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Clinical Application of Free Flaps Supplied by Radial Osteocutaneous Branches of the Dorsal Branch of the Anterior Interosseous Artery for Reconstructing Bone and Skin Defects in the Hand

Yunhao Xue, Yaobin Yin, Chen Yang and Shufeng Wang*

Department of Hand Surgery, Beijing Jishuitan Hospital, PR China

Correspondence should be addressed to Shufeng Wang, Department of Hand Surgery, Beijing Jishuitan Hospital, Xicheng District, Beijing 100035, PR China

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ABSRACT

OBJECTIVE

To explore the clinical application and efficacy of the transplantation of free composite flaps supplied by radial osteocutaneous branches of the dorsal branch of the anterior interosseous artery for reconstructing bone and skin defects in the hand.

METHODS

Anatomically, radial osteocutaneous branches of the dorsal branch of the anterior interosseous artery have constant collateral anastomoses that can provide a large dorsoradial flap from the dorsum of the forearm. This flap was used for reconstruction in 5 cases of cutaneous and phalangeal defects.

RESULTS

Reconstruction was successful in all 5 cases, with good functional and cosmetic results. All donor sites could be closed directly.

CONCLUSION

Reconstruction with dorsoradial forearm flaps is a simple and reliable procedure that causes minimal trauma. Thus, this is an ideal approach for repairing cutaneous and phalangeal defects.

KEYWORDS

Free flap; Anterior interosseous artery; Surgical flap

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INTRODUCTION

There have been many clinical reports on the repair of hand soft tissue defects or carpal bone necrosis using flaps based on the dorsal branch of the anterior interosseous artery. Most of the reports have been on the reverse transplantation of pedicled flaps [1-4], while the transplantation of free flaps has rarely been reported [5,6]. Based on the anatomical findings of Syed et al. [7], we reconstructed phalangeal and soft tissue defects in 5 patients using dorsoradial forearm flaps based on radial osteocutaneous branches of the dorsal branch of the anterior interosseous artery and achieved good outcomes, as reported below.

MATERIALS AND METHODS

Materials

Over the period from January 2015 to June 2020, 5 patients with phalangeal and soft tissue defects caused by trauma were treated with osteocutaneous flaps based on the dorsal branch of the anterior interosseous artery at the Hand Surgery Department of Beijing Jishuitan Hospital. These patients included 3 males and 2 females aged 22 years - 45 years. The trauma was caused by machine crush injuries (3 cases) or traffic accidents (2 cases). The size of the skin defects ranged from 4 cm × 2 cm to 6 cm × 4 cm. The length of the bone defects was 2 cm - 3 cm. All patients underwent first-stage emergency operations at other hospitals. Due to untreated defects caused by the trauma or postoperative nonunion of the phalanges, these patients developed skin necrosis with digital bone exposure. Later, these patients underwent composite tissue flap transplantation at Beijing Jishuitan Hospital. The average time between trauma onset and the second-stage operation was 2 months.

Methods

Applied anatomy

At the upper edge of the pronator quadratus, the anterior interosseous artery perforates the interosseous membrane approximately 6.0 ± 1.0 cm proximal to the radial styloid process to reach the dorsal compartment of the forearm and continues as a dorsal carpal branch. The dorsal carpal branch, approximately 4.7 ± 1.1 cm long, is located on the deep surface of the extensor digitorum communis tendon and descends along the interosseous membrane. Approximately 4.5 ± 0.7 cm proximal to the radial styloid process, the dorsal branch gives off a radial osteocutaneous branch, which extends obliquely to the distal end along the ulnar border of the extensor pollicis brevis tendon, passes through the gap between the extensor pollicis longus tendon and the extensor pollicis brevis tendon, and divides into an ascending branch and a descending branch. The ascending branch runs under the skin and anastomoses with the radial musculocutaneous branch; the descending branch descends along the dorsal side of the radius, divides into a cutaneous branch and a periosteal branch distributed on the dorsal side of the distal radius, and anastomoses with a radial styloid process branch given off from the dorsal carpal branch of the radial artery. The radial musculocutaneous branch is derived from the descending branch of the posterior interosseous artery, extends to the radial side via the superficial surface of the abductor pollicis longus, enters the subcutaneous tissue approximately 11.4 ± 1.1 cm proximal to the radial styloid process, and gives off several cutaneous branches, with the trunk descending and anastomosing with the radial osteocutaneous branch. The radial musculocutaneous branch of the posterior interosseous artery constantly anastomoses with the radial osteocutaneous branch of the dorsal branch of the anterior interosseous artery. The branches of the posterior interosseous artery supply a large area of the dorsal forearm, while the anterior interosseous artery supplies the distal end; the posterior interosseous artery anastomoses with the anterior interosseous artery near the wrist through the osteocutaneous branch; the dorsal carpal branch of the ulnar and radial arteries together with the medial and lateral terminal branches of the dorsal branch of the

anterior interosseous artery form the dorsal carpal network and communicate with the dorsal metacarpal artery.

Surgical methods

Recipient site preparation

Debridement was performed at the recipient site, and the edges of the skin wound were excised to make the wound fresh. The phalanges on the dorsal side were exposed, sclerotic fracture ends were excised, the medullary canal was opened, and the wound surface was washed. The proximal proper palmar digital arteries (or common palmar digital arteries) and dorsal digital veins were exposed by lateral incision; then, the defect area and bone defect length were measured, and crossed Kirschner wires were inserted into both ends of the bone graft for later use. When necessary, a miniature external fixator was used to immobilize the proximal and distal phalanges.

Flap design and flap elevation

Flaps were designed according to the point, line and plane principle, and the measured skin defect area was taken as a reference to determine whether the donor site could be directly sutured after flap creation.

Point

The origin was 4 cm proximal to Lister's tubercle; the connecting line between the origin and Lister's tubercle served as an axial line, and the range of the flap was designed according to the flap area. First, the ulnar edge of the flap was incised to expose the tendon of the extensor digitorum communis, and the tendon was retracted to the ulnar side. The distal descending branch of the dorsal carpal branch of the anterior interosseous artery was exposed in the deep region; osteal and cutaneous branches were exposed, and the cutaneous branch was checked to ensure that it entered the flap. The vascular pedicle was freed to the proximal end until the origin of the dorsal carpal branch of the anterior interosseous artery, and the vascular pedicle was freed to the distal end until the cutaneous and osteal branches; the cutting range of the bone flap was designed according to the size of the phalangeal defect. The skin surrounding the flap was incised, and the corresponding bone flap was harvested using an osteotome. Then, the tourniquet was loosened to evaluate whether the blood supply of the flap was normal.

Flap transplantation

The vascular pedicle was dissected from the origin of the dorsal carpal branch of the anterior interosseous artery, the proximal end was ligated, and the donor site was sutured directly after the bone flap was removed. The tissue flap was transplanted to the recipient site, while the bone flap was transplanted to the phalangeal defect site. The distal and proximal ends were fixed by penetrating the bone flap with the crossed Kirschner wires, which were placed in advance. The arteries and veins of the tissue flap were anastomosed with the proper palmar digital arteries or common palmar digital arteries and dorsal digital veins, and the blood supply of the flap was restored. Postoperative anticoagulation and anti-vascular spasm treatments were given routinely, and antibiotics were routinely used to prevent infection.

RESULTS

All donor sites, incisions, and recipient sites healed in the first stage, and all the flaps survived. At 3 months postoperatively, the elasticity of the flap was maintained, the skin of the treated fingers was slightly more swollen than that of the healthy fingers, and the phalangeal recipient site had healed completely.

Typical case

A 38-years old male patient suffered from skin necrosis of the proximal phalanx of the right ring finger due to open wounds, as well as nonunion of the proximal phalanx with bone defects (Figure 1A and Figure 1B). After debridement, the patient had a skin defect of 2 cm × 3 cm in size and a bone defect of 3 cm in length (Figure 2A and Figure 2B). Composite osteocutaneous flaps based on the dorsal branch of the anterior interosseous artery were

transplanted to repair the defects, and all donor sites were sutured directly (Figure 3). All skin flaps and skin grafts survived. At 9 months postoperatively, the bone graft had healed well, and the patient was satisfied with the appearance of his hand (Figure 4 and Figure 5).

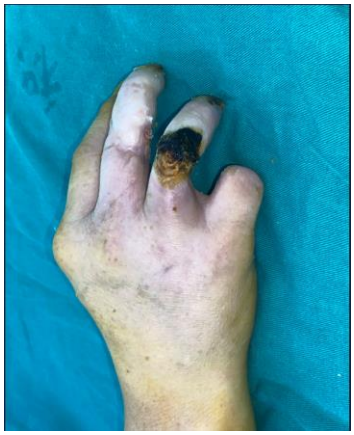

Figure 1A: Skin and soft tissue necrosis of the right ring finger caused by trauma.

Figure 1B: Nonunion of the proximal phalanx of the ring finger with bone defects.

Figure 2A: Soft tissue defects after debridement.

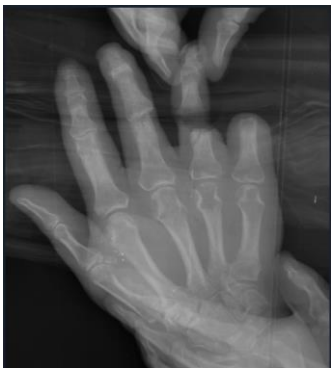

Figure 2B: X-ray image of the bone defects after debridement.

Figure 3: Bone flap transplantation to repair phalangeal and soft tissue defects.

Figure 4A: X-ray image of bone graft healing at 3 months postoperatively (PA).

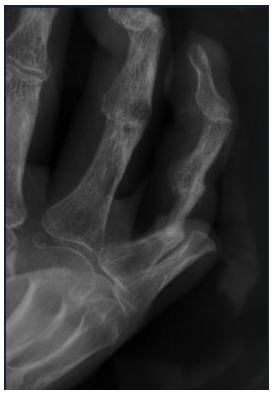

Figure 4B: X-ray image of bone graft healing at 3 months postoperatively (L).

Figure 5: The flap survived well and was slightly swollen.

DISCUSSION

Hand bone and soft tissue defects caused by trauma are not uncommon in clinical practice, especially skin necrosis, bone exposure, and bone nonunion after emergency surgery. In these cases, staged surgery is generally required, including a first-stage surgery to restore soft tissue coverage and a second-stage surgery for bone grafting, which means that the treatment period is quite long. Since the soft tissue under the skin of the hand is thin, there are few choices for free flaps for the hand [8,9]; after the operation, most flaps are swollen and poor in appearance, and donor-site complications are common [10]. Composite osteocutaneous flaps based on the dorsal branch of the anterior interosseous artery can be used to repair phalangeal and soft tissue defects of the hand. These flaps help reduce the number of required surgeries. Moreover, the flaps do not appear to be swollen, and the donor sites can be closed directly. The posterior interosseous artery and the dorsal carpal branch of the anterior interosseous artery anastomose with the dorsal carpal branch of the ulnar and radial arteries on the dorsal side of the distal forearm. These constant anastomoses provide a stable anatomical basis for bone and skin flaps. Based on this anatomical structure, either the reverse transplantation of pedicled flaps or the transplantation of free flaps can be performed flexibly as needed.

The main advantages of this flap are as follows: (1) The tissue flap preserves the main arteries of the forearm; after flap creation, the blood supply of the forearm and hand is not be affected. The flap can be applied even in the case of ulnar or radial artery injury. (2) The skin at the donor site is thin and suitable as a flap for the hand. (3) The tissue flap is simple in anatomical structure and can be easily raised from the deep fascia. (4) The vascular pedicle is sufficient in terms of length and diameter to support microsurgical anastomosis. (5) The superficial branch of the radial nerve and tendon run in the flap donor site, which means they can be transplanted at the same time if necessary.

Disadvantages of flap include the following: (1) The donor site is visible; after flap creation, an unsightly scar is left on the dorsal side of the distal forearm. (2) Dissection is technically demanding. In consideration of the above advantages, these disadvantages are acceptable.

Reconstruction with dorsoradial forearm flaps is a simple and reliable procedure that causes minimal trauma. This approach is an ideal choice for the repair of cutaneous and phalangeal defects.

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