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Reconstructive microsurgery – a review

We present some important current applications of reconstructive microsurgery. This field is expanding rapidly and the techniques are finding application in many branches of surgery. There is a pressing need for educational programs and training in microsurgery, as well as for continued research.
Many of the procedures reviewed here have already been shown to substantially reduce costs, shorten hospitalization, and lessen patient disability; and as a result, several conventional procedures have been out-dated. We have stressed the concept that this is team surgery. To cover the needs of replantation and emergency free flaps around the clock, several microsurgeons must work together in established centers, and the team must possess expertise from all the involved surgical specialities. This may imply revision of many organizational aspects of patient care. Replantation centers would provide the necessary educational bases and give an impetus to the development of microsurgery.

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Reconstructive microneurovascular surgery has been dramatically transformed from preliminary laboratory projects to established clinical practice during the last 15 years. Multidisciplinary teams of orthopedic surgeons, plastic reconstructive surgeons, and hand surgeons now apply these new techniques of replantation, free-flap transfer (primary or delayed), osteocutaneous flaps, or vascularized bone grafts in an integrated management of severe compound injuries, congenital defects, osteonecrosis, osteomyelitis, and tumor resections. Replantation has been the key to clinical microsurgical development since teams capable of achieving high success rates and useful functional results in replantation have applied their experience to elective reconstructive problems.

With the aid of the many practical courses that are now available, more surgeons have become competent in microsurgical technique. However, there are several prerequisites for a microsurgical team or a replantation center to be able to satisfy the needs of the patient and society at large. Laboratory training is important and should be included in the educational program for specializing residents. Research will stimulate and maintain interest and knowledge. Continuous exposure is necessary. "There is little place for the occasional microsurgeon" (O'Brien 1977). The clinical microsurgical team must therefore have good facilities, a sufficient number of cases, and knowledge of basic hand surgery, orthopedics, and plastic reconstructive surgery.

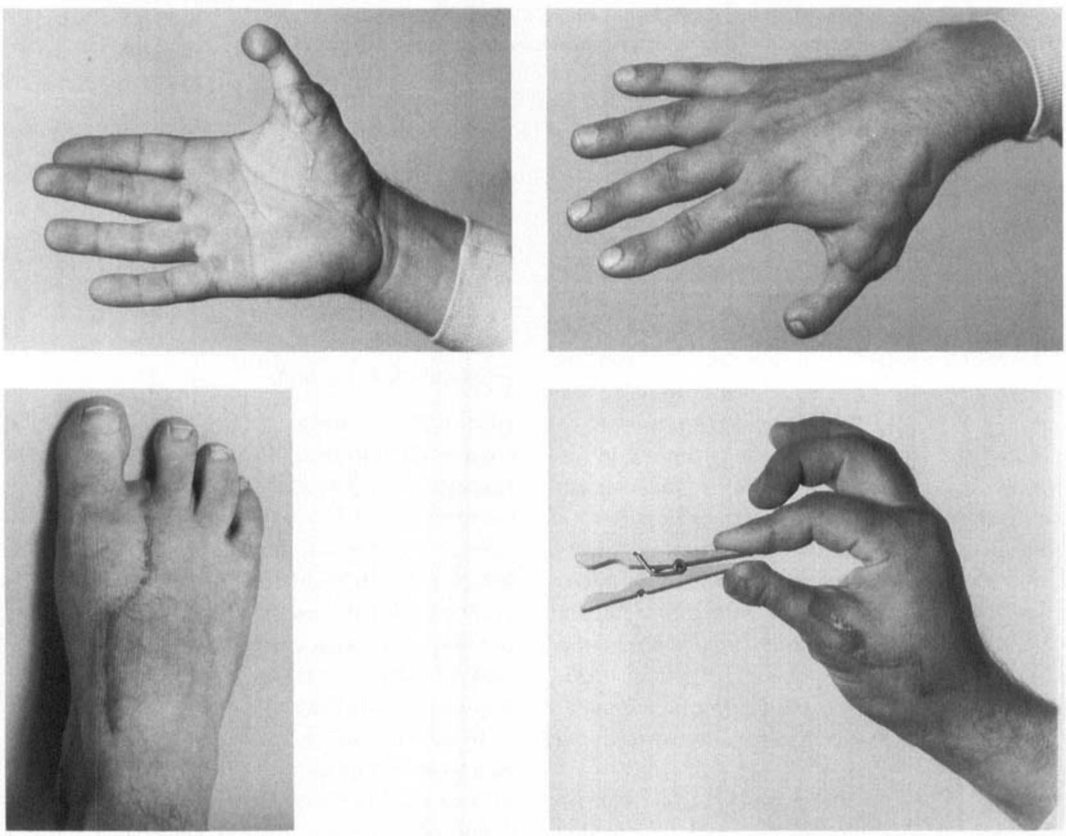
Replantation surgery

After Tamai's first successful replantation of a completely amputated thumb in 1965, the enthusiasm for the method spread, and most countries now have replantation teams with success rates exceeding 80 per cent of the attempted reattachments. Most of the patients obtain good function, which can be attributed to standardization of procedures, e.g. preparation of the amputated part, surgical techniques, and postoperative care (Vilkki 1983)

To assure the population of a country full coverage, teams of replantation surgeons must be available around the clock, serving large geographic regions; and the decision to replant or not to replant should be left to such a team. Replantation is for experts! This is especially true in the case of major amputations, where a 10 per cent mortality has been reported in a material collected from departments with insufficient case load (Baudet 1980).

Even a severely mangled extremity, which appears to be totally destroyed, may, on closer examination, show little actual tissue loss. It is essential that all amputated parts are recovered, placed in a clean plastic bag inside an ice container (without freezing), and brought in

Figure 1. A 24-year-old carpenter had a crush injury with loss of his right thumb. 3 months after the injury the thumb was reconstructed with a one-stage second toe transfer. He obtained a natural and rather strong pinch grip. The four-digit donor foot did not cause any problems.



with the patient. With modern techniques, the first 12–24 hours after injury represent the optimal time for replantation. The osteocytes and osteoblasts can survive during this period of cold ischemia (Berggren 1981).

The main indications for replantation surgery in the upper extremity are amputation injuries that seriously diminish the ability of the hand to grip or pinch, or make the patient single-handed. Anatomically, this means lack of the thumb, lack of more than two fingers, or total loss of the hand. Worthwhile functional results can also be achieved after replantation of major lower limb amputations through or above the ankle (Vilkki 1986).

Function after replantation depends on the type of injury, the age of the patient, and the length of the ischemic period. Nerve regeneration, especially with respect to the recovery of sensibility, is of particular importance.

The results after thumb replantation are usually good, the expected healing time being about 6 months (Vilkki 1983). Recovery of sensibility is comparable to the situation after common nerve injuries. The recovery of motor function is related to the operative technique and the rehabilitation expertise. Although rehabilitation follows normal hand surgery principles, it is more difficult due to the total lack of sensibility during the first postoperative months. After major amputations (wrist or antebrachial level), substantial efforts are needed from the rehabilitation team because recovery of useful sensibility may take 2–3 years, and mobility is maintained only by continuous training with special splinting devices. However, if the ideal conditions have been met, the final functional result is equivalent to the results after nerve injuries at the same level.

Cold sensitivity is often experienced during the first 2–3 years after replantation, but will disappear or greatly diminish with time. This may be more noticeable in a nordic climate. In a series of 15 macroreplantations, no patient had pains or aching at a later stage after replantation.

Our experience is that replantation is superior to the use of a prosthesis, and this accords with most reports in the literature.

According to recent studies in Finland (Vilkki & Göransson 1982) and in Sweden (Nylander et al. 1984), the number of severe amputation injuries in the Scandinavian countries is about 14–20 per year per million inhabitants, although somewhat lower figures were reported from Denmark (Kiil 1982). International experience (Biemer 1984, O'Brien 1984) suggests an optimal load of 35–50 cases per replantation center per year, carried by a total of 8–10 microsurgeons, 3 or 4 of whom are available at any one time. Based on these premises, Sweden should have three centers, Finland two or three, and Denmark one. The epidemiology of replantation cases in Norway and Iceland has not been investigated. Environmental factors, such as the agricultural-industrialized structure, cause large regional variations in the frequency of amputation injuries (Nylander et al. 1984), and this may be of importance in the organization of a country's total replantation service.

Toe-to-hand transfer

Microsurgical methods are frequently used in late reconstruction of the hand. The main indications for a toe-to-hand single-stage transfer is lack of a thumb (Figure 1) or the loss of multiple fingers. There are usually no harmful effects of taking the second toe if enough normal skin is left on the foot, and the method has proven its value as one of the best means of thumb reconstruction. Excellent grasping and pinching functions are achieved and the sensory recovery varies from excellent to fair. Protective sensation is always regained.

There are now many indications for the toe-to-hand transfer. Krukenberg plasty has been a common procedure in bilateral hand amputations or for a forearm stump in the blind patient, but a microsurgically reconstructed grip, with a moveable toe transferred to the antebrachial stump (Vilkki 1985), may present a solution that offers higher precision and more powerful function (Figure 2). The new grip does not exclude the possibility of intermittent use of a prosthesis. Another new application is the replacement of traumatically destroyed finger joints with vascularized joints from the toes (Tsai et al. 1982).

Microvascular growth-plate transplantation

The principles of elective hand reconstruction are also applicable to congenital anomalies because growth is not arrested in an adequately revascularized physeal transplant (Mathes et al. 1980, Wray et al. 1981), and a successful toe-to-hand transfer will continue to grow at its new site.

Nettelblad (1984) recently carried out extensive experimental studies on microvascular growth-plate transplantation. Although further investigations are necessary, his findings seem to suggest possibilities for management of children who lack or have a destroyed growth plate, e.g., radial aplasia.

Free tissue transfers

The one-stage transfer of tissues by microvascular anastomoses is a rapidly expanding area in reconstructive surgery. The basic anatomic

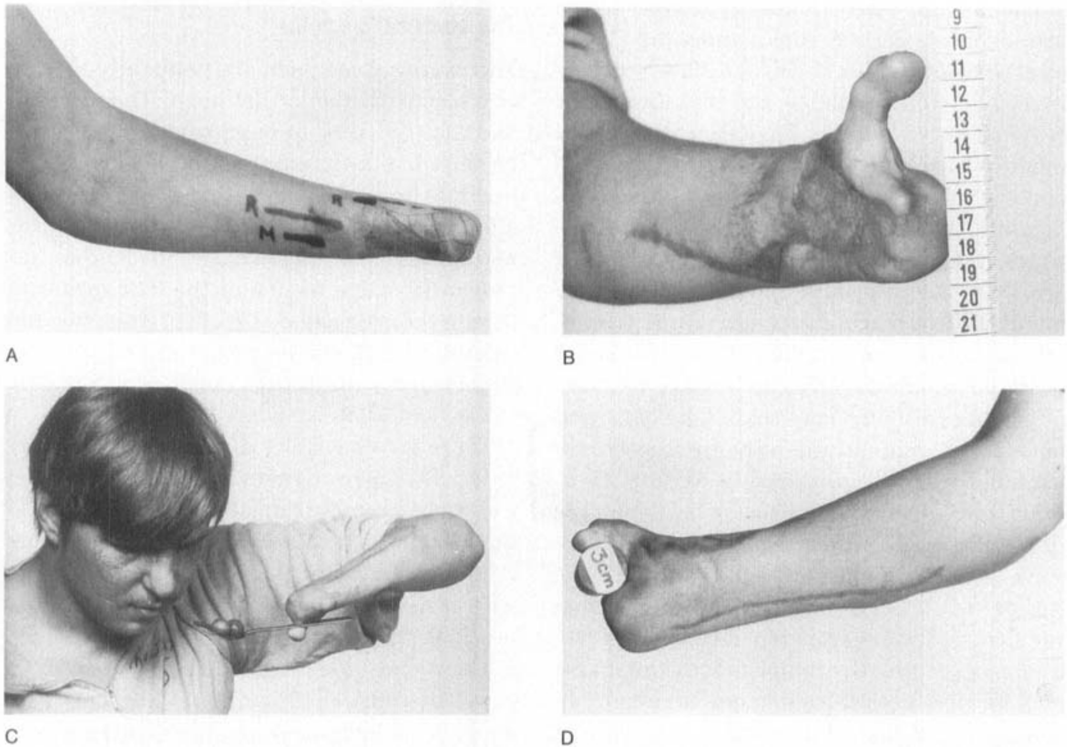


Figure 2. A 20-year-old man with loss of left hand through the wrist joint. In the same explosion accident, he became blind and his right hand was badly damaged, leaving it with three incompletely feeling fingers. A. Left stump with preoperative landmarks, showing locations of radial artery and nerve, median nerve neuroma and poor quality skin area at the tip of the stump. B. Microsurgical reconstruction of useful grip between radius and transferred second toe. C. and D. The mobility in the new "thumb" is excellent, and the grip strength exceeds 6 kg/cm², i.e., about half of the normal pinching power. The patient is very happy with the result.

requirement for these free flaps is a vascular pedicle containing an artery that supplies the entire tissue block and one or two veins draining the same area. Both single tissues (skin, bone, muscle, intestine, omentum, nerves, etc.) and compound tissues are transferable in this way. One of the great advantages is the fact that the transplant brings its own blood supply, and is thus much less susceptible to disadvantageous recipient bed conditions than a conventional graft.

The first clinical free flap was the iliofemoral groin flap, composed of skin and subcutaneous tissue and used to provide skin coverage at the ankle (Daniel & Taylor 1973). Since then, a large number of free-flap donor sites have been described. Different flaps have different qualities and contain different tissue combinations, e.g., osteocutaneous, musculocutaneous, or neurovascular flaps; and suitable flaps can be selected for the management of most combined tissue defects.

In addition to the iliofemoral flap, skin coverage can be obtained using the dorsalis pedis flap, the "Chinese" radial forearm neurovascular flap, the tensor fascia lata flap, and the latissimus dorsi flap with or without an overlying skin island.

Although of great importance in tumor resection and in the management of chronic osteomyelitis and infected nonunion, there is no doubt that microvascular free flaps have had the greatest impact on the management of severe compound injuries, especially in the lower leg. Together with pedicled muculocutaneous flaps (gastrocnemius or soleus) and island flaps (dorsalis pedis and in-step flap), free flaps have led to the salvage of limbs that would otherwise have been amputated. Injuries to the lower part of the leg, to the ankle or foot, with

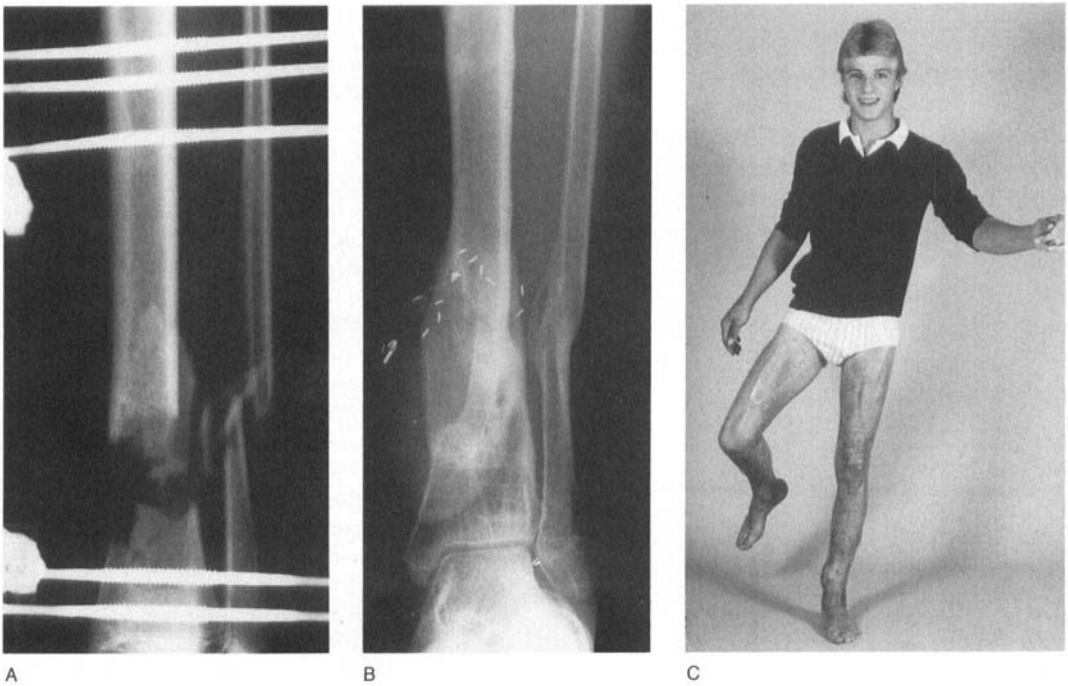


Figure 3. An 18-year-old man who sustained extensive third-degree burns and a compound injury with loss of 6 cm of the tibial shaft above the left ankle joint in a motorcycle accident. Amputation had been planned, but the patient insisted on being referred to a microsurgical team. A. Tibial defect. B and C. Result 11 months after reconstruction with an osteocutaneous iliofemoral free flap, containing a vascularized segment of the iliac crest. Uneventful "fracture healing" at both ends of vascularized bone graft.

extensive bone and skin loss, are often associated with serious crush injuries to other soft tissues: muscles, vessels, and nerves. To date, most reconstructive procedures have been carried out at a secondary stage. However, an increasing number of surgeons have found it easier to isolate and prepare suitable recipient vessels for anastomosis in the acute stage, and another great advantage of the emergency free flap is the soft-tissue cover of exposed bone.

Free vascularized bone transfer

Of special interest to the orthopedic community is the free transfer of vascularized bone segments (Østrup & Fredrickson 1974, Østrup 1975). With reestablishment of the nutrient blood supply by microvascular anastomoses, a bone graft will remain viable after distant transfer. It unites quickly at both ends by normal fracture healing as opposed to conventionally grafted bone segments with their prolonged incorporation by creeping substitution. Further, a bone graft is virtually independent of recipient bed conditions and can be transplanted into irradiated or infected areas.

Vascularized bone grafts are transferred either with a thin muscle sleeve to preserve their microcirculation or as parts of compound free flaps, e.g., osteocutaneous flaps. The preferred donor sites are the fibula, a rib, and the iliac crest. A straight segment of iliac crest, 6–8 cm long, can be harvested beyond the anterior superior iliac spine together with a rather large overlying skin island supplied by a series of musculocutaneous perforators. This composite graft, based on the deep circumflex iliac vessels as a vascular pedicle, is ideally suited for intermediate defects of the tibia with associated skin defects (Figure 3). Defects larger than 8 cm and all defects of the femur or long bones of the upper extremity are best treated with free fibular grafts, whereas conventional bone grafts are still the method of choice in tibial shaft defects shorter than 4–5 cm.

The value of vascularized bone grafts in the one-stage repair of compound leg defects has been reported in several large series (Taylor et al. 1975, Taylor et al. 1979, Weiland & Daniel 1979, Solonen 1982, Krag 1985). The free composite osteocutaneous groin flap is currently enjoying wide application in mandibular reconstruction (Krag 1985, Østrup 1983), and vascularized fibula and iliac crest grafts are being used with encouraging results in the treatment of femoral head necrosis (Urbaniak 1984, Chen 1984, Gilbert 1984) and congenital pseudarthroses.

Muscle transplantation

Until recently, free muscle transplantation was regarded as futile because of degeneration and fibrosis, but microneurovascular techniques now allow transplantation of muscles with maintenance of their contractile abilities. Reinnervation is obtained by suturing the motor nerve of the graft to a suitable motor nerve at the recipient site. So far, the most common applications have been in facial paralysis and in replacement of forearm musculature. Usable donor muscles are the gracilis, the tensor fascia lata, the gastrocnemius, and the latissimus dorsi.

Peripheral nerve surgery

The prime goal of surgery in peripheral nerve injury is to provide optimal conditions for the axons crossing from the proximal to the distal stump. This includes healing with minimal scar formation and an ideal neurophysiologic response. Trimming of the nerve ends, alignment of motor and sensory fascicles, and elimination of suture line tension, as well as correct timing of the repair and efficient postoperative immobilization, are some of the requirements for this. Optical magnification substantially facilitates intraneural dissection, accurate fascicular or epineural suture, and nerve grafting; and it has improved the results (Millesi et al. 1976).

Much experimental and clinical work lies ahead before the pathophysiology of injured nerves is understood and therapy is fully effective.

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