Late Salvage of the Ischemic Finger After Crush Injury Using Flow-Through Flaps: Case Report

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The progressive evolution and late salvage of a posttraumatic digit with poor vascularization has not been discussed in the literature. We report the cases of 3 patients whose fingers were rescued at referral 5 to 16 days after the traumatic event by restoring the arterial inflow by means of flow-through free flaps. All 3 fingers were compromised vascularly with patchy necrosis and absence of Doppler signal distal to the injury. All were salvaged. In our experience, in the setting of a posttraumatic digit with poor vascularization, it is possible to reverse impending necrosis by late revascularization. Frank infection or mummification is considered an irreversible state and a contraindication to salvage. *(J Hand Surg 2009;34A:453–457. © 2009 Published by Elsevier Inc. on behalf of the American Society for Surgery of the Hand.)*

Key words Finger reperfusion, subacute finger necrosis, flow-through flap, microsurgery, finger ischemia.

THE PROGRESSION OF finger necrosis after a failing finger replant is familiar to hand surgeons. Similarly, after interruption of both digital arteries, a finger can survive via the vessels present in the dorsal skin. Fingers do so at the price of some atrophy, frequently a decrease in sensibility, and always cold intolerance. The patients state that when exposed to a mild decrease in temperature, the finger becomes blue and painful.

An intermediate stage is the posttraumatic digit with poor vascularization. Typically, after a crush, the finger shows a blue discoloration compared with the rest (always reported by the patient). Concomitantly, if the nerves have not been severed, pain and tingling in the pulp, which progresses to anesthesia, occurs in hours to days. Over the ensuing days, the color of the finger may improve but necrotic plaques appear both in the area of the direct trauma, exposing vital structures, and distal to the zone of injury. If left untreated, slow mummification, or more rapid necrosis, complicated by infection will occur (Fig. 1).

Flow-through flaps are compound flaps containing a vascular conduit that allows coverage and restoration of the arterial inflow in a single stage. They have been used in trauma surgery since the early days of microsurgery for hand and finger revascularization.[1,2] It has been our experience that aggressive debridement of open wounds and revascularization by means of flow-through free flaps can be used to treat such posttraumatic digits with poor vascularization even several days after the traumatic event. We report 3 consecutive cases where such digits were salvaged by late reperfusion.

CASE 1

A 35-year-old man sought a second opinion 16 days after sustaining a complex injury to his dominant hand, including open fractures that were treated through a dorsal approach with open reduction with internal fixation 48 hours after the accident. At admission, the index finger had no Doppler signal, was anesthetic, and had a large soft tissue defect. The middle finger had a massive volar defect and had some distal mummification already. The patient's original surgeon had recommended amputation of the middle finger and had

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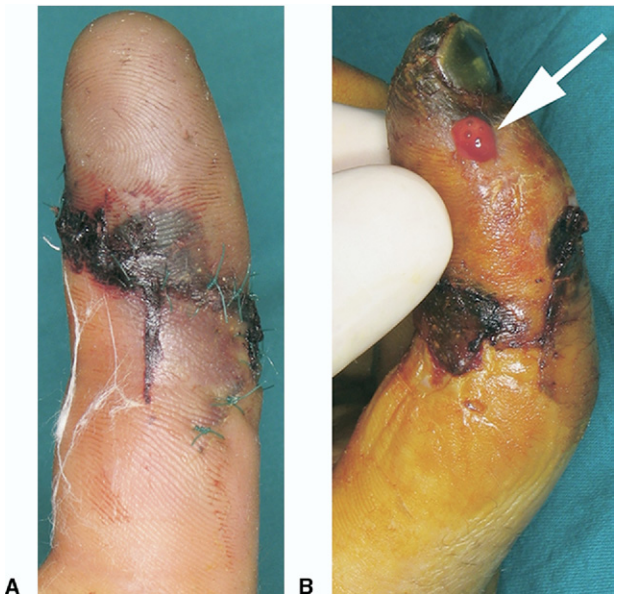

FIGURE 1: A Bluish discoloration and no distal Doppler signal were present in the index finger when first seen 72 hours after the original injury. The injury looked so innocuous that, despite our advice to restore arterial inflow, the patient himself rejected treatment. **B** Thirteen days later, distal mummification (now evident) and infection (arrow) set the finger in an irreversible stage. One-stage amputation and toe transfer was carried out at this point.

warned the patient of the likelihood of the index finger requiring amputation as well. The patient asked for a second opinion because he was seeing the same course of events happening in the index finger as in the middle finger with only 2 days of difference. The latter was now beyond salvage (Fig. 2A).

After debridement, lack of flow in the index finger was evident (Fig. 2B). The index finger was revascularized by means of a neurocutaneous flap taken from the tibial side of the second toe.[3] Proximal and distal arterial anastomoses were carried out, as well as reconstruction of the radial digital nerve by interposing the tibial digital nerve. The middle finger was beyond salvage, but to preserve the skeleton and the proximal interphalangeal (PIP) joint, we performed a second toe wrap-around[4] with a proximal fascio-subcutaneous extension[5] in the same surgery. No complications were noticed and primary healing occurred.

At his last follow-up visit 2 years later, the patient had minimal range of motion at both the PIP and distal interphalangeal joints of both fingers. The contribution of the ischemia, the delay in start range of motion, and the severity of the comminution on the stiffness are unknown. The patient declined a tenolysis because he felt he had a good result (Fig. 2C).

CASE 2

A 25-year-old man sustained a crush injury to his hand 5 days before referral and experienced burst fractures of the middle and proximal phalanx of all 4 fingers. The middle finger was bluish since the injury (the patient pointed this out to his surgeon) but was considered of no consequence because it improved somewhat over the next 24 hours. No treatment was provided apart from a volar splint to avoid exacerbating the situation. Some days later, the appearance of patchy areas of necrosis volarly and dorsally led the patient's surgeon to recommend amputation of the middle finger.

On examination, we noted the absence of Doppler signal, anesthesia, and a bruised flap in the volar aspect of the finger. In one stage, fixation of the fractures of all fingers was undertaken. The finger was revascularized by means of a reversed arterialized venocutaneous flap from the forearm.[6,7] Arterial anastomoses were carried out at the base of the proximal phalanx and at the distal interphalangeal joint level. The donor site was closed primarily.

Doppler signal appeared over the next day, and the color of the finger improved slowly. The flap survived completely after a bluish period, swelling, and blistering. Over the ensuing days, a necrotic plaque that had appeared in the volar aspect of the finger at the distal interphalangeal joint level and had been managed by local care healed spontaneously. Immediately after revascularization, the patient reported improvement in sensibility. Atrophy of the pulp and lack of nail growth were evident in follow-up visits. Motion at the PIP joint was poor in all fingers, but the bony injury was extremely severe around all the PIP joints.

CASE 3

A 34-year-old man suffered a crush on his ring finger. A ragged flap was sutured at the volar aspect on the proximal phalanx. An episode of cyanosis made him return to his primary physician, but this was deemed inconsequential because the finger regained a normal color. The patient came back several times because of pain, which was treated with pain medication. During the last dressing change, the patient noted a bluish discoloration on the pulp tip that again was disregarded by the original doctor.

On day 8 after trauma, the patient was referred for a second opinion. Pulp necrosis had evolved, as well as necrosis on the volar wound that threatened tendon exposure over the proximal phalanx. On examination, the finger was bluish and had reduced tissue turgor. Doppler signal was absent distal to the injury. Two-point discrimination was greater than 15 mm. The pa-

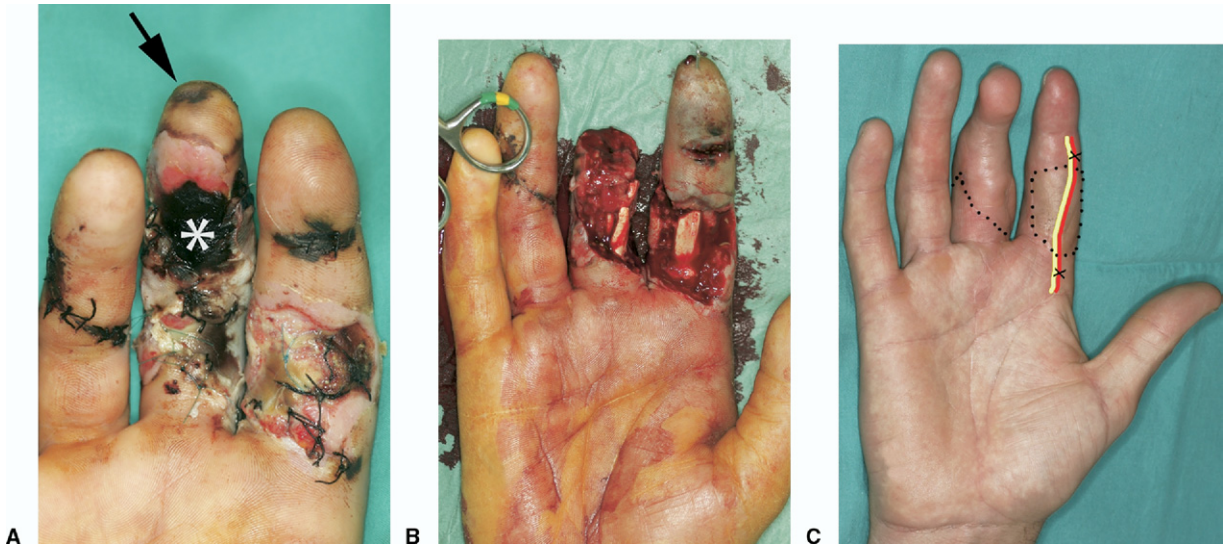

FIGURE 2: Patient 1. **A** Preoperative status. The index finger has no Doppler signal and no sensibility. The area of necrosis in the volar aspect of P2 of the middle finger recently appeared, according to the patient (asterisk). The presence of both apical mummification (arrow) and purulent material around the P2 fracture made the middle finger unsalvageable. **B** After the debridement, the marginal blood supply of the index finger became evident, shown in this picture taken 20 minutes after the tourniquet was released. **C** Result 2 years after the one-stage reconstruction.

tient experienced only a tingling sensation when the pulp was touched.

We carried out extensive debridement of the volar wound. Both arteries were interrupted at the level of the proximal phalanx. To overcome the soft tissue defect and reconstruct the digital artery, we used a flow-through second toe tibial-side neurovascular flap.[3] The flap was inset and the arterial flow was restored by means of the interposed tibial digital artery. The vein was passed dorsally and anastomosed to a subcutaneous vein in the web. End to side neurorraphies between the digital nerve and the flap's nerves were carried out to preserve part of the digital nerve that was crushed but was in continuity.

The postoperative course was similar to that of previous patients (Fig. 3). The finger took 24 hours to recover a normal color. At that time, Doppler signal was still weak. Sensibility recovered after the operation. Satisfactory range of motion was obtained. Some pulp atrophy remained, however.

DISCUSSION

The progressive evolution of the ischemic posttraumatic digit is predictable in its stages but unpredictable as to when each will occur. After a first traumatic event in which the finger sustains bilateral digital artery interruption, the finger readapts to a modified arterial flow-through collateral circulation. This is sufficient to maintain viability but not normal function; the sensibility would be decreased and pain (if no nerve severance occurred) would occur. The healing ability of these fingers is limited, and at any stage during the process, exposure of vital structures or infection will tilt the balance toward necrosis. When this will occur (in terms of days after the traumatic event) is unpredictable because it depends on several factors: namely, the amount of collateral circulation remaining, the severity of the associated wound, the vital structure exposed (open fracture, exposed tendon, and so forth), and the appearance of infection. By the same token, we do not know how many of those fingers heal spontaneously and survive (with some atrophy and cold intolerance).

Therefore, it is vital to promptly diagnose the posttraumatic digit with poor vascularization. Any finger with a crush injury, bluish or reddish discoloration, and no Doppler signal is in this high-risk group.

For a flow-through flap to succeed, the distal arteries need to be patent. We were worried that after the days that elapsed without blood running through the distal digital arteries, the arteries would be blocked by clotted blood. However, after a minor resection, we found them acceptable for anastomosis. Nevertheless, although the intima looked healthy, the vessel was stiffer and more friable than a normal one. This may have happened because some blood still flowed through the distal digital artery fed by collateral circulation, as the digital arteries were patent distal to a sizable side branch, such as one of the transverse arches,[8] or a dorsal branch. On the contrary, over days the distal capillary bed slowly

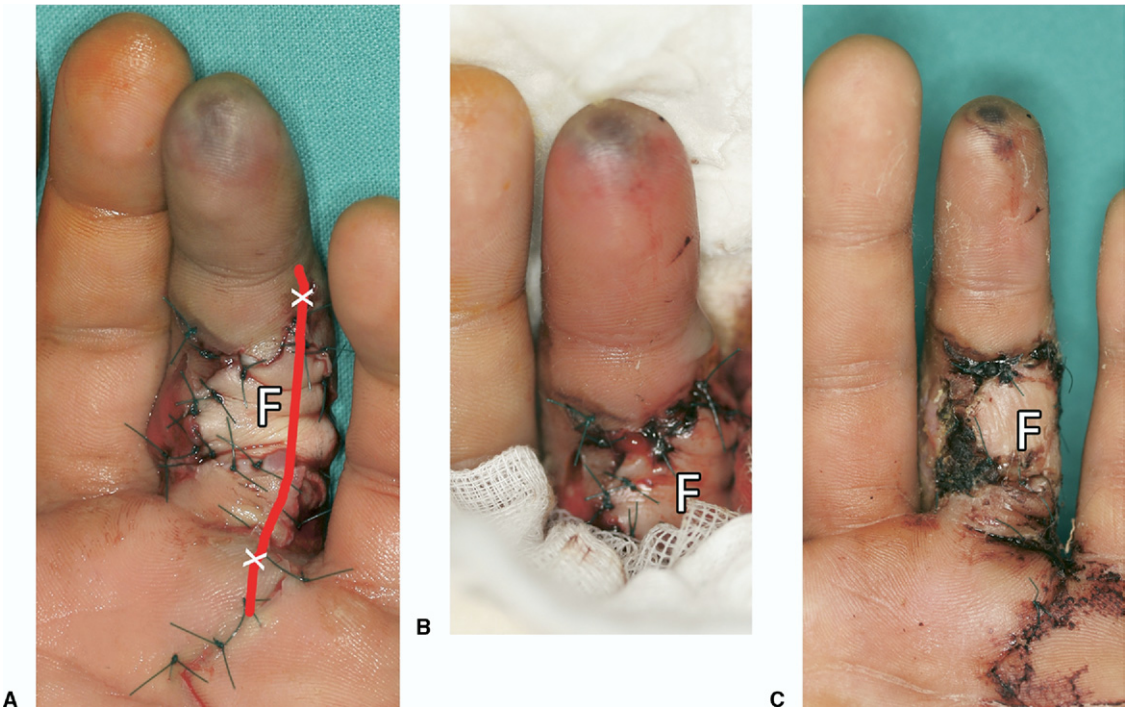

FIGURE 3: A Status 30 minutes after revascularization. The color of the toe flap F is normal, but the cyanotic hue remains in the distal finger (for several hours to days). **B** Reddish discoloration of the finger distal to the flap 24 hours after the surgery. The finger is now full but Doppler signal is still weak in the finger and stronger in the flap. **C** Normal color and appearance 10 days after the surgery. (Doppler signal has been normal since day 2.)

collapses, to a final point where mummification occurs. If pulsatile flow is restored, the blood will slowly clear any deposits and the capillary bed will open up. This is supported by our surgical findings and the way reperfusion occurred in these cases. Usually the flap itself shows immediate capillary refill, but the pulp may take several hours to show a bluish hue and days for the whole pulp to show a true pink color (Fig. 3). Likewise, Doppler signal takes several hours to be audible distal to the anastomosis only. At the pulp it may take several hours or even days.

This behavior differs substantially from other fingers that have sustained a high degree of ischemic damage, such as those replanted after prolonged ischemia times. According to Iglesias and Serrano,[9] in the cases of prolonged warm ischemia, capillary blood flow was obtained immediately after completion of the arterial repair, but after 5 to 15 minutes it was followed by a nonperfusion phase that lasted 30 to 60 minutes; at this time, the capillary circulation was re-established. In both rescued posttraumatic digits with poor vascularization and digits with prolonged warm ischemia, fat and skin atrophy will occur.[9,10] This atrophy affects the gliding ability of the tendons, often with stiffness. Associated injuries may have affected the results in cases 1 and 2, but we were struck by the amount of stiffness in all 3 patients and the pulp atrophy of case 2.

Owing to its inherent thinness and large size, and the possibility of carrying a vascularized nerve, the second-toe, tibial-side neurocutaneous flap[3] seems ideal to rescue a posttraumatic digit with poor vascularization. Furthermore, a near perfect match of the flap and recipient arteries may be expected. Arterialized venous flaps from the forearm[6,7] can be an alternative, but dissimilarities in size and wall thickness make anastomosis of these small vessels more difficult. Skin grafting may be required at the volar forearm, leaving an unsightly scar.[7,11] In addition, Woo et al.[11] warned that necrosis, or flap sufferance, of arterialized venous flap is more common when the bed is totally avascular, as is the case in this setting. Heterodigital arterialized flaps[12,13] could also be an alternative, because they can revascularize the affected finger by means of a single anastomosis (the distal stump of the donor to the distal stump of the damaged finger). However, local damage will be added to the hand. Furthermore, the flap may be unusable because the trauma rarely is limited to a single digit.

It is unknown whether other modalities such as hyperbaric oxygen could improve the functional prognosis after revascularization. A recent study denies any ben-

efit in arterial ulcers,[14] and we are not aware of any prospective study in this setting. At best, hyperbaric oxygen can be used in an empirical manner. Because prolonged ischemia may jeopardize function, and at some stage the posttraumatic digit with poor vascularization becomes unsalvageable, it should be considered a surgical emergency. The presence of infection or distal mummification is a contraindication to salvage.

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