femur.



(a) (b) (c)

Fig 2(a, b c): Masquelet technique first stage

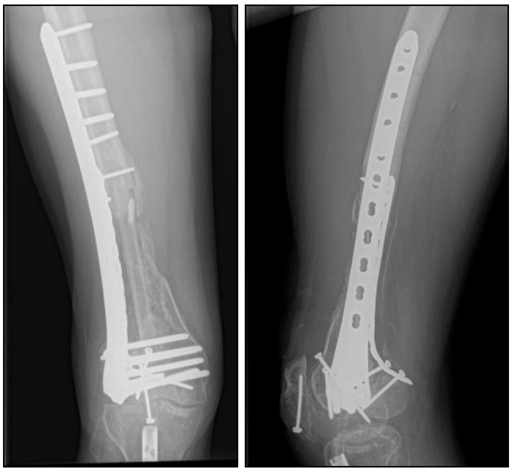
Masquelet technique second-stage intervention was done five weeks after the first stage. The patient has even stopped smoking after the first stage to improve his chances of recovery. An induced membrane was found over the cement spacer, and carefully open. Cement spacer was removed and stabilization of Hoffa fracture (posterior side of lateral femoral condyle) initially performed with two screws (a locking one in the plate and an anteroposterior lag screw out of the plate) was improved by an additional posterior anti glide plate. An autologous cancellous bone graft previously harvested from the iliac crest with a posterior approach was used along an autologous contralateral non vascularized fibula was added to bring volume and three-dimensional structure (Fig. 3a and 3b).



(a) (b)

Fig 3(a, b): Masquelet technique second stage

Follow-up was performed at 2 and 6 weeks and at 3, 6, 9 and 12 months. Physiotherapy was performed 3 to 5 times a week. Weight-bearing below the pain threshold was allowed at 7 weeks after foot surgery (3 weeks after induced membrane technique second stage), due to foot limitation for weight-bearing. Full weight-bearing was achieved at three months following Masquelet second stage**.** Consolidation was achieved at 9 months (Fig. 4a and 4b).



(a) (b)

Fig 4(a, b): Nine months post Masquelet second stage

A femoral valgus is residual at one year but with good functional outcome, patient is not painful, has no hip limitation. At the knee is missing 5° of extenssion and flexion is limited to 90° which equates to the pre trauma flexion (sequella of a previous patella fracture). Knee is stable both in sagittal and coronal plane. No clinical or radiological infection signs were detected during the follow-up.

3. Discussion

3.1 Management of bone defect through the lasts decades

Over the past decades, the surgical possibilities for the management of complex trauma have evolved, and now allow limb survival beyond estimates initially provided by scores such as the Mangled Extremity Severity Score (MESS), developed 25 years ago without anticipating current therapeutic advances [1]. However, the choice of possible repair techniques requires balancing the advantages and disadvantages, of a technical, financial or ethical nature. On the other hand, the possibilities of repairing an injured limb depend on the potential for bone but also vascular and neurological recovery [2].

When it comes to focusing on the management of a post-traumatic large bone defect, high-level evidence to guide treatment is lacking [3]. The therapeutic choice is based on the extent of the bone defect, associated soft tissue lesions, local vascularization as well as the risk of infection [4, 5]. The “diamond concept” was introduced by Giannoudis *et al.* during these last years to summarize the four main factors needed to achieve successful bone regeneration: viable osteogenic cells, osteoconductive scaffolds, growth factors as well as the stability of the mechanical environment [6, 7].

Historically, Ilizarov's bone transport method, developed by Gavrill Ilizarov and widely used throughout the 20th century and beyond, was a comprehensive technique in the management of both bone defect and cover defect. The gradual traction of the corticotomy performed in a healthy bone margin, with the possible association of an autologous bone marrow grafting within the defective zone, presents the drawbacks of a sometimes complex management of the associated external fixator, of the induced ankylosis to the adjacent joints and lack of control over premature or delayed union [5, 8].

Since the contraindication to the use of bone autograft alone for a bone defect greater than 5 cm is well described in the literature [5, 9], the use of a vascularized autograft for the management of a bone defect is proved to be a reliable option for a significant post-traumatic defect, smaller defects that have failed to heal with non-vascularised bone grafting and previously infected bone non-union with or without a defect associated with osteonecrosis [5]. In presence of infection, vascularized graft has shown a lower risk of post-surgery infection in Azi ML *et al*. analysis [10]. The donor site options, from the fibula to the iliac crest, will depend on structural needs and consultation with patients given the related implications. However, patient expectations and the need for an experienced staff to perform microsurgery are elements that must be carefully considered before making a decision for this surgical option and the graft to be used [10].

3.2 Masque let technique and published results

The induced membrane technique introduced and developed since 1986 by the French surgeon A.C. Masque let *et al*. consists of a 2-step management of a bone defect, based on the development of a membrane characterized by different specific biochemical, cellular and vascular components around a spacer. The first step, during which the area of bone defect or nonunion is debrided from necrotic tissue, can be considered either straight away or after planning the admission of an open fracture stabilized with an external fixator. Following this debridement, implantation of a PMMA spacer will allow the development of an induced 2-layer membrane after 4 to 8 weeks [11]. This membrane, which generation has been studied during the last decades with different kind of foreign bodies, has an internal layer generating osteogenic and angiogenic cytokines [vascular endothelial growth factor (VEGF), bone morphogenetic protein 2 (BPM2), interleukin 6 (IL6)], and an external layer, approximately 2 times thicker than the first, which variability of physical properties is not yet well understood [12]. Biological activity of induced membrane, represented by protein levels including VEGF, transforming growth factor beta (TGF-β) and BMP reach maximal activity at the 2-4 weeks and then decreases at 6-8 weeks [13]. Despite the increasing use of this technique and its evolution since its introduction, it should be noted that the exact mechanisms behind the generation of this membrane remain unknown, as are the optimal conditions for improving the chances of success of the technique [12].

The second stage of the technique, which is recommended to be carried out 4 to 8 weeks after the first one to allow the constitution of a membrane with optimal properties, consists of the extraction of the cement while sparing the membrane and grafting into it a non-vascularized autologous cancellous bone graft, and at this time external fixation can be turned into an internal fixation. In case of insufficient autologous transplant, the addition of allograft may be considered but as a maximum ratio of 3:1 [14].

The 2016 systematic review from Morelli *et al*. [8], including 427 patients from 17 studies, compared specifically infection eradication and union rates for long bones defects and non-union in adults. With bone defect length between 0.6 to 26 cm, it demonstrated a union rate was 89.7% and the infections rectified in 91.1% of cases. It has to be noted that the complication rate was high (49.6%) amongst all studies, the main complications concerning superficial (4.9%) and deep surgical site infections (4.4%), failure of one of the IMT steps (persistence of infections or non-unions) (18%), with subsequent requirement for further union surgery or another kind of intervention in 9.6% and 26.7% patients respectively. The overall failure rate was 10.3%, including non-union (5.9%), amputation (4%) or persistent infection (8.9%). These results should lead the surgeon to have an appropriate discussion with the patient about the ins and outs of the technique, in an intrinsically challenging clinical picture.

This review showed a wide range of adaptation from the original technique, including the use of antibiotic-coated spacers, internal fixation during the first step, iliac crest grafting, bone substitutes and growth factors. Those results could be interpreted as demonstrative of the Masquelet technique to be a reproductive technique for surgeons with different experiences and with possible adaptation for each patient.

3.3 Future advances

With regard to bone transport, a breakthrough could be self-distracting devices such as plates or nails (currently under clinical trial in Europe). This would shorten the external fixation time and possibly increase the range of movement [3].

3D printed bioceramic techniques are still in a developmental stage for clinical application. At this time, some obstacles persist. First, they are brittle and not suitable for load-bearing. Then printing 3D bioceramics use toxic solvents and high-temperatures during the fabrication process which may compromise cell viability. And finally fabricating large-sized bioceramic scaffolds remains expensive and time-consuming [15].

Another 3D printing technique, bioprinting, brings the potential of producing a customized and vascularized living bone transplant. The process uses cell-laden hydrogels to print structures that will develop complex tissues, such as skin, cartilage, and bone after a period of maturation. But this process is still in development and thus has not yet been tested in clinical cases [15].

4. Conclusion

Reconstruction of large bone defects remains a challenging situation as multiple treatment options exist but lack of reliable models or best practice evidence persists. Each decision has to be tailored to the specific patient’s needs and medical history, as well as the local situation which includes size and location of bone defect, soft tissues condition, local vascularization and risk of infection. Autologous bone graft alone for bone defects greater than 5 cm has shown to be a contraindication in the literature. Bone transport remains a good option but with a sometimes more complex follow-up. Vascularized auto graft is a reliable option but microsurgery skills are needed. Masque let technique, as shown in this case, seems to be comprehensive, accessible from a technical point of view and at a lower cost, for an appreciable success rate in the management of large bone defects. In the future, several tracks remain open to enhance the management of major bone defects: first, providing best practice evidence of large bone defect management, then, improving the implantable devices, and finally the field of 3D printing seems to be revolutionary and very promising but has yet everything to prove.

5. Disclosure of interest

The authors declare that they have no conflict of interest concerning this article.

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