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Case Report

Simultaneous induced membrane technique to reconstruct an obliterated floating knee

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ABSTRACT

The induced membrane technique, first described by Masquelet, is a powerful surgical approach that can be used to address segmental bone loss of various aetiologies. Despite ongoing debate regarding optimal delivery, the indications and limits of its application have been tested in increasingly complex situations, highlighting its considerable potential.

We present a case of a devastating open lower limb injury with simultaneous femoral and ipsilateral tibial bone loss including articular injury on both sides of the joint. The Masquelet technique was used to successfully address both segments of bone loss within the same limb.

Introduction

The induced membrane technique (IMT) is used to address segmental bone loss. It involves the induction of a pseudo-synovial membrane by local tissue reaction to a synthetic spacer, followed by application of osteogenic graft material into the resultant biologically active chamber. The IMT overcomes the issue of graft resorption and promotes graft consolidation to form a regenerate column [1].

Simultaneous segmental defects in the same limb present a particular challenge. Whilst distraction osteogenesis remains an option, managing long segment defects at the same time is challenging and likely to require an extended period in the fixator. This case report documents the management of simultaneous traumatic femoral and tibial bone loss in an open floating knee with intra-articular extension on both sides. The IMT was successfully employed to both defects.

Case report

A 48-year-old male motorcyclist presented to a level 1 trauma centre following a high-speed collision with a wall. Due to haemodynamic instability he underwent aggressive resuscitation including Resuscitative Endovascular Balloon Occlusion of Aorta (REBOA) [2]. Primary survey and cross-sectional imaging revealed an unstable pelvic ring fracture with bladder injury, renal lacerations, multiple foot and hand fractures and bilateral rib fractures associated with pneumothoraces. The patient also suffered multi-fragmentary, segmental, Gustillo-Anderson 3B distal femoral and ipsilateral proximal tibial fractures with articular injury on both sides

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of the joint and avulsion of the extensor mechanism (Fig. 1). He had a previous femoral shaft fracture in the same limb which had mal-united with sagittal plane translation and apex anterior deformity. The patient was successfully resuscitated with normalised acid-base parameter. Given the severity of the injury and initial haemodynamic instability, the patient underwent immediate debridement, lavage and temporary damage control external fixation. Post debridement images are shown in (Fig. 2). Both joints had been cleaved open centrally with separation of medial and lateral femoral condyles.

After debridement, segmental femoral and tibial bone defects measuring 115 mm and 110 mm respectively, were present. The tibial and femoral articular surfaces and tibial tuberosity were preserved and held with percutaneous k-wires. A temporising knee spanning external fixator was placed, further supplemented with two intramedullary guidewires taken from a nailing system to improve stability (Fig. 3). An antibiotic loaded PMMA spacer was placed in both bone defects around the intramedullary wires. A VAC dressing was placed on the open wound.

The patient remained stable post operatively and the soft tissues healthy. Four days later, a first stage reconstructive procedure was undertaken. The external fixator was exchanged for definitive site-specific locking plates at both the femoral and tibial fractures, stabilising the joint surfaces, and spanning the segmental defects (Fig. 4). The cement spacers were replaced. A small periarticular portion of the tibial defect was filled with injectable calcium phosphate (Hydroset, Stryker) to allow fixation through this area of the metaphysis, with PMMA used on the remaining areas. The extensor mechanism injury was repaired, and the tibial tuberosity avulsion fixed with an independent plate. Soft tissue coverage was provided via an anterolateral thigh (ALT) flap at the same procedure.

The soft tissues remained healthy and the patient recovered from his other injuries. A second stage Masquelet procedure was undertaken at 15 weeks post injury. Bone graft was harvested from the contralateral femur and tibia via the reamer-irrigator-aspirator (RIA) technique [3]. This was supplemented with autologous osteoinductive platelet rich plasma (PRP) and osteogenic bone marrow aspirate concentrate (BMAC), harvested from the peripheral blood and iliac crest respectively. Calcium phosphate graft expander along with the autologous graft materials (RIA graft, BMAC, PRP) were inserted within the induced membrane at both sites following removal of the spacers. Initial rehabilitation included toe-touch-weight-bearing and progressive range of movement in a hinged knee brace, with a plan to introduce graduated weight bearing as consolidation of the defects progressed. This was slow in the femoral segment and partial weight bearing was maintained to protect the fixation. Unfortunately, the patient's rehabilitation including physiotherapy was then interrupted by the COVID-19 pandemic for a prolonged period.

At 25 months following injury, the patient remained partial weight bearing with an arc of motion from 0 to 50 degrees. No additional operations have been undertaken and there is no clinical evidence of infection. The tibial segment has achieved full radiological and clinical union. Although the femoral segment has not achieved a normal diameter, the patient's perception of instability on weight bearing is no longer present and he remains pain free. A CT scan appears to show a fully consolidated, narrow column of bone (Fig. 4). The plan is to progress weight bearing and intervene if the patient is unable to tolerate this or the fixation fails.

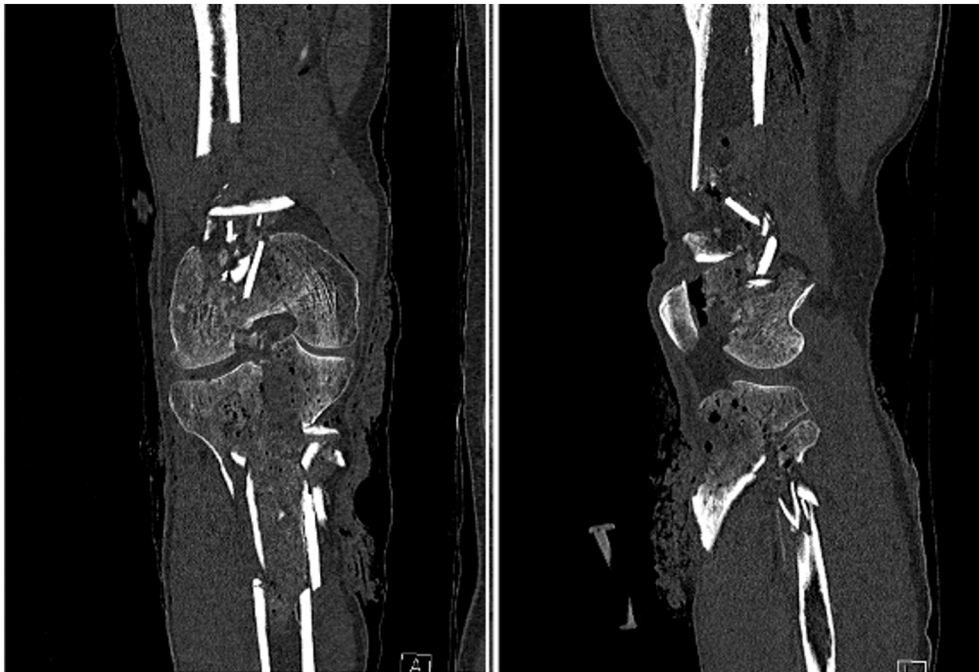


Fig. 1. Coronal (left) and sagittal (right) slices of obliterated floating knee injury.

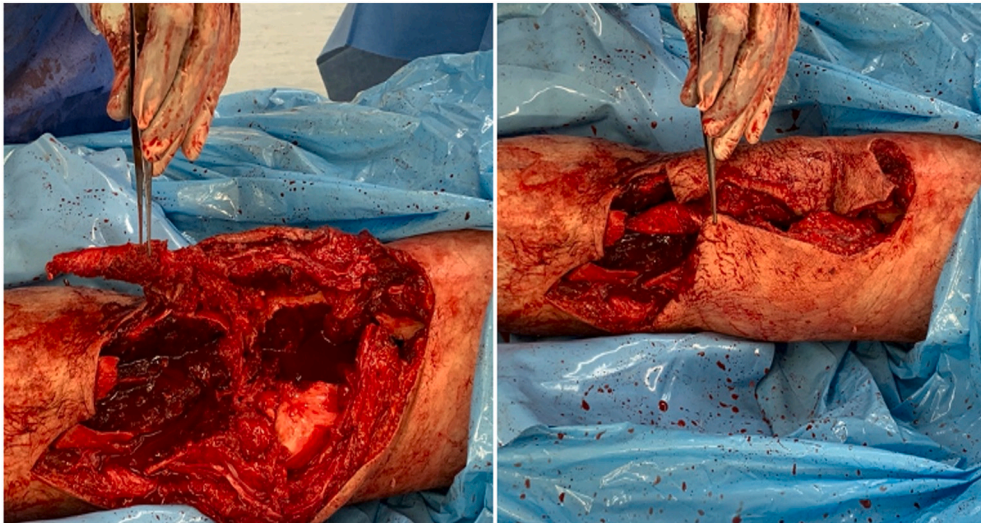


Fig. 2. Intra-operative clinical photographs after emergent debridement.

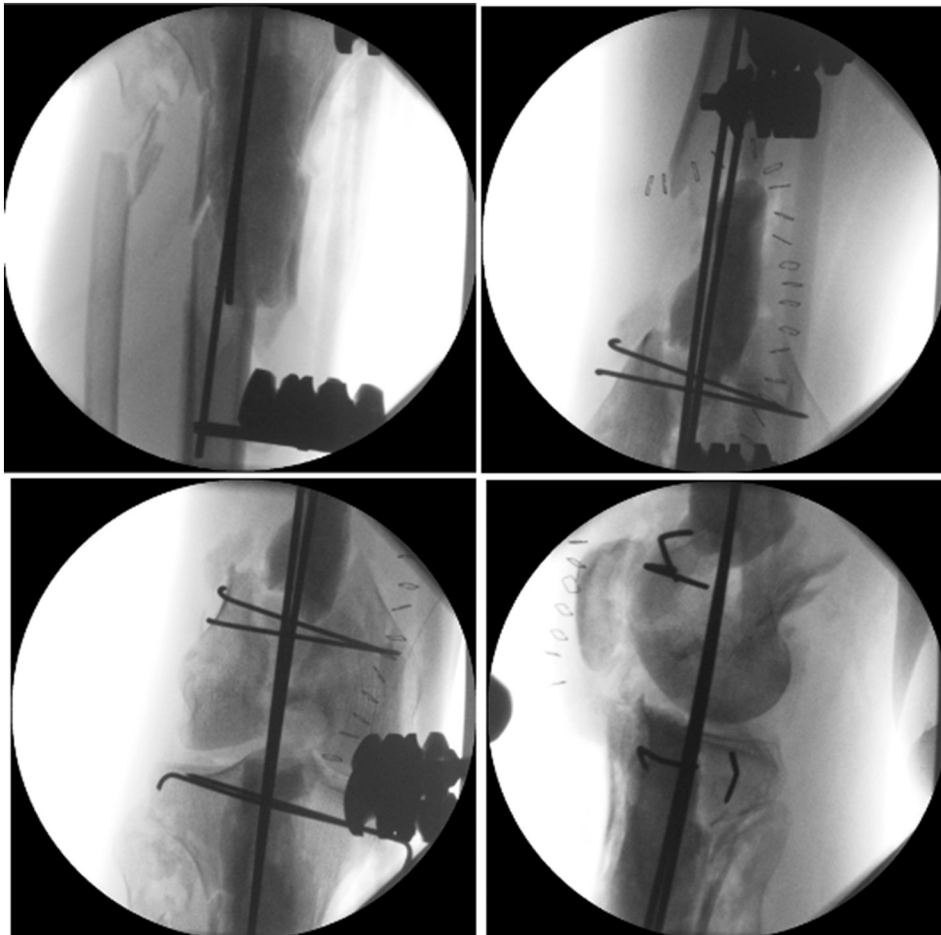


Fig. 3. Intra-operative radiographs following initial debridement and temporary fixation using external fixator, Kirschner wires and knee spanning intra-medullary wires. Top left: AP proximal tibia bottom left: AP tibial-femoral joint top right: AP distal femur bottom right: lateral tibial-femoral joint.



Fig. 4. Plain radiographs showing progression of consolidation in the femoral and tibial segments. (From left to right) radiographs at 1, 3 and 6 months. (Far right) sagittal CT section showing narrow regenerate column in the femoral segment.

Discussion

Critical bone defects in open fractures and periarticular fractures afford two of the most difficult challenges facing orthopaedic trauma surgeons. With a large defect (230 mm) spread over two separate anatomic areas in the same limb, extensive soft tissue damage and significant polytrauma, this patient's injury represented a significant reconstructive challenge. Several options exist for addressing large defects including distraction osteogenesis, vascularised fibular autograft and IMT [4]. Distraction osteogenesis has historically been the workhorse for large defects [5] with success reported in periarticular injuries [6]. The periarticular nature of the injury in this clinical case meant bone transport and distraction osteogenesis would be exceptionally difficult to achieve using the Ilizarov method. Vascularised fibular autografts for defects greater than 100 mm should be considered only when other simpler techniques are unavailable or have failed [7]. In this instance, the ipsilateral fibula was compromised and well within the zone of injury, therefore the use of one single donor site to fill both defects, each in excess of 100 mm, would have been impractical. Therefore, the IMT was utilised. Noteworthy, IMT has comparable union rates (82.5%–100%) to bone transport (83–100%) and vascularised fibular autograft (88–100%) [8]. Moreover, complication rates of IMT are not significantly different from bone transport in terms of deep infection, non-union, malunion and amputation [5].

The timing of the second stage Masquelet procedure is debated. It has been shown that induced membrane expression of VEGF, IL6 and Col-1 peaks within one month and declines thereafter, suggesting that the optimum time for spacer exchange may be within this time [9]. In contrast, another study has suggested that induced membranes retain their osteogenic properties following an average of 6 months prior to performing the 2nd stage, with maintenance of osteogenic potential demonstrated in-vitro on mesenchymal stromal cells recovered from the induced membrane [10]. The successful second stage in our patient, 15 weeks following the first stage, further supports the belief that time to union is independent of stage interval.

Despite apparent success, the patient has mobilised with restricted weight bearing for a prolonged period with limited return of knee motion. Although this was partly due to the logistic challenges associated with COVID-19, it may have been possible to improve outcome. Greater mechanical stability at the femoral segment might have permitted earlier weight bearing and mechanically enhanced progression of bone formation. The articular injury and pre-existing femoral mal-union made intramedullary fixation unattractive. A medial plate may have increased mechanical stability and was initially planned. However, spacer removal would have been difficult and simultaneous micro vascular free tissue transfer prevented access for medial fixation. Therefore, on balance, it was elected not to supplement fixation in this way. Finally, despite taking RIA graft from the contralateral femur and tibia and supplementing this as described, there was perhaps insufficient material at the femoral segment. The use of a larger reamer head or adding iliac crest graft might have helped.

Conclusion

This case illustrates the potential to use the IMT in the management of large synchronous periarticular bony defects involving two

ipsilateral long bones. Specific challenges were faced in the patient's follow-up which have limited clinical outcome and union in the femoral segment is not fully confirmed. Suggestions have been made to avoid this. Despite these limitations, the patient remains infection free and appears at least radiographically to have achieved union.

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