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A case report of extensive segmental defect of the humerus treated with Masquelet technique

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The treatment of extensive segmental bone defects is a complex task for orthopedic surgeons. There are several reconstruction options that exist: bone transport, vascularized bone transposition or transplantation, and induced bone membrane technique.[5,7,10,14,21] These methods are technically demanding, and each has its own different limitations and complications. However, knowing the particular pitfalls of these techniques will help choose one to achieve the desirable result.

Bone transport requires applying the Ilizarov principles of distraction osteogenesis.[10] This is one of the most complex techniques in orthopedics, with significant costs due to the active participation of the surgeon throughout the treatment process. Most often, this technique requires wearing the circular external fixator for an extended period of time, which can make the treatment uncomfortable for the patient and increases the risk of complications due to infection.[19] Bone transport with internal fixators is also described in the literature. However, it is associated with high implant costs and lacks empirical data on its complication rates and outcomes compared with other methods.[12]

The use of free vascularized fibular graft is another common treatment for large segmental bone defects. However, this technique has significant drawbacks, such as the necessity to use microsurgical techniques, high risk of transplant devascularization, and donor site morbidity.[3]

The induced bone membrane technique, introduced by A. Masquelet, allows one to repair large segmental bone defects without application of distraction osteogenesis techniques and microvascular surgery. A big advantage of this technique is its ability to replace almost any long bone defect in a fixed amount of time.[14]

In this article, we present a clinical case report of a patient treated with an induced membrane technique for a 12-cm humerus shaft defect that resulted from unsuccessful treatment of primary simple transverse humerus fracture.

Case report

The patient was a 46-year-old woman who worked as a conductor. In March 2017, she sustained a simple transverse humeral shaft fracture (AO Foundation / Orthopaedic Trauma Association classification [AO/OTA] 12-A3) as a result of a fall from a standing height. The patient was treated by intramedullary nailing in one of the city hospitals. Four months later, the patient fell again and sustained another fracture below the nail. The first facture had not completely healed by that time.

The patient got back to the same hospital, where nail removal and plate osteosynthesis was performed. Postoperative radiographs demonstrated that the nail removal was complicated by additional fragmentation of the intermediate bone. The treatment strategy was anatomic

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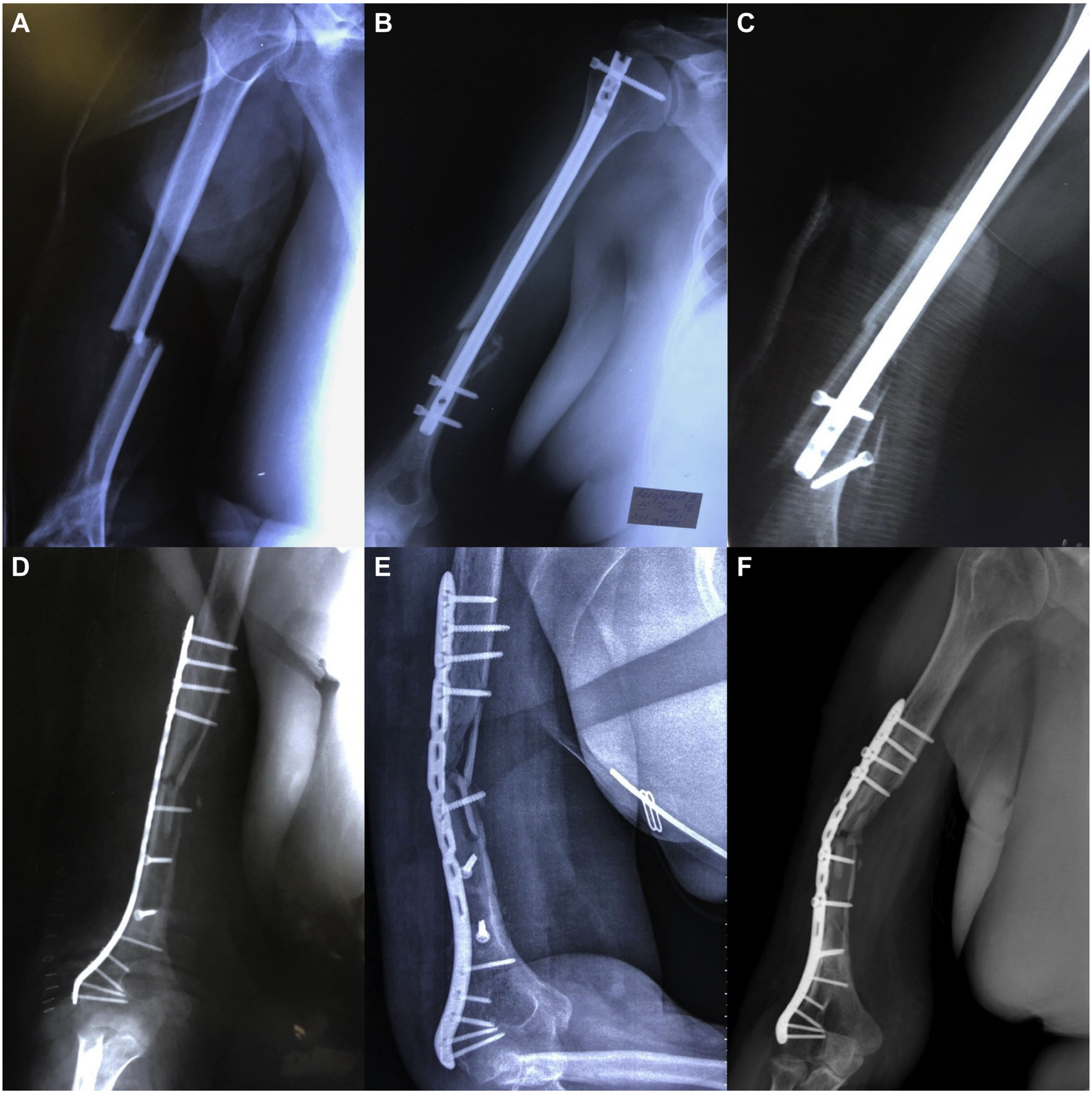

Figure 1 (**A** and **B**) AO/OTA 12-A3 fracture treated with intramedullary nailing; (**C**) peri-implant fracture after 4 months; (**D**) postoperative films after nail removal and plate fixation; (**E** and **F**) follow-up radiographs after 4 and 8 months. *AO/OTA*, AO Foundation/Orthopaedic Trauma Association classification.

reduction and absolute stability with disregard to the biology of bone healing.

On the follow-up visits at 2 and 4 months, there was no evidence of callus formation. The plate deformation was noted on postoperative films. The patient came to another hospital and was recommended to use a splint to add stability and prevent further plate deformation and breakage. Retrospectively, even at that moment it was evident that the main reason for delayed healing was an impaired biology rather than lack of stability. On later radiographs, there was still no evidence of fracture healing (Fig. 1).

The patient came to our department on May 2018, more than 1 year since the fracture and 6 months of elbow immobilization. At that moment, there was evidence of atrophic nonunion and severe shoulder and elbow contracture. Because of the difficulty in assessing the bone defect, a series of alternate approaches were developed, with the treatment decision to be made intraoperatively: (A) if the bone defect

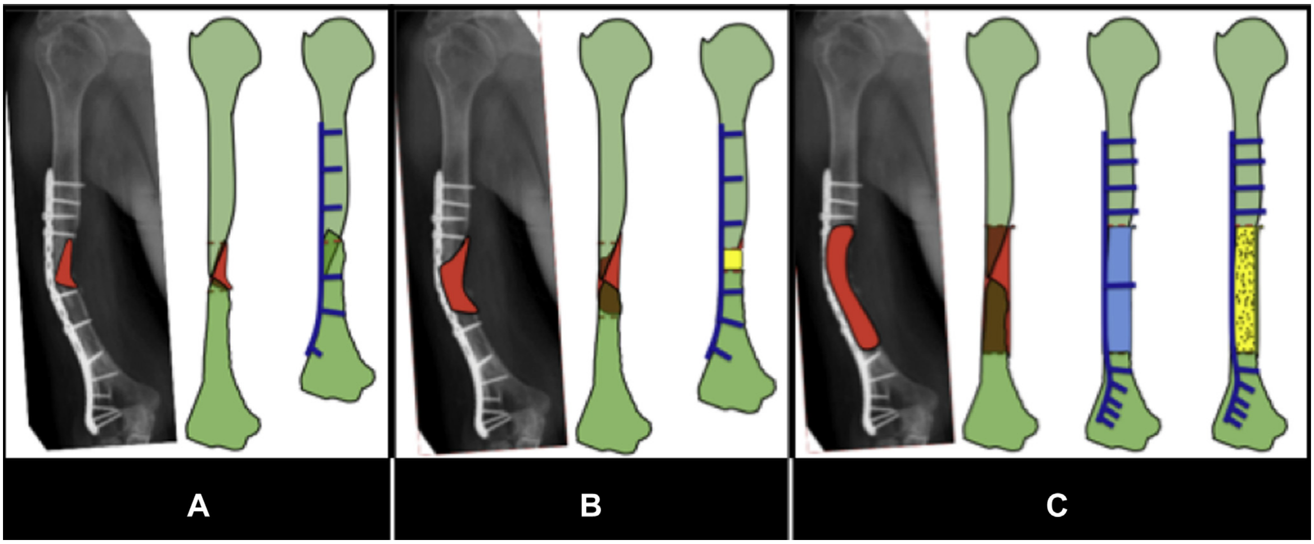

Figure 2 The reconstructive options that were considered: Plan A, shortening; plan B, shortening + autograft; plan C, Masquelet procedure.

was less than 4 cm, we would make an acute shortening without any significant functional deficit; (B) in case of a bone defect of 4-7 cm, we would partially shorten the humerus and fill the remaining interfragmentary gap with autologous bone graft from the iliac crest; (C) for a bone defect of more than 7 cm, we would consider a 2-stage procedure using an induced-membrane technique (Fig. 2).

Surgery

Stage 1

We chose to use a posterior paratriceptal approach through a 20-cm skin incision. Radial and ulnar nerves were identified and protected. After plate and lag screws removal, the intermediate fragments were freed, detached from each other and the soft tissues, without any signs of viability. All devitalized fragments were removed, and after marginal resection of the main fragments, the bone defect was 12 cm. Thus, we went for option C, the Masquelet technique.

The 3.5 LCP Extra-articular Distal Humerus Plate (DePuy Synthes, Oberdorf, Switzerland) was initially fixed to the main fragments creating the 12-cm gap. The appropriate size of the required spacer was determined and a cylindrical polymethylmethacrylate antibiotic-loaded cement (DePuy CMW 1 Gentamicin 40 g; DePuy Synthes) spacer was created. The spacer was placed into the defect in such a way as to cover the bone ends with cement. To avoid thermal injury, the spacer was taken out at the time of its hardening. The spacer was fixed to the plate by a cortical screw.

There was no neurologic deficit after the surgery. The wound had healed uneventfully. The patient was recommended to use the arm as tolerated and come for the second stage in 4 weeks (Fig. 3).

Stage 2

The patient came for the second operation at week 5. In surgery, the patient was positioned in the lateral position with the right arm on an armholder fixed to the radiolucent operating table. A reamer-irrigator-aspirator system (DePuy Synthes) was used for bone graft harvesting. We collected 50 mL of autologous bone, which was pressed in a syringe and mixed with granulated β-tricalcium phosphate (b-TCP) (ChronOS Bone Void Filler; DePuy Synthes) in a proportion of 4:1.

We approached the spacer through a skin incision of 10 cm by the previous postoperative scar. The ulnar nerve was identified and protected. The membrane over the spacer was gently incised with 1 incision parallel to the plate. The spacer was removed. The autologous bone graft mixed with b-TCP granules was placed into the chamber created (Fig. 4). The membrane was sutured over the graft and the wound was closed.

We did not recommend postoperative rehabilitation because of the necessity of rigid stability, a very long working length of the implant, and the presence of severe contracture of elbow and shoulder joints. The arm was immobilized with a sling. Postoperative radial nerve neuropathy developed and resolved spontaneously within 3 weeks.

Resorption of proximal 2 cm of the transplant was noted on follow-up radiographs after 6 and 12 weeks (Fig. 5). This problem can be attributed to the lack of proper spacer preparation during the stage as a result of scar tissue formation in between the spacer and proximal bone fragment,

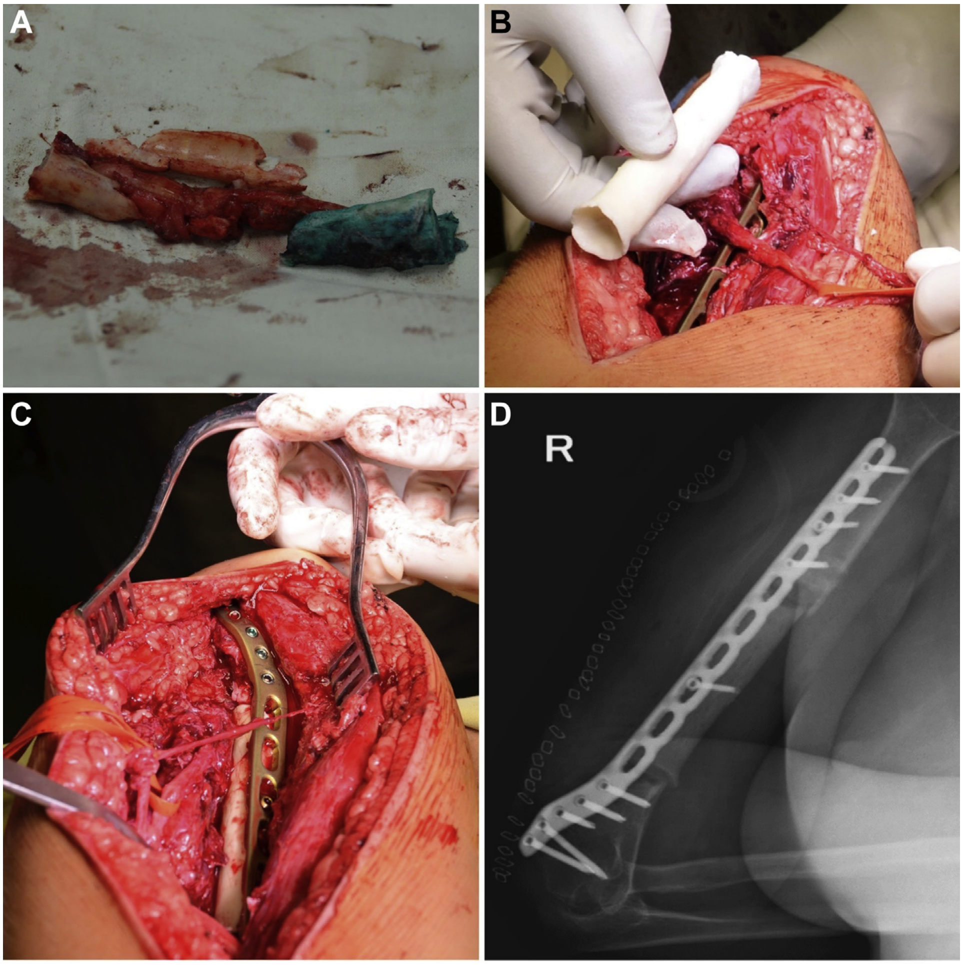

Figure 3 Stage 1: (**A**) Resected dead bone stained with Brilliant Green stain; (**B**) cylindrical polymethylmethacrylate 12-cm spacer; (**C** and **D**) the spacer under the plate fixed with a cortical screw.

which may have interfered with bone healing. We believe a more thorough revision with visualization of both bone ends and removal of all scar tissue could have prevented this complication. A third surgery was planned.

Third surgery

The patient was placed in a supine position and an approach to the resorption side was prepared through a 6-cm skin incision. The scar tissue was excised, and the defect was filled with a corticocancellous autograft taken from the ipsilateral iliac spine. Intraoperatively, consolidation of the remaining part of the autograft was noted. The patient was placed in a sling for 6 weeks. The wound healed uneventfully.

Follow-ups

Graft consolidation was noted on the postoperative radiograph after 8 weeks. We started the patient on an active rehabilitation program targeted to improve shoulder and elbow joint range of motion at that moment.

Complete consolidation of the graft was observed on follow-up visits (Fig. 6). The patient achieved a good function of elbow (range of motion: flexion, 80°; extension, 170°; full pronation and supination) and shoulder joints (full recovery of range of motion), and a complete weight-bearing function of the arm with a mild loss (4/5) of triceps strength.

Discussion

The Masquelet technique is an effective method for the reconstruction of segmental long bone defects, using which defects of up to 25 cm can be succssfuly treated.[14] One meta-analysis had revealed that this technique is most often used in lower extremity bone defects.[17]

However, humeral shaft defects are not the most common localizations for this technique. Morelli and colleagues[17] found only about 23 cases of humeral defects in the 427 cases they analyzed. In another study, this localization was involved in 2 of 11 cases, with the maximum

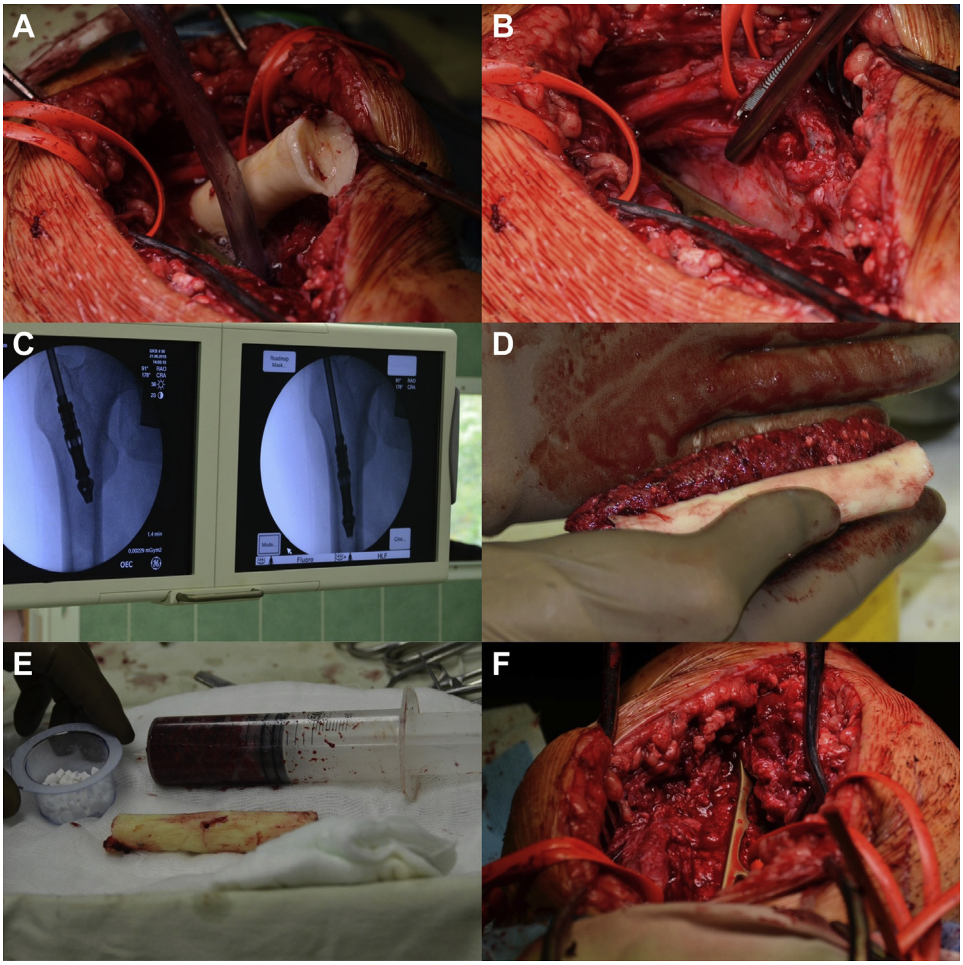

Figure 4 Stage 2: (**A**) spacer removal; (**B**) the membrane; (**C**) reamer-irrigator-aspirator system for bone graft harvesting; (**D** and **E**) harvested bone mixed with b-TCP granules; (**F**) the bone graft inside the chamber. *b-TCP*, β-tricalcium phosphate.

defect being only 3 cm.[11] Zappatera et al[22] reported on 9 cases of acute humerus shaft defects (range: 2.5-8 cm) that were treated with the Masquelet technique. In all cases, consolidation was achieved within 14.5 months (range: 10.2-52.7).

Special attention should be paid to the surgical technique, which ultimately determines the final outcome. At the first stage, the most important aspects are proper bone fixation, spacer preparation, and spacer placement. Although there is not enough evidence supporting the superiority of one fixation method over another, the literature shows that plate fixation is preferred by most authors.[8,17] Still, in a recent study, Morwood et al[18] have shown that intramedullary nailing has better results in lower extremity cases. External fixation can be the preferred method in case of infection.[9]

The ends of the cement spacer should overlay the bone ends covered by periosteum. This will allow formation of a membrane that completely covers the created chamber and avoids the formation of scar tissue at the spacer-bone junction.[8,15] Some authors recommend temporarily removing the spacer to avoid thermal damage to soft tissues.[16] Masquelet recommends using a piece of glove to protect the soft tissues from heat damage.[15] The installed spacer can be fixed to the plate with a screw. This will prevent spacer migration and membrane damage.[16]

Of great importance is the time elapsed between the first and second stage. According to some authors, the formed membrane has the most favorable osteogenic properties at 2-4 weeks, but at this stage, it is too thin and may be damaged during the operation. Over time, the membrane gets thicker; however, it gradually loses its osteogenic properties. According to the authors, the optimal time for the second stage is 4-6 weeks, when the membrane becomes strong enough and at the same time maintains a high osteogenic capacity.[15] After 12 weeks, the membrane almost completely loses its osteogenic properties.[1]

The technique of bone graft harvesting is also of utmost importance. In a cadaveric study, Burk et al[4] demonstrated the quantity of bone graft that can be harvested from different parts of the iliac crest. According to the authors, the posterior iliac crest yields the highest amount of graft

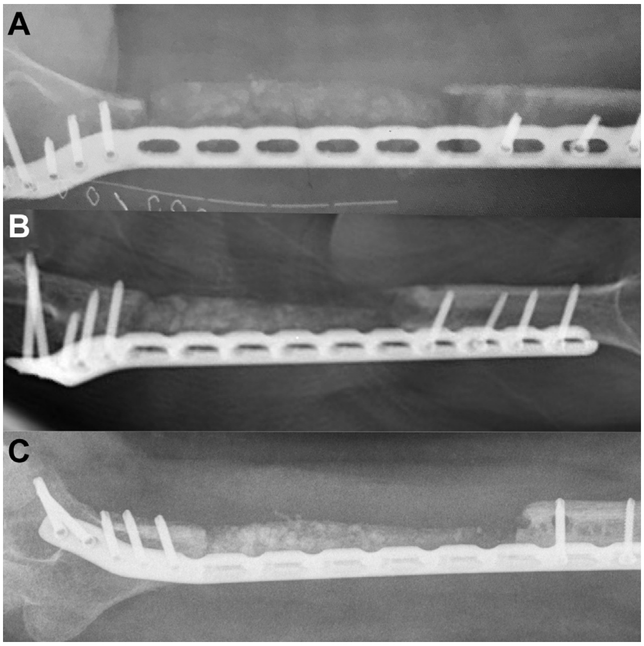

Figure 5 Follow-up radiographs after stage 2: (**A**) post-operative; (**B**) 6 weeks; (**C**) 12 weeks.

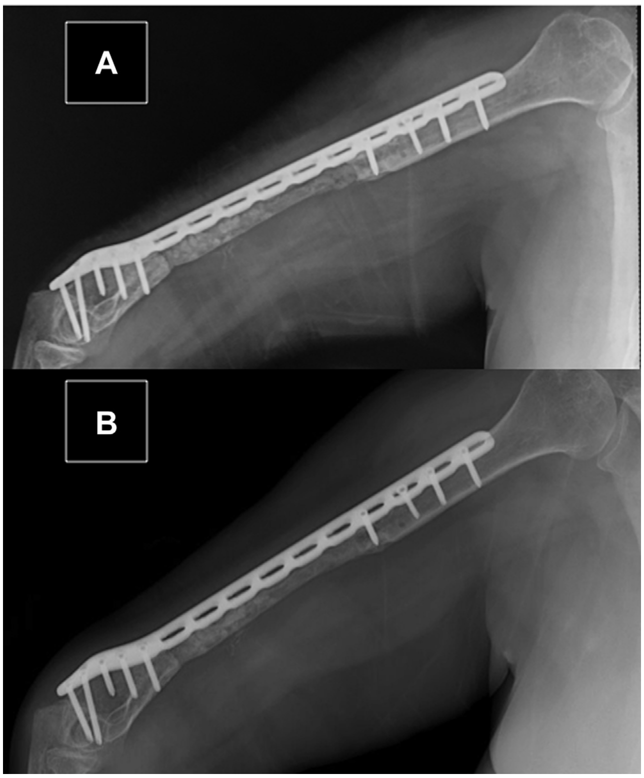

Figure 6 Follow-up radiographs after stage 3: (**A**) 2 months; (**B**) 5 months.

(33.8 mL). In large segmental bone defects, this amount is usually not sufficient. An alternative is to use a reamer-irrigator-aspirator system, which allows one to collect up to 90.0 mL of bone. In addition, this technique is less time consuming and associated with less donor-site morbidity.[2,6] The TCP granules can be used as a volume expander in a proportion not less than 1:3 (autograft to TCP).[13] However, according to some authors, the optimal ratio of autograft to TCP is 2:1.[15]

The planned surgical approach should ensure an adequate visualization of the bone grafting site. The membrane above the spacer should be cut carefully with a single incision. The screw fixing the spacer should be removed and the spacer should be carefully extracted. The bone graft is placed in the chamber. Special attention should be paid to visualizing both bone ends. If after the first stage there is space between the spacer and the bone, then it should be filled with scar tissue. This scar tissue must be carefully excised before the bone grafting. Otherwise, graft resorption will result in nonunion, as it happened in our case. In addition, too dense an implantaton of the graft can lead to its resorption.[15,20] After the chamber is filled with autograft, the membrane should be sutured.

A complete non-weight-bearing and restriction of vigorous movements should be recommended until radiologic signs of consolidation are achieved. If necessary, a cast or a brace can be used to increase the stability.

Conclusion

The Masquelet technique is a relatively simple method for reconstruction of large segmental bone defects of almost any size. The use of this technique in an upper extremity allows patients to avoid the discomfort observed in bone transport with prolonged wearing of an external fixator. The presented case has shown that the use of an induced membrane technique allows one to achieve a good functional outcome in patients with severe bone defect of the humerus. However, there is not enough evidence supporting the superiority of one method over another in this complex problem.

Disclaimer

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