New Concepts and Technologies in Reconstructive Hand Surgery

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KEYWORDS

• Hand trauma • Tissue engineering • Microvascular anastomosis • Nerve repair

KEY POINTS

- The induced membrane, or Masquelet technique, has great potential in managing bone defects.
- Tendon tissue engineering is a an innovative solution for repairing extensive tendon deficits.
- Fibrin glue, laser activated chitosan, end-to-side neurorrhaphy, and nerve conduits are used for peripheral nerve repair, along with more novel and untested approaches of nerve regeneration with molecular and cell therapy.
- Sutureless anastomosis, a combination of Food and Drug Administration–approved thermoreversible poloxamer gel and cyanoacrylate glue is in use for microvascular anastomosis.
- Botulinum toxin may become a promising treatment of Raynaud syndrome.
- A dynamic stress-shielding polymer device is effective in reducing scar formation.

INTRODUCTION

In 1944, the pioneer hand surgeon, Sterling Bunnell, described the specialty in these words, "As the problem in hand surgery is composite, the surgeon must also be. There is no shortcut. The surgeon must face the situation and equip himself to handle any and all of the tissues in a limb."[1] Nearly 70 years later, this principle remains the same, but innovations in all composite tissues of the hand have given the hand surgeon advantages that did not previously exist. Concepts and technologies in reconstructive hand surgery continue to evolve, improving patient outcome and surgeon ease. Intelligently designed devices, bioengineered tissues, allografts, and tissue substitutes will soon be available. The systematic method by which perform finger replantation is performed, from bony fixation to skin closure, provides a platform for discussion of the newest innovations available to reconstructive hand surgeons.

BONE

Problem: Bone Reconstruction in Severely Mutilated Digits or Septic Conditions

High-energy trauma or osteomyelitis can lead to complex composite defects in fingers with extensive bone loss. When the finger can be salvaged, bone stabilization becomes the first step of the reconstruction. However, there is often a deficit of bone tissue required for adequate reconstruction. Classic solutions include the use of bone grafts or vascularized bone grafts to fill the bone defect. However, these procedures are not

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practical in the context of emergency hand situations in which salvage is the primary goal.

Innovative Solution

Initially described by Masquelet and Begue[2] for large diaphyseal bone defects caused by tumor resection, trauma, or osteoarthritis, the induced membrane technique is a two-stage procedure allowing bone reconstruction. The concept is to place space-maintaining material in the region of the defect. This leads to a foreign body reaction, which creates a membrane mimicking the periosteum. Once this is formed, bone graft can be placed in the periosteal sleeve. Recently, Flamans and colleagues[3] applied the Masquelet technique to the hand with promising results.

The first stage involves soft tissue and bone debridement followed by implantation of a polymethyl methacrylate cement spacer in the area of the bone deficit and/or defect. Bone stabilization is then provided with internal and/or external fixation. Soft tissue defects may need to be addressed with free flap coverage.

The second stage is performed 2 months later. The periosteal membrane is incised and the spacer is removed. Autologous cancellous bone graft is placed within the membrane.

The results in the hand are from studies with small numbers but are promising. There are over 15 other studies investigating this technique in bone reconstruction outside the hand.[4–7]

Clinical results in the literature

For clinical results in the literature, see **Table 1**.

Advantages

The membrane induced by the Masquelet technique has been shown to secrete vascular endothelial growth factor, transforming growth factor beta-1, and bone morphogenetic protein-2. Therefore, it has more than a mechanical role—it induces angiogenesis and proliferation of osteoblasts and chondrocytes. Bone graft substitutes, such as hydroxyapatite or tricalcium phosphate, can be used instead or in addition to autologous cancellous bone grafts to increase osteoconduction.

Complications

Nonunion and infections have been noted. However, it is not clear at this time whether this technique has an increased rate of complications over other techniques of reconstruction in these complex cases. Loss of function and finger stiffness is also a risk, but this is often inherently due to the infection or trauma. Overall, the technique is simple and easy to perform. This technique can be used for reconstructive problems of the hand in which vascularized bone graft and flaps are not viable options.

TENDONS

Problem: the Need for More Tendon Graft Material

Tendons are essential to hand function and are frequently involved in hand injuries. When tendon deficits exist, the current solution is to harvest expendable autologous tendon grafts (ie, palmaris, plantaris) or use tendon allograft. However, the extrasynovial nature of these tendons increases the resulting adhesions at the repair sites and often leads to a suboptimal functional outcome.[8]

Innovative Solution

Tendon tissue engineering may be a future solution in cases requiring extensive tendon reconstruction. Neotendons would ideally have the capacity to reduce adhesions and have adequate tensile strength, allowing early active rehabilitation and normal mobility.

Bioengineered tendon constructs first consist of a scaffold—natural or synthetic.[9] Some hand surgeons choose to follow Gillies' reconstructive principle of replacing "like with like" and use decellularized human tendon scaffolds[10] from a donor bank. Other surgeons choose collagen derivatives,[11] polysaccharides, small intestine submucosa,[12] or human umbilical veins[13] as natural scaffolds; whereas the synthetic scaffold uses polymers such as poly(a-hydroxyl acid)s, polylactic acid,[14] or polypropylene. The ideal candidate remains to be decided. Natural scaffolds have the advantage of a high affinity to host cells

Table 1
Summary of the available clinical results of the Masquelet technique in hand surgery

Study	N	Cause of Bone Defect	Results	Complications
Flamans et al[3]	11	Trauma (n = 8) Infection (n = 3)	Bone union rate 82%	2 Nonunion
Proubasta et al[49]	1	Osteomyelitis	Bone union	None