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Case Report

The posterior interosseous pedicle free flap in soft-tissue coverage for small-area tissue defects of the hand

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Abstract: A skin flap refers to a living tissue mass with its own blood supply, which is the most effective way of repairing skin and soft tissue defects resulting from trauma. We want to evaluate the effects and clinical use of a forearm posterior interosseous pedicle free flap during soft-tissue coverage of small-area hand skin defects. From March 2010 to May 2012, 13 posterior interosseous free flaps were used to correct hand-tissue defects: 2 dual-paddle flaps and 11 finger-derma defects. These soft-tissue defect areas had a maximum size of 3.6×7 cm, a minimum size of 2.5×3.5 cm, and an average size of 2.8×4.8 cm. All of the flaps survived: 12 cases were followed for 2-15 months and both the function and appearance of the limbs showed acceptable results. The posterior interosseous free flap may be a valuable option for small-area hand-tissue defects.

Keywords: Tissue injuries, dorsal interosseous artery, free flap

Introduction

With the rapid development of the economy, urban and rural areas continue to see increased degrees of mechanization, but safety awareness in the people operating many kinds of machines has lagged behind. Thus, the incidence of hand trauma injuries remains high. Indeed, hand trauma accounts for ~26.8% of the total number of trauma patients, and of these cases, about one-third need restoration with skin grafts [1]. Moreover, some hand diseases such as congenital malformations, tumors, and some skin defects can also be corrected by surgery, so skin defects account for a large proportion of hand disorders [2]. However, because of the unique anatomical characteristics of the skin and soft tissues of the hand, hand wounds are often relatively large and often damage deeper tissues, resulting in metacarpal, tendon, and other deep tissue leakage or defects, which can be very difficult to deal with. Thus, a skin flap is generally chosen to repair such wounds [3, 4].

A skin flap refers to a living tissue mass with its own blood supply, including skin tissue, which is the most effective way of repairing skin and soft tissue defects resulting from trauma. The history of the development of skin flap use can be divided into the following stages. At first, there was a limited understanding of the laws of skin blood supply, so the clinical use of random flaps was mainly to repair local areas. After much basic and clinical research, the concept of an axial flap was proposed, setting a theoretical cornerstone for surgical flaps. With advances in microsurgical techniques and the development of clinical anatomy came the reverse island flap, the fascia flap, the subdermal vascular network flap, and the vein flap, and various clinical reports have described successful flap surgery. Since the 1990s, skin nerve nutrition vascular skin flaps and perforator flaps have been reported [5]. Combined with the relevant literature, we conclude that the types of clinical application of flaps have been through two stages: “from less to more” and “from more to less” in the ongoing process of continued development and refinement. Goldugn *et al*. [6] first used dogs to conduct experiments with the transplantation of skin flaps with vascular anastomosis. In five cases, three survived for 48 h. Thus, the authors considered that anastomotic

Table 1. Cases information

Number	General	Age	Injured part	Combined with finger injury	Time	Injury area (cm)	Follow up (month)	Outcome
1	M	30	R	N	10 d	2.5*5.1	9	Survive/normal function
2	F	48	R	N	3 d	3.6*7.0	15	Survive/normal function
3	M	27	L	N	5 h	2.7*4.4	3	Survive/normal function
4	M	43	R	N	4 d	2.6*5.4	6	Survive/normal function
5	M	45	L	N	3 d	2.7*5.2	5	Necrosis/afunction
6	F	39	R	N	7 h	2.9*4.6	6	Survive/normal function
7	M	36	R	N	1 h	3.1*3.5	4	Survive/normal function
8	F	31	L	Y	3 h	2.8*3.7	2	Survive/normal function
9	F	47	L	N	3 h	3.3*5.9	3	Survive/normal function
10	M	22	L	N	0.5 h	2.5*3.5	7	Survive/normal function
11	F	36	R	N	4 d	2.5*4.5	6	Survive/normal function
12	M	32	L	N	2 h	2.8*5.0	6	Survive/normal function
13	M	47	L	Y	2 h	2.6*3.8	3	Survive/normal function

vascular flap transplantation was possible. In a dog study, Krizek et al. [7] reported the first use of a vascular groin flap graft. Since then, Strauch and Murray [8] transplanted a rat groin flap to the neck, and the outer diameter of the main vessels was l mm; their success rate in 33 cases was 60%. O'Brien et al. [9] reported 27 cases of rabbit inguinal skin flaps, all of which survived. Anastomosis of the femoral artery was performed and the vein diameter was ~1 mm. Since then, there have been many reports of the successful use of free-flap transplantation. Daniel et al. [10, 11] reported the anastomosis of blood vessels with groin flap transplantation in the clinic, which further promoted the clinical use of free flaps with vascular anastomosis. Skin-pedicle flap grafting has been used because of improving function and esthetics. However, the pedicle flap and establishment of a blood supply to the area requires a forced fixed position for 4-6 weeks, and the need for two pedicle surgeries. With the continued development of surgical flaps, hand wound repair methods have also improved, and currently, even large-area hand wounds can be repaired with good clinical results. However, for the various types of flaps, the overall efficacy of each is not the same, and even the currently used skin flaps for the repair of large-area skin defects have certain shortcomings. Moreover, the clinical efficacy of hand skin defect repairs largely depends on timely treatment and the surgical options available.

Presently, there are many choices for skin flaps in the clinic, which including adipofascial flap, myocutaneous flaps, fasciocutaneous flaps and so on. A guiding principle is that where the hand trauma involves vascular, nerve, muscle, or bone exposure, simple free skin grafts cannot be used when repairing the wound; rather, skin flap transplantation is needed to cover the wound and the choice should be flexible, based on the condition of the wound. Generally, the surgeon should follow the rule of using minor organization to repair the main organization, for example, translocation of the pedicle, posterior free anastomosis, branch blood vessels before trunk blood vessels, first the simple then the complex, and attention to area esthetic and functional recovery at the same time. In addition, debridement is important; fine, accurate, and gentle debridement; removal of ~1 mm of inactivated tissue from the wound; and associated small blood vessels and nerve branches can be advantageous. Debridement generally refers to the use of surgical instruments to remove injured/contaminated tissue that has lost its ability to live and to remove any foreign bodies from the wound. Cleaning the wound is also a mechanical irritation, and it is easy to also harm normal tissue. Traditional debridement methods emphasize the complete elimination of contaminated tissue, reducing the rate of postoperative wound infection for the success of microsurgery. However, removing too much tissue can result in tissue defects, repair difficulties, and poor recovery of postoperative function, so caution is needed.

Since 1986, In-depth studies have been conducted on the treatment of hand disability with

anterior interosseous artery reverse island flap. This surgery has been widely used and has achieved good results [12, 13]. We reported some cases suffering from hand tissue defects in the period from March 2011 to May 2012. We used distal free flap pedicle repair in our hospital for small hand tissue defects and have achieved good clinical results.

Patient information

There were eight males and five females with an average age of 37.1 (range, 22-48) years. The injury site was on the right side in six cases and on the left side in seven. There were finger skin defects in 11 cases (five cases were finger pulp defects, four were dorsal skin defects, and two were other defects) and finger web skin defects in the other 2 cases. Among them, six cases were skin defect from hand injuries in emergencies, six cases involved tendon trauma and exposed bone, and one case was infected, with skin necrosis and exposed bone. The skin defect area maximum was 3.6×7 cm, the minimum area was 2.5×3.5 cm, and the average area was 2.8×4.8 cm. The injury time in the emergency surgery patients was 0.5-7 h earlier, and in the other surgery patients was 3-10 days (**Table 1**).

Surgical methods

Surgical design: First, a flap was designed at the elbow, and the line between the external epicondyle of the humerus and the radial side of the ulna (that is, the projection line of the interosseous dorsal artery) was the axis of the flap. According to the size and shape of the defect site, the design allowed an appropriate expansion of 10-20%. The flap design in the forearm was in the middle third, which is the region that has constant perforator flaps. The flap was marked with regard to the medial superficial veins so that when the it was cut; the veins could be anastomosed in the transplanted area.

Surgical procedures: With the patient in a supine position, brachial plexus or general anesthesia was used. A pneumatic tourniquet was applied to the upper arm of the diseased limb and the limb was lifted for 5 min before inflating. The wound was expanded, removing necrotic and inactivated tissue. Then the arteries and veins that could be used for anastomosis in the transplanted area were located, the required length was measured, and the wound shape and size were accurately assessed. The local area was covered with povidone-iodine gauze, in preparation for surgery. According to the requirements of wound covering, a dorsal interosseous artery flap was designed in the middle third of the dorsal forearm. First, along the flap axis, the skin was cut in the ulnar margin and distal of the flap, as was the free skin on both sides of the superficial fascia layer. The deep fascia was cut in the shallow area between the little finger extensor tendon and ulnar carpi ulnaris tendon; with blunt separation, we could see the deep subfascial dorsal interosseous artery where the distal end of the forearm separated into the gap and the deep fascia are closely linked, determining the interosseous dorsal artery location. We determined whether the branches would be in the flap; surgery can be based on the branch location, adjusting the flap position, to ensure that the branches enter the flap. Then, according to the relationship between the flap and the affected area, the flap ulnar or radial superficial veins were chosen with sufficient free lengths for anastomosis. Then, the edges of the flap were cut from proximal to distal, in turn freeing the flap. Then the wound was sutured to prevent deep fascia and subcutaneous tissue separation that could damage the skin perforation vessels, leading to surgical failure. After removal of the flap, redundant fascia and adipose tissue on the flap pedicle were trimmed under a microscope. The branches of the dorsal interosseous arteries were ligated, the arterials and veins were marked, and the wound was repaired with the flap transplant adjusting the tension of the arteriovenous vein, anastomosing the veins and arteries (generally, it is conventional to anastomose veins before arteries). If the diameter of the flap is less than 4 cm, it can generally be sutured directly; if the diameter is larger, a full-thickness skin graft may be desirable with pressurized packing.

Post-operative management

Short arm plaster immobilization of the limb in a functional position may be useful. Continued local heat diathermy, post-operative administration of the “three antis” (antibiotic prophylaxis, anti-vasospasm, and anti-coagulant drugs), and other treatment, as needed, were provided. The flap blood supply must be closely

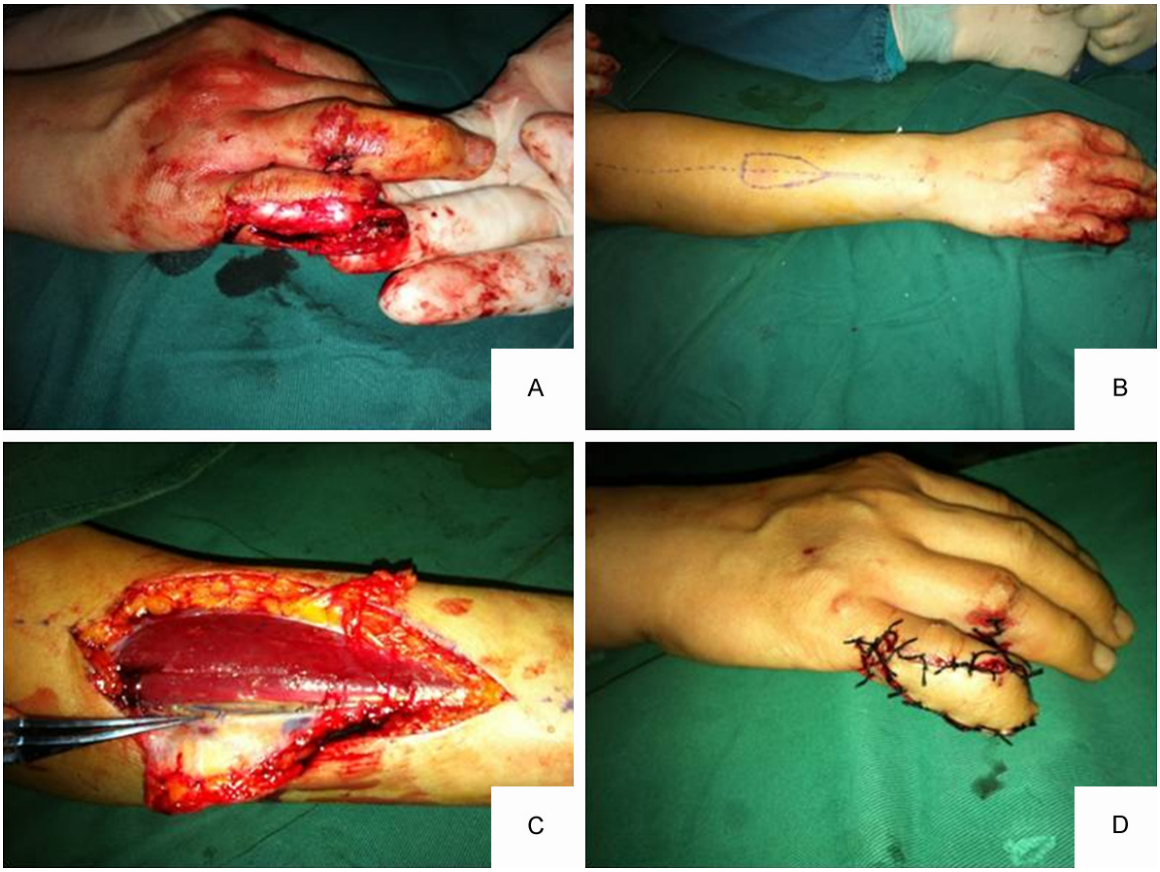

Figure 1. A. Right little finger injury. B. Forearm interosseous artery flap design. C. Determining skin-perforating vessels in the flap. D. At 10 d, the flap had survived.

observed, and timely treatment, such as in the occurrence of vascular crisis, is essential, with surgical re-exploration if necessary. The flap and pedicle should reduce skin drainage, so after 24-48 h, the drainage was removed, the gauze bag was removed at 7-10 d, and the stitches were removed around 12 d to prevent flap edge dehiscence.

Results

In this group of 13 cases, all of the flaps survived, including 1 case of postoperative arterial crisis where the flap survived after surgical re-exploration. Of the cases, 12 were followed for 2-15 months, and the incisions healed well. The hand wounds showed good color, texture, temperature, pain and tactile recovery, and the two-point discrimination test results were 7-11 mm; the 12 cases demonstrated excellent functional recovery. The flap texture is better for the second phase of reconstruction and for second-stage surgeries to create good skin coverage.

Typical case

The patient was a 36-year-old woman who had suffered from an injury (machine crush) to her right little finger 2 h earlier. We could see hyponychium damage through a physical examination and the distal dorsal skin defect (**Figure 1A**). Emergency surgery was recommended. Inactivated tissue was debrided in the surgery. The skin defect was about 2.5×4.5 cm and the designed skin flapwas about 3.0×5.5 cm (**Figure 1B**). According to the method described above, the cutaneous branches were incorporated into the flap (**Figure 1C**). After the release of the tourniquet, the flap blood supply was good. We cut the free edge to the wound edge and anastomosed the veins and arteries; the flap survived after the surgery (**Figure 1D**). At the 6-month follow-up, the flap had recovered well, the appearance was good, and the forearm narrowing was also recovering (**Figure 2A**, **2B**). Recovery in flexion and extension function of the right little finger was good (**Figure 2C**,

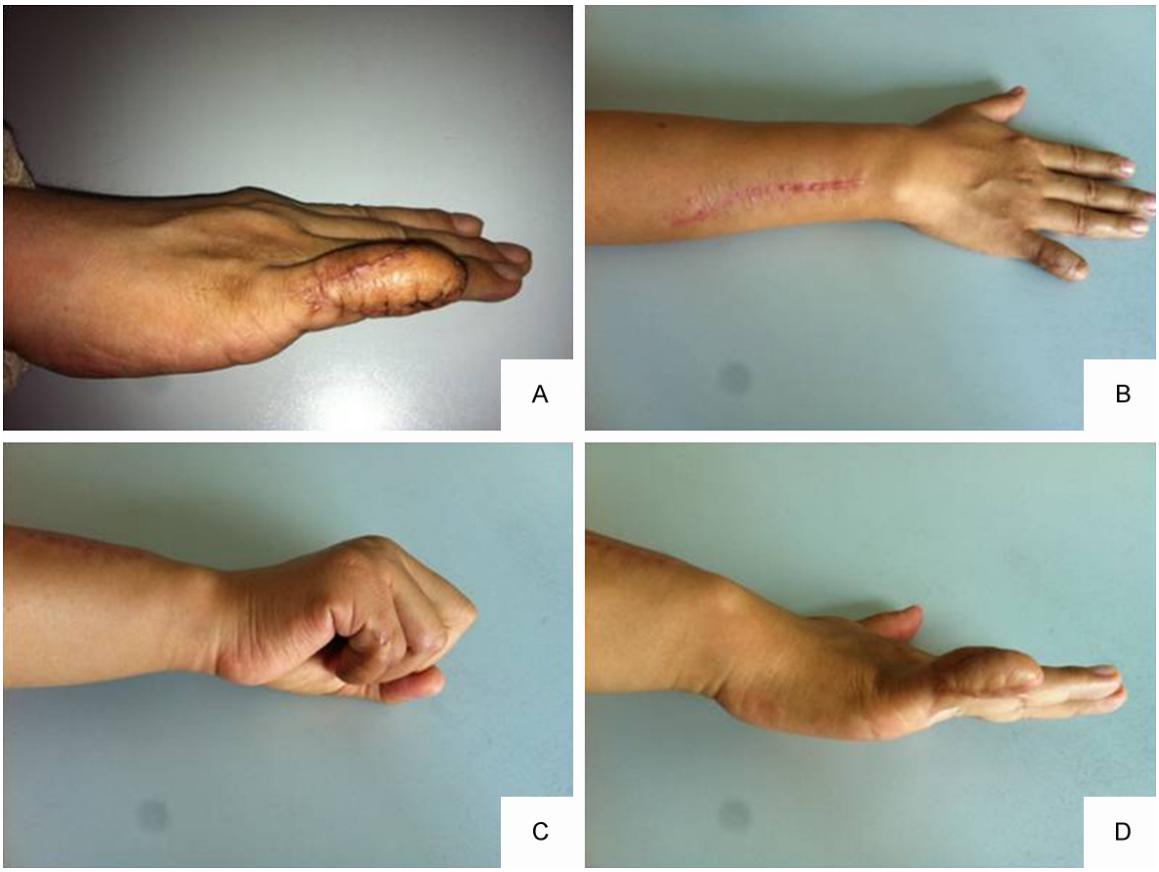

Figure 2. A, B. At 6 months after the operation, appearance of the flap and of the forearm donor site. C, D. At 6 months, right little finger flexion and extension activities recovered well.

2D), and the two-point discrimination test results were 8 mm.

Discussion

The surgeon should accurately determine the nature of the hand injury and choose an appropriate surgery. The clinical treatment for simple single finger skin and soft tissue defects are not complex, and a complicated hand injury generally has characteristics of a large area of damage and a severe injury, increasing the difficulty of any surgical treatment, particularly when accompanied by large finger skin defects. Accurate judgment in the choice of surgical options is important, as poor judgment before surgery and a poor choice in using a skin flap at the site of injury may eventually lead to flap necrosis. For such complicated hand injuries, surgeons should strive to save the fingers and choose a relatively simple operation and a skin flap that is 'easier' to cut when faced with a choice of methods. In this case a proximal skin flap should be used rather than a distal skin flap.

In this study, the use of a forearm interosseous artery reverse island pedicle distal free flap to repair small hand-tissue defects achieved good clinical results. Its anatomical characteristics include that the dorsal interosseous dorsalis artery originates from the interosseous common arteries and in the supinator of the spinous muscle, through the interosseous membrane. Along the ulnar side, the wrist extensor and finger extensor send many muscular branches and skin branches to support the dorsal skin of the forearm, fitting into an arch with the interosseous artery at about 2.5 cm from the ulnar styloid process; there are two veins with the same name working together. The artery is one of best-known blood vessels. Anatomical variation and congenital absence of this artery are rare. There is little effect on the forearm blood supply in cutting off this vessel. The proximal end of the vessel is adjacent to

the dorsal interosseous nerve of the deep branch of the radial nerve; this treatment does not involve the interosseous dorsal nerve, and there is a stable skin branch in the middle of the forearm.

Advantages of interosseous pedicle free flap

This flap has known arteries and veins, does not affect the main blood-supplying arteries (ulnar and radial arteries), and can be cut with sufficient area to effectively cover a hand wound [14]; The vascular anatomy is relatively constant, with little variation, a stable blood supply, and a high flap survival rate; The artery has two accompanying veins; once the retrograde flap in cut, the flap's venous return is good and does not affect the main superficial veins (cephalic and basilic veins), and its use can effectively prevent the hand from swelling [15]. The dorsal subcutaneous tissue of the forearm is relatively thin, the skin color of the flap is similar to that of the skin on the back of the hand and thumb, and the skin flap can provide a good appearance and function after surviving the surgery.

Disadvantages of this flap

The procedure requires a skilled microsurgical operation and a non-invasive technique, so it is not easy to conduct. There may also be a poor esthetic result in the flap-supplying area after direct suturing. In this study, even with a local massage after suture removal, at 1 month post-operation, the narrowed forearm was somewhat restored but the surgical scar was obvious. The repairing of dorsal skin defects inobese patients using the flap may cause problems with fat, in which case, a phase II surgery should be conducted if necessary. Anterograde free grafts can sometimes carry the lateral cutaneous nerve of the forearm [16], but it can be difficult to find the cutaneous nerve for anastomosis in a retrograde pedicle flap. The recovery of flap sensory function may be relatively poor postoperatively, with two-point discrimination tests of 7-11 mm, on average.

Key pointsthat the surgeon should be aware of when cutting the flap

Finding blood vessels along both sides of the axis of the flap is important before cutting the interphalangeal artery pedicle island flap. Finding the gap where the skin branch out occurs (extensor carpi ulnaris and little finger extensor) is important, as is sharply separating the flap between the forearm fascia and sarcolemma when cutting both sides of the edge of flap as designed. To avoid failure of the surgery caused by injured blood vessels, an adequate fascia pedicle must be reserved when cutting; The interosseous dorsal artery cutaneous group is part of the subcutaneous formation of a wide ranging vascular network, according to the five-layer anatomy. So as long as there is a skin branch into the flap, the vascular pedicle in the deep fascia with shallow flap separation will not affect blood supply to the flap. To determine whether a branch goes into the flap, the surgery can be based on branch position, adjusting the location of the flap as needed. The flap area is not so important as long as there is a perforation into the flap, but it must also carry some deep fascia [17]; Venous return plays a key role in flap survival; there are reports that the risk of flap necrosis induced by venous crisis is obviously higher than for arterial crisis [8], so it is particularly important to address the issue of venous return. There are two sets of veins in the flap-superficial and deep veins or the subcutaneous veins and the veins associated with the forearm interosseous artery. When anastomosing subcutaneous veins, it is necessary to take the wound into account. The veins associated with the forearm interosseous artery can also be anastomosed; typically, there is one vein accompanying the interosseous dorsal artery that can be anastomosed with the finger dorsal vein. In our clinical experience, the flap will function as long as one of the major veinsin anastomosed; The choice of the inferior side of the inherent artery for anastomosis is better, because its use shows less damage to blood supply of the fingers postoperatively and it matches the dorsal interosseous artery in diameter. Thus, this surgery has some advantages, such as higher primary patency and a lower risk of thrombosis. This also avoids large changes in luminal hemodynamics, which may lead to vascular crisis caused by big differences in lumen size; It can be a good choice for emergency surgery to repair defects in hand skin due to the limited variation in the anatomy of the interosseous dorsal artery, but caution is still needed when the main blood supply artery of the hand is impaired; To avoid failure, when

cutting the flap, it is important to fix it with the fascia.

Disclosure of conflict of interest

None.

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References

[1] Larouche D, Cantin-Warren L, Desgagne M, Guignard R, Martel I, Ayoub A, Lavoie A, Gauvin R, Auger FA, Moulin VJ and Germain L. Improved methods to produce tissue-engineered skin substitutes suitable for the permanent closure of full-thickness skin injuries. Biores Open Access 2016; 5: 320-329.

[2] Nel CP and Daya M. Buttock reconstruction in sarcoma surgery: an esthetic sigmoidplasty closure for large circular defects using double opposing skin flaps. Plast Reconstr Surg Glob Open 2016; 4: e1039.

[3] Liao Y, Luo Y, Lu F, Hyakusoku H, Gao J and Jiang P. Pre-expanded intercostal perforator super-thin skin flap. Clin Plast Surg 2017; 44: 73-89.

[4] Sakai G, Suzuki T, Hishikawa T, Shirai Y, Kurozumi T and Shindo M. Primary reattachment of avulsed skin flaps with negative pressure wound therapy in degloving injuries of the lower extremity. Injury 2017; 48: 137-141.

[5] Baudet J, Pelissier P and Casoli V. [1984-1994: ten years of skin flaps. Prefabricated flaps]. Ann Chir Plast Esthet 1995; 40: 597-605.

[6] Goldwyn RM, Lamb DL and White WL. An experimental study of large island flaps in dogs. Plast Reconstr Surg 1963; 31: 528-536.

[7] Krizek TJ, Tani T, Desprez JD and Kiehn CL. Experimental transplantation of composite grafts by microsurgical vascular anastomoses. Plast Reconstr Surg 1965; 36: 538-546.

[8] Strauch B and Murray DE. Transfer of composite graft with immediate suture anastomosis of its vascular pedicle measuring less than 1 mm. in external diameter using microsurgical techniques. Plast Reconstr Surg 1967; 40: 325-329.

[9] Oakes BW, North I, Rosen P and O'Brien B. A study of the development of arterial elastin in the dog and rabbit, following vascular surgery, and in the neonatal rat. J Anat 1971; 110: 503.

[10] Taylor GI and Daniel RK. The free flap: composite tissue transfer by vascular anastomosis. Aust N Z J Surg 1973; 43: 1-3.

[11] Daniel RK and Taylor GI. Distant transfer of an island flap by microvascular anastomoses. A clinical technique. Plast Reconstr Surg 1973; 52: 111-117.

[12] Puri V, Mahendru S and Rana R. Posterior interosseous artery flap, fasciosubcutaneous pedicle technique: a study of 25 cases. J Plast Reconstr Aesthet Surg 2007; 60: 1331-1337.

[13] Turker T, Gonzalez JP and Capdarest-Arest N. Deepithelized posterior interosseous artery flap for 3-dimensional defect coverage in the hand. Tech Hand Up Extrem Surg 2015; 19: 51-54.

[14] Yoon CS, Noh HJ, Malzone G, Suh HS, Choi DH and Hong JP. Posterior interosseous artery perforator-free flap: treating intermediate-size hand and foot defects. J Plast Reconstr Aesthet Surg 2014; 67: 808-814.

[15] Sun C, Wang YL, Ding ZH, Liu P, Qin XZ, Lee HL and Jin AM. Anatomical basis of a proximal fasciocutaneous extension of the distal-based posterior interosseous flap that allows exclusion of the proximal posterior interosseous artery. J Plast Reconstr Aesthet Surg 2015; 68: 17-25.

[16] Gao W, Yan H, Li Z, Li X, Jiang L, Yu Q, Maxwell EH and Zhang F. The free dorsoradial forearm perforator flap: anatomical study and clinical application in finger reconstruction. Ann Plast Surg 2011; 66: 53-58.

[17] Pan ZH, Jiang PP and Wang JL. Posterior interosseous free flap for finger re-surfacing. J Plast Reconstr Aesthet Surg 2010; 63: 832-837.