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## Surgical technique

# Metacarpal bone reconstruction by a cementless induced membrane technique

## *Reconstruction métacarpienne par la technique de la membrane induite sans ciment*

J.-C. Murison<sup>\*</sup>, G. Pfister, S. Amar, S. Rigal, L. Mathieu

Department of orthopedic, trauma and reconstructive surgery, Percy Military Hospital, 101, avenue Henri Barbusse, 92140 Clamart, France

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### ABSTRACT

Gunshot wounds to the hand often produce complex injuries and large segmental bone defects. Bone reconstruction remains a challenge in this context. The induced membrane technique is a simple and effective procedure for reconstruction of segmental bone defects. The technique is straightforward but must be performed rigorously. Usually polymethylmethacrylate (PMMA) cement is required for the first stage of the surgery. We describe four cases of metacarpal bone reconstruction after gunshot wounds in a limited-resource setting. Two patients were treated using the induced membrane technique with a polypropylene syringe body instead of PMMA cement, which was unavailable in this situation. A thick membrane was observed 6 weeks after spacer implantation. Bone union was achieved in all cases.

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### R É S U M É

Les traumatismes balistiques de la main occasionnent souvent des lésions pluritissulaires complexes et des pertes de substance osseuses importantes dont le traitement reste difficile. La technique de la membrane induite a fait la preuve de son efficacité pour la reconstruction osseuse à ce niveau. Bien que simple, elle doit obéir à des règles strictes pour être efficace. Habituellement, du ciment en polyméthylméthacrylate (PMMA) est utilisé pour la réalisation de l'entretoise lors du premier temps chirurgical. Nous décrivons ici la reconstruction de quatre métacarpiens après traumatisme balistique en situation sanitaire dégradée. Deux patients ont été traités par la technique de la membrane induite en utilisant le corps d'une seringue en polypropylène (PP) en lieu et place de l'entretoise en ciment PMMA non disponible dans ce contexte. Une membrane épaisse était présente lors du deuxième temps réalisé six semaines plus tard. La consolidation osseuse a été obtenue dans tous les cas.

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## 1. Introduction

The induced membrane (IM) or Masquelet's technique is a simple and effective procedure for reconstruction of segmental bone defects [1]. Initially indicated for long bone defects, it has been extended to hand bone defects [2]. Despite requiring no sophisticated expertise, the technique must be performed rigorously. This two-stage procedure is based on the implantation

of a polymethylmethacrylate (PMMA) cement spacer inside the defect to trigger a foreign body reaction leading to membrane formation. We describe two cases of multiple metacarpal bone reconstruction using Masquelet's technique without PMMA cement in a limited-resources setting.

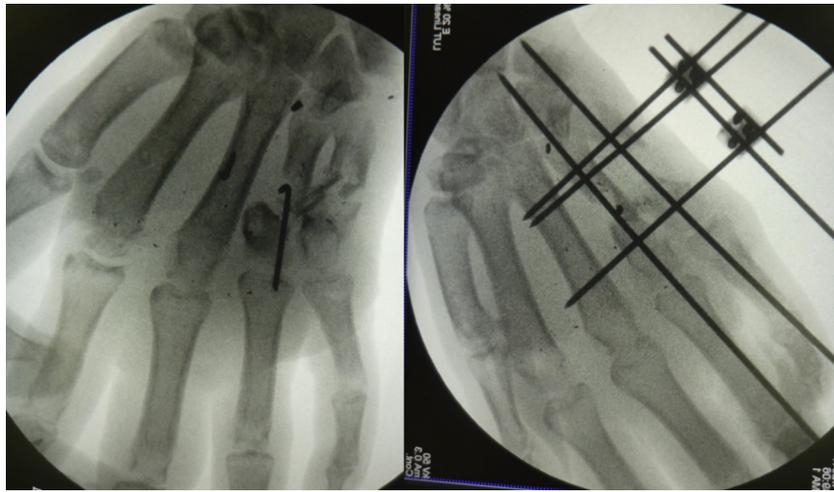
## 2. Case reports

### 2.1. Case 1

A 33-year-old Malian male patient was admitted in a French forward surgical unit for a gunshot wound in his left hand due to a high velocity bullet (7.62 mm caliber). Located on the ulnar side of

<sup>\*</sup> Corresponding author at: Department of orthopedic, trauma and reconstructive surgery, Percy Military Hospital, 101, avenue Henri Barbusse, 92140 Clamart, France.

E-mail address: [james-charles.murison@intradef.gouv.fr](mailto:james-charles.murison@intradef.gouv.fr) (J.-C. Murison).



**Fig. 1.** Case 1. Preoperative (left) and postoperative (right) X-rays.



**Fig. 2.** Case 1. Intraoperative view of the IM around the syringe (left) and X-rays showing bone union after 2 months (right).

the hand, the injury included complex fractures of the metacarpal bones and flexor digitorum superficialis tendon lacerations on the 4th and 5th rays. Primary treatment consisted in debridement, bone stabilization using K-wires and tendon repairs. Six weeks later, the patient suffered an infection and the injured fingers were found shortened with rotational deformities. Repeat debridement resulted in an extensive diaphyseal bone defect on the 4th and 5th metacarpal bones (Fig. 1). Because of the infection, we decided to use the IM technique despite PMMA cement not being available. For each metacarpal bone, we made a spacer using a polypropylene (PP) syringe body (5 mL) that fits the metacarpal diaphysis shaft. Temporary bone stabilization was achieved with K-wires. A methicillin-susceptible *Staphylococcus aureus* was isolated and treated by Oxacillin and Rifampicin during 6 weeks before the 2nd stage of the procedure was performed. A thick membrane was found around the syringe and incised gently (Fig. 2). After easy removal of the syringe, the defect was filled with corticocancellous bone grafts harvested from the proximal tibia. Tibial baguettes were perforated multiple times with a small K-wire to promote their revascularization. Definitive bone stabilization was achieved with 2.5 mm plates. Early self-directed rehabilitation was initiated. Because microbiology samples were positive to the same organism, the antibiotic treatment was extended for an 6 additional weeks. Two months later, there was no evidence of persistent

infection and bone union was satisfactory on both X-ray views; however, the 4th and 5th metacarpophalangeal joints were stiff.

## 2.2. Case 2

A 25-year-old Malian male patient was referred in the same facility 72 hours after a gunshot injury to his left hand due to a 7.62-mm caliber bullet. Initial management was performed in the field by a general practitioner. The patient was hardly examinable. X-rays showed comminuted fractures with bone loss of the 2nd and 3rd metacarpal bones. The wound was dirty and required extensive debridement leading to large bone defects in the 2nd and 3rd metacarpals. As in the first case, we decided to carry out the IM technique using a PP syringe body to act as the spacer combined with an external fixator. Microsurgical repair of the 2nd digital nerve and suture repair of the index flexor digitorum profundus tendon were also performed. Soft tissue coverage required a regional interosseous posterior flap transfer (Fig. 3). The second stage occurred 6 weeks later. The external fixator was removed, and the flap elevated on its ulnar side. A thin induced membrane was found around the PP spacer. Because the proximal part of the metacarpal bones was lost, the trapezoid and capitate cartilage were removed to perform carpometacarpal arthrodesis on both rays. Two corticocancellous bone grafts harvested from the



Fig. 3. Case 2. Intraoperative views after debridement (left) and flap coverage (right).

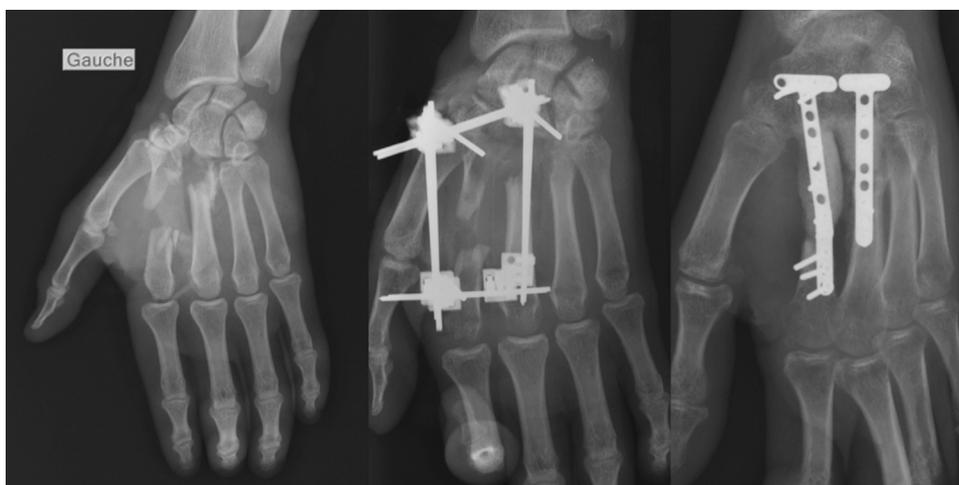


Fig. 4. Case 2. Radiological appearance in the preoperative period (left), after the first stage (middle) and at the last follow-up (right).

anterior iliac crest were placed in both defects and stabilized with 2.0 mm plates. The induced membrane could not be sutured. At the 4-month follow-up visit, bone union was achieved but the patient had general stiffness of the index finger despite early self-directed rehabilitation (Fig. 4).

### 3. Discussion

The IM technique has proven to be effective in bone defect reconstruction [1]. However the cell biology of the human biomembrane is still a huge field of research. The two-step surgical procedure with a cement spacer is helpful in the context of bone infection or nonunion. The IM also improves the probability of achieving bone union in the hand and wrist [2–6]. Like with long bone defects, the effectiveness of the IM technique in hand surgery relies on strict compliance. The spacer should wrap the bone ends on each side of the defect. Appropriate soft tissue coverage is mandatory to allow membrane creation and stable bone fixation is required for the 2nd stage [2]. Our plastic spacers wrapped both bone extremities as recommended. To our knowledge, successful metacarpal bone reconstruction using the IM technique has only been described in three cases in the literature [2,4]. While cancellous bone is recommended, we decided to add corticocancellous grafts to increase the stability of the definitive fixation

given that the available plates were not rigid enough [7]. The cortical bone was perforated to facilitate its integration in the bone graft.

We report on cases treated in a limited-resource environment where PMMA cement was not available. However, we decided to use the IM technique given the nature of lesions: gunshot wounds with large segmental bone defects. We had to identify the foreign body that will induce the best membrane. We thought about the most inert material possible that would be as similar as possible to the membrane induced by the cement. Some authors showed that different materials like metal or polymers could induce membranes with different properties [8]. We decided to use syringes (Omnifix syringe 10 mL Luer Solo, B-Braun™) because they are made of PP and because the plastic surface is macroscopically flat. This technique was first described at the SICOT congress by Mozumder et al. [9]. Textured implants are known to induce synovial-like metaplasia and villous hyperplasia more than slick implants [10]. PMMA cement provides a smooth spacer surface and is correlated with a rare villous hyperplasia and very few foreign-body reactions [11]. After 6 weeks, an IM membrane macroscopically similar to a cement-related IM was found in all cases. Biomolecular analyses are needed to confirm the presence of VEGF, TGFP1, osteoinductive factor, BMP-2 or other factors involved in the bone reconstruction process. Those factors are

found in the biomembrane stroma induced by PMMA cement [8,11].

Another role of the spacer is mechanical as it prevents fibrous tissue invasion of the bone defect and prevents soft tissue retraction. In our cases, the inner part of the spacer was full of soft tissues, which were easily removable. Bone stabilization by K-wires or external fixator prevented the tissues from retracting. The spacer has a biological role. The membrane, once created, will prevent graft resorption and help bone graft integration and vascularization [12,13]. In case 1, the PP spacer induced a thick membrane that could be sutured after grafting. This protective barrier may prevent graft resorption. The PP spacer has other interesting characteristics. First, it does not contain antibiotics contrary to most PMMA cements. Antibiotics may increase the biological resistance of germs and may change the membrane's biological properties [7]. Next, the PP spacer does not heat the soft tissues around it. The nerves and vessels surrounding the bone defect area will not suffer heat stress during spacer installation [6].

#### 4. Conclusion

The IM technique is reliable for bone reconstruction in the hand. The use of a PP spacer instead of a cement spacer allowed us to achieve bone union in four critical metacarpal bone defects related to gunshot wounds. This procedure can be performed in a limited-resource setting and complies with the technical execution of the IM technique. The membrane induced by the PP spacer seems to have similar macroscopic properties to that induced by cement spacers. Further biomolecular studies are necessary to assess the PP IM's biological properties.

#### Disclosure of interest

The authors declare that they have no competing interest.

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