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Distally Based Dorsal Digital Fasciocutaneous Flap for the Repair of Digital Terminal Amputation Defects

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The preferred plastic surgery regimen for distal digital segment wounds remains unknown, although multiple options are available for the repair. The purpose of this investigation is to study its anatomic rationale and clinical outcomes, in addition to the role of dorsal digital veins in digital reconstruction. Patients (n = 765) suffering from digital terminal segment traumatic wounds (823 digits) were identified and reviewed in a retrospective manner. The wounds were repaired using distally based dorsal digital fasciocutaneous flaps with venoneuroadipofascial pedicles. Skin flaps survived in 818 digits (99.4%), whereas 5 flaps (0.6%) became partially necrotic. Postoperative follow-up data were available from 521 patients involving 559 digits, for an average duration of 10 months (range, 4–36 months). The wider pedicled fascial flap (1.0–1.5 cm) was significantly associated with a decreased occurrence of blebs, whereas the first few patients with pedicled fascial flaps 0.5 to 1.0 cm wide exhibited more frequent occurrence of blebs and flap contractures. The flaps retracted in size within the first 2 to 3 months at the rate of 10% compared with the intraoperative outlined size. The skin flaps became mildly pigmented within the first postoperative month, and at 6 months the flaps turned brighter in color, almost approximating the color of the normal digits. At 12 months, both the texture and appearance of the flaps were acceptable. The donor sites healed without any scar contracture. The digital terminals appeared grossly normal with acceptable digital function. Without any neural reconstruction, skin flap sensation was rated as S2 to S3+, whereas with neural reconstruction the 2-point discrimination sensitivity measured 4 to 9 mm. The use of a distally based dorsal digital fasciocutaneous flap with venoneuroadipofascial pedicle was a simple, safe, and less invasive regimen for repairing digital terminal segment wounds.

Key words: Digital terminal amputation – Dorsal digital fasciocutaneous flap – Venoneuroadipofascial pedicle – Repair – Surgical outcomes

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Table 1 Wound conditions of digital terminal amputation defects (n = 823 digits)

	n (%)
Range of wounds	
Digital pulp defect	197 (23.9)
First-degree digital defect	285 (34.6)
Second-degree digital defect	204 (24.8)
Nailbed defect	112 (13.6)
Lateral terminal defect	25 (3.0)
Location of wounds	
Index finger	443 (53.8)
Middle finger	211 (25.6)
Ring finger	104 (12.6)
Little finger	65 (7.9)

Note: first-degree defect only involves terminal soft tissues, and second-degree defect refers to partial or complete loss of terminal phalange.

The repair of soft tissue defects in digital terminal segments, such as fingertip, digital pulp, and nail bed, remains a challenging plastic procedure. The treatment of digital terminal wound becomes more complicated if the soft tissue defect coexists with phalangeal fracture and tendon tear.[1] Multiple options are available for repairing such defects, including the conservative treatment with the amputation and healing by secondary intention, replantation of fingertip, and fingertip reconstruction using flap transfer.

The distally based dorsal digital fasciocutaneous flap with a venoneuroadipofascial pedicle has a blood supply from the nourishing vessels of dorsal digital nerve and fascia.[2] This technique has been increasingly used in patients with hand defects. In addition to the advantages observed in the aforementioned procedures, such new flaps are also superior because of less interference with digital blood supply and concomitant neural reconstruction.

We have attempted to successfully repair various subtypes of digital defects by using the distally based homodigital fasciocutaneous flap with a venoneuroadipofascial pedicle since 2003. In this study, we aim to examine the surgical outcomes of this technique for the repair of digital terminal amputation wounds, as well as the role of dorsal digital vein in flap survival, in a large case series involving 765 patients.

Patients and Methods

Patient data

The study was approved by the Institutional Review Board at Rui-Hua Hospital. Eligible patients had partial digital tissue loss from hand trauma (left, n = 413; right, n = 342); the study included 535 male and 230 female patients, with an average age of 34 years (range, 7–68 years). The wound conditions are described in Table 1. The deep tissues, including tendons and bones, were exposed in all of the injured digits, and the wounds could not be covered by skin grafts. The patients received either emergency repair (749 digits in 691 patients) or delayed repair (74 digits in 74 patients) due to untimely visits or excessive contamination. All patients volunteered to give informed consent prior to surgery. On preoperative workup, the eligible patients had intact digital dorsa and had no history of shock or other serious morbidities.

Surgical procedure

Debridement was performed on the recipient site. The flap donors were taken from the proximal homodigital dorsa. The radial or ulnar digital margin was taken as the flap axis, and the rotating point was adjusted to the wound profile but not beyond the distal interphalangeal joint. The flap size ranged from 1.5 to 3.5 cm in length and from 1.0 to 3.0 cm in width. In the pedicle, the cutaneous and subcutaneous tissues were incised. The skin flap was mobilized from the extensor tendon surface, and the epitenon was well preserved. The dorsal digital nerve was carefully identified and transected, followed by being distally based. The fascial tissue, approximating 0.8 to 1.5 cm in width, was attached to the pedicle, and the proper palmar digital arteries and intrinsic superficial veins were well protected to preserve the inflow and outflow. The flap was dissected proximal to the rotating point and was subsequently rotated and inserted into the defect through the open tunnel (Fig. 1). Attention should be paid to preserve some superficial venous trunks located at the proximal flap end, whose end extended to the outside of wound. These superficial venous trunks were allowed to drain the congested veins and then ligated after 5 to 7 days. For the neural reconstruction (265 digits) in patients who had digital pulp defects or who wanted to recover fine sensation due to work, the dorsal digital nerve of the flap was anastomosed to the proper digital nerve of the recipient site in an end-to-end manner. Full-thickness skin flaps were harvested from the flexion side of the upper arm or forearm to cover the donor sites. The skin flaps should not be harvested from the dorsa of the radial-side index finger or ulnar-side little finger because of their critical role in digital sensation. The pedicle should be indented to

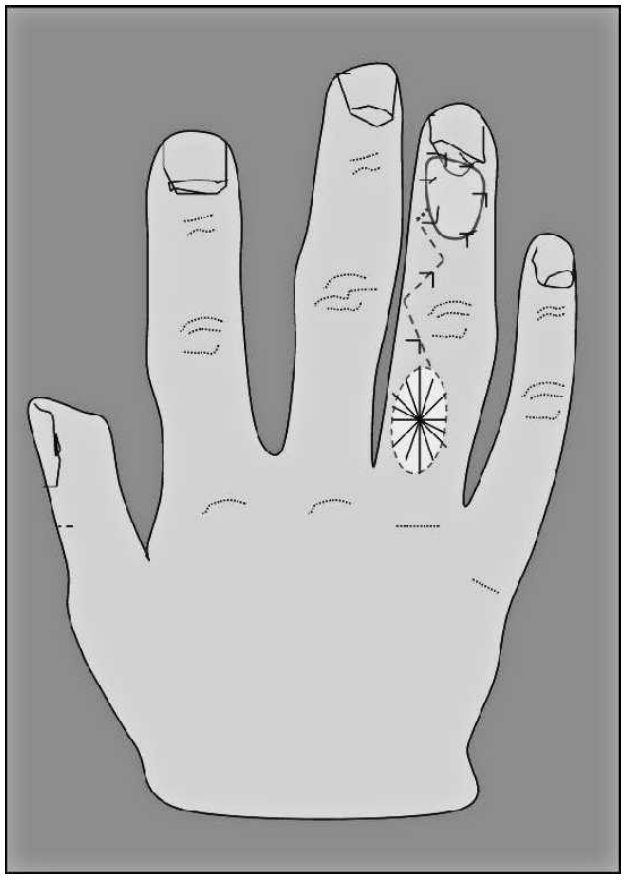

Fig. 1 The outlining of the skin flap (schematic). The radial or ulnar digital margin was taken as the flap axis. The skin flap was mobilized, reversely raised, and rotated 180° to resurface the distal end defect.

prevent the linear scar from compromising the digital function postoperatively.

Postoperative care and follow-up visits

Patients received routine postoperative care following the flap transfer. Patients received prophylactic intravenous cephalosporins and wound dressing care. The flap circulation was closely monitored to identify any circulation crisis. In instances of flap circulation crises (n = 249; 30.3%), the sutures at the pedicle were removed and the patients were medicated with anticoagulants and antispasmodics.

Patients were followed monthly for 4 to 36 months (mean, 10 months) postoperatively. The survivability of flaps was visually examined, including the coverage of defect and the size or contracture of the surviving flap, in addition to any occurrence of bleb and pigmentation (in contrast to the contralateral hand). The sensation of the flap graft was semiquantitatively evaluated, as follows (British Medical Association 1954): S0, the loss of sensation in the innervated area; S1, the recovery of deep pain sensation; S2, the recovery of partial superficial pain and tactility with hyperesthesia; S3, the recovery of superficial pain and tactile sensation without hyperesthesia; S3+, the presence of 2-point discrimination; and S4, the normal sensation. The total active motion (TAM) was calculated to evaluate the digital movement[3]: excellent, normal motion; good, TAM of the affected digit >75% of the unaffected counterpart; fair, TAM of the affected digit 50-75% of the unaffected counterpart; poor, TAM <50% of the unaffected counterpart; and extremely poor, a postoperative TAM worse than the preoperative profile. The contralateral corresponding (uninjured) digits were examined using the same protocol as control.

Results

Survival profile of flaps

Of the 823 digits from 765 patients, the skin flaps survived in 818 digits from 760 patients, at the take rate of 99.4%, whereas the flaps in 5 digits from 5 patients became partially necrotic. The operating time and duration of hospitalization were 3.0 ± 0.5 hours and 11.0 ± 1.0 days, respectively. On postoperative days 2 to 4, the skin flaps developed blebs in 249 digits and became cyanotic. The wider pedicled fascial flap (1.0–1.5 cm) was significantly associated with a decreased occurrence of blebs, whereas the first few patients with pedicled fascial flaps 0.5 to 1.0 cm wide exhibited more frequent occurrence of blebs and flap contractures. On postoperative days 5 to 7, the skin flaps turned red and the blebs disappeared, and on postoperative days 8 to 12, the flaps became normal in color. The flaps retracted in size within the first 2 to 3 months at the rate of 10% compared with the intraoperative outlined size. The skin flaps became mildly pigmented within the first postoperative month, and at 6 months the flaps turned brighter in color, almost approximating the color of the normal digits. At 12 months, both the texture and appearance of the flaps were acceptable. The donor sites healed without any scar contracture.

Sensation of flaps and range of motion of repaired digits

At the visits at 12 months after the operation, the flap sensation was rated as S2 to S3+. In the 265 digits receiving neural reconstruction, the sensation was favorable, with a 2-point discrimination sensitivity of 4 to 9 mm. The TAM results were also

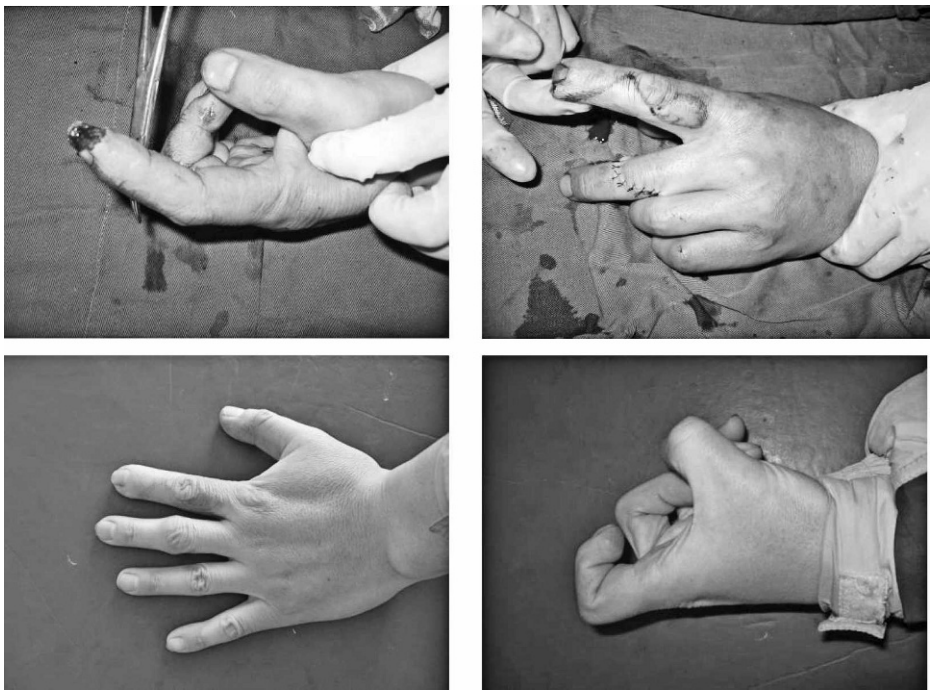

Fig. 2 Case III. (a) Preoperative appearance showing the terminal amputation defect of the left index finger. (b) The outlining of the skin flap. The ulnar digital margin was taken as the flap axis, and the rotating point was the median of the middle segment, at a flap size of 1.5 × 1.5 cm. At postoperative 12 months, the reconstructed finger pulp showed favorable appearance (c) and the fingers had full range of motion (d).

excellent (92%; repaired versus control; 230° ± 30° versus 250° ± 10°).

Case report

A 58-year-old man presented a terminal amputation defect of the left index finger following the punch press crushing. The defect involved the distal digital segment and partial distal phalange. The patient underwent debridement of the left index finger and dorsal digital neurofascial pedicled skin flap transfer under the brachial blockade. The flap survived the transfer completely; at 12 months after the operation, the flap exhibited a favorable appearance and texture, the nail grew well (0.9 versus 1.0 cm in the contralateral nail), and the index finger had a full-range TAM (270° versus 270° in the contralateral index finger; Fig. 2).

Discussion

Multiple plastic regimens have been reported for the treatment of digital terminal amputation defects. Stump revision with primary wound closure used to be preferred for the repair of such defects because of its simple nature, lower cost, and accelerated postoperative recovery, but it is seldom used in younger patients because of the inevitable shortening deformity of digital terminal. Repair with a digital end V-Y skin flap is also acceptable, but the resulting linear scars in the median digital pulps may compromise the sensation and fine movements of the digital terminals in addition to the limited advancement for the smaller defects.[4] A distally based pedicled skin flap is also acceptable, but subsequent pediculectomy and flap denervation are concerns.[5] A reverse-flow arterial island flap has been widely accepted as an effective modality for the repair of digital defects but has drawbacks, including the compromise of blood flow, the restriction of digital extension and flexion, and the adverse effects on proper digital nerve.[6] In our large series report, repair of digital terminal wounds of various severities using the distally based dorsal digital fasciocutaneous flap with a venoneuroadipofascial pedicle exhibits a favorable reconstruction outcome and sensory return with a minimal plastic morbidity.

The blood supply for the proximal dorsum derives mainly from the terminal branches of the dorsal metacarpal artery, whereas that for the more distal segment derives from dorsal branches of the proper digital arteries. The middle and distal one-

third parts of the proximal segment, middle segment, and distal interphalangeal joint are well vascularized by the dorsal branches. The blood supply of the dorsal digital neurofascial pedicled skin flap derives mainly from: (1) the dorsal branches of the proper digital artery communicating with the dorsal digital artery to the middle part of the proximal digital segment and distal interphalangeal joint[7]; (2) the penetrating branches from the deep nominate artery; and (3) the orientated vascular network form the fascial pedicle, including the deep fascial surface, cutaneous nerve, and superficial veins.[8]

The skin flap venous flow is drained into the fascial pedicle and the subcutaneous venous network underlying the digital dorsum in a direct or labyrinthic manner.[9] The superficial venous trunk that orients the outline of the skin flap parallels with the dorsal digital cutaneous nerve. The superficial venous trunk is the main venous backflow route of the digit.[10] The intrinsic venous valves prevent the venous reverse flow. The venous blood from the digital end contains high-concentration oxygen and nourishes the skin flap. The perivenous vascular network also participates in the nourishment of the skin flap. Therefore, the preserve of outflow superficial veins increases the survival area in the proximal pedicled flap, and the dorsal digital vein should be well preserved in the flap outlining.

The superficial venous trunk in the ulnar-side digital dorsum contains abundant venous valves, whereas the distal venous trunk still remains patent following the flap transfer. In such cases, the superficial venous trunk cannot reduce the reverse venous flow, but infuses the venous blood into the flap. This increases the outflow load and disrupts the flap circulation, thus resulting in venous congestion and flap swelling. The wound oozing within postoperative 48 hours may ameliorate the venous outflow dysfunction, which becomes marked following the cessation of wound oozing. A new dynamic balance is established between flap arterial inflow and venous outflow afterwards, and the neoangiogenesis also occurs in the recipient site. These factors help the regression of venous congestion and the survival of flap. However, the flap is prone to insufficient venous backflow.[11] We use multiple techniques to minimize the occurrence of venous congestion following the flap transfer. First, a skin bridge is attached to the flap pedicle, and the flap is transferred through an open tunnel without any distortion and compression of the pedicle. Second, the anastomosis of superficial veins in the recipient site is preferred if time permits. Third, the superficial venous trunk is ligated distal to the pedicle, which reduces the backflow into the flap. Fourth, some superficial trunks are intentionally excluded out of the wound and opened 2 to 3 days following the flap transfer to further drain the flap when the wound oozing stops. Fifth, the flap suture should be tension free and at a larger interval to allow the overflow of tissue fluid. Lastly, hand elevation and rubber drainage also increase the flap outflow but reduce the flap inflow as well.[12]

In contrast to digital arterial, thenar, cross-finger, abdominal, and free flaps, distally based dorsal digital fasciocutaneous flap with venoneuroadipofascial pedicle is superior in the following aspects. (1) The donor site is similar to the recipient site in cutaneous color, texture, and thickness, ensuring the favorable gross appearance postoperatively.[13] (2) The neurorrhaphy recovers the sensation in the recipient site from the dorsal digital nerve. (3) The homodigital autografting does not sacrifice the adjacent digits or compromise the digital blood supply and can be also used in the patients with unilateral handicap of the proper digital artery.[14] (4) The reconstructed digit is not readily subject to the stump pain or traumatic neuroma, because of the skin re-coverage. (5) The simple procedure shortens the operating time significantly compared with free flap grafting. (6) The outline of the skin flap can be adjusted with the appropriate rotating point to cover the wound. (7) The affected digit is not shortened, and there is no damage to the healthy digits.

However, mild ischemia often occurred in the skin flap postoperatively due to the multiple, but random, blood supply sources to the skin flap, in addition to the inadequate digital subcutaneous tissue and the relatively narrow fascial pedicle, justified by the slow oozing of the flap wound.[15] In some patients, blebs occurred as early as postoperative days 2 to 4 because of the ischemia. Blebs should be sterilely aspirated with a syringe, and sutures should be removed to improve the circulation if a tension bleb develops. The skin flap contracture observed at the follow-up visits might be from the inadequate blood supply.

In summary, the use of a distally based dorsal digital fasciocutaneous flap with a venoneuroadipofascial pedicle is a simple, safe, and less invasive regimen for repairing distal digital segment wounds, including distal end, digital pulp, and even partial terminal amputation defects. For the defects involving nail, nailbed, lateral cutaneous soft tissue, or unreplantable digital amputation, the distally based dorsal digital fasciocutaneous flap is a potential means of providing coverage.

References

1. Chen SY, Wang CH, Fu JP, Chang SC, Chen SG. Composite grafting for traumatic fingertip amputation in adults: technique reinforcement and experience in 31 digits. *J Trauma* 2011;**70**(1):148–153
2. Xianyu M, Lei C, Laijin L, Zhigang L. Reconstruction of finger-pulp defect with a homodigital laterodorsal fasciocutaneous flap distally based on the dorsal branches of the proper palmar digital artery. *Injury* 2009;**40**(12):1346–1350
3. Chiu HY. A method of two-dimensional measurement for evaluating finger motion impairment: a description of the method and comparison with angular measurement. *J Hand Surg Br* 1995;**20**(5):691–695
4. Ozyigit MT, Turkaslan T, Ozsoy Z. Dorsal V-Y advancement flap for amputations of the fingertips. *Scand J Plast Reconstr Surg Hand Surg* 2007;**41**(6):315–319
5. Vuppalapati G, Oberlin C, Balakrishnan G. ''Distally based dorsal hand flaps'': clinical experience, cadaveric studies and an update. *Br J Plast Surg* 2004;**57**(7):653–667
6. Omokawa S, Tanaka Y, Ryu J, Clovis N. Anatomical consideration of reverse-flow island flap transfers from the midpalm for finger reconstruction. *Plast Reconstr Surg* 2001; **108**(7):2020–2025
7. Chang SM, Gu YD, Li JF. Comparison of different management of large superficial veins in distally based fasciocutaneous flaps with a venoneuroadipofascial pedicle: an experimental study in the rabbit model. *Microsurgery* 2003;**23**(6): 555–560
8. Uchida R, Matsumura H, Imai R, Tanaka K, Watanabe K. Anatomical study of the perforators from the ulnar palmar digital artery of the little finger and clinical uses of digital artery perforator flaps. *Scand J Plast Reconstr Surg Hand Surg* 2009;**43**(2):90–93
9. Tadiparthi S, Akali A, Felberg L. The ''open book'' flap: a heterodigital cross-finger skin flap and adipofascial flap for coverage of a circumferential soft tissue defect of a digit. *J Hand Surg Eur Vol* 2009;**34**(1):128–130
10. Dabernig J. Re: use of a dorsal adipofascial flap for reconstruction of large volar finger defects. *J Hand Surg Eur Vol* 2008;**33**(4):541.
11. Sharma RK, Tuli P, Makkar SS, Parashar A. End-of-skin grafts in syndactyly release: Description of a new flap for web space resurfacing and primary closure of finger defects. *Hand* 2009; **4**(1):29–34
12. Lee DC, Kim JS, Ki SH, Roh SY, Yang JW, Chung KC. Partial second toe pulp free flap for fingertip reconstruction. *Plast Reconstr Surg* 2008;**121**(3):899–907
13. Wong CH, Teoh LC, Lee JY, Yam AK, Khoo DB, Yong FC. Free digital artery flap: an ideal flap for large finger defects in situations where local flaps are precluded. *Ann Plast Surg* 2008;**60**(3):254–259
14. Beldame J, Havet E, Auquit-Auckbur I, Lefebvre B, Mure JP, Duparc F. Arterial anatomical basis of the dorsal digitometacarpal flap for long fingers. *Surg Radiol Anat* 2008; **30**(5):429–435
15. Vergara-Amador E. Anatomical study of the ulnar dorsal artery and design of a new retrograde ulnar dorsal flap. *Plast Reconstr Surg* 2008;**121**(5):1716–1724