Original Article

Resurfacing the complex finger defect and sensation reconstruction with the free distal ulnar artery perforator flap: a self-controlled case series study

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Background: The purpose of this clinical research is to report our results using the free distal ulnar artery perforator flap for resurfacing complex tissue defects in the finger, and to provide empirical reference for the treatment of subsequent clinical cases.

Methods: In our research, eight patients with complex skin defects were treated with free distal ulnar artery perforator flaps. There were 4 index, 3 long, and 2 ring fingers. All the flaps were raised from the ipsilateral ulnar lateral wrist. The donor sites were covered with a full thickness skin graft or closed by direct suture.

Results: Comprehensive analysis of the clinical treatment process of eight patients, all flaps survived completely without any necrosis during the 6–18 months follow-up. The patients were satisfied with the finger mobility, the sensation function, and the aesthetic appearance.

Conclusions: Resurfacing complex tissue defects in the finger using the free perforator flap in a single stage, especially when the defect is medium in size and accompanied by digit nerve loss, is a valuable technique to achieve satisfaction in both sensation and aesthetic appearance. The ulnar artery perforator flap seems to be a reliable and flexible flap for addressing complex hand injuries with tissue loss.

Keywords: Hand injury; distal ulnar artery; perforator flap; digit nerve defect

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Introduction

Finger skin defect is often meet in hand injury and causes functional limitations in digit. Resurfacing of complex skin and soft tissue defects represents a challenge for the hand surgeon. Hand injury may include medium or large size loss of skin, damage or defects in digit nerve, vessel, tendon, and bone. Small defects can be addressed with simple flap coverage such as the V-Y advancement flap (1), which is the most classic treatment for skin defects in the fingertip. Larger defects require importation of tissue from elsewhere in the body. Various surgical techniques including the local pedicle flaps in the hand, the digit neurovascular flap (2-4), and the metacarpal artery flap (5-7) are commonly used for skin defect reconstruction in the finger. Limitation in resurfacing medium size skin defects is their common drawback. The donor morbidity caused by region flap elevation such as scar formation and unpleasant pigmentation further affects the injured hand. Functionally, the sensor nature of volar aspect of the finger represents a particular challenge for reconstruction. When the skin and digit nerves lose simultaneous, coverage with flap transfer and restoring the digit nerve defect are performed separately in 3–6 months after the wound healing. Restoring both the skin and digit nerve

loss in a single stage will benefit the recovery time and overall outcome. The best option for volar sensory skin reconstruction is the toe flap transplantation, both in skin coverage and sensation restoring. However, donor-site morbidity in foot also hinders its popularity. Considering the necessary function and cosmetic demands of the hands, meticulous repair of losses in multiple structures is critically required. With the development and refinement of microsurgery techniques, the focus of flap transfer has shifted from improving survival rates to meticulous restoration. Free perforator flap transfer is a reliable method which is widely used to resurface complex tissue defects in the hands.

Free distal ulnar artery perforator flap transfer was first reported by Inada *et al.* (8). It uses the distal ulnar lateral site skin, which is nourished by the perforator branch of the distal ulnar artery, and can be raised as a compound flap that contains skin, tendon, an osseous segment of the ulna, and a sensory nerve. Due to its constant pedicle vessel and superficial location, the process of elevation is easy and fast. The sensory nerve in the flap can be harvest matched to the digital nerve stump, restoring the skin tissue loss and digit nerve defect in a single stage.

Resurfacing skin defects with free distal ulnar artery perforator flap transfer is not a novel technique, but emphasis on its feature of sensation reconstruction is rare. The aim of this study is to report our results using an ulnar artery perforator flap to resurface complex tissue defects in the hand. We present the following article in accordance with the AME Case Series reporting checklist (available at https://atm.amegroups.com/article/view/10.21037/atm-22-1975/rc).

Methods

Between July 2009 and September 2016, we treated 8 patients (8 hands). There were 7 men and 1 woman, with a mean age of 32 (range, 20–45) years, who had complex skin defects involving volar and dorsal skin beyond 1 knuckle, with at least 1 digit nerve defect and vital structure exposed. The patients were treated with free distal ulnar artery perforator flap transfer combining the sensory branch of the ulnar nerve. After debridement, the wound sizes ranged from 5×3 to 8×4 cm. Clinical records were reviewed to determine the mechanism of injury, associated injuries, surgical details, complications, and postoperative follow-up. The outcomes in terms of mobility, the aesthetics contour, and 2-point discrimination were evaluated.

The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by Ethics Committee of the Second Affiliated Hospital of Wenzhou Medical University (No. 2022-K-16-01). Informed consent was obtained from each patient.

Surgical technique

Careful and thorough debridement was performed at the recipient site before the flap harvest under tourniquet hemostasis and brachial plexus block. If another concomitant injury existed, such as phalanx fracture, phalangeal joint dislocation, and tendon or vessel injuries, these would be repaired before flap raising. The recipient vessels, the common digit artery, and subcutaneous veins in the volar or dorsal aspect were dissected in the recipient wound and remained at the proper length, preparing for the end-to-end anastomosis.

Flap design

A flap sample pattern made of surgical cloth and shaped according to the wound would facilitate irregular defect resurfacing. The arm from which the flap was raised needed to be fully suspined to gain a best visual of flap harvest, since the flap was located on the lateral ulnar side. The axis line of the flap was outlined between the pisiform and humerus medial condyle. The shape of the flap was designed according to the defect dimension, which was routinely amplified 10% to the defect's size to release the tension of postoperative swelling. The pivot point of the ulnar artery perforator was marked proximally 4 cm to the pisiform in the axis line of the flap.

Raising the flap

The skin incision was first made on the radial side of the flexor carpi ulnaris (FCU) muscle. The ulnar artery and ulnar nerve were easily exposed after retracting the FCU to the ulnar side (*Figure 1A,1B*). The main trunk of the ulnar artery was traced along from the pisiform to the proximal to identify that the perforator was in the skin outlined before. If vessel variation occurred and the pedicle was absent in the previous marking point, the incision direction and location would be adjusted according to the variated pedicle location.

The dissecting level of flap elevation was on the plane of the FCU sarcolemma from proximal to distal. The

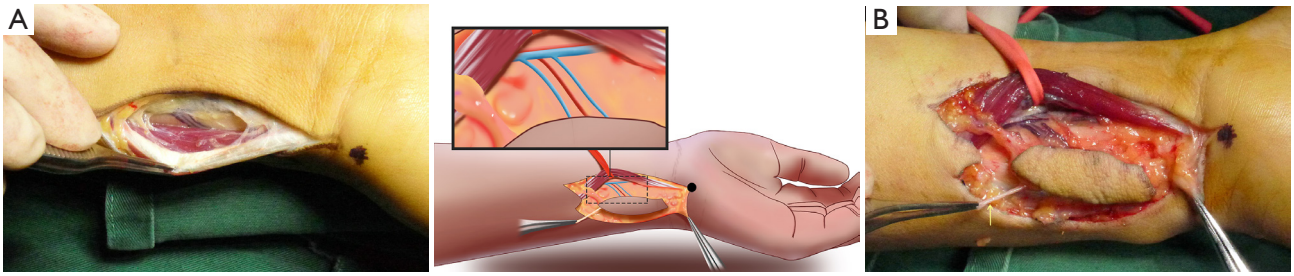

Figure 1 Intraoperative exposure of the distal ulnar artery perforator. (A) Retraction of the FCU muscle to the ulnar side to confirm the perforator. (B) Retraction of the FCU muscle to the radial side to pursue the perforator, retaining a matching nerve in the flap. The arrow shows the sensory nerve remaining in the flap for the subsequent nerve bridging repair. FCU, flexor carpi ulnaris.

distal ulnar artery perforator and concomitant veins were ligated at the bottom and as close as possible to the main trunk of the ulnar artery to maintain an adequate length for anastomosis. The cutaneous vein was combined in the flap as the main reflowing vein of the flap. The sensory branch of the ulnar nerve was cut off partially in a matched diameter to the digit nerve stump for bridging repair of the digit nerve loss.

The pedicle artery was anastomosed to the proper digit artery and the concomitant vein was anastomosed to the volar subcutaneous vein. The diameter of the subcutaneous superficial vein in the flap was matched with the proximal digit dorsal vein and dorsal metacarpal vein. The superficial veins would undertake the major outflowing work of the flap, stabilizing the survival of the flap. The digit nerve defect was repaired by bridge grafting with the ulnar sensory branch nerve that was combined in the flap. If the digit nerve defects were bilateral, the priority for repair would be given to the dominant side.

Postoperative care

Routine microsurgical care, including 7-day strict bed confinement, arm elevation, finger immobilization, careful wound dressing, and observation of flap blood circulation, were crucial for flap survival. In the first 3 postoperative days, opium alkaloid was used to prevent vasospasm. Insufficient perfusion of the flap caused by postoperative swelling could be effectively relieved after partial suture removal. Hematomas are thought to exert pressure on surrounding tissues, leading to vascular pedicle compression and thrombosis, and other biochemical and cellular mechanisms have also been implicated in hematoma-associated flap compromise (9). Attentive wound dressing and timely cleaning of hematomas were performed, preventing the risk of infection and ensuring a stable situation for survival. Finger rehabilitation was suggested to begin after 3 weeks if any complication did not occur.

Results

All flaps survived completely without any complications such as vascular crisis, partial necrosis, and infection during the 6–24 months follow-up. The patients were satisfied with finger mobility, sensation function, and the cosmetic appearance. In this group, the overall outcomes were assessed, including return to previous work and the aesthetic appearance of the recipient and the donor sites. Functional recovery was evaluated with a visual analog scale ranging from 0 (completely disappointed) to 10 (completely satisfied), and scores were divided into 3 classes (good, 10–8; fair, 7–5; poor, 1–5) (10). The mean subjective satisfaction score was 9 (range, 8–10). The static 2-point discrimination of the digital nerve returned to 7 (range, 5–7) mm. The scars at the donor sites were hidden, and there was no effect on wrist motion. No patients had complications at the donor sites. Detailed patient information and surgical data are summarized in *Table 1*.

Case report

Case 1

A 30-year-old man presented with skin and tissue loss on the proximal and middle phalanx on the volar side of his left index finger by a machine accident. The skin defect involved the lateral and dorsal side of the finger, and the digit nerve on the radial side had a 3-cm long defect. Debridement was performed, revealing a circular defect measuring 6×3 cm (*Figure 2A*). The defect was reconstructed with a 6.5×3.5 cm ulnar artery perforator flap which was harvested

Table 1 Clinical cases of the free distal artery perforator flap

Case	Age (years)	Gender	Defect location	Flap size (cm)	Digit nerve defect (cm)	s2PD (mm)	Patients' self-assessment
1	28	M	Volar side of left middle and distal of the ring finger	3.0×7.0	3.5	6.0	Good [9]
2	24	M	Volar and lateral sides of left middle and distal index finger	3.0×4.0	2.5	4.0	Good [9]
3	32	M	Volar side of right distal palm and proximal of middle finger	3.0×7.5	4.0	6.0	Good [8]
4	28	F	Volar side of proximal and middle phalanx of right index finger	3.0×8.0	3.0	5.0	Good [8]
5	50	M	Volar side of proximal and middle phalanx of right middle finger	4.5×8.5	4.0	7.0	Good [8]
6	30	M	Volar and lateral side of proximal phalanx of left index finger	3.0×6.5	3.0	6.0	Good [8]
7	36	M	Volar side of proximal and middle side of left middle finger	3.0×5.0	3.0	6.0	Good [9]
8	20	M	Totally skin avulsion of distal middle finger	3.0×6.0	2.0	5.0	Good [10]

s2PD, static 2-point discrimination.

from the ipsilateral forearm (*Figure 2B,2C*). The donor site was closed directly. There were no complications or complaints during the follow-up. The flap survived and the donor wound healed well. At 1 year after surgery, the static 2-point discrimination test was performed, and the result was 6 mm (*Figure 2D,2E*). The patient was satisfied with the sensation function and cosmetic appearance.

Case 2

A 50-year-old man suffered with a soft tissue defect on his right index finger by a crush machine injury. The defect involved the proximal phalanx, the middle phalanx, and the distal phalanx, on both the volar and dorsal side, with tendons exposed. After debridement and exploration of the defect wound, the defect dimension was 8×4 cm and the radial common digit nerve had a loss of 4 cm (*Figure 3A,3B*). An 8.5×4.5 cm free distal ulnar artery perforator flap combining a 4 cm sensory nerve in the flap was raised to resurface the defect and restore the digit nerve (*Figure 3C,3D*). The donor site was covered by a full thickness skin graft. The flap completely survived. The 24-month follow-up showed satisfactory sensation function, mobility, and aesthetic outcome (*Figure 3E-3G*).

Discussion

When complex tissue defects occur in the finger, more than 1 phalanx is often involved, multiple tissue loss and deep tissue is exposed. Reconstruction of multiple tissue loss in one surgical process in a single stage remains challenging. Sensation reconstruction in the volar aspect of the finger greatly influences the eventual outcome of the hand injury, particularly in finger pinching and grasping ability. Although skin coverage and nerve grafting repair can be performed in separated stages. Prolonged hospitalization, contracture of the digit nerve stump, delayed recovery, and extra cost of treatment are disadvantages that both the patients and surgeons try to avoid. If the general condition of the patient allows, composite tissue repair in a single stage will optimize the final outcome. In this respect, an ideal flap which has features of good similarity, containing a matched sensory nerve, being harvested in medium to large size, and having minor morbidity at the donor site will resolve these complexities.

As the hand is called "the second face", the aesthetic concerns and requirements of restoration are demanding. An ideal flap that meets the meticulous resurfacing needs

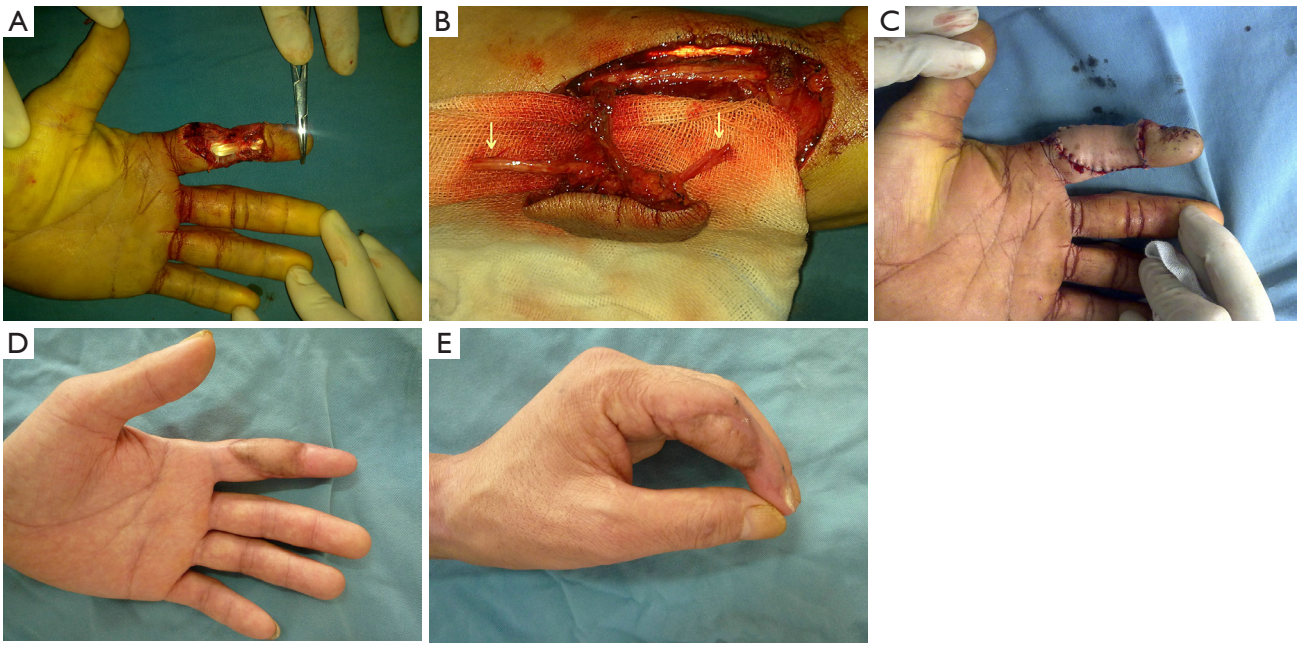

Figure 2 Preoperative, intraoperative, postoperative and follow-up pictures of case 1. (A) A 30-year-old man presented with skin and tissue loss on the proximal and middle phalanx on the volar side of his left index finger by a machine accident. (B) Completion of the raised flap. The arrows reveal the proximal and distal sensory nerve in the flap which has the same size as the nerve stump in the defect wound for bridging repair of the nerve defect. (C) Postoperative view of finger resurfacing with the free distal ulnar artery perforator flap. (D) View of the volar aspect 1 year postoperatively. (E) The index finger has satisfactory pinching ability and good distal pulp sensation.

of the skin defect in the finger needs to be thin, sensory, and hairless, with minimal impairment to the donor site. Partial toe tissue flap transfer may be the best alternative method to repair finger skin tissue loss due to its anatomical similarity (11,12). Nevertheless, a complicated surgical procedure, high operative risk, and limitation in coverage size are the barriers for its widespread use. Unavoidably, malfunction in the donor foot is often a complaint by patients (13). The digit neurovascular island flap, the cross-finger flap, and dorsal metacarpal artery flap can satisfy coverage requirements and can also partially restore innervation. However, for medium-size skin defects involving both volar and dorsal skin defects and exceeding 1 phalanx with an irregular shape, neither toe tissue flap nor local flap transfer are limited in coverage size Unsatisfactory sensory recovery is the other reason why surgeons hesitate to apply these flaps for resurfacing volar skin defects in the finger. Furthermore, raising the flap from the injured hand may cause an extra impairment which leads to extra donor morbidity to the injured hand.

Koshima and Soeda (14) reported the first clinical application of the perforator flap technique. As an alternative method, the perforator flap is frequently used and results in great improvement in the coverage of the skin defect. It has versatile application without sacrificing the main artery and results in low donor morbidity. The clinical application of the distal ulnar perforator flap was first reported by Becker and Gilbert (15) and was widely used in reconstruction of tissue defects in the hand in the subsequent two decades, owing to its advantage in constant anatomy, concealed donor site, satisfaction in cosmetic appearance, and good sensory restoration (16-20).

Sun *et al.* (21) reported that two main clusters at the distal and proximal regions of the ulnar artery were identified at locations corresponding to 22.34% and 58.73%, respectively, of the length of the line extending from the pisiform bone to the medial epicondyle. Owing to the close location to the hand, the distal perforator of the ulnar artery that originates proximally to the pisiform is commonly used for pedicle flap transfer or free transfer to repair complex defects in the finger. The main trunk of the distal ulnar artery perforator originates from the ulnar artery, proximally 4.57±0.59 (range, 3.52–5.19) cm to the pisiform, with a diameter of 0.63±0.09 (range, 0.52–0.81) mm (20). This

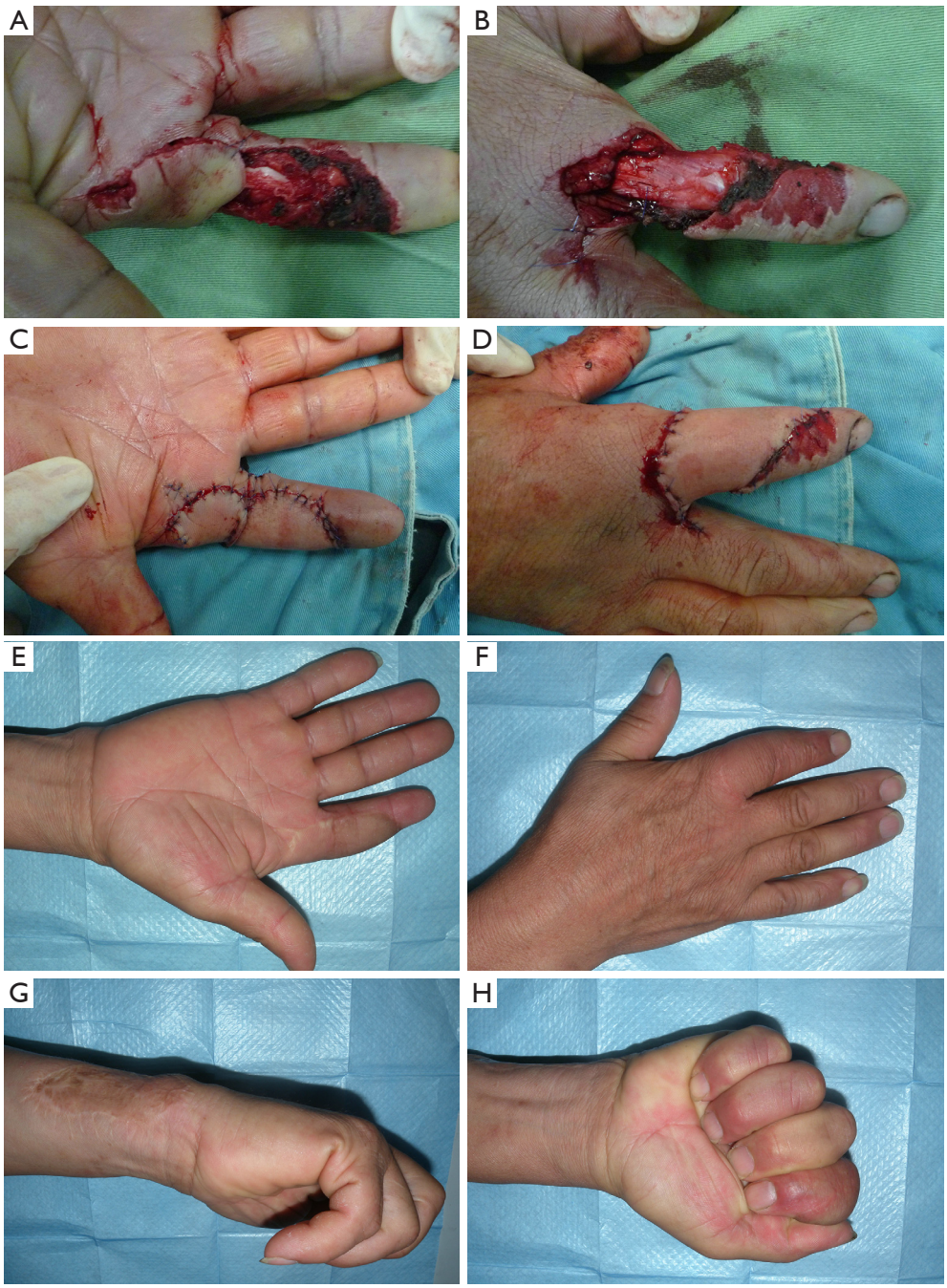

Figure 3 Preoperative, intraoperative, postoperative and follow-up pictures of case 2. (A,B) A 50-year-old man suffered a soft tissue defect involving the volar and the dorsal aspect on his right index finger, accompanied by a 3-cm radial digit nerve defect by a crush machine injury. (C,D) The view of completion of resurfacing with the distal ulnar artery perforator flap, and digit nerve bridging repair has been performed. (E) The dorsal postoperative view of the injured index finger after 1 year. (F) Postoperative view of the donor site of the flap that healed well by the full skin graft after 2 years. (G,H) Full mobility of the affected hand was regained.

is similar in size to the diameter of the palmar digit artery, which is 0.9 (range, 0.7–1.1) mm (22), and matched for anastomosis. However, short pedicle length is a drawback for free transfer. The length of the distal ulnar artery perforator is 1.49±0.34 (range, 1.02–2.02) cm (21). Hence, superfluous microsurgical dissection of the vessel in the wound is required, and an adequate length of the proximal palmar digit artery stump can make up the length shortage of the pedicle. Both the location convenience and diameter similarity between the pedicle artery and the proximal palmar digit artery are other reasons why we chose the distal perforator flap to resurface the hand skin defects.

Various applications of the distal perforator of the ulnar artery flap in hand skin defect coverage have been reported in recent years (16-20), but sensation reconstruction has not received much attention or has been ignored. Sensation recovery is a key factor that allows the fingers to participate effectively in all hand functions. The availability of combining a sensory nerve in the flap to rebuild the digit nerve is also the advantage of choosing the distal perforator, due to the matchable nerve in the flap. On the ulnar lateral side of the wrist, the ulnar dorsal branch nerve originates from the ulnar nerve in the donor region with a bigger diameter than the digit nerve stump, which offers the possibility of matching with the digit nerve stump. Sensation reconstruction is closely related to final patient satisfaction. When the injured finger has poor sensation function after soft tissue reconstruction, even with excellent mobility and good contour, patients will not be satisfied with "the blind fingers" and may be reluctant to use them due to either the lack of sensation or painful paresthesias when the fingers are stimulated (23). The timing of digit nerve repair is an important predictor of sensory recovery, as the sooner the digit nerve defect is fixed, the better the satisfaction (24). Early repair of the digit nerve defect is as significant as the resurfacing of the skin tissue defect. The traditional pedicle sensory flap from the dorsum of the hand combines the sensory nerve whose size is smaller than that of the palmar digit nerve, which is limited in matched repair, with deficiency in satisfactory sensation recovery. Therefore, if skin defect reconstruction and digit loss restoration are simultaneously performed in a single step, the optimal outcome will be gained.

When Inada *et al.* (8) first reported the distal ulnar artery perforator flap free transfer method, their main application was in resurfacing small tissue defects. Our opinion is slightly different from their point of view, in that the distal artery perforator flap has greater advantage in coverage for medium-size skin defects. Medium-size skin defects in the finger are commonly an irregular shape, involving both the volar aspect and the dorsal aspect, exceeding more than one phalanx, which adds difficulty in coverage with a sole local pedicle flap in the hand. Using this flap for medium-size defects will maximize its advantages in resurfacing. Each perforator supplies a unique vascular territory (perforasome) (25). The perforasome of the distal ulnar artery perforator flap has been reported to be safely elevated up to 20×9 cm (26). Owing to the fact that the forearm is relatively more important than other regions and has a certain cosmetic function, large flap harvest in the forearm might be avoided, also due to the long scar formation and the morbidity both in the forearm and wrist. When large flaps are needed, flaps from other regions are preferred for raising, such as the free anterolateral thigh flap (ALT), free paraumbilical flap (FPUF), and free medial sural artery perforator flap (FMSAPF) (27,28), but secondary debulking surgery is required. When the width of the flap is within 3.5 cm, the donor site can be sutured directly with normal tension, thereby not affecting healing. If the donor width is beyond 3.5 cm, full-thickness skin grafting is performed to cover the donor site. The scar is hidden due to its concealed location. Either the primary closure or the full-thickness skin graft does not affect wrist function in this group. The loss of sensation caused by nerve graft harvest in the ulnar dorsal hand has not been a complaint by patients.

The distal sensory ulnar artery perforator flap can be used to resurface a complex volar defect in digit with a good appearance and reliable sensory recovery. Due to the close location to the hand, the durability and thickness of this flap also can achieve satisfactory outcome. In this study, patients with a palmar digit defect, the repair of cutaneous nerves in our flaps with nerves at different positions in the hand promotes sensory recovery. The nerves were coaptated with the proper digital nerve in this eight patients. To reconstruct the sensory function in the recipient site, the cutaneous nerves are carried when elevate the flap. The nerve coaptation can be performed in an end-to-end manner. The final static 2-point discrimination can achieve (4–7 mm), showing that the flap has significantly sensory reconstruction ability and is reliable.

When complex defects in the finger are encountered, with digit nerve defects in the wound, the surgical reconstruction method might mainly be considered in choosing an ideal option to meet the requirements for the medium-size skin defect and sensation reconstruction in a single stage. The free distal perforator of the ulnar artery

flap has the advantages of easy harvest, similar texture, minimal morbidity at the donor site, matched vessels for anastomosis, and in particular, contains the sensory nerve that can be harvested and matched for digit nerve bridging repair.

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Footnote

Reporting Checklist: The authors have completed the AME Case Series reporting checklist. Available at https://atm.amegroups.com/article/view/10.21037/atm-22-1975/rc

Data Sharing Statement: Available at https://atm.amegroups.com/article/view/10.21037/atm-22-1975/dss

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://atm.amegroups.com/article/view/10.21037/atm-22-1975/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by Ethics Committee of the Second Affiliated Hospital of Wenzhou Medical University (No. 2022-K-16-01). Informed consent was obtained from each patient.

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