OPEN

ORIGINAL ARTICLE
Hand/Peripheral Nerve

Repair of Fingertip Defect Using an Anterograde Pedicle Flap Based on the Dorsal Perforator

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Background: The purposes of this article are to introduce and assess the results of a long-term follow-up of using anterograde pedicle flap based on the dorsal branches of proper digital neurovascular bundles from the dorsum of the middle phalanx for the fingertip defect.
Methods: Between February 2011 and December 2012, 31 patients underwent reconstruction of fingertip defects using a homodigital flap based on the dorsal perforator in the middle phalanx. The defect size ranged from 1.3 cm × 1.5 cm to 2.4 cm × 3.0 cm. During surgery, the flap was designed on the dorsal middle phalangeal region. The pedicle was a neurovascular bundle consisting of an artery, vein, and sensory nerve; the rotation of pedicle was <90 degrees.
Results: The clinical results were satisfactory after 3 to 9 months of follow-up. The flaps were considered cosmetically acceptable by both patients and doctors. The sensory recovery was excellent, 2-point discrimination was 4.96 ± 1.47 mm, and the recovery of range of motion of the interphalangeal joints was very good.
Conclusions: The anterograde island flap based on the dorsal branches of proper digital neurovascular bundles is an ideal aesthetic reconstruction method for fingertip defect. A 90-degree rotated island pedicle flap was very versatile, easy to design, and had good survival. This technique is simple with less damage to the donor site, without sacrificing the branch of the digital artery and nerve. The reliable source of blood supply and satisfactory recovery of sensation can be achieved without affecting the interphalangeal joint activity. *(Plast Reconstr Surg Glob Open 2016;4:e730; doi: 10.1097/GOX.0000000000000732; Published online 7 June 2016.)*

Fingertip soft tissue defects are an extremely common type of trauma sustained by the hand. The anatomy of the finger is complex. Its integrity is absolutely essential for our everyday functional living. So fingertip reconstruction is not only for appearance but also for motor and sensory function. Various treatment options are available for fingertip defects, including digital artery perforator (DAP) flaps,[1,2] cross-finger flaps,[3] advancement flap,[4] volar flap,[5] neurovascular Tranquilli-Leali flap,[6] dorsal island pedicle flap,[7] and retrograde flow flaps[8–10] but there is no single best way to handle all situations yet.[10] Several homodigital island or subcutaneous pedicle flaps have been

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Received for publication August 12, 2015; accepted March 12, 2016.

DOI: 10.1097/GOX.0000000000000732

Disclosure: *The authors have no financial interest to declare in relation to the content of this article. This study was supported by the National Natural Science Foundation of China (31371214) and Department of Anatomy, Wenzhou Medical College, Wenzhou, Zhejiang, China. The Article Processing Charge was paid for by the authors with grant no. 31371214.*

developed to avoid the disadvantages of local, regional, and distant flaps, but even these have some disadvantages.[5] The retrograde flow digital artery island flap involves a single-stage procedure limited to the injured digit, which provides for soft-tissue coverage, maintenance of length, and full digital motion. However, the reverse flaps cause more trauma to the proper digital artery and nerve than the anterograde flow flaps.[11] The versatility of the perforator flap makes it ideal for fingertip reconstruction. The DAP flap, originally reported by Koshima et al,[1] is less invasive, reliable, and technically easy for fingertip reconstructions. The pedicle perforators were at the adjacent midlateral pulp of the tip defect, and a flap was transposed with 180 degrees.[1] We designed a homodigital anterograde pedicle flap based on the dorsal perforator in the middle phalanx; the flap is transposed with 90 degrees.

During the February 2011 to December 2013, 31 cases of distal finger skin defect were admitted to our department and underwent anterograde pedicle flap based on the dorsal branches of the proper digital artery. Twenty-nine flaps (93.5%) fully survived and 2 (6.5%) had minor complications consisting of an infection and mild venous congestion with mild swelling. Follow-up observations were conducted for 3 to 9 months, and the good aesthetic and functional outcomes of the flaps were obtained with all the patients.

PATIENTS AND METHODS

Between February 2011 and December 2013, we used homodigital anterograde pedicle flaps to reconstruct fingertip soft-tissue defects at fingertip in 31 patients (21 men and 10 women, with average age of 37.8 ± 13.9 years); 17 cases were caused by crush injury, 10 cases were caused by rolling injury, and 4 cases were caused by avulsion injury. Seven cases were accompanied with distal fracture and 1 case with fracture of the distal interphalangeal joint. These defects were located at the thumb (n = 3), index finger (n = 11), midfinger (n = 8), ring finger (n = 6), and little finger (n = 3). The defect size ranged from 1.3 cm × 1.5 cm to 2.4 cm × 3.0 cm.

Operative Technique

Under brachial plexus block anesthesia and tourniquet, the operations were performed under direct vision with 4× magnification. After the debridement, Kirschner wires were used for fixation of the fracture cases. The flap was designed on the dorsal ulnar or dorsal radial aspect of the distal interphalangeal joint according to the defect size. The blood supply to the flap derives from the dorsal branches of the proper digital artery. With "wave-like" incision along the side of the finger, the flap extended to the proximal end of the middle phalanx. The skin is dissected subcutaneously and elevated from both lateral sides. The underlying neurovascular bundle and 2–3 perforators were preserved within the flap. Then the flap was transferred to the defect with the proximal neurovascular bundle to the base of the middle phalanx. The flap was inset with interrupted sutures. The donor site was covered with a full-thickness skin graft from the upper arm and pressure bandaging. Antibiotics were used during the perioperative period. The pressure bandaging was removed in 10 days, and then the patient started range of motion exercises. When the pressure was released, we instructed the patients to exercise their own initiative, and gradually increase the intensity until the finger was back to normal range.

Postoperatively, we closely observed the situation of vascular crisis, infection, flap and skin graft survival. We also observed the condition of the flap sensory recovery, the joint activity, scarring or contracture, wound area hyperalgesia or numbness of the wounded finger, and fractures healing with an average follow-up of 5.7 ± 0.9 months. The assessment of hand function is according to the provisional functional assessment criterion for upper extremity issued by the Hand Society of Chinese Medical Association[12]; the assessment of sensation is 2-point discrimination. Activity of the interphalangeal joints was assessed with the hand function assessment instrument (Biometrics E-link v900s, Biometrics LTD, Newport, UK). The patients were asked about the subjective feeling of the flap, whether they experienced cold intolerance, frostbite, and neuropathic ulcers; a pain scale (grading 0-10 points) was employed for the wounded finger.

RESULTS

All flaps and skin grafts survived completely and the donor sites healed well. There was 1 case where the distal flap was mildly purple, which resolved without treatment. And 1 case became infected with *Staphylococcus*; the wound edge had mild swelling, the wound healed after treatment with antibiotics adjusted to the appropriate sensitivity. Thirty-one patients were followed up for 3–9 months, and 31 cases of skin flap survived completely; soft texture and ideal shape were obtained. Thirty-one flaps had good sensory recovery (S3–S4 grade), with 2-point discrimination averaging 4.96 ± 1.47 mm. The distal interphalangeal joint motion of the defected finger averaged 63.83 ± 9.89 degrees and the proximal interphalangeal joint motion averaged 89.6 ± 12.29 degrees. The

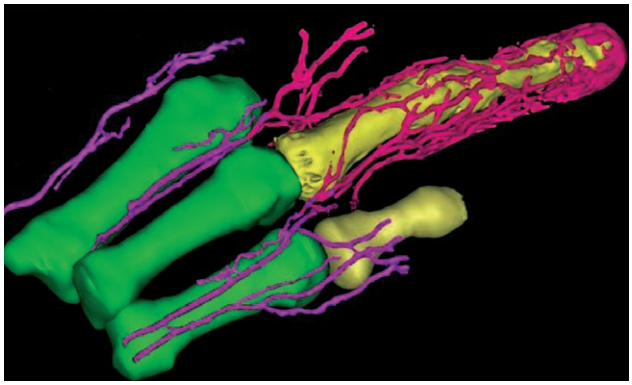

Fig. 1. Three-dimensional visualization of the hand. The vascular networks of the dorsal perforator in the middle phalanx and bony landmarks were shown.

total active movement rating was excellent in 24 fingers and good in 7.[12] Flap showed neither chills nor frostbite in the winter during the postoperative follow-up. There is no case with reoperation for complications.

Case Reports

The clinical results were satisfactory after 3 to 9 months of follow-up. The flaps were considered cosmetically acceptable by both patients and doctors. The sensory recovery was excellent; 2-point discrimination was 4.96 ± 1.47 mm; the range of motion of the interphalangeal joint was very good.

Case 1

A 30-year-old man suffered crush soft tissue defect of his left distal phalanx. The defect size of 2.8 cm × 2.0 cm and fracture were exposed after debridement (Fig. 4). The antegrade pedicle flap based on the branch of proper digital artery of the middle phalanx is designed (Fig. 5). The dorsal branch of distal interphalangeal joint (Fig. 6) and proper neurovascular bundles were identified. The defect was covered by the flap with the perforator piercing point as the axis of rotation. The flap was transferred to the defect (Fig. 7). The donor site was sutured with the full-thickness skin graft from the upper arm (Fig. 8). The flap and graft survived 2 weeks later. With 6 months of follow-up, flap was good in shape with no ulcers, no pigmentation, no scar contracture, good activity of interphalangeal joint, and good functional recovery of the left index finger.

Case 2

A 47-year-old woman presented with left distal phalanx defect involving bone and soft tissue loss caused by a crush injury. The defect of the pulp after debridement was 2.5 cm × 1.8 cm. The antegrade pedicle flap based on the branch of proper digital artery of the middle phalanx is designed

Fig. 2. The anatomy of the dorsal perforators of proper digital artery. Dissection of the finger from a red latex-injected human cadaver showing the dorsal perforators of proper digital artery (provided by Professor Wang Zengtao).

(Fig. 9). The dorsal branches of distal interphalangeal joint and proper neurovascular bundles were identified. The defect was covered by the flap with the perforator piercing point as the axis of rotation. The flap was transferred to the defect (Fig. 10). The donor site was sutured with the full-thickness skin graft from the upper arm (Figs. 11,

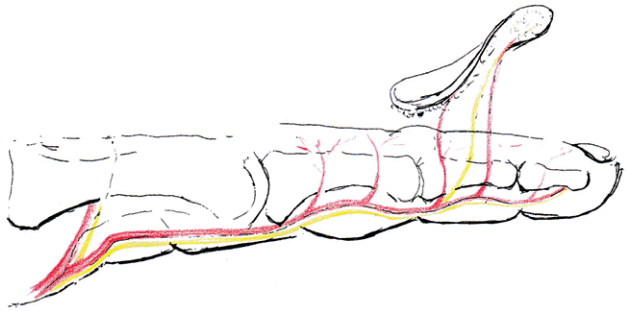

Fig. 3. Schematic diagram of the perforator flap based on the dorsal perforators of proper digital artery.

Fig. 4. Preoperation.

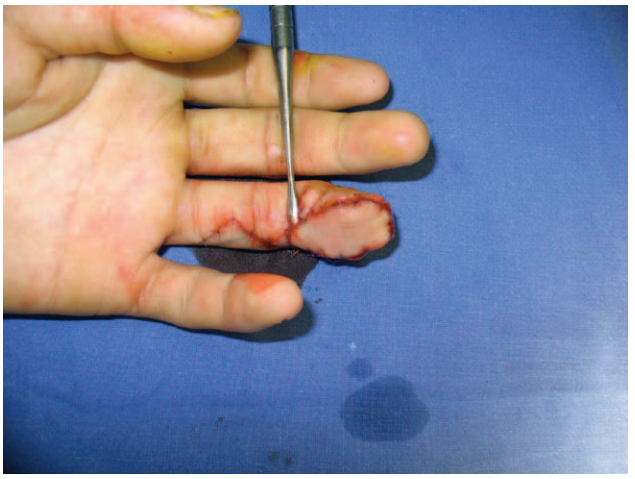

Fig. 7. Postoperative good blood supply.

Fig. 5. Flap design.

Fig. 8. Graft to the donor site.

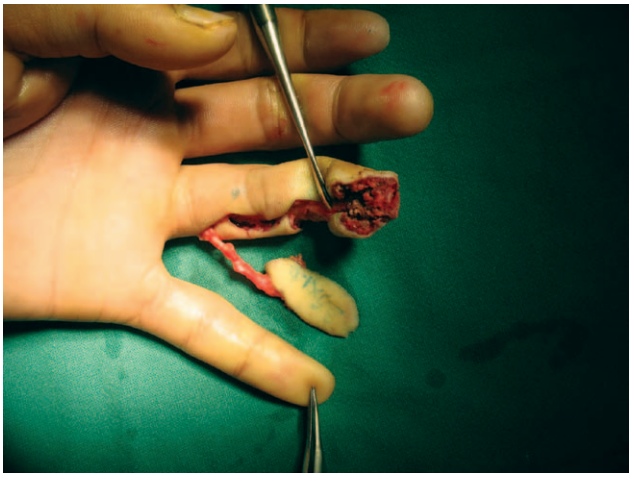

Fig. 6. Intraoperation.

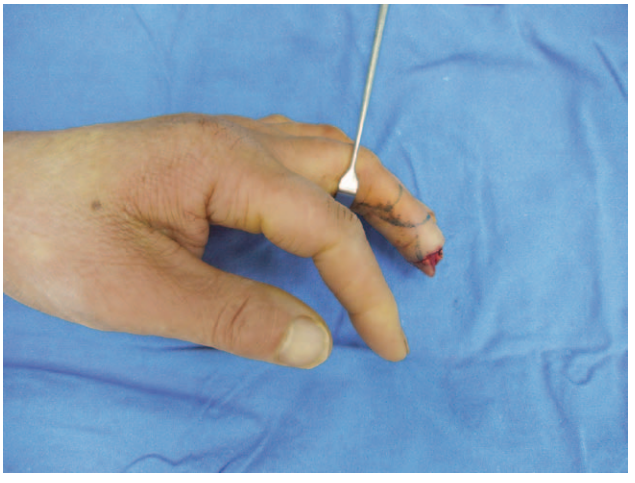

Fig. 9. Preoperation.

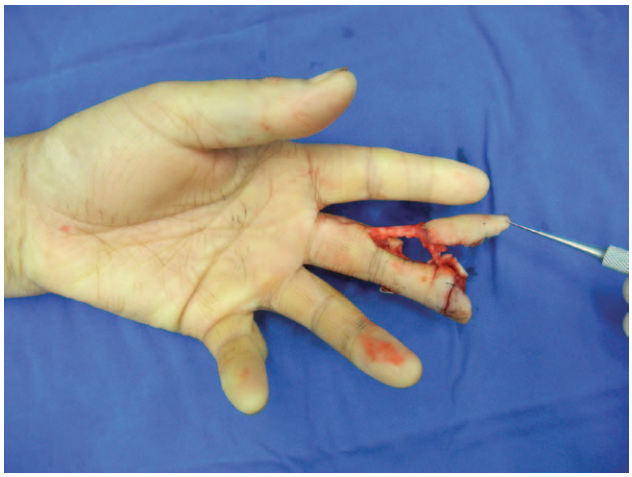

Fig. 10. Intraoperation.

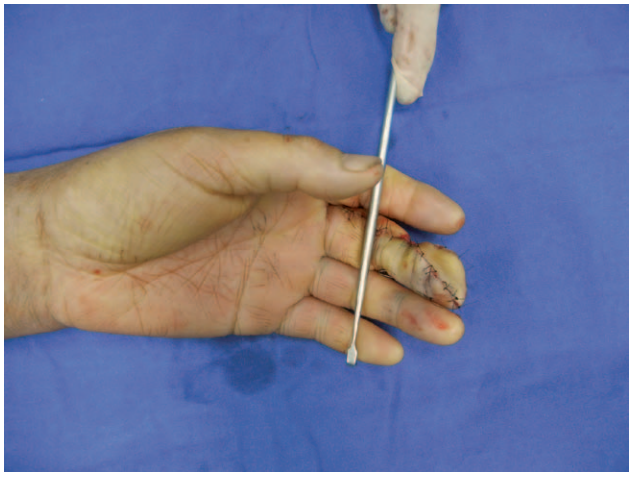

Fig. 11. Postoperative good blood supply.

Fig. 12. Graft to the donor site.

Fig. 13. Flap after 5 months.

Fig. 14. Donor site after 5 months.

Fig. 15. Flap after 5 months.

12). With 5 months of follow-up, flap was good in shape with no ulcers, no pigmentation, no scar contracture, good activity of interphalangeal joint, good functional recovery of the left index finger (Figs. 13–15).

DISCUSSION

Fingertip injuries with skin and soft tissue loss are common.[1,2,13] Random pedicled flap can be used but the disadvantage is the need for additional stages in pedicle division[14]; its use has been limited by its bulkiness and poor sensory recovery. Free flap requires the advanced microsurgical techniques, which are generally not available in basic-level hospitals.[15,16] Island pedicle flap with retrograde blood supply, such as digital artery island flap, dorsal fascia flap, and digital artery chain flap, is currently applied to reconstruct fingertip defect. However, the poor blood supply and inadequate venous drainage tend to occur in the island pedicle flap with a risk of partial or total necrosis.[11] The sensory recovery of traditional island flaps is not ideal by relying on peripheral neurotization or anastomosis of the cutaneous nerve of the flap with that of the recipient.[14,17] The operation is performed ranging from the proximal digital phalange to the fingertip, across the distal interphalangeal and proximal interphalangeal joints. The joint activity will be impacted by the operation. And the digital artery island flap will sacrifice a proper palmar digital artery. When dissecting the proper palmar digital artery, the nerve is preserved with the operation of peeling the nerve bundle membrane off. The postoperative scarring around the nerve will rarely lead to hyperalgesia or numbness.

The propeller flap based on perforator of the digital artery that originates in the lateral aspect of the finger or the distal interphalangeal joint was reported by Mitsunaga et al.[2] It is an anterograde flow flap. The limited donor size and short pedicle enhance the risk of venous or arterial crisis. Although the pedicle flap based on the dorsal branches of proper digital neurovascular bundles preserves the perforator of proper palmar digital artery from the middle phalanx, both the arterial and venous blood flow is anterograde. And as the dorsal nerve branch is preserved, the transfer will be sensory.

The dorsal perforator is constant, near the distal digital phalanx.[18] Four to five perforators naturally anastomose with each other near the middle of the proximal phalanx, the proximal of the middle phalange, and the distal interphalangeal joint (Fig. 1). The dorsal perforator is given off in relatively constant position, with little variation (Figs. 2, 3). The blood flow is provided by the anterograde flow from the perforator of the digital artery. In only 1 case did venous compromise occur and this was relieved without treatment.

The proper digital nerve gives off 2–3 branches at the middle phalanx and the distal interphalangeal joint.[19] The flap preserves the proper digital nerve to recover the sensation without the anastomosis of the dorsal digital nerve. The operation is simple, as it does not require the operating microscope. In all 31 cases, the flap obtained partial sensory recovery to S3–S4, with 2-point discrimination averaging 4.96 ± 1.47 mm. Flap-to-touch, 2-point discrimination, and temperature perception were correlated.

Advantages of the Anterograde Island Flap

Advantages of the anterograde island flap based on the dorsal branches of proper digital neurovascular bundles from the dorsum of the middle phalanx include: (1) It avoids scarifying the digital artery and nerve and has little sensory impact. The antegrade blood supply ensures a high survival rate. (2) The accompanying veins of the proper digital artery are anterograde and less prone to venous crisis. (3) The rotation of pedicle is <90 degrees; it is less prone to crisis and kinking, thus improves survival when compared with when pedicle was rotated by 180 degrees. (4) The pedicle is partially covered by avnsdesma with proper digital neurovasular bundle inside, can free proximally to cover the most distal defect without tension. (5) It is unnecessary to anastomose nerve because there are 2–3 dorsal branches of proper digital nerve in the flap. So the sensory recovery is more reliable. (6) The proper digital neurovascular bundle is preserved and has little impact on sensation and blood supply. (7) The operation is performed on the middle and proximal phalanx, with little effect on the activity of the interphalangeal joint. The early exercise helps digital function recovery and activity of the joint. (8) The flap is a reliable source of skin of excellent color, contour, and texture match for fingertip reconstruction. (9) The flap is separated at shallow level and by clear vision and simple surgical technique.

Disadvantages of the Anterograde Island Flap

Elevation of perforator flaps requires meticulous dissection of the perforators. The dissection is often tedious and can be challenging. Other disadvantages include (1) The limited size of the digital dorsal flap does not apply to the large area, such as degloving injury. (2) The density of the dorsal sensory nerve is less than that of the pulp; the postoperative sensation is different from that of nature. (3) The donor site requires the free skin grafting and tends to form scar, which will limit the activities of the interphalangeal joint.

While performing appropriate design and dissection, the operator should keep the pedicle in loose condition in case of bad blood supply. Confronted with the lack of the pedicle, the pedicle can be dissected into the proximal. The flap is based on one side of dorsal perforator of digital artery, requiring the proximal phalanx without soft tissue injuries, fracture, or dislocation. Meanwhile, the Allen test must be carried out preoperatively. The flap is not suitable if there is a vascular or soft tissue damage.

In summary, the anterograde island flap based on the dorsal branches of proper digital neurovascular bundles from the dorsum of the middle phalanx has physiological antegrade flow. The low morbidity of venous crisis, few complications, and simple surgical procedures make it an ideal method to cover fingertip defects. Ninety-degree rotated island pedicle flap is very versatile, is easy to design, and has good survival.

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