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Original Article

Anatomy-based application of finger fascia pedicled skin artery branches flap

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Abstract: Objectives: To study the anatomy of the dorsal metacarpal arteries and their branches, to understand the positions and shapes of the arteries and their branches, and to observe the capillary network formed on the lateral and the dorsal sides of the finger under a microscope. Based on this anatomy, a finger fascia pedicled skin artery branch flap was designed to repair fingertip wounds. Methods: A total of 5 fresh adult cadaveric hand specimens were infused with red latex. The anatomy of the dorsal finger intrinsic arteries of the 40 fingers (excluding the thumbs) were observed under a microscope, and a capillary network was formed on the lateral and the dorsal sides of the fingers. Then, 10 cases of finger soft tissue defects were repaired using an anatomy-based design finger fascia pedicled skin artery branch flap. Results: The anatomical observations indicated that the intrinsic artery on each side of the finger sends four thicker cutaneous branches toward to the dorsal side, wherein the descending branch of the upper cutaneous branch coincides with the ascending branch of the next cutaneous branch to form a lateral vascular chain. A fascia flap pedicled (>0.5 cm) skin artery branch flap was used to repair the patients' finger injuries (8 males and 2 females, aged 21 to 52 years). The wound surface ranges were about 2.8 cm × 1.9, and the flap ranges were about 3 cm × 2.1 cm. During the 5-12 months of follow-up, all the flaps survived well. Conclusion: The bilateral finger arteries emit a number of macroscopically identifiable capillary branches and form a capillary network using anastomosis between the cutaneous branches. The finger fascia pedicled skin artery branches flap, not <0.5 cm wide, contains the capillary branch of the dorsal finger artery as the flap for the blood supply. The flap can cover various types of distal finger wounds.

Keywords: Skin branch flaps, applied anatomy, microsurgery, transplantation, fascia pedicles

Introduction

Fingertip defects usually occur due to life and work accidents, especially in factories and at construction sites where cutting and crushing injuries are more common. Because of fingers' important functions, it is necessary to cover a finger end wound using a graft. There are certain difficulties in the clinical repair and reconstruction of those wounds. Reportedly, there have been many repair methods. Flap surgery is a subspecialty of plastic and reconstructive surgery. It is a piece of tissue transferred from the donor site to the recipient site that maintains its own blood supply, including: 1. Local flaps. 2. Regional flaps. 3. Distant flaps [1].

For local flaps, Atasoy flaps (transverse and dorsal oblique tip amputations) [2], Kutler flaps (V-Y advancement flaps from both sides of the finger for midlateral distal amputations) [3], first dorsal metacarpal artery flaps (kite flaps) [4], cross-finger flaps (in volar soft-tissue defects) [5], thenar and hypothenar flaps (pulp and fingertip defects in young patients) [3], and digital artery perforator flaps (transverse or side oblique fingertip defects with exposed bone) [6] are among the most commonly-used options which can be performed in emergency settings [7]. The local skin flaps can be further classified into random or axial pattern flaps according to their blood supply [8, 9]. However, the conventional flap design has certain limitations, because it reduces the clinical efficacy of soft tissue repair due to the tension of the subcutaneous tunnel and the flap's lower survival rate.

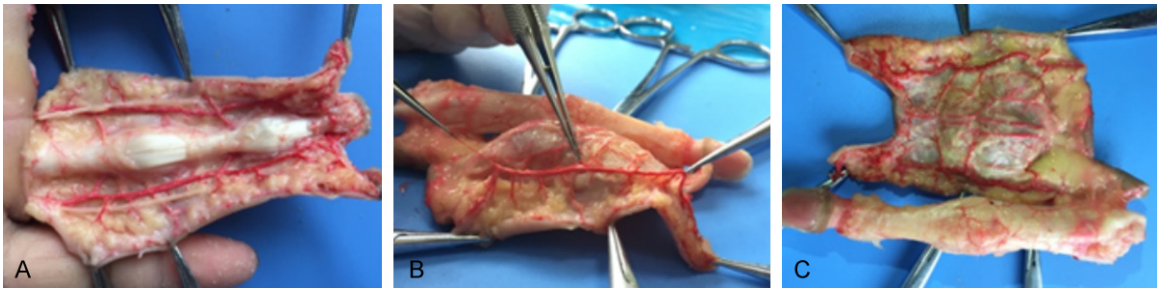

Figure 1. Dorsal cutaneous branches of the digital artery. A: A longitudinal incision is made on the side of the palm of the finger. B: The dorsal cutaneous branch of the finger's intrinsic artery. C: The dorsal cutaneous branch of the artery forms a vascular chain between the lateral and the dorsal sides of the finger.

Over the past decades, several reconstructive procedures and their modifications have evolved to provide the ideal soft tissue coverage of the hand [10]. Conventionally, these included a range of options of primary wound closures, skin grafts, local flaps, distant flaps, and micro-vascular free tissue transfers [10-13]. Selecting the most suitable type of soft tissue cover for a particular defect can be challenging process. According to the distribution of finger vessels, we designed a new type of finger fascia pedicled skin artery branch flap, and we repaired ten fingertip defects in ten patients, and the clinical results were satisfactory. The report is as follows.

Materials and methods

Anatomy

The project was approved by the ethics committee of Southern Hospital of Southern Medical University. All the patients were informed of the contents of the study and signed an informed consent form. During the period from 2013-2016, we dissected five pairs of hand specimens together with the Department of Anatomy of Shenzhen University. The anatomical work was done by the same person. Red silica gel (20 ml) was perfused into the ulnar artery, and after it was solidified, a longitudinal incision was made in the middle of the metacarpophalangeal joint, and the skin was cut to the fingertips along the palm side, deep enough to reach the flexor tendon.

The flexor tendon of the finger was separated to expose the intrinsic artery, and the dermis was carefully dissected to find all the cutaneous branches on the dorsal side. Then the subcutaneous tissue was separated into the nail bed in the aponeurotic layer of the extensor tendon, taking care to protect the integrity of the dorsal cutaneous branch of the artery.

We removed the subcutaneous fat from the back of the finger, dissected the intact vascular network of the finger, and observed the direction and spacing of all the dorsal branches under the microscope. The distance between the starting point of the dorsal cutaneous branch and the proximal interphalangeal joint with a constant position were recorded.

Flap design

According to the size of the finger defect, the flap was designed near the finger to be repaired (as shown in **Figure 1**). Rotation point: l 0.5 cm near the proximal edge of the finger artery. Axis line: placed at an arbitrary angle with the finger artery. Flap position: located on the back of the finger. The far side did not surpass the midline of the opposite side of the finger, and the size should be <3 cm × 2.5 cm.

The patients' information

From October 2015 to September 2017, we operated on ten patients with finger wounds, including 8 males and 2 females (aged 21-52 years), with an average age of 34 years. Of them, 5 cases had machine cutting injuries, 3 cases had crushing and bruising injuries, and 2 cases had knife cutting injuries. 5 cases had distal phalanx fractures, 8 cases were wounded at the distal interphalangeal joint, and 2 cases were wounded in the middle segment of the finger. All the injured fingers were previously healthy (**Table 1**). All the cases were emergency cases, and the times to the medical

Table 1. Clinical data

Cases	Gender	Age (yr)	Cause	Finger injured	Segment	Flap size	Complications
1	M	28	Cut	Index	Distal	2.8 cm × 2 cm	No
2	M	45	Bruised	Ring	Distal	2.5 cm × 1.8 cm	No
3	M	33	Cut	Small	Distal	3 cm × 2 cm	No
4	M	38	Cut	Index	Distal	2 cm × 1.8 cm	Venous crisis
5	M	29	Cut	Index	Middle	2.3 cm × 2 cm	No
6	M	52	Cut	Middle	Distal	2.5 cm × 2 cm	Venous crisis
7	F	21	Bruised	Index	Distal	2.4 cm × 1.9 cm	No
8	F	36	Cut	Ring	Distal	2.8 cm × 2 cm	No
9	M	37	Bruised	Middle	Distal	2.2 cm × 1.9 cm	No
10	M	21	Cut	Middle	Distal	2.9 cm × 2.5 cm	No

Table 2. Distances between the dorsal artery of the finger and the joint between the proximal fingers (mm)

Finger	Proximal artery branch		Mid-arterial branch	
	The first artery branch	The second artery branch	The 3rd artery branch	The fourth artery branch
Index	10	4	7	11
Middle	11	5	8	12
Ring	11	4	7	11
Small	9	3	6	10

treatment after the injuries ranged from 0.5 hours to 8 hours.

Surgical methods

The patients were in placed in a supine position, and nerve block anesthesia was performed at the base of the finger. Each flap was cut distally from the proximal edge along the design line of the flap. The free flap was opened at the proximal edge of the flap to reveal the deep fascia, and measures were taken to retain the tendon outer membrane tissue and cut the marginal vein of the flap and ligature to stop any bleeding. Only the skin layer was cut. The fascia pedicle was 5 mm wide, and the rotation angle was 180° without any tension sutures.

Postoperative follow-up

The surgery was evaluated using the following parameters: the skin scar contracture in the donor and recipient areas of the flap, the cold tolerance, the static and moving two-point discrimination (S2PD and M2PD), the Semmes-Weinstein monofilament (SWMtest) and patient subjective evaluations (satisfied, general, poor). Our statistical analysis was performed using SPSS 22.0 software (SPSS Inc., Chicago, IL).

Results

Anatomy

In the proximal and middle segments of the index, middle, ring finger, and small fingers, the intrinsic artery on each side branches out to four thicker blood vessels at a constant position, facing the dorsal side of the finger. The distance between these fingers and the proximal interphalangeal joint is substantially constant (**Table 2**), and the arteries are symmetrically presented on both sides. In addition, the intrinsic artery also branches out a number of macroscopically identifiable skin capillaries that are unequal in thickness, unevenly spaced (<5 mm), and asymmetrical to the contralateral side. Their diameter can be measured under a microscope. The dorsal skin branches of these internal arteries, from both sides of the finger toward the dorsal side of the finger, also emit multiple secondary branches, wherein the descending branch coincides with the ascending branch of the next skin branch to form an outer vascular chain. The cutaneous branch on one side coincides with the cutaneous branch on the opposite side of the finger, forming the dorsal capillary chain of the finger (**Figure 1A-C**).

Clinical surgery

In this group of 10 patients, all the flaps survived after the operations, and the wounds healed in the first stage without any arterial crises. Two of the flaps showed local cutane-

Table 3. Evaluation index

Cases	Follow-up time (months)	Two-point discrimination test		postoperative-sensing threshold	Subjective evaluation
		Static	dynamic		
1	8	11	8	3.25	Satisfaction
2	12	14	12	3.32	Satisfaction
3	11	11	10	3.46	Satisfaction
3	12	9	15	Normal	Satisfaction
4	10	7	9	3.85	Satisfaction
5	9	12	8	3.29	Satisfaction
6	11	5	7	3.28	Satisfaction
7	10	11	12	3.52	Satisfaction
8	8	10	8	4.3	Satisfaction
9	10	10	11	Normal	Satisfaction
10	11	9	8	3.65	Satisfaction

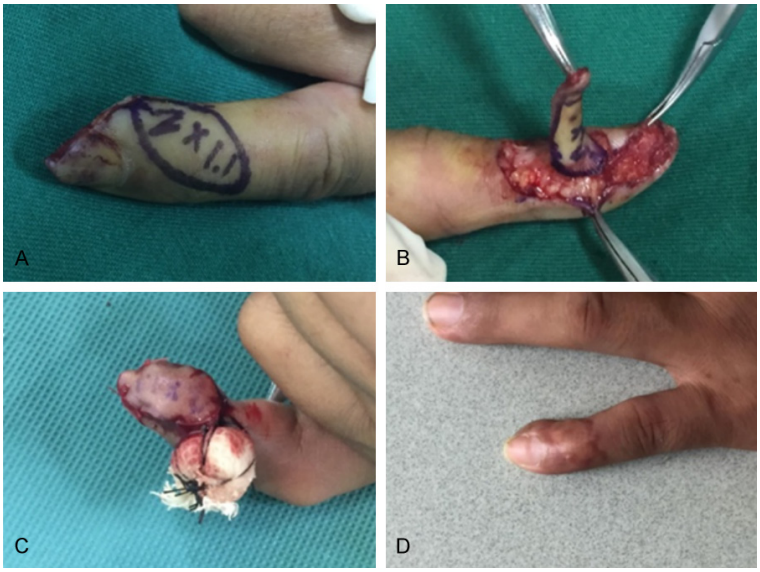

Figure 2. Clinical cases. A: Shows the fingertip defect of the small finger. B: Shows that the flap is cut during the operation. C: Shows that the blood supply of the postoperative flap is good. D: The follow-up at six months after the surgery showed the finger in good shape.

ous venous return obstructions at the distal ends of the flaps, which were caused by tight sutures at the distal ends of the flaps. After efforts were made to remove some surgical sutures, keeping the fingers warm, clearing the blood stasis, etc., the wound healed after two weeks of dressing changes.

The postoperative evaluation is shown in **Table 3**. All the patients' flaps presented good blood supplies, moderate suture tension, and balanced pressure, and no significant scarring. The static and dynamic two-point discrimination on the flap was tested between 7 mm and 15 mm. As a result, 2 patients felt normal, 6 had weakened tactile sensations, and 2 had weakened protection; all the patients were subjectively satisfied with the surgical results. A representative case is shown in **Figure 2**.

After 5-12 months of follow-up, all the flaps survived and looked good.

Discussion

The currents status of flaps

A flap is a mass of skin and subcutaneous tissue that covers the wound and has a specific blood supply (not relying on the surface of the tissue it covers to obtain a blood supply). The part of the flap responsible for supplying blood is called the vascular pedicle [14]. The skin graft is a tissue that has no intrinsic blood supply and must be revascularized by the tissue bed below it to survive [14]. The blood supply to the flap is not from a single arteriovenous vascular pedicle, but from tiny blood vessels in the subdermal or subcutaneous vascular network. The design should generally follow the 1:1 principle (the length of the flap cannot exceed its width).

The reverse digital artery island flap can effectively cover the wound surface, and the texture of the donor area is similar to the texture of the recipient area. However, the procedure requires a sacrifice from the finger on one side of the native artery, and the cold tolerance of the injured finger will decrease.

V-Y advancement flaps can repair wounds with small defects, but wounds with large defects are difficult to cover.

Although cross-finger flaps are large enough, they limit the activities of the injured fingers

and the cross-finger, and this technique requires grafting of the donor site and a second operation for the flap separation. It is not suitable for patients who do not wish to have their fingers remain attached to each other for 2-3 weeks. Physical therapy is necessary to attain normal movements, and this delays the return of the patient to work [15].

The survival mechanism

Based on the anatomical study, we found that the finger artery constantly sends cutaneous branches or capillary branches of different diameters to the lateral back of the finger. The capillary chain is formed between the ascending branch and the descending branch on the same side cutaneous branch and between the ipsilateral cutaneous branch and the contralateral cutaneous branch. This is the anatomical basis for cutting the skin branch flap. To this end, we have designed a new skin-branch flap called the finger fascia pedicled skin arteries branch flap. The flap is designed on the finger back near the wound, and the dorsal subcutaneous fascia is its pedicle with a width of not less than 0.5 cm.

According to the blood supply theory of chain flaps, the pedicle should contain a number of macroscopic capillaries with a diameter of at least 20 μm. The capillary chains of the finger fascia pedicled skin arteries branch flap are formed between the lateral and dorsal sides of the finger and the ipsilateral and contralateral cutaneous branches, which is the blood supply principle of the finger fascia pedicled skin arteries branch flap. It is pedicled with the subcutaneous fascia adjacent to the finger artery. The capillary chain of the dorsal side of the finger is the source of the blood supply to the flap.

The V-Y advancement flap is mostly suitable for the coverage of transverse or dorsal oblique fingertip amputations with exposed bone and sufficient nail bed support and length [16]. The thenar flap is indicated for volar skin avulsions over the pulp of the finger [17]. The cross-finger flap is for more distal defects in which more tissue is required for coverage than what can be obtained from a local advancement flap such as the V-Y flap [18]. The homodigital island flap that is based on the volar blood supply of the fingers, either the radial or ulnar digital artery and its venae comitantes [19]. The dorsal metacarpal artery flap that is based on a constant palmar-dorsal perforator is seen in the digital web-space, and it increases the span of the flap to reach even more distal defects [20].

The finger fascia pedicled skin arteries branch flap retains the advantages of the reverse digital artery island flap, for covering the area of the donor site of the finger end is large enough and does not require secondary pedicle surgery. In comparison, it has a greater clinical significance.

Advantages and disadvantages

The current literature reports a variety of designed arterial skin flaps that require surgeons to find the exact finger artery cutaneous branch, but searching for skin branches in clinical operations is quite difficult [21]. In addition, the reported arterial skin branch flaps are designed in the direction of the finger artery axis. The flaps need to be rotated 180° after they are cut, which increases the torsion of the pedicle with a large scar [22].

Conclusion

This new type of flap is designed on the dorsal side of the finger near the wound with a shorter cutting path. Its blood supply is derived from the capillary branch in the lateral fascia. The base of the flap is not limited to the vicinity of the interphalangeal joint, and the flap rotation point can be selected according to the size and location of the wound. The axis of the flap is at an arbitrary angle with the native artery of the finger, and the smaller the angle is, the easier it is to rotate after cutting it, and the effect on the blood flow is small. The main disadvantage of this flap is the blood supply from the capillary branch of the finger artery, so the area of the flap should not be too large, and we recommend it be no more than 3 cm × 2 cm in size.

Limitations

First, the number of samples we used did not meet the standards required by evidence-based medicine. Second, a study of small blood vessels should include comparisons of the surgery and specimens, which was not limited by the study design. In addition, the clinical cases in this study were relatively small and the follow-up period was relatively short, which also requires improvement.

Prospects

The repair of finger wounds has high requirements for function and beauty, and traditional repair methods will inevitably have a certain impact on the function and appearance of the fingers. With the further development of microanatomy, the research on the vascular system of the hand will be more in-depth, followed by the emergence of some new ideas and new skin flaps, which will advance the repair of finger wounds.

Disclosure of conflict of interest

None.

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References

[1] Zhang XZ, Shao XZ, Ren C, Ren CZ, Zhang ZJ, Wen S and Sun JX. Reconstruction of thumb pulp defects using a modified kite flap. J Hand Surg Am 2011; 36: 1597-1603.
[2] Lister G. The theory of the transposition flap and its practical application in the hand. Clin Plast Surg 1981; 8: 115-127.
[3] Russell RC, Van Beek AL, Wavak P and Zook EG. Alternative hand flaps for amputations and digital defects. J Hand Surg Am 1981; 6: 399-405.
[4] Tränkle M, Sauerbier M, Heitmann C and Germann G. Restoration of thumb sensibility with the innervated first dorsal metacarpal artery island flap. J Hand Surg Am 2003; 28: 758-766.
[5] Kappel DA and Burech JG. The cross-finger flap. Anestablished reconstructive procedure. Hand Clin 1985; 1: 677-683.
[6] Matsui J, Piper S and Boyer MI. Nonmicrosurgical options for soft tissue reconstruction of the hand. Curr Rev Musculoskelet Med 2014; 7: 68-75.
[7] Koshima I, Urushibara K, Fukuda N, Ohkochi M, Nagase T and Gonda K. Digital artery perforator flaps for fingertip reconstructions. Plast Reconstr Surg 2006; 118: 1579-1584.
[8] McGregor IA and Morgan G. Axial and random pattern flaps. Br J Plast Surg 1973; 26: 202-213.
[9] McGregor IA and Jackson IT. The extended role of the deltopectoral flap. Br J Plast Surg 1970; 23: 173.
[10] McGregor IA. Flap reconstruction in hand surgery: the evolution of presently used methods. J Hand Surg Am 1979; 4: 1-10.
[11] Rockwell WB and Lister GD. Soft tissue reconstruction. Coverage of hand injuries. Orthop Clin North Am 1993; 24: 411-424.
[12] Giessler GA, Erdmann D and Germann G. Soft tissue coverage in devastating hand injuries. Hand Clin 2003; 19: 63-71.
[13] Friedrich JB, Katolik LI and Vedder NB. Soft tissue reconstruction of the hand. J Hand Surg Am 2009; 34: 1148-1155.
[14] Green Hand Surgery (6th Edition), People's Medical Publishing House, 2012.
[15] Mutlu OO, Colak O, Dilber A, Bingol D and Egemen O. Complicated fingertip defects: clinical approach to their reconstruction and the flaps that can be used in emergency settings. Turk Plastik 2019; 27: 14-18.
[16] Ramirez MA and Means KR Jr. Digital soft tissue trauma: a concise primer of soft tissue reconstruction of traumatic hand injuries. Iowa Orthop J 2011; 31: 110-120.
[17] Gatewood A. A plastic repair of finger defects without hospitalization. JAMA 1926; 87: 1479.
[18] Cronin T. The cross finger flap: a new method of repair. Am Surg 1951; 17: 419-425.
[19] Gaul JS. Management of acute hand injurys. Ann Emerg Med 1980; 9: 139-146.
[20] Maruyama Y. The reverse dorsal metacarpal flap. Br J Plast Surg 1990; 43: 24-7.
[21] Li YF and Cui SS. Innervated reverse island flap based on the end dorsal branch of the digital artery: surgical technique. J Hand Surg Am 2005; 30: 1305-1309.
[22] Yildirim S, Avci G, Akan M and Aköz T. Complications of the reverse homodigital island flap in fingertip reconstruction. Ann Plast Surg 2002; 48: 586-592.