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Research paper

Clinical Investigation and Experience with Distal phalanx Replantation ☆

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Abstract

Objective: To explore the measures and methods for improving distal phalanx replantation. **Methods:** One hundred and forty-eight cases with distal phalanx replantation from Sep 2004 to Sep 2007 were investigated. The indication for surgery and the operative program was determined by the trauma type and the degree of injury. As many microcirculation pathways as possible were reconstructed during the operation, and postoperative tissue decompression was also performed. **Results:** The survival rate of distal phalanx replantation was 89.9% (169/148). **Conclusion:** To improve the survival rate of distal phalanx replantation it is essential to reconstruct an effective local blood circulation, determine the degree of injury in cases with ecchymosis, and employ comprehensive postoperative measures.

Key words: replantation; finger injury; clinical investigation; microsurgery

INTRODUCTION

Finger fractures are a frequent effect of hand injury. When an injury rises to the level of requiring phalanx replantation, appropriate emergency care is necessary. Due to the complexity of the anatomaical structures of the distal finger and the replantation surgery itself, it has been difficult to improve survival rates of digital replantations. Here, we discussed our experience in distal phalanx replantation.

MATERIALS AND METHODS

Clinical materials

This study encompassed 148 cases, 92 males and 56 females, who required distal phalanx replantation, performed from Sep 2004 to Sep 2007. The 148 patients with 188 amputated fingers included 40(21.2%) thumbs, 49(26.1%) index fingers, 36(19.1%) middle fingers, 29(15.4%) ring fingers, and 34(15.4%) little fingers. According to the Yamano classification, 24 amputations were categorized as Zone Ⅰ (extends from arteria digitalis distal transverse palmar arches to fingertip, including distal end of finger nail semilunar line and distal end of finger pulp thread center), 106 as Zone Ⅱ (extends from distal transverse palmar arches to distal interphalangeal joint), and 58 as Zone Ⅲ (extends from distal interphalangeal joint to distal third of the middle phalanx).

Operative procedure

Microsurgical repair was performed using brachial plexus anaesthesia or digit nerve block anaesthesia in all patients. A rubber band was used to stop bleeding in the finger root. Before replantation using conventional procedures, a complete debridement was performed under an operating microscope. Following bone fixation (Zones Ⅲ and jointed severed finger), arthrodesis was performed in 38 cases, while the others were first fixed using Kirschner wire and then a flexor tendon repair was performed before suturing the skin.

Vascular anastomosis:① Twenty-eight fingers had two arteries and three veins along with digit nerves anastomosed; ②Fifty-eight fingers had one artery and two veins along with digit nerves anastomosed; ③Thirty-

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two fingers had one artery and one vein along with digit nerves anastomosed; ④Thirty-two fingers had one artery and one digit nerve anastomosed; ⑤ Twenty fingers had one artery anastomosed; ⑥ The others fingers did not undergo any repair.

Fourteen fingers of 24 Zone Ⅰ severed fingers did not have any vascular anastomosis. Wound trimming and suturing in situ was performed in all 14 fingers. Ten fingers had only one proper artery repair without any vascular and nerve anastomoses. Following exploration of the vessel wall under the microscope, 24 severed fingers with ecchymosis were injected with a mixture of heparin and dexamethasone. After exudates appeared in the wound, vascular anastomosis was performed.

Due to vessel diameter of amputations close to the nail, mostly less than 0.3mm in Zone Ⅱ, and the dorsal digital vein's proximity to the skin, plus the thin vessel wall, it is necessary to apply heparin and lidocaine to wash the cut ends of blood vessels to expose vessel lumen for anastomosis.

During the vascular anastomosis procedure, eight fingers had distal artery and proximal vein repair after one side artery anastomosis; six fingers had distal vein and proximal artery repair after one side vein anastomosis; twenty fingers had cross-bridge vascular anastomosis, but did not have proximal proper artery and opposite proper artery repair; eight fingers had dorsal hand vein and proper artery bridge anastomosis. Fingertip lateral incisions were made in 56 fingers without vascular anastomoses. Finger nails were uprooted to allow drainage and bloodletting. Postoperative heparin(12,500 U/250mL saline) was used to wash the incision and the base of the nail. Blood clots needed be extracted to maintain blood exudation and decrease tissue swelling.

Close postoperative monitoring was essential for successful replantation. The patient had hourly monitoring of digital color, surface temperature, Doppler pulse, and oxygen saturation for the first 24 hours. For the next 48 hours, a vascular assessment was performed. The room was warmed to 75 to 80° F prior to the patient's arrival, and kept at that temperature. Patients were not allowed to eat or drink for the first 24 to 48 hours, as this is the period of highest risk for thrombosis. They then progressed to a regular diet, avoiding caffeine and chocolate, as both can cause vasoconstriction. Following surgery, the patients were put on anticonvulsive therapy to prevent vasoconstriction, and low molecular weight dextran(500 ml/d) for 5 days. The local lateral incision was washed with a heparin solution, and subcutaneous heparin was administered in a dose of 12,500 U/500 mL(8 drops/min) for 1 week. No antibiotic treatment was administered to any patient.

RESULTS

Of 188 fingers, six fingers(3.2%) were infected after replantation. There were 12 fingers in which a circulation crisis occurred. Followed by 2 hours comprehensive treatment, surgical exploration was immediately performed in these 12 fingers. Subsequently, thrombus clearance and vascular anastomosis were started. Of those 12 fingers, six fingers survived, and others were failures. Of 24 fingers in Zones Ⅰ, 8 fingers sutured in situ survived, and 9 fingers with a single artery anastomosis survived, giving a success rate of 70.8%; Successful finger replantation was achieved in 97 of 106 cases in Zone Ⅱ, giving a success rate of 91.5%; Successful finger replantation was achieved in 55 of 58 cases in Zone Ⅲ, giving a success rate of 94.8%.

DISCUSSION

Anatomical considerations

The vascular anatomy of the distal finger is quite consistant. In our experience, the pulp thread center is the location of fingertip arterial arch on the finger surface. The bilateral proper artery forms a distal transverse palmar arch stopping at the flexor digitorum profundus tendon. From the distal interphalangeal joint to the base of the nail, the artery size is 0.3-0.6 mm, and there are abundant veins from the pulp to the dorsal surface(size 0.3-0.8 mm).

The thumb arteriovenous anastomoses are the largest of these veins. Because of the distinct anatomical relationships of the distal proper artery, distal transverse palmar arch, distal interphalangeal joint, and termination of the flexor digitorum profundus tendon, we can find artery markers and easily perform a vascular amputation suture[1]. From the base of the nail to the pulp thread center the radial and ulnar digital arteries turn centrally to join each other, forming the distal transverse palmar arch, which forms a round arch and crosses at the level of the base of the nail. Its size is 0.085-0.1 mm. The distal transverse palmar arch gives off several longitudinal branches that travel to the tip of the pulp and turn dorsally to communicate with the distal matrix arch[1]. The size of these branches averages 0.058-0.1 mm. At the distal end of pulp thread center, the distal transverse palmar arch gives off artery branches averaging 0.1-0.2 mm. Owing to the thin vessel wall at this location, we can only find branches after heparin and procaine washing[2]. The pulp vein is close to the dermis and averages 0.2-0.4 mm, extending between the pulp center and the lateral margin of the finger. Bilateral digit nerves which innervate pulp and the dorsal aspect of the finger mostly give off

4 to 5 branches in the base of the bones of the distal finger. Their size is 0.2 mm. We feel that it is mandatory to use a 7-0 suture for the tunica vaginalis suture.

Vascular reconstruction and establishment of the peripheral circulation

In the distal phalanx, especially in the soft tissue, there is a rich collateral circulation. These branches communicate artery with vein, artery with artery, vein with vein through capillaries that form many glomus bodies. As there are no valves in the venules, perfusion of any vessel can reach the glomus bodies. Thus, as long as there is not occlusion in the collateral circulation, peripheral circulation can be established in a distal phalanx[3]. Vascular reconstruction post-injury might face an anatomical morphology that differs from normal. Even then, if the blood supply of the amputated finger is maintained, the replanted finger can still survive. By making use of the specific anatomical structures in the distal phalanx, non-physiological circulation established after reconstruction also can support tissue nutrition.

In 8 cases we reconstructed vascular perfusion where the anatomical relationship was abnormal due to injury. The problems encountered were arteriovenous anastomosis difficulty, multiple arterial anastomosis failures, and severe injury of artery and vein. In one case the distal vein could not be used and we performed artery and vein anastomosis and established peripheral circulation. The amputated finger survived. Some researchers have reported venous retrograde perfusion after artery-vein anastomosis. This caused blood to flow from vein to small vein, to venule, and then to glomus by the following three pathways:① Most of blood flowed through communicating branches, venules to venule, with a drainage function;② Part of blood directly reflowed from venule to capillary for distal tissue nutrition; ③ Part of blood flowed through communicating branches between venule and arteriole to arteriole and then to capillaries for distal tissue nutrition[4,5]. Our clinical investigation also demonstrated that blood perfused through any vessel could reach glomus bodies and establish circulation, as long as any one circuit existed.

We reconstructed perfusion in two types of conditions of 20 cases by using vascular cross- anastomosis. The types of cases were those in which anastomosis between proximal proper artery and ipsilateral distal artery was impossible, such as defect or excessive tissue tension, and those in which after anastomosis the peripheral circulation was not satisfactory, even when treated for spasm with hot compress and massage. The anastomosis between proximal proper artery and opposite distal artery peripheral circulation was considered as a salvage technique. After anastomosis, the amputated finger filled, regained color, and the tissue became elastic. The replanted fingers survived.

Using a vascular bridge between the dorsal vein and proper artery, we reconstructed an artery in Zone Ⅲ of 8 cases.

Venous anastomosis

When compared with an artery in which pressure is strong, blood flow is fast, and the vessel number few, a vein is more suitable for anastomosis in amputated fingers. From a haemodynamic standpoint it is essential to balance arterial perfusion and venous drainage after an anastomosis. Moreover, we also should pay attention to the number and diameter of vessels repaired. From a theoretical perspective, as many veins should be repaired as possible. If only one venous anastomosis works well, pressure and flow velocity in the vessel will compensate, and the amputated finger will survive[6]. In fact, venous anastomosis is usually even more difficult than arterial anastomosis in distal phalangeal replantations because few suitable veins are available and skin mobility is limited on the dorsal side at this level. Thus, the ratios of venous anastomosis to arterial anastomosis does not reach the expected 1:1 or 1:2 ratio. In our series, there were 56 cases without venous anastomosis, and a survival rate of 100%. Therefore, on the basis of our experience, the determinants for a successful finger replantation is:①Making a side incision of the finger pulp during surgery; ② Pulling out the finger nail; ③Loosening of the cut end skin suture; ④Washing the side incision with a heparin solution to promote hemodiapedesis, lowing the tissue tension, improving capillary reconstruction in the cut end as soon as possible, and forming novel venous drainage.

Based on our experience, only making one arterial anastomosis is a common event because of limiting conditions in the amputated finger. However, the quality of the arterial anastomosis, the combined anti-infection, anti-vasospasm, and antithrombosis therapy, and reduction of tissue tension, are the major determinants of finger replantation.

Treatment of amputated fingers with ecchymosis

The cause of, and the degree of injury to, an amputated finger are different. Finger injury can destroy the vascular bed between the soft tissue and skin, and some severe injuries might destroy the capillary bed and dorsal digital vein net. After vascular anastomosis, the physiological function cannot be restored, and the replanted finger cannot survive. Venous drainage blockage is a main factor determining survival of a replanted amputated finger when there is ecchymosis[6]. The success of

the replantation is in serious doubt: ① if we observe microscopic breakage of the vascular wall, then the artery-vein circulation cannot be established; ② when we perfuse the vasculature with a heparin solution (heparin 12,500U-dexamethasone, 5 mg, in 250 mL saline) and meet strong resistance, and there is no liquid overflow from the cut edge, then the finger is not suitable to replantation.

In the series reported here, we performed vascular anastomosis to establish blood circulation in 24 cases with ecchymosis. There were 4 cases of replantation failure because of venous embolism. In 2 of these cases there was initial swelling, followed by a side incision, but necrosis occurred within the next 5 days. In the other 2 cases swelling occurred 3 days after surgery. In the following five days the finger became infected and then necrotic, requiring eventual amputation. Care should be taken when the distal phalanx replantation finger exhibits ecchymosis.

On the basis of the cases reported here we conclude that the following factors are determinants of replantation success:①slight soft tissue injury;②reliable aterial and venous anastomosis; ③ well-established blood circulation.

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