Free Digital Artery Flap

An Ideal Flap for Large Finger Defects in Situations Where Local Flaps Are Precluded

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Abstract: The heterodigital arterialized flap is increasingly accepted as a flap of choice for reconstruction of large finger wounds. However, in situations where the adjacent fingers sustained concomitant injuries, the use of this flap as a local flap is precluded. This paper describes our experience with the free digital artery flap as an evolution of the heterodigital arterialized flap. Four patients with large finger wounds were reconstructed with free digital artery flap. Our indications for digital artery free flap were concomitant injuries to adjacent fingers that precluded their use as donor sites. The arterial supply of the flap was from the digital artery and the venous drainage was from the dominant dorsal vein of the finger. The flap was harvested from the ulnar side of the finger. The digital nerve was left in situ to minimize donor morbidity. The donor site was covered with a full-thickness skin graft and secured with bolster dressings. Early intensive mobilization was implemented for all patients. All flaps survived. No venous congestion was noted and primary healing was achieved in all flaps. In addition to providing well-vascularized tissue for coverage of vital structures, the digital artery was also used as a flow-through flap for finger revascularization in one patient. Donor-site morbidity was minimal, with all fingers retaining protective pulp sensation and the distal and proximal interphalangeal joints retaining full ranges of motion. In conclusion, the free digital artery flap is a versatile flap that is ideal for coverage of large-sized finger defects in situations where local flaps are unavailable. Donor-site morbidity can be minimized by preservation of the digital nerve, firmly securing the skin graft with bolster dressings, and early mobilization of the donor finger.

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Digital island flaps raised from the sides of the finger were popularized by Littler[1,2] and Tubiana and Duparc.[3] Initially designed as neurovascular island flaps, donor morbidity resulting from the sacrifice of the digital nerve was significant.[4,5] Therefore, its clinical application has largely been restricted to restoration of sensation of the thumb. Rose[6,7] later described an island digital flap based on the digital artery and its vena comitantes while leaving the digital nerve in situ. However, this flap was often plagued by venous congestion as separation of the nerve from the artery inevitably damages the delicate vena comitantes of the digital artery. We have earlier proposed that the inclusion of the dominant dorsal vein can prevent congestion by augmenting venous drainage of the flap, providing for stable and reliable soft-tissue coverage.[8] This heterodigital arterialized flap provides a thin, nonsensate, islanded skin flap, with minimal donor-site morbidity, and is increasingly accepted as a choice flap for resurfacing large defects of the fingers, hand, and web space.

Concomitant injuries to adjacent fingers may preclude the use of this flap as a pedicled-local flap. Defects over the distal dorsal area of the finger and the far side of border digits are also inherently more difficult to reach with a pedicled flap. To overcome these difficulties and as a natural evolution of the heterodigital arterialized flap, we have used digital artery flap as a free flap. In this paper, we present our experience with using the free digital artery flap for coverage of large finger defects.

METHODS AND MATERIALS

The pedicled heterodigital arterialized flap is our preferred flap for coverage of medium- to large-sized (10–15 cm^2) hand defects.[8] In selected situations, where the adjacent fingers were unavailable as donors due to concomitant injuries, this flap was raised as a free digital artery flap from the contralateral hand.

Surgical Technique

Our technique of harvesting the heterodigital arterialized flap as a pedicled-local flap has previously been described in detail.[8–10] The following description outlines the specific technical considerations when raising this flap as a free digital artery flap.

At the defect site, the wound is debrided and a template of the defect is fashioned. An incision in the palmar surface is used to locate suitable recipient vessels outside the zone of trauma. One of the proper digital arteries and a deep palmar vein or a dorsal vein are the usual recipient vessels. The flap dimensions and the required pedicle length are noted.

The flap was harvested from the noncontact border of the donor digit. Preoperatively, a digital Allen test is performed to confirm the adequacy of the contralateral digital artery of the donor finger. Flap dissection is performed under tourniquet and with 2.5× loupe magnification. The axis of the flap is over the midlateral line, with its transverse boundaries extending from the middorsal to the midvolar line of the finger (approximately 3 cm in width). Vertically, it can extend from the base of the finger to the distal interphalangeal joint, providing up to 5 cm of length. The arterial pedicle of the flap is the digital artery and the venous pedicle is the dominant dorsal digital vein passing through the flap.

Flap elevation commences from the volar aspect of the finger, with the palm facing up. The incision is carried into the palm to access the digital artery down to the level of the common digital artery to maximize pedicle length. Superficial palmar veins and subcutaneous palmar transverse branches of the artery are meticulously cauterized and divided as they are encountered. Grayson ligament is divided near the phalanges to free the neurovascular bundle. The digital artery is meticulously separated from the more superficially located digital nerve to preserve fingertip sensation of the donor digit. The deep palmar communicating branches to the palmar digital arches must be ligated and divided. The proximal limit of dissection is the bifurcation of the common digital artery.

Dorsally, the flap is raised off the paratenon of the extensor tendon, taking care to leave this layer intact as a bed for skin grafting. The dominant dorsal vein leaving the flap is identified and dissected proximally as far as required to provide an adequate length. A skin flap is raised as necessary to access this vein as it travels dorsally away from the flap's axis. Once the arterial and venous pedicle has been isolated, the proximal ends of the digital artery and dorsal vein are ligated and cut. The flap is completely islanded and raised in a distal to proximal manner. The flap is lifted off its bed by dividing the remaining fibrous septae and the Cleland ligament. The dorsal communicating branches of the artery must not be injured when dividing the Cleland ligament. To protect the digital nerve in areas where it is exposed, surrounding fat is tagged over it with fine absorbable sutures. Full-thickness skin graft is used to cover the donor site, and this is secured with a firm bolster dressing.

Microanastomoses are performed with 10/0 Ethilon sutures (Ethicon Inc., Somerville, NJ). Flap inset and wound closure are done with fine sutures in a tension-free manner. Postoperative management follows standard free-flap procedures, with the hand elevated and placed in a warmer. Gentle mobilization of the donor finger is commenced from the second postoperative day. The bolster dressing is removed on the fifth postoperative day, and intensive rehabilitation of the donor finger starts after dressing removal.

RESULTS

From 1991 to 2005, 4 free digital flaps were performed. Table 1 details the clinical presentation, indications, surgical procedure, and outcome of these 4 patients. All patients had free digital artery flaps performed because of concomitant injuries to adjacent fingers that precluded the use of these as donor sites for local flaps. In one patient with segmental loss of both the radial and ulna digital arteries, the free flap was used for soft tissue cover, as well as for revascularization in a flow-through manner. In another patient with a segmental loss of the radial digital nerve, a nerve graft was used for reconstruction.

The mean follow-up was 11 months. All 4 flaps survived completely and provided robust coverage in all cases. Primary wound healing was achieved in all patients, and this allowed for early rehabilitation of the involved digits, with improved clinical outcome in reducing finger stiffness. The flaps were harvested from the contralateral hand on the ulna side of the finger. On the donor digit, the full-thickness skin graft took completely and the cosmetic outcome was good. Total active motion (as described by Strickland[11]) of the donor finger was excellent (75% to 100% normal total active interphalangeal joint motion) in all 4 patients. In all cases, the donor pulp retained normal sensation, with the 2-point discrimination ranging from 3 to 5 mm.

CASE REPORTS

Three illustrative cases are presented.

Case 1

A 29-year-old male sustained a left hand crush injury while at work. His middle finger was degloved, and the defect size measured 6.5 × 2.2 cm (Fig. 1). He also sustained deep lacerations to index, ring, and little fingers and fractured the proximal phalanx of his ring finger. His wounds were debrided, finger lacerations were repaired and primarily closed, and the fracture was fixed. Three days later, closure of the middle finger was performed with a free digital artery flap from the contralateral middle finger. The donor site was covered with a full-thickness skin graft and secured with tie-over dressings. Primary healing was achieved. At 9 months, both the donor and recipient finger had regained full range of motion with aggressive postoperative rehabilitation.

Case 2

A 39-year-old construction worker sustained a crush injury of his right hand (Fig. 2). He sustained a 4-×-2.5-cm

TABLE 1. Patients' Summary

Patient	Mechanism of Injury	Injury	Indication for Free Flap	Donor Site/Flap Size (cm)	Donor Finger Outcome	Donor Finger ROM (Degrees)	Donor Finger 2PD (mm)	Reconstructed Finger Outcome	Reconstructed Finger ROM (Degrees)
1	Left-hand crush injury	MF skin defect 6.5 × 2 cm IF deep lacerations RF deep lacerations and fracture of the proximal phalanx LF lacerations	Exposed flexor tendons and neurovascular bundle. Adjacent fingers were unavailable as donor site	Left MF (ulna side), flap size: 7 × 2	Excellent	PIPJ 0–100 DIPJ 0–60	4	Excellent	MCP 0–90 PIPJ 45–50 DIPJ 60–60
2	Right-hand crush injury	MF large soft tissue defect with segmental loss of ulna digital artery and nerve IF deep lacerations RF and LF severe bruising	Exposed nerve graft. Adjacent fingers were unavailable as donor site	Left MF (ulna side), flap size: 4.5 × 2.5	Excellent	PIPJ 0–100 DIPJ 0–70	3	Excellent	MCP 0–90 PIPJ 0–85 DIPJ 0–45
3	Right-hand crush injury	LF degloving injury IF amputation at the level of the proximal phalanx MF amputation at the level of the proximal phalanx RF amputation at the level of middle phalanx	Exposed neurovascular bundle. Adjacent fingers were unavailable as donor site	Left MF (ulna side), flap size: 4.5 × 2.0	Excellent	PIPJ 0–100 DIPJ 0–70	5	Moderate	MCP 0–80 PIPJ 50–85
4	Right-hand crush injury	MF volar skin loss 3 × 2 cm. Cut ulna and radial digital artery with segmental loss of the arteries and the RF comminuted fracture of the proximal phalanx IF deep lacerations	Exposed neurovascular bundle and need to revascularize the MF. Both these requirements can be achieved by a flow-through free flap. Adjacent fingers were unavailable as donor due to crush injury	Left MF (ulna side), flap size:	Excellent	PIPJ 0–100 DIPJ 0–70	3	Excellent	MCP 0–90 PIPJ 20–85 DIPJ 0–60

skin loss over the radial aspect of his middle finger, with segmental loss of his radial digital neurovascular bundle. He also sustained a deep laceration of his index finger and severe contusion of his ring and little fingers that precluded the use of these fingers as donor sites for local flaps. A medial antebrachial cutaneous nerve graft was used to bridge the radial digital nerve, and a free digital artery flap was harvested from the contralateral middle finger. Primary healing was achieved, and early mobilization allowed the injured finger to achieve good range of motion. Final 2-point discrimination of the reconstructed finger was 8 mm 12 months after the injury.

DISCUSSION

The pedicled heterodigital arterialized flap is a nonsensate, robust, and reliable flap, providing like-for-like coverage of large finger defects up to 15 cm^2.[2,8–10] In situations where its transfer as a local flap is precluded, it may be used safely and reliably as a free digital artery flap. Our indications for performing free digital artery flap are (1) large-size finger defects exposing vital structures that preclude the use of homodigital flaps and (2) injuries to the adjacent fingers that preclude the use of the heterodigital arterialized flap. In addition, this flap can be used for revascularization of the finger as a flow-through flap.

Digital artery free flaps for coverage of finger defects have previously been described. In 1990, Idler and Mih[12] reported the use of a free fillet flap from an amputated ring finger to cover a defect over the ulnar border of the hand. This flap used the digital artery and its vena comitantes as its pedicle. The vena comitantes of the digital artery is variable in size and its adequacy is unpredictable. Furthermore, to preserve the digital nerve, the digital artery needs to be separated from the nerve, a process that may inadvertently damage the delicate vena comitantes.[6,7,13–15] We therefore stress the inclusion of a dorsal vein for venous drainage to give the flap's vascularity greater reliability and predictability.[8–10,16]

Central to the considerations when harvesting the flap as a pedicled flap is the *reach* of the flap. Maneuvers have been described to increase the reach of the heterodigital arterialized flap, and these include division of the dorsal vein to prevent it from tethering the flap and subsequently reanastomose the vein after inset or by performing the flap in a cross-finger manner.[9,10] Despite these maneuvers, some areas of the fingers, such as over the distal interphalangeal joint, are inherently difficult to reach. Certain wound configurations

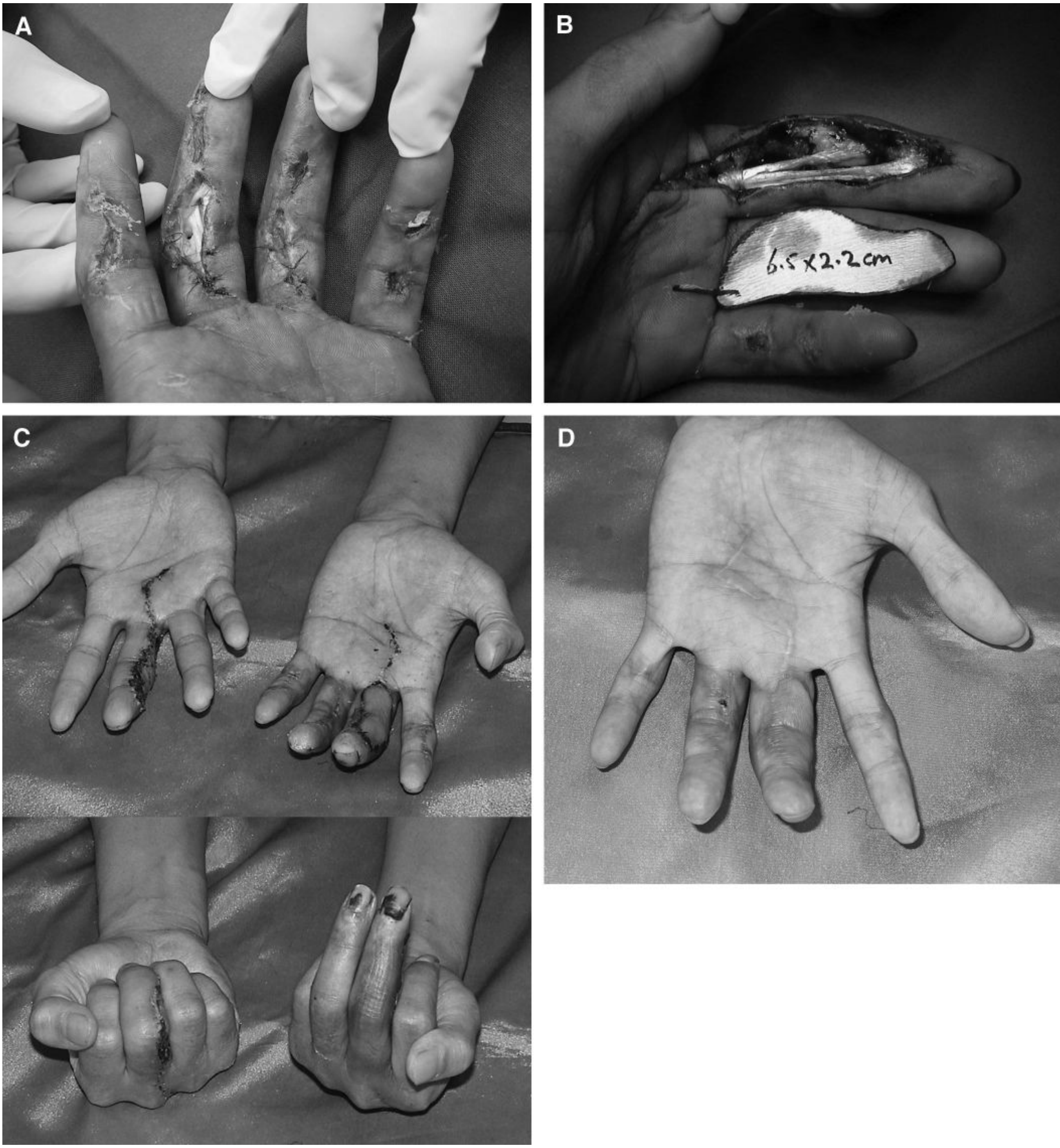

FIGURE 1. A, A middle finger defect exposing tendons and neurovascular bundle. The adjacent fingers were also injured. B, The defect after debridement. C, A free digital artery was harvested from the contralateral middle finger. Rapid primary healing allowed the patient to start early rehabilitation. D, Patient at 1-year follow-up showing durable coverage with minimal scarring.

such as circumferential wounds are also difficult to be covered with pedicled flaps. Finally, large defects to the middle finger as described in the cases in this series may be too large to resurface with transfers from the smaller adjacent digits. Free digital flaps liberate the surgeon from these restrictions and allow more freedom in donor selection.

Donor-site morbidity is a major concern with the use of digital flaps.[17] Digital flaps should be taken from the non-

FIGURE 2. A, A middle finger defect with segmental loss of the neurovascular bundle. The adjacent fingers were also injured. B, A free digital artery flap was harvested from the contralateral middle finger, based on the digital artery (arrowhead) and the dominant dorsal vein (black arrow). The segmental digital nerve loss was reconstructed with a nerve graft (gray arrow). C, Primary healing enabled early rehabilitation and good functional recovery of the reconstructed finger, with excellent range of motion. D, Early intensive rehabilitation of the donor finger enabled recovery of full ranges of motions.

contact side of the finger to minimize donor-digit morbidity. When performing the heterodigital arterialized flap as a pedicled flap, this may not be always possible because of limitations in reach of the flap, and occasionally a digital flap from the contact surface may be necessary. With the digital artery free flap, pedicle length is no longer an issue, and the flap should always be raised from the noncontact side. To further minimize donor-site morbidity, we recommend observing the following: (1) The distal pulp should not be harvested with the flap. This retains a surface conducive for pinching. (2) The digital nerve should be left in situ, with a cuff of subcutaneous tissue to minimize scarring and preserve pulp sensation. (3) The donor defect should be resurfaced with a full-thickness skin graft that is firmly secured with a bolster dressing to prevent contractures and improve esthetic outcome. (4) Early mobilization of the fingers should be done to minimize postoperative stiffness. Mobilization can be started gently as early as the second postoperative day and aggressive mobilization commenced when the bolster dressings are removed on the fifth postoperative day. All our donor sites had a normal 2PD (3–5 mm) and full range of finger movements in the metacarpal phalangeal, proximal, and distal interphalangeal joints. The use of full-thickness skin grafts resulted in an esthetic appearance that was satisfactory to the patient in all cases.

One of the major advantages of the digital artery flap is the provision of a reliable, robust, and thin flap that is ideally suited for finger defects.[8] Few flaps available today are comparable to the digital artery flap in terms of thickness, quality, and pliability. While some authors favor venous flaps and perforator-based radial or ulnar forearm free flaps for digital defects in view of their lower donor morbidity,[17–22] these flaps are inherently at risk for congestion, swelling, and delayed healing. In this context, the reliable and superior tissue quality of the digital artery free flap offers a definite advantage by allowing early primary healing, with minimal scarring and swelling. This in turn will allow earlier mobilization and rehabilitation that we believe will ultimately deliver better functional outcome to the reconstructed finger.

CONCLUSIONS

The free digital artery flap is a good option for coverage of large digital soft tissue defects in situations where concomitant injuries preclude the use of local flaps from adjacent fingers. While a major concern with the use of digital artery flaps is their potential morbidity to the uninjured hand, this can be minimized by meticulous care of the donor site and intensive early rehabilitation. This technique further extends the armamentarium of the reconstructive surgeon and may provide a solution in situations where local bridges have all been burnt.

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