Complex reconstruction of the dorsal hand using the induced membrane technique associated with bone substitute: A case report

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Abstract

Introduction—High-energy trauma of the hand often causes tissue loss involving bone, tendon and skin and is sometimes accompanied by devascularization of digits. Bone stabilization is the first step in the management of such injuries.

Materials and methods—A young patient presented composite tissue loss of the dorsum of his right (dominant) hand following an accident with a surface planer. Tissue loss involved the diaphyses of the first 4 metacarpals, tendons and skin with almost complete amputation of the 3rd finger.

Bone stabilization comprised osteosynthesis using pins associated with cement to fill the bone defect. Hunter tendon rods were used for tendon repair and a pedicle groin flap (McGregor) was used to achieve skin coverage.

The cement was replaced with autologous cortico-cancellous bone graft combined with bone paste (Nanostim) 3 months after the cement stabilization.

Results—Eleven months after the accident, the patient was able to return to work as a carpenter. Pinch and Grasp strength in the injured hand were half that in the contralateral hand, but there was no loss of sensitivity. Mobility was very satisfactory with a Kapandji score of 9 and a mean TAM of 280°. The patient can write, open a bottle and does not feel limited for everyday activities.

Radiographically, the bone of the 3 reconstructed metacarpals appears consolidated.

Conclusion—The induced membrane technique allowed the reconstruction of small bone deficits in the long bones of the hand in a two-step procedure, the first step taking place in an emergency context of composite tissue trauma.
Keywords
Bone defect; Induced membrane; Bone substitutes; Hand trauma

Introduction

Complex multi-tissue lesions of the hand cannot always be repaired in a single step and thus allow early rehabilitation.

In emergency situations involving several bone segments and/or sepsis, it is not always possible to harvest composite micro-vascularized osseous pedicles. The management of these lesions requires rigour in the planning of reconstruction surgery.

Bone stabilisation, the first step in the reconstruction, is of major importance.

We present here a case of reconstruction using the induced membrane technique in a patient with compound tissue loss of the hand.

Case

A 26-year-old, right-handed man with no particular medical history was admitted to our unit for compound lesions of the dorsal surface of the right hand, following an accident at work with a straightening planer. There was severe damage to the dorsal surface of right hand measuring 10 cm × 8 cm and extending to the thenar eminence (Figure 1).

The clinical neurological and vascular examination was normal apart from anaesthesia and delayed coloration of the third finger due to almost complete amputation at the base of the first phalange. Further exploration revealed partial section of the radial artery and complete section of the extensor tendons with tissue loss greater than 5 cm in the first four fingers. For the fifth finger, the extensor tendon was partially cut. There was complete destruction of the diaphyses of M1 to M4, and of P1-D3, confirmed by the pre-operative radiography (Figure 2). The digital pedicles were preserved, except in D3, where the ulnar and radial digital pedicles were completely sectioned.

The injuries were managed in several phases:

- **The first phase was emergency management as follows:** distal ligation of the radial artery and trans-metacarpal amputation of the third finger, because of the severe damage, followed by osteosynthesis of the metacarpals using 1.6 mm diameter pins to restore length. The lost metacarpal tissue was replaced with acrylic cement (methylmethacrylate) forming a sleeve around the pins and incorporating the proximal and distal fragments, in accordance with the «Masquelet» technique. Tendon reconstruction was achieved using silicone «Hunter» tendon rods and skin coverage was obtained using a «McGregor» pedicle groin flap.

- the second phase consisted of flap separation associated with a split skin graft from the iliac donor site at three weeks.
- the third phase, three months after the emergency procedure, was bone reconstruction. The radial half of the flap was raised, the induced membrane was incised and the methylmethacrylate was removed from the three metacarpals. Cancellous bone grafts were harvested from the right iliac crest and a cortical graft was harvested from the right anterior tibial tuberosity (Figure 4). These grafts were shaped and placed inside the induced membrane in M1, M2 and M4, and stabilized with new pins (Figure 5). Then, 10 ml of Nanostim® synthetic bone paste was spread around the grafts. The induced membrane and then the skin were closed (Figure 6). The wrist and hand were then immobilised in the intrinsic plus position for two months.

The patient was seen at regular intervals. He presented an episode of local sepsis at the site of the M1 graft 6 months after secondary reconstruction following a new injury above the site. This episode was treated successfully with local treatment and appropriate antibiotherapy for one month according to bacteriological analysis of bone samples.

Eleven months after the initial injury, the patient presented with a psychologically accepted hand. Assessment of joint mobility showed a Total Active Motion (TAM) of 260° for the index, 240° for the ring finger and 280° for the little finger (Figure 7).

Thumb mobility was assessed at a Kapandji score of 9. Extension of the MCPs of D2 and D4 showed a limitation of 10° because of the osteosynthesis pin.

Grasping strength and pinching strength were 25 Kg and 4 Kg, respectively, corresponding to half those in the uninjured left hand.

The patient reported full function of his right hand without limitation as he was able to return to his work as a carpenter with no need to modify his job 13 months after the injury. The DASH was 38 with the onset of pain when the hand was exposed to cold.

Radiography showed ossification of the three grafts indicating definitive consolidation (Figure 8). The graft at M1 was deformed subsequent to the infection that occurred at 6 months.

**Discussion**

This case presents the use of the Masquelet technique in a compound trauma of the hand with bone tissue loss from several metacarpals.

**Repair of the skeleton**

Bone stabilisation was achieved using pins to restore the space between the proximal and distal fragments, thus leading to better stability of the assembly and easier primary skin coverage than is the case with external fixation.

We opted for the induced membrane technique, first because it was a high-energy trauma (compression and tearing mechanism), which jeopardized the survival of the soft tissues, and then because of the severe bone deficit affecting four fingers. The cement made it possible to maintain the reconstruction space by creating a veritable biological chamber.
We also chose not to use cancellous bone exclusively, which is currently the reference technique, but to include synthetic bone paste and a cortical bone graft. Indeed, the bone paste stimulates osteogenesis and osteo-induction.

The «finger bank» was not used, but given the remaining bone fragments, it could have been used for reconstruction of the diaphysis of one of the metacarpals.

**Tendon repair**

Given the severe damage to the extensor tendons, we opted for two-step repair. We preferred to perform the tendon graft, which is associated with rapid mobilization, at a later stage, since it was incompatible with the initial bone reconstruction which requires post-operative immobilisation. The silicone rods made it possible to maintain the route of the tendon between the forearm and the fingers. A sheath formed around this silicone rod, which facilitated the subsequent tendon graft. This therapeutic approach, however, is only feasible if the problem of skin coverage has been overcome.

**Skin coverage**

In most cases, local pedicles are used in emergencies. For this patient, given the regional damage and the tear in the radial artery, it was preferred to raise a reliable distant flap. We chose a pedicle groin flap. A free flap could have been considered, but it is more prudent to give oneself 48 h to confirm or to complete the wound care and to determine the choice of recipient vessels.

**Reconstruction methods**

There are many reconstruction techniques for bone deficit. The reference treatment is conventional bone graft, though this is only possible for small volumes and in an environment that is favourable for the maintenance of the graft. In fact, in a septic environment, bone grafts are unable to defend themselves and are subject to resorption via inflammatory cells.

The second conventional technique is a vascularised pedicle or free graft, which because it is vascularised is able to survive in a septic environment. Such grafts can be used to reconstruct major bone deficits. In contrast, vascularised bone grafts can only be performed by surgeons trained in microsurgery with the appropriate surgical equipment. In addition, free flaps increase operation times and may lead to complications at the donor site. Finally, the patient must have a good vascular status to undergo this type of surgery.

The principle of osteogenesis by distraction according to Ilizarov, described for the first time in 1971, makes use of the natural laxity of tissues and notably bone tissue to restore the length of a bone segment by expansion. This technique requires patients to wear an external fixator, which deprives them of their social life and exposes them to risks of sepsis via the pins between the bone and the external fixator.

The induced membrane technique was described by Masquelet in 1986. It is a two-step reconstruction procedure to repair bone deficits.
- The first step consists in debriding the necrotic tissue and in placing a cement spacer to fill the bone defect. The cement prevents colonisation by fibrous tissue and dries the site of infection. The bone segment is stabilised either by an external fixator or by intramedullary pins. A biological membrane forms around the cement spacer.

- The second step consists in incising the induced membrane, removing the cement spacer and in filling the bone deficit with cancellous bone grafts. The newly formed membrane plays a mechanical role in maintaining the grafts as well as a biological role in promoting their vascularization. Pellissier et al.8 showed that this membrane was active and secreted growth factors (VEGF, TGFβ1) and osteoinducers (BMP-2). In this way, the environment created within this biological chamber favours stability of the graft and its corticalisation. It diminishes bone resorption and necrosis while protecting and revascularising the bone. The technique described by Masquelet concerned long dia-physary bones. More recently in 2010, Obert and Masquelet5,9,10 adapted this technique for use in the hand. The reconstruction of small bone deficits follows the same surgical procedure as that for large deficits, but seeks to achieve rapid mobilization of the hand.

Unlike long bones, short or flat bones have a trabecular structure. They are made up of a three-dimensional lattice of bony trabeculae with branches and anastomoses that create a labyrinth of intercommunicating spaces filled with marrow and vessels. Short bones have less mechanical strength than long bones, which have the Haversian structure. Obert evaluated bone consolidation and the corticalisation of minor bone deficits in the hand and wrist. More recently Zwetyenga et al.11,12 showed that the induced membrane technique could be used for the reconstruction of flat bones, such as the mandible even in unfavourable conditions (sepsis, radiated tissues).

There is no standard management strategy for multi-tissue complex deficits of the hand. Reconstruction using the induced membrane technique may have a place in the therapeutic strategy as it saves precious operating time compared with microsurgery or tendon reconstruction. Early mobilisation after the first step of the surgery makes it possible to limit joint adherences and to preserve the functions of the hand.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

Funding: None.

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Figure 1.
Preoperative view of the back of the right hand showing loss of skin, tendon and bone tissue.
Figure 2.
Preoperative anterior and lateral radiography.
Figure 3.
Postoperative radiography: induced membrane technique, visualisation of the cement.
Figure 4.
Clinical aspect 3 months after the 1st operation, back and palm view of the right hand.
Figure 5.
Peroperative photographs of the cortical and cancellous bone grafts during the 2nd operation: bone reconstruction.
Figure 6.
Immediate postoperative clinical aspect after the bone graft.
Figure 7.
Clinical aspect 11 months after the bone graft.
Figure 8.
Radiography 11 months after the bone graft.