

THE CLINICAL APPLICATION OF ADIPOFASCIAL TURNOVER FLAPS FOR COVERAGE OF SEVERE BURN WOUNDS ON THE DIGITS

UTILISATION PRATIQUE DES LAMBEAUX ADIPO- FASCIAUX DE ROTATION POUR LA COUVERTURE DES PERTES DE SUBSTANCE DIGITALES APRÈS BRÛLURE

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SUMMARY. This article presents particular occupational burn injuries resulting in a complex defect of the digits. Nine patients with exposed bone or tendon wounds on the digits were successfully treated using the pedicle adipofascial turnover flap overlaid with skin grafts. Electrical and high-temperature contact burns resulted in five and four severe cases, respectively. Flaps were harvested from the adjacent dorsal area of the injured digit and the dimension was 2 to 4 mm wider than the defect base on their reliable blood supply. It was suggested that the advantages of adipofascial turnover flaps include a simple, one-stage procedure and minimal donor site deformity.

Keywords: electrical injury, thermal burns, digits, adipofascial turnover flap

RÉSUMÉ. Cette article se penche sur des accidents de travail responsables de pertes de substance digitales complexes. Neuf patients avec des expositions osseuses ou des lésions tendineuses digitales ont été traités avec succès par des lambeaux adipo- fasciaux de rotation recouverts d'une greffe de peau. Cinq d'entre eux avaient subi une électrisation et quatre une brûlure par contact. Les lambeaux étaient pris sur la face dorsale adjacente, choisis sur la qualité de leur vascularisation, et mesuraient 2 à 4 mm de plus que la surface à couvrir. Cette technique a pour avantages une reconstruction en 1 temps et une conséquence minime pour le site donneur.

Mots-clés : électrisation, brûlure thermique, doigts, lambeau adipo- fascial de rotation

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Introduction

Reconstructing soft tissue defects following electrical and thermal burns in the digit remains a challenge in hand surgery. Electrical injuries and high-temperature contact burns are likely to cause skin necrosis and damage deep tissues, including tendons, nerves, arteries, and even bones and joints, which can result in significant dysfunction. This reflects the fact that such reconstruction of a complex digital defect must aim not only to prevent infection but also to achieve functional and aesthetic outcomes. A good reconstructive option that meets this recommendation is the adipofascial turnover flap, which is documented to cover complicated hand and digit defects.¹⁻⁵

Previous studies^{4,6,7} indicate that electric current is found to cause thrombosed dorsal subcutaneous vessels within the subcutaneous necrotic zone adjacent to the defect. Due to this necrosis area never extended over 5 mm in size,⁴ these defects require an early coverage by vascularized tissue transfer from local, regional region^{8,9} or free flaps.¹⁰ As knowledge of the blood supply to the skin has improved, random-pattern flaps are being utilized less frequently, as incorporating a perforator within the flap increases its reliability and size. Thus, including perforators into traditional random-pattern flaps makes them safer. The aim of this study was to analyze the results of the pedicle adipofascial turnover flap overlaid with skin grafts to reconstruct severe burn wounds on the fingers associated with exposed bone or tendon.

Patients and methods

Between 2020 and 2022, nine cases who suffered from soft tissue defects of the digits following electrical low-voltage injuries (less than 1000 V) and thermal burns were treated with adipofascial turnover flap overlaid with skin grafts. Of these, five were electric injuries and four high-temperature contact burns. Patients with bone and tendon injury and high-voltage injury were excluded. All the burn wounds resulted from occupational accidents. The affected fingers included 4 index fingers, 2 ring fingers, 1 middle finger and 2 thumbs. In four and five cases, the bones and tendons were found to be exposed, respectively (*Table I*). There were 5 males and 4 females with a mean age at surgery of 35.8 years (range: 20 to 57 years). All patients had given informed consent in writing to undergo the surgery and for their clinical details to be used for research. The Institutional Review Board of the hospital waived the requirement of ethics approval due to the retrospective nature of the study. The study was conducted according to the principles of the Declaration of Helsinki.

Operative technique

All patients were in a supine position with the affected extremity on the hand table during the reconstructive procedure. The procedure is performed under general anesthesia and tourniquet control. Necrotic tissue was adequately debrided with a 15-blade. In the electrical burn cases, the necrotic area

Table I - Patient and flap details

Patient	Sex	Age (yrs)	Type of burn	Occupation	Side	Location	Digit	Structure exposed	Arterial pedicle	Size (cm)	Outcome
1	M	36	Electrical	Electrician	Left	Dorsum	Middle finger	Tendon	DA	1.2 x 2.0	Survived
2	M	39	Electrical	Electrician	Left	Volar	Thumb	Bone	1st DMA	1.5 x 2.8	Survived
3	F	57	Thermal	Industrial worker	Left	Dorsum	Thumb	Bone	1st DMA	2.3 x 3.0	Survived
4	F	41	Thermal	Industrial worker	Left	Dorsum	Index finger	Tendon	DA	1.4 x 2.4	Survived
5	F	21	Thermal	Industrial worker	Left	Dorsum	Ring finger	Tendon	DA	1.2 x 2.5	Survived
6	F	40	Thermal	Industrial worker	Right	Dorsum	Index finger	Tendon	DA	1.2 x 2.2	Survived
7	M	42	Electrical	Industrial worker	Left	Dorsal radial	Index finger	Bone	1st DMA	2.4 x 3.8	Survived
8	M	27	Electrical	Electrician	Left	Dorsum	Index finger	Bone	1st and 2nd DMA	4.0 x 7.0	Survived
9	M	20	Electrical	Industrial worker	Left	Dorsum	Ring finger	Tendon	4th DMA	1.7 x 3.2	Survived

DA: digital artery, DMA: dorsal metacarpal artery

consisted of a full thickness eschar and a zone of subcutaneous necrosis 2-3 mm adjacently, which were all adequately debrided. Then, the size of the full-thickness defect was measured. The flap outline was marked on the dorsum of the hand or fingers, including the dorsal metacarpal artery perforators (DMAP) or the dorsal branches of the proper digital arteries in the pedicle of the flaps, respectively. The location of the flap pedicle was defined empirically or by preoperative Doppler 8Mhz probe to detect the vessels. The dimension of the flap was designed 2 to 4 mm wider than the defect. Initially, the dermal layer was carefully excised through the skin. The adipofascial flap was dissected from the overlying dermis by undermining the skin at the subcutaneous layer. This was performed in order to expose the deeper layers of the flap. While performing this dissection, some of the subcutaneous fat was left attached to the dermis. Bipolar cautery was used to coagulate the blood in the smaller capillaries that lead from the dorsal veins to the overlaying skin. Then, the flap was dissected off from the muscle fascia or the paratenon, and the in-depth dissection was ended 0.5 cm proximal to the margin of the defect. The distance that remained between the proximal edge of the defect and the pedicle of the flap was ensured to be no less than the width of the flap. On the dorsum of the fingers, as a general guideline, a pedicle length of 10 mm proximally to the proximal interphalangeal joint (PIPJ) was shown to be safe. On the dorsum of the hand, the dissection was commenced ulnarly and distally, preserving the peritenon over the extensor muscle at the distal half of the flap. The location of the perforator marked the pivot point of the flap. In the intermetacarpal space, the selected perforator was indicated at the level of the neck of the metacarpal bone. It is recommended that the maximum size of the flap limits along the midradial and midulnar lines of the fingers. Due to the large-size defect coverage, the border lines of the flap have the potential to expand between two midradial lines of two adjacent fingers. In this case, the flap included two DMAP in its pedicle (*Fig. 1*). The adipofascial flap was then rotated distally in order to cover the cleaned recipient site. A split thickness skin graft, harvested from the lateral aspect of the thighs, was then laid over the flap and gauze was applied gently

without tie-over fixation. The donor site was closed primarily. The digit was indeed immobilized, and after 7 days, the first dressing change was performed.

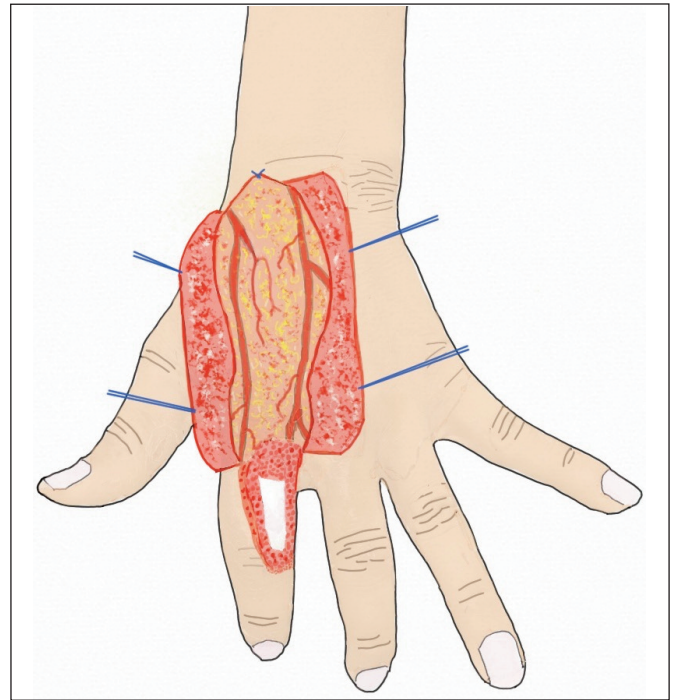


Fig. 1 - Descriptive illustration of designing a dorsal metacarpal artery perforator (DMAP) adipofascial flap.

Results

All nine complex defects were reconstructed successfully with adipofascial turnover flaps. No post-operative infection at either the donor site or the recipient site was recorded. All flaps effortlessly reached the boundaries of the defect without loss of the overlaying skin graft. The size of the flaps varied according to the size of the defects and donor sites. The smallest flap measured 1.2 x 2.0 cm and the largest flap measured 4.0 x 7.0 cm. The average flap size was 1.8 x 3.2 cm. In all of the cases, the skin grafts showed signs of hyperpigmentation. Signs of venous insufficiency were not observed postoperatively in either the flaps or the fingers. Minor hypertrophic scars were observed on the donor site in six cases. All patients were satisfied with the surgery and returned to their occupation. The mean follow-up time was 4 months (range 3-5 months).

Case reports

Case 1

A 36-year-old man presented with a small exposed tendon defect over the dorsum of his left middle finger (Fig. 2). Debridement of the wound resulted in a defect extending from the distal until the proximal interphalangeal joint. A 1.2 x 2.0 cm adipofascial flap was designed proximal to the defect, rotated 180 degrees for coverage. A linear closure of the donor defect was possible and the flap healed uneventfully.

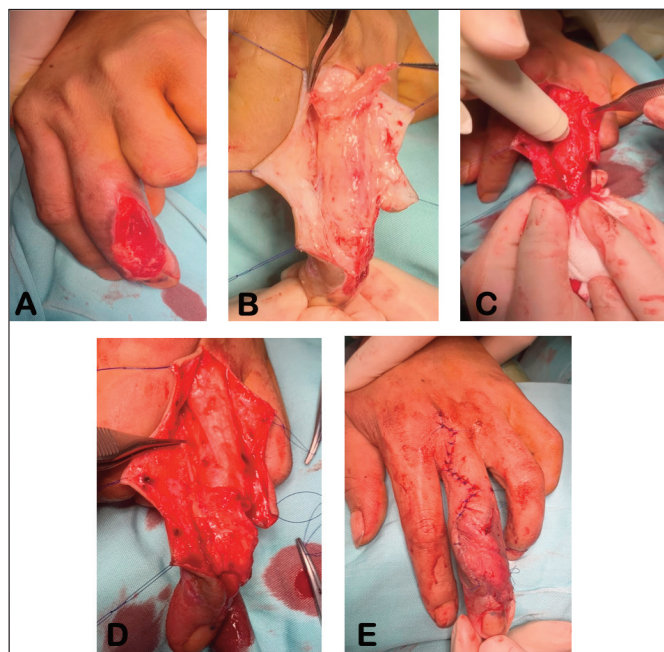


Fig. 2 - Case number 1: (A) The defect on dorsum of the middle finger with an exposed tendon; (B) The flap is raised from the dorsal of the proximal phalanx; (C) The dorsal branches of the proper digital artery is detected by the Doppler 8MHz; (D) The flap is turned over and sutured to the defect. The donor site was closed primary; (E) Immediate post-operation result.

Case 7

A 42-year-old man presented with a small exposed bone defect on dorsal radial of the index finger of his left hand that required a pedicle flap (Fig. 3). A 2.4 x 3.8 cm adipofascial flap was designed including the first dorsal metacarpal artery perforator in its pedicle, then rotated 180 degrees and inset. The donor site was closed linearly and the flap healed uneventfully.

Case 8

A 27-year-old electrician presented with a medium exposed bone defect on the dorsum of his index finger that required the flap including two DMAP in its pedi-

cle (Fig. 4). A 4.0 x 7.0 cm adipofascial flap was outlined between the midradial line of the index finger and the middle finger. The flap was then rotated and inset to cover the defect. The donor site was closed in an H shape and the flap healed completely.

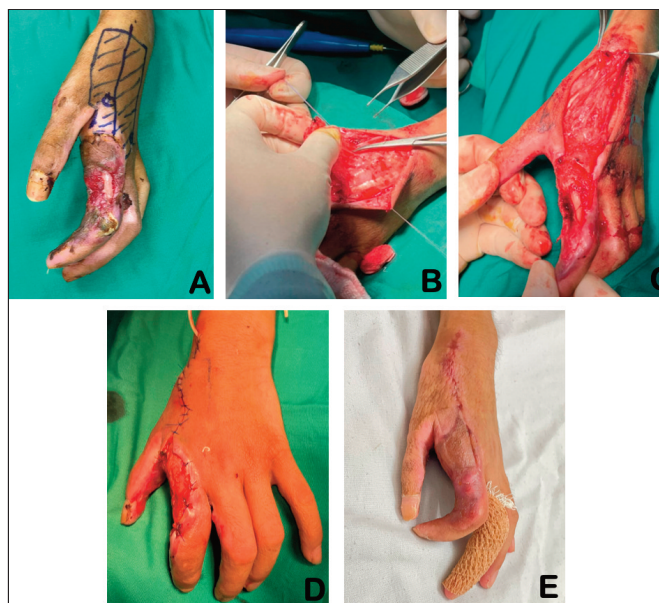


Fig. 3 - Case number 7: (A) The defect on dorsal radial over the dorsum of the ring finger and adjacent third web space with an exposed bone; (B) Flap dissection from the proximal of the second metacarpal bone; (C) The flap was completely elevated; (D) The flap turned over and sutured to the defect. The donor site was closed primary; (E) Appearance 3 months later.

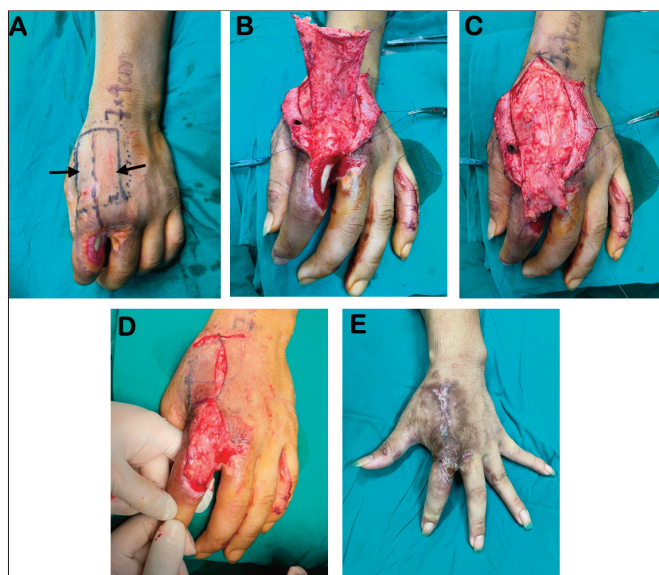


Fig. 4 - Case number 8: (A) The defect in the proximal phalanx exposing bone without periosteum after debridement and the flap is designed with the first and second DMAP (black arrow) in its pedicle; (B) Flap dissection from proximal of the second and third metacarpal bones; (C) The flap is turned over at the level of the neck of the metacarpal bones as a pivot point; (D) The flap is sutured to the defect, then skin grafted and the donor skin is closed primary; (E) The result at 4-month-follow up.

Discussion

Occupational burns, which include events that result from electrical injuries and direct high-temperature contact, are devastating injuries and can cause severe burns with significant morbidity. These accidents are certainly avoidable, and lack of safety knowledge plays an important role that puts employees at risk for occupational hand injuries. These defects require multiple surgeries for reconstruction of exposed tendons or bones in the affected extremities to achieve complete wound healing.¹¹⁻¹⁴ Our observation is similar to previous studies that found a higher incidence of occupational burn-related injuries in males.^{15,16}

In 1991, Lai et al.¹ were the first to describe a random adipofascial turnover flap technique to cover defects over the distal interphalangeal joint. Since then, multiple studies show that the flap is clinically useful.^{2-4,9,17} However, many of these flaps were not random but included dorsal branches from the proper digital artery in their pedicles. This is supported by the fact of the existence of dorsal branches originating from the proper digital artery at the midproximal phalanx.¹⁸⁻²⁰ Our and other studies all used the data from these previous anatomical studies on the vascularization of the finger dorsum on a predictable and reliable flap design.²¹⁻²³ The adipofascial flap was elevated over the proximal phalanx and was able to cover a dorsal defect beyond the PIPJ by rotating the flap from proximal to distal (*Fig. 5*). In order to cover extensive defects over both the middle and distal phalanges, the flap length could be expanded to include the subcutaneous tissue over the metacarpophal-

angeal joint (MCJ) and a portion of the dorsal metacarpal surface. This could be performed based on the anastomosis between the dorsal vascular system over the proximal phalanx and the dorsal metacarpal arteries (DMAs).²⁴⁻²⁷ In the present study, the first and four dorsal metacarpal artery perforators were included in the flap pedicles to cover the defects on the thumb and ring finger, respectively. Preoperative and intraoperative Doppler assessment was required to ensure the DMA perforators were always present. Theoretically, the artery is usually accompanied by one or two concomitant venae. To the best of our knowledge, the digits are effectively drained by the palmar venous system, which ensures venous return when the main dorsal system is disrupted.²⁸⁻³⁰ The flap acquires its drainage through a network of subcutaneous venae. Due to the exclusion of tendon or bone injuries, no notable tendon adhesion was observed in our study.

Various flaps have been described to cover soft-tissue defects of the hand and digits based on multiple factors that need to be considered.³¹ Flap selection should be based on characteristics of the defect (size, location and depth), characteristics of the flap (color, texture, thickness, sensitivity, reliability and donor site morbidity), patient characteristics (age, sex, handedness, occupation), and operative experience of the surgeon. Ono et al.²⁶ categorized dorsal finger defects as small, medium and large in size, and suggested that they should preferably be covered by dorsum of finger or hand tissues. A defect from fingertip to PIPJ can be covered with local flaps. They are conventionally considered as random-pattern flaps which are vascularized by the subdermal vascular network. However, there is a possibility that this vascularization is at risk as a result of electric current and thermal cause by high temperature. The use of a distant pedicled flap, such as a pedicle thin abdominal flap or groin flap, has the disadvantages of requiring a lengthy period of immobilization, which may result in articular stiffness, multiple-stage procedures, and frequently leaves the significant donor site with a poor cosmetic appearance. These similar issues are also encountered with the use of cross-finger flaps, which require two surgical stages and always involve immobilization.^{32,33} The digital artery perforator (DAP) flap is a useful option for coverage of small to medium dorsal digital defects. This

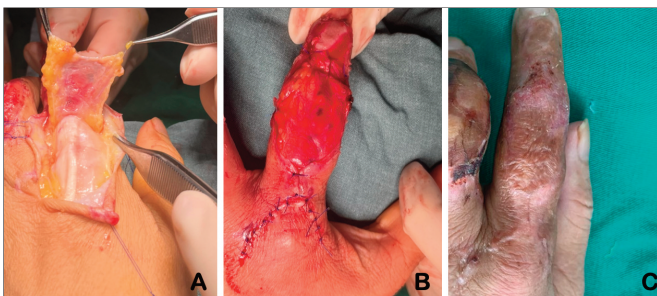


Fig. 5 - (A & B) Flap dissection from the proximal phalanx including the dorsal branches from the proper digital artery in its pedicle. The flap is then elevated and turned over to the distal phalanx. Note the intact paratenon above the flexor extension of the proximal phalanx, which preserves postoperative tendon gliding; (C) Flap healed uneventfully, small linear scar was observed on the donor site.

flap is usually designed on the dorsal skin over the middle phalanx and vascularized by perforating branches palmar-to-dorsal of the digital artery.^{34,35} Nonetheless, the flap is not appropriate for defects which extend from proximal to middle phalanx.

Despite various modifications of the adipofascial flap to its use for burn wounds,^{2,4,36} its location is a major consideration that might impede the adoption of this technique.⁵ This reflects the fact that in electrical burns, the necrotic area consists of a full thickness eschar and a zone of subcutaneous necrosis 2-3 mm adjacently, and the vascularization in the adjacent area is compromised. This requires the addition of a perforator within the flap, which enhances both its reliability and its size. In this study, both the 1st and 2nd DMAP are selected in the flap design to increase blood supply potential. In addition, the pedicle turnover adipofascial flap has been successful in treating burns that did not extend to the flap donor region in some cases. In the present study, flaps were harvested 2-4 mm wider than the defects and the pre-operative and intraoperative Doppler assessment was required for an optimum coverage.

This study had several limitations. First, 9 cases were examined, which is a relatively small sample size. More clinical reports and basic research are necessary to confirm reliability and indication of this flap for severe electrical burn wounds on the hand and digits. Second, because of the pandemic lockdowns, it can be difficult to assess results of long-term follow-up. Nonetheless, previous study indicated that the turnover adipofascial flap was best suited for complex dorsal defects located on distal part of the digits.⁹

Conclusion

All exposed bone or tendon burn wounds on the digits were covered by pedicle turnover adipofascial flaps overlaid with skin grafts. The benefits of this flap are its simplicity, the possibility of a single-stage operation, minimal donor site deformity, and sparing of the digital arteries with satisfactory cosmetic outcomes.

BIBLIOGRAPHY

- Lai CS, Lin SD, Yang CC, Chou CK: The adipofascial turn-over flap for complicated dorsal skin defects of the hand and finger. *Br J Plast Surg*, 44(3): 165-169, 1991.
- Yang JY, Noordhoff MS: Early adipofascial flap coverage of deep electrical burn wounds of upper extremities. *Plast Reconstr Surg*, 91(5): 819-827, 1993.
- Jeffery SL, Pickford MA: Use of the homodigital adipofascial turnover flap for dorsal cover of distal interphalangeal joint defects. *J Hand Surg Br*, 24(2): 241-244, 1999.
- Al-Qattan MM: The use of adipofascial turnover flaps for coverage of complex dorsal ring finger defects caused by electric burns. *Burns*, 31(5): 643-646, 2005.
- Silva JB, Faloppa F, Albertoni W, Gazzalle A, Cunha GL: Adipofascial turnover flap for the coverage of the dorsum of the thumb: an anatomic study and clinical application. *J Hand Surg Eur Vol*, 38(4): 371-377, 2013.
- Luce EA: Electrical burns. *Clin Plast Surg*, 27(1): 133-143, 2000.
- Lee DH, Desai MJ, Gauger EM: Electrical injuries of the hand and upper extremity. *J Am Acad Orthop Surg*, 27(1): e1-e8, 2019.
- Pearl RM, Johnson D: The vascular supply to the skin: an anatomical and physiological reappraisal - Part II. *Ann Plast Surg*, 11(3): 196-205, 1983.
- Al-Qattan MM: The adipofascial turnover flap for coverage of the exposed distal interphalangeal joint of the fingers and interphalangeal joint of the thumb. *J Hand Surg Am*, 26(6): 1116-1119, 2001.
- Chen HC, Buchman MT, Wei FC: Free flaps for soft tissue coverage in the hand and fingers. *Hand Clin*, 15(4): 541-554, 1999.
- Lee DH, Desai MJ, Gauger EM: Electrical injuries of the hand and upper extremity. *J Am Acad Orthop Surg*, 27(1): e1-e8, 2019.
- Fordyce TA, Kelsh M, Lu ET, Sahl JD, Yager JW: Thermal burn and electrical injuries among electric utility workers, 1995-2004. *Burns*, 33(2): 209-220, 2007.
- Handschin AE, Vetter S, Jung FJ, Guggenheim M et al.: A case-matched controlled study on high-voltage electrical injuries vs thermal burns. *J Burn Care Res*, 30: 400-407, 2009.
- Belliappa PP, McCabe SJ: The burned hand. *Hand Clin*, 9(2): 313-324, 1993.
- Islam SS, Nambiar AM, Doyle EJ, Velilla AM et al.: Epidemiology of work-related burn injuries: experience of a state-managed workers' compensation system. *J Trauma*, 49(6): 1045-1051, 2000.
- Fordyce TA, Kelsh M, Lu ET, Sahl JD, Yager JW: Thermal burn and electrical injuries among electric utility workers, 1995-2004. *Burns*, 33(2): 209-220, 2007.
- Cavadas PC, Puertes-Corella L: The subcutaneous turn-over flap in the treatment of difficult wounds of the digits. *J Hand Surg Br*, 23(4): 472-475, 1998.
- Levame JH, Otero C, Berdugo G: Arterial vascularization of teguments of the dorsal surface of the hand and fingers (in French). *Ann Chir Plast*, 12: 316-324, 1967.
- Yang D, Morris SF: Vascular basis of dorsal digital and metacarpal skin flaps. *J Hand Surg Am*, 26: 142-146, 2001.
- Braga-Silva J, Kuyven CR, Fallopa F, Albertoni W: An anatomical

- cal study of the dorsal cutaneous branches of the digital arteries. *J Hand Surg*, 27B: 577-579, 2002.
- 21 Delia G, Casoli V, Sommario M, Risitano G et al.: Homodigital dorsal adipofascial reverse flap: anatomical study of distal perforators and key points for safe dissection. *J Hand Surg Eur*, 35(6): 454-458, 2010.
- 22 Braga-Silva J, Kuyven CR, Albertoni W, Faloppa F: The adipofascial turn-over flap for coverage of the dorsum of the finger: a modified surgical technique. *J Hand Surg Am*, 29(6): 1038-1043, 2004.
- 23 Delia G, Battaglia F, Colonna MR, Barresi V, d'Alcontres FS: Is the adipofascial flap the key to regenerative surgery? *JPRAS Open*, 18: 49-58, 2018.
- 24 Sebastin SJ, Mendoza RT, Chong AKS et al.: Application of the dorsal metacarpal artery perforator flap for resurfacing soft-tissue defects proximal to the fingertip. *Plast Reconstr Surg*, 128(3): 166e-178e, 2011.
- 25 Facchin F, Sonda R, Faccio D et al.: Multi-dorsal metacarpal artery perforator adipofascial turnover flap for index to little finger reconstruction: anatomical study and clinical application. *Hand Surg Rehabil*, 40(2): 177-182, 2021.
- 26 Ono S, Sebastin SJ, Ohi H, Chung KC: Microsurgical flaps in repair and reconstruction of the hand. *Hand Clin*, 33(3): 425-441, 2017.
- 27 Aizawa T, Hirayama T, Kiyosawa T, Kobayashi Y: First dorsal metacarpal artery perforator-based propeller flap: functional anatomy and clinical application in soft-tissue defects of the dorsal hand and digits. *Surg Radiol Anat*, 44(2): 215-221, 2022.
- 28 Lucas GL: The pattern of venous drainage of the digits. *J Hand Surg*, 9A: 448-450, 1984.
- 29 Moss SH, Schwartz KS, von Drasek-Ascher G, Ogden LL 2nd et al.: Digital venous anatomy. *J Hand Surg Am*, 10(4): 473-482, 1985.
- 30 Lhuair M, Wavreille G, Hivelin M et al.: Venous system mapping of the digits and the hand: an anatomical study and potential surgical applications. *JPRAS Open*, 33: 171-183, 2022.
- 31 Rehim SA, Chung KC: Local flaps of the hand. *Hand Clin*, 30(2): 137-v, 2014.
- 32 Al-Qattan MM: De-epithelialized cross-finger flaps versus adipofascial turnover flaps for the reconstruction of small complex dorsal digital defects: a comparative analysis. *J Hand Surg Am*, 30(3): 549-557, 2005.
- 33 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*, 34(1): 128-130, 2009.
- 34 Mitsunaga N, Mihara M, Koshima I et al.: Digital artery perforator (DAP) flaps: modifications for fingertip and finger stump reconstruction. *J Plast Reconstr Aesthet Surg*, 63(8): 1312-1317, 2010.
- 35 Kostopoulos E, Agiannidis C, Konofaos P, Dounavis A et al.: Predictable pattern digital artery perforator flap: an alternative concept in digital reconstruction. *Hand (N Y)*, 11(1): 88-96, 2016.
- 36 Lai CS, Lin SD, Chou CK, Tsai CW: Clinical application of adipofascial turn-over flaps for burn wounds. *Burns*, 19(1): 73-76, 1993.