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Ulnar and radial artery based perforator adipofascial flaps

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ABSTRACT

Aim: The clinical value of adipofascial flaps based on distal ulnar or radial artery perforators, is demonstrated in a series of 23 patients with severe hand injuries and soft tissue defects requiring coverage.

Patients and Methods: There were 16 men and 7 women, aged 2 to 73 years. The defects were dorsal and/or palmar, with or without transpalmar or transcarpal amputation, or amputation of the thumb or the digits. Tendon injuries have been treated primarily or secondarily, or reconstructed using silicon rods. In all cases, after surgical debridement of the wound, reconstruction of the defect was done using ulnar (18 patients, in 3 patients primary reconstruction) and radial artery (7 patients, in 2 patients primary reconstruction, in 2 patients after failed ulnar flap) based perforator adipofascial flaps for traumatic defects of the hand.

Results: Mean follow up was 6 months. The donor and the recipient sites healed uneventfully. Functional and cosmetic results were very good in 13 patients and good or satisfactory in the remaining. Range of motion of the wrist and hand joints was almost within normal limits (less than 25 degrees extension or flexion deficit). Two ulnar flaps showed partial necrosis (approximately 35%) and have been treated successfully by radial distal perforator based adipofascial flaps.

Conclusion: Ulnar and radial artery based perforator adipofascial flaps for traumatic defects of the hand offer several advantages compared to other local flaps; they are easy to obtain and cover effectively both dorsal and palmar hand defects without significant functional deficits or complications to the upper limb.

Key words: *hand trauma, perforators of distal ulnar and radial artery, fascial flap, perforator flap, septocutaneous flap.*

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INTRODUCTION

The reversed flow forearm fascial flaps based on distal perforators of the ulnar or radial arteries are much expanded and we can say the dominant type of flap in the last decade for covering hand and wrist defects without scarifying major vascular shafts or causing bad aesthetic result at the donor site. We also don't need preoperatively additional or clinical investigations such as angiography, doppler or triplex ultrasonography or Allen test[1-13]. With the advent of perforator flap surgery, it has been made possible to reduce donor site morbidity, improving the functional and aesthetic result[6-8].

The reversed ulnar forearm flap[1-5], as described by Lovie, is a septocutaneous flap based on the septocutaneous perforators of the ulnar artery, but it can also be harvested as a fascial flap[2,3]. Use of the fascial flap is indicated in patients with soft tissue hand defects. The ulnar forearm flaps present the advantage of a thin and elastic fascia and it can be harvested with bone, muscle and sensory or motor nerves[1]. The main trunk of the pedicle is called ulnodorsal artery and arises from the ulnar artery at a distance of 3-5cm proximal to the pisiform. The artery passes beneath flexor carpi ulnaris and divides into three branches. The proximal branch supplies the distal part of flexor carpi ulnaris, and the distal branch supplies the pisiform. The middle branch supplies the skin and divides into two thin arterial branches

Figure 1. A. A 38-year-old man with wound necrosis after hand trauma secondary to a working accident (patient 1). Primary stabilization of the metacarpal fractures using Kirschner wires and wound closure was done. **B.** At 3 weeks after the initial operation, because of wound necrosis, surgical debridement and a distal ulnar artery based adipofascial perforator flap was done. **C. i -ii.** Very good functional and cosmetic postoperative result.

that pierce the fascia. The ascending branch passes between ulna and flexor carpi ulnaris, supplying the skin of the medial aspect of the distal forearm and the descending branch accompanies the sensory dorsal branch of the ulnar nerve supplying the skin.

Over the past decade, the distal radial artery perforator flap based on the small perforators around the radial styloid process and the longitudinal chain-linked vascular plexuses was described[9-13]. Since then, it has become a very popular loco-regional flap for hand reconstruction. By using these flaps instead of the traditional Chinese flap, we achieve to overcome the two major disadvantages of the Chinese donor site area: first, the sacrifice of a major artery, second, a displeasing scar deformity after split-skin grafts are used for closure.

The purpose of this study is to describe the use of the adipofascial perforator flaps based on distal ulnar or radial artery perforators to cover traumatic defects of the hand, to present patients with large traumatic defects of the hand treated with such flaps, and to discuss the indications and advantages of these flaps.

PATIENTS AND METHODS

Twenty three patients with significant traumatic soft tissue and bone defects of the hand were admitted and treated at the authors' institution by adipofascial distal ulnar or radial artery based perforator flaps. There were 16 men and 7 women, aged 2 to 73 years. The defects were dorsal and/or palmar, with or without transpalmar or transcarpal amputation, or amputation of the thumb or the digits, or fractures of the bones of the hand. All dorsal defects had associated bone fractures that were primarily fixed using Kirschner wires or plates. In 6 cases extensor

Figure 2. A. A 24 year-old woman with skin defect on the dorsum of the hand, metacarpal fractures and extensor tendons laceration secondary to a working accident (patient 10). **B.** Primary osteosynthesis of the metacarpal fractures, tendon repair and reconstruction using the distal ulna artery based adipofascial perforator flap was done. **C. i - ii** Very good functional and cosmetic postoperative result.

tendon laceration was present. Tendon injuries have been treated primarily or secondarily, or reconstructed using silicon rods. All patients were operated immediately or within 2-4 weeks after the initial injury, except 1 patient with a gunshot injury of the hand (patient 9) (figures 1a,2a). Patients data regarding age and gender, mechanism of injury, location of the defects, associated injuries, flap type and postoperative result are shown in table 1.

In all cases, after surgical debridement of the wound, the defect area was measured and the flaps were reflected on the defect. We performed adipofascial perforator flaps based on the distal ulna (18 patients, in 3 immediately after injury) and the distal radial (7 patients, in 2 immediately, and in 2 after failed distal ulna perforator flaps) perforators (figures 1b,2b). Two distal radial artery based perforator flaps have been performed after partial necrosis of the initially performed distal ulna based perforator flaps (patients 6 and 12).

In ulnar perforator flaps, the incision was done on the ulnar side of the wrist and forearm overlying the tendon of flexor carpi ulnaris muscle. The pisiform was identified and the pedicle was located emerging between 2 and 5cm from it. Subdermal dissection allowed exposure of the fascia and the subcutaneous tissue was preserved. The flap was released on its radial side and retracted progressively until the underlying flexor carpi ulnaris muscle was revealed. The pedicle can be seen in the distal third of the flap. After locating the pedicle, the ulnar side of the flap is released maintaining a distal hinge. Simple rotation of the flap permits coverage of defect located at the midpalm or the proximal two thirds of the dorsum of the hand.

The radial septocutaneous perforator flaps have been designed almost as a Chinese traditional flap. We performed 7 distal radial based adipofascial flaps based on the small

Table 1. Data of the 23 patients with hand traumatic defects

Case	Age, gender	Location of defect	Tendon injury	Fractures
1	38, M	Dorsal	No	Metacarpals
2	23, F	Dorsal	Extensors of fingers, tendon graft	Metacarpals, Galeazzi
3	25, M	Amputation	Extensors and flexors, suture	No
4	40, M	Dorsal	Extensors, silicon rods	Radius and ulna
5	42, M	Palmar	No	No
6	35, F	Radial	EPL, tendon transfer	1st metacarpal
7	67, F	Dorsal	No	Metacarpals
8	54, M	Both	Extensors and flexors	Transcarpal amputation, skin necrosis
9	33, M	Dorsal	Extensors, silicon rods	Metacarpals
10	24, F	Dorsal	Extensors, suture	Metacarpals
11	28, F	Distal, transpalmar amputation	Extensors and flexors	Amputation
12	40, F	Dorsal, wrist	Extensors	Radius-epiphyseal, carpal bones
13	52, M	Palmar	Flexors, silicon rods	Metacarpals
14	2, M	Transpalmar degloving	Flexors	Fingers
15	24, M	Dorsal radial	Flexors	Index
16	27, M	Palmar radial	Flexors	1st ray partial thumb amputation
17	62, M	Palmar radial	Flexors	Thumb and index amputation
18	17, M	Ulnar, 5th ray amputation	No	5th metacarpal
19	24, M	Ulnar, 4th and 5thray amputation	No	Metacarpals
20	73, M	Palmar	No	3rd ray amputation
21	32, M	Palmar	Thenar	No
22	29, F	Dorsal radial	Extensors	Radius and humerus
23	22, M	Transmetacarpal amputation	No	All metacarpals

perforators of the radial artery (approximately 10 small perforators 0.3-0.5mm in diameter) and the longitudinal chain-linked vascular plexuses (suprafascial, paraneural, and perivenous) around the radial styloid process. The pivot point was designed at 1-2cm proximal to the radial styloid. The skin island plus the adipofascial pedicle measured 6-20cm in length, with the adipofascial pedicle measuring 3-6cm in width. The cephalic vein has no positive role for venous drainage in distally based flaps. In two patients, the radial flap was primarily performed as the initial treatment (patients 15 and 16); in another 2 patients the radial perforator flap was applied for the management of failed distal ulna artery based perforator fascial flap (patients 6 and 12).

In all cases, flap harvesting was carried out within 35-45 minutes. The donor site was covered with split of full thickness skin graft. The hand has been immobilized for 2 weeks in a plaster splint for flaps protection. Postoperatively, all patients received instructions for participation

treated with distal ulnar and radial arteries perforator based adipofascial flaps.

Mechanism of injury	Operation after injury	Initial treatment	Final result
Work accident	At 3 weeks, ulnar flap	Direct closure	Very good
MVA	At 2 weeks, ulnar flap	Split thickness skin graft	Good
Work accident	At 2.5 weeks, ulnar flap	Transpalmar replantation	Very good
MVA	At 4 weeks, ulnar flap	Split thickness skin graft	Very good
Work accident	At 3 weeks, ulnar flap	Ulnar nerve repair	Good
Work accident	At emergency, ulnar flap, secondary radial flap	Split skin grafting. After 2 weeks radial flap	Good
Work accident	At 2,5 weeks, ulnar flap	Direct closure	Very good
MVA	At 2 weeks, ulnar flap	Amputation, skin closure	Good
Gunshot	At 7 months, ulnar flap	Full thickness skin graft	Very good
Work accident	At 2 weeks, ulnar flap	Split thickness skin graft	Very good
Work accident of 2-5 fingers	At 2 weeks, ulnar flap	Revascularization attempt (50% successful)	Very good
MVA	At emergency, ulnar flap, at 15 days radial flap	External fixation, ulnar flap, split skin graft	Good
MVA	At 4 weeks, radial flap	K-wire fixation, skin closure	Good
MVA	At 1 week, ulnar flap	K-wire fixation, skin closure	Satisfactory
Gunshot	At emergency, radial flap	External fixation, radial flap	Very good
Explosion	At emergency, radial flap	Radial flap	Very good
Work accident	At emergency, ulnar flap	Skin closure-graft	Very good
Work accident	At 2 weeks, ulnar flap	Ray amputation	Very good
Work accident	At 3 weeks, ulnar flap	K-wire fixation	Good
Work accident	At 10 days, radial flap	Ray amputation, skin closure	Satisfactory
Explosives, fireworks	At 5 days, radial flap	Debridement, left skin open	Good
Work accident	At 10 days, ulnar flap transposition	External fixation, skin closure	Very good
Work accident	At 1 week, ulnar flap	Revascularization attempt	Very good

in a specific physical therapy and rehabilitation protocol for 2-7 months.

RESULTS

All patients were followed up for at least 6 months. Both the donor and the recipient sites healed uneventfully (figures 1c, 2c). Two of the ulnar flaps showed partial necrosis (25-35%) that was managed with the distal radial based perforator flap (patients 6 and 12). Regarding the palmar defects, because of the initial injury, necrosis occurred in a patient 2 weeks after a transpalmar replantation (patient 11), and in a patient with necrosis of the hypothenar 2 weeks after a compound injury with ulnar nerve repair (patient 5). In the first case following meticulous debridement, the median nerve was left uncovered, while in the second case a group-fascicular nerve repair of the motor branches of the ulnar nerve and neurotube interposition for bridging the two

sensory branches was done. In both cases, reconstruction was done using the ulnar flap at 3 weeks after the injury (table 1, cases 5 and 11).

The sensory and functional result was classified as satisfactory, good and very good, depending on the range of motion of the adjacent joints and the overall function of the hand (significant, moderate or slight restriction, respectively), the occurrence of complications (necrosis and infection), and cosmesis. The sensory and functional result was very good in 13 patients and good or satisfactory in the remaining. Range of motion of the wrist and hand joints was almost within normal limits (less than 25 degrees extension or flexion deficit) in 21 patients. Moderate wrist stiffness with more than 25 degrees limitation of motion was observed in 2 patients. Complications related to the flaps such as infection, and non-union of the associated fractures were not observed in any patient.

DISCUSSION

The frequency of the hand trauma involving major tissue losses has led to the development of new technical solutions, more simple and effective. The regional flaps, such as the distal pedicle Chinese flap, were usually surgeon's first choice whenever the local resources were over passed. Still, this type of Chinese flap would present an important disadvantage, as they involve the sacrifice of a vascular axis of the hand, sometimes even the dominant one. The surgeon would be able to avoid this inconvenience when using distal radial artery based perforator flaps; moreover, this flap would allow the covering of hand defects extending as far as the metacarpophalangeal joints[10].

In 1988, Chang et al.[9] described a radial forearm reverse fasciocutaneous flap that did not include the radial artery. In their report, this procedure was successful in all 10 cases of hand reconstruction in which it has been applied. The flap was a mixture of fasciocutaneous and venocutaneous muscle, and the deep fascia, especially the cephalic vein in the pedicle, played an important, positive role in flap survival. To elucidate the vascular basis of this new flap, Chang and Chen[14,15] performed an anatomic study in 1990 of 14 fresh cadaver forearms, then designed a distally based, radial forearm fascial flap for hand reconstruction. In this study, they found about 10 small branches (0.3 to 0.8mm in diameter) extending from 1.5cm above the radial styloid process to the bifurcation of the radial artery. These perforators pass through the septum, fan out on both surfaces of the deep fascia, and form a rich, chain-linked longitudinal plexus of the integument along the course of the main artery, the septum, the fiber of the deep fascia, and the superficial vein. The venous system of the deep fascia drains blood to the profunda venae comitantes directly through the concomitant perforating veins. The pivot point of the pedicle was located 1.0 to 1.5cm proximal to the radial styloid process. Chang and Chen[16,17] also demonstrated that the large, superficial, cephalic vein has no positive role for flap survival; it cannot help venous drainage by reverse flow through valves, but it does conduct venous blood from the hand to the flap, causing congestion and swelling that are hazardous to flap viability. In 1992, Goffin et al.[18] also performed an anatomic study of the perforators of the distal radial artery; an island distally based flap was designed. These authors emphasized that the pedicle should be located 2cm above the tip of the radial styloid process to include all the peristyloid perforators.

The ulnar forearm flap can be fascial or fasciocutaneous[1,2]. Harvesting of a fascial graft reduced the overall morbidity without causing additional skin loss. The distal ulnar artery flap can be used to cover dorsal wrist and hand defects[2]. It has several advantages over the radial forearm flap. Flap harvesting is pretty straightforward, no flexor tendons are exposed, a major artery is not sacrificed, there is no need to perform vascular anastomoses, the donor site scar is well covered on the medial side of the forearm and in case of failure other more intricate flap can be easily employed. The ulnar artery perforator based fascial flap is indicated for the coverage of defects in areas where increased mobility of the underlying structures is mandatory. It can also be used to cover both hand and forearm defects fashioned as a distally or proximally based island flap, respectively. The flap dimensions are 20cm in length and 9cm in width, with the ulna lying at its median axis. The flap can also be based on the proximal perforators of the ulnar artery[8]. One disadvantage of the flap is the small length of its pedicle (approximately 3cm), which limits the flap rotation arc. However, since the length of the flap can reach almost 20cm, a part of the flap can be used as a pedicle. In our patients the extended variant of this flap (up to the middle of the forearm) was employed, which proved sufficient to cover the proximal third of the midpalm or hypothenar areas and more than the proximal 2/3 of the dorsal aspect of the hand.

The same principles of flap vascular supply via perforators can be applied in the radial forearm flap[2] that is an adipofascial radial flap based on perforators of the radial artery[5]. The small arterial branches and the longitudinal chain-linked vascular plexuses[11,12] (suprafascial, paraneural, and perivenous) formed by the forearm ascending and descending branches of septofasciocutaneous perforators meet and cross over with the transverse carpal vascular plexuses around the radial styloid region. Based on these directional-oriented plexuses, distally based adipofascial pedicled radial forearm fasciocutaneous and adipofascial flaps were designed and successfully applied in 7 of our patients (in 5 patients immediately after the injury and in 2 patients after a failed distal ulna based perforator flap).

Several variants of the ulnar artery based perforator flap have been described such as the neurocutaneous island flap of the dorsal branch of the ulnar nerve, which is based on cutaneous perforators of the ulnar artery[3,5], and the neurocutaneous, neurofascioseptocutaneous or tubed vascularized flaps based on the distal radial perforators[19-26]. In 1994, Weinzweig et al.[27] reported on the distally based radial forearm fasciosubcutaneous flap nourished by perforators

situated 5 to 8cm above the radial styloid process. The anatomic study by Rambe and Pho[28] in 1995 showed similar results. At the same time, Koshima et al.[29] described a distally based adipofascial flap for dorsal hand coverage. This flap is supplied by a lateral intertendinous perforator of the radial artery located 10cm proximal to the radial styloid process. Braun et al.[30] reported a distally based radial forearm fascia-fat flap supplied by distal perforators 5 to 8cm above the wrist crease. They used this flap to pad and protect the median nerve, to provide a gliding surface for tendon transfer, and to separate the fresh-cut surfaces of ulna-radius synostosis. In 1997, El-Khatib and Zeidan[31] introduced an anatomic study of 8 cases citing their experience using an island adipofascial flap based on distal perforators of the radial artery located 2 to 7cm from the radial styloid process. Subsequently, Jeng and Wei[32] reported their clinical experience with 12 cases using the distally based radial forearm flap for hand reconstruction. The pivot point of the adipofascial pedicle was about 2 to 4cm above the radial styloid process. More recently, Georgescu et al.[10] described an extended alternative edition of the above mentioned flap which arrives up to 20cm at length. This flap has almost the same possibilities with the traditional Chinese flap to cover a distal hand defect.

In the present study, we used the adipofascial perforator flaps based on the perforators of the distal ulnar and radial arteries to reconstruct major dorsal and palmar defects of the hand. The ulnar fascial flap has been mainly used to cover defects on the palmar surface of the wrist, especially when well-vascularized tissue is needed to cover the median nerve, which may be surrounded by dense scar tissue following previous injury or surgery. The distal radial based perforator flap is more adequate for covering defects of the radial area of the dorsal or palmar aspect of the hand or the lateral aspect of the wrist.

CONCLUSION

Distal ulnar and radial artery based fascial or adipofascial perforator flaps are very useful for the reconstruction of significant dorsal and palmar defects of the hand, easy to obtain, and they are associated with good results and low donor site morbidity. The blood supply is based on the perforators of the distal ulnar and radial arteries in the hand and wrist. If necessary, a skin paddle can be included with these flaps. Distal ulnar and radial artery based perforator flaps are easy to elevate, with operative times usually less than one and a half hours, and covering ability that may range from an individual finger to the entire dorsum of the hand. By using these flaps, the need for a lengthy free flap procedure, the meticulous dissection required for the posterior interosseous flap, and the loss of the radial artery for the classic radial forearm flap are avoided.

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