Int J Clin Exp Med 2015;8(10):18058-18065
www.ijcem.com /ISSN:1940-5901/IJCEM0011791

Original Article

Clinical experience of multiple flaps for the reconstruction of dorsal digital defects

Hongsheng Jiao[1], Xiaoheng Ding[1], Yujie Liu[1], Hongxun Zhang[1], Xuecheng Cao[2]

[1]*The Hand Surgery Center of Chinese People's Liberation Army, The 401st Hospital of CPLA, Qingdao, P. R. China;* [2]*Department of Orthopedic and Traumatic Surgery, General Hospital of Jinan Military Command, Jinan, P. R. China*

Received June 22, 2015; Accepted August 6, 2015; Epub October 15, 2015; Published October 30, 2015

Abstract: Objective: In this report, we present our experience with reconstruction of the skin defects on the dorsum of the digits using multiple flaps. Methods: Between November 2010 and March 2013, 45 patients with dorsal digital defects underwent reconstruction using homodigital dorsal digital fasciocutaneous flap (n = 17), heterodigital dorsal digital fasciocutaneous flap (n = 14), dorsal metacarpal artery fasciocutaneous flap (n = 8) and free venous flaps (n = 6). The average flap size was 1.5 × 1.5 cm to 2.0 × 2.5 cm. Donor sites were covered with full-thickness skin graft. Results: All flaps survived completely and the donor sites healed without complications. The mean follow-up period was 18 weeks. During the follow up period, 7 patients treated with reverse homodigital fasciocutaneous flaps developed swelling in the distal portion of flaps, 3 patients treated with reverse dorsal metacarpal artery fasciocutaneous flaps developed mild swelling in the distal portion of flaps but survive well, and 4 patients treated with free venous flaps experienced venous congestion. Of the 14 patients treated with heterodigital fasciocutaneous flaps, there were 11 cases with a retrograde pedicle and 3 cases with a direct pedicle. No full-thickness graft necrosis was noted. Conclusion: Multiple options are available for the repair of skin defects on the dorsum of the digits. Besides, the use of a heterodigital fasciocutaneous flap was a simple, safe, and less invasive regimen for repairing dorsal digital skin defects.

Keywords: Dorsal digital defects, dorsal digital fasciocutaneous flap, free venous flap, finger, microsurgery

Introduction

The dorsum of the fingers is covered by a thin skin envelope with little subcutaneous tissue, underneath which lies the extensor tendons and bony structures. Therefore, it is crucial to achieve coverage after dorsal digital injury to protect these essential structures [1]. Appropriate therapy should use local tissue whenever possible, preserve the aesthetic appearance, provide stable skin coverage, minimise donor-site deformities, and preserve motor function of the finger [2]. According to these principles, the local flap from the adjacent tissue of the defected regions may be used to reconstruct a dorsal digital defect. There are many therapeutic methods to treat dorsal digital defects, however the selection of these flaps remains contentious in clinical practice. The aim of our study was to present our experience of reconstruction of the dorsal digital defects with the homodigital dorsal digital fasciocutaneous flap, heterodigital dorsal digital fasciocutaneous flap, dorsal metacarpal artery fasciocutaneous flap and free venous flaps and evaluate their merits and demerits in this clinical setting. From November 2010 to March 2013, we treated 45 patients with dorsal digital defects using these four flaps. The procedure produced good clinical results which are summarized in this report.

Materials and methods

Patients

The study was approved by the Ethics Committee of the 401st Hospital of Chinese People Liberation Army (Qingdao, China), and written informed consent was obtained from all subjects. From November 2010 to March 2013, a total of 45 patients with skin defects of dorsal

Table 1. Baseline characteristics in four groups

	Homodigital fasciocutaneous flap (n = 17)	Heterodigital fasciocutaneous flap (n = 14)	Dorsal metacarpal artery fasciocutaneous flaps (n = 8)	Free venous flaps (n = 6)
Age	27 (range 17-35)	30 (range 22-45)	31 (range 18-51)	29 (range 20-41)
Sex (male/female)	8/5	11/3	6/6	4/2
Dominant/nondominant hand	5/10	4/8	4/8	2/4
Defect location				
Index finger (right/left)	5 (1/4)	3 (1/2)	1 (0/1)	3 (2/1)
Middle finger (right/left)	4 (3/1)	6 (2/4)	1 (0/1)	2 (1/1)
Ring finger (right/left)	4 (2/2)	4 (1/3)	3 (1/2)	1 (0/1)
Little finger (right/left)	4 (3/1)	1 (1/0)	3 (1/2)	0
Defect type				
A	7	6	0	0
B	10	5	0	3
C	0	3	8	3
Flap size	1.5 cm × 1.5 cm ~ 2 cm × 2.3 cm	1.5 cm × 2.0 cm ~ 1.8 cm × 2.0 cm	1.8 cm × 2.0 cm ~ 2.0 cm × 2.5 cm	1.5 cm × 2.0 cm ~ 2 cm × 2.3 cm

A, dorsal distal phalanx and nail bed defects; B, skin defects on the dorsum of the middle phalanx; C, skin defect on the dorsum of the proximal phalanx.

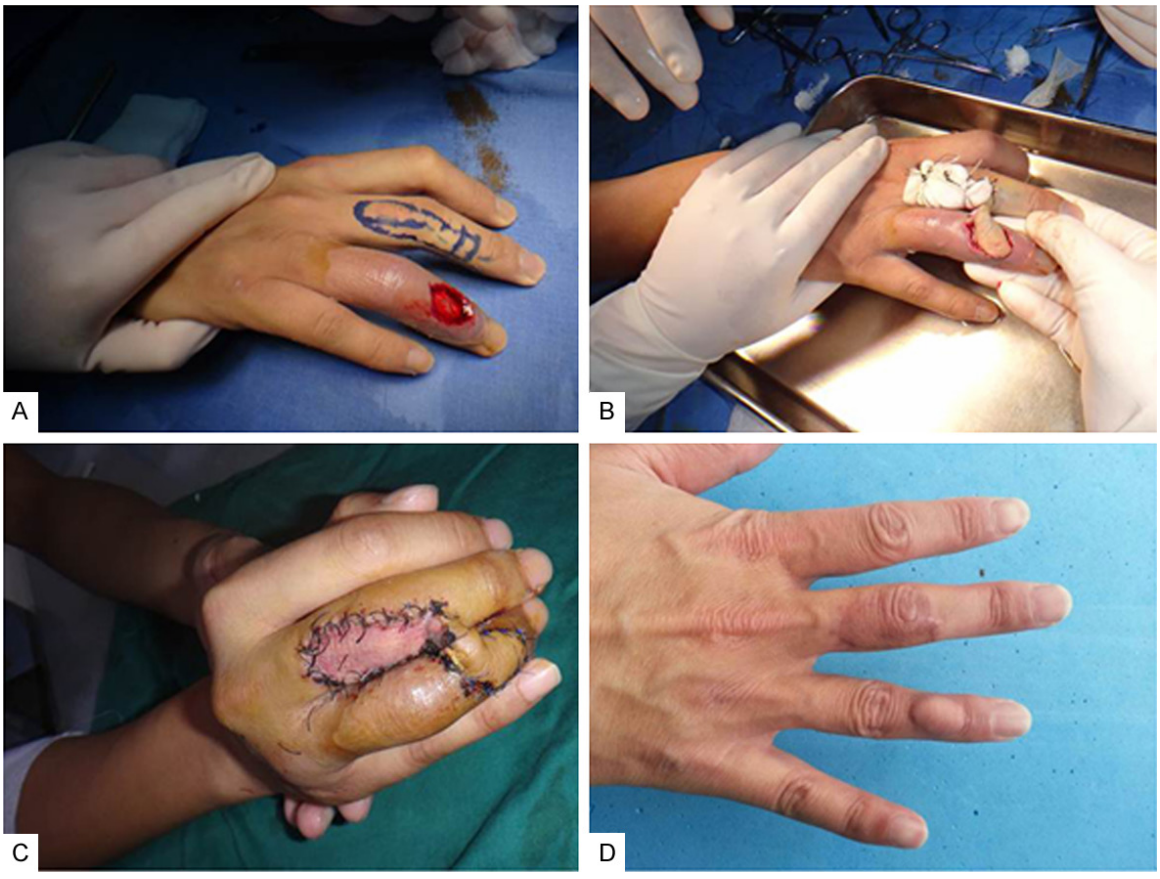

Figure 1. Preoperative appearance showing necrosis of the dorsum of middle phalanx of the right ring finger after skin infection. The skin defect was about 2.0 × 1.5 cm (A). A hetero-digital reverse fasciocutaneous flap based on the dorsal branch of the proper digital artery (pedicle length, 1.5 cm; pedicle width, 0.8 cm) was used to cover the defect (B). The middle segment of the middle phalanx was designed as the rotating point. The flap size was 2.0 × 1.5 cm. Postoperative view of the reconstructed finger 10 days postoperatively (C) and postoperative view of the reconstructed finger 4 months postoperatively (D).

fingers admitted to our department were included in the study. The inclusion criteria were: 1) patients who had simple dorsal finger skin defects or associated with recoverable

Figure 2. (A) Preoperative appearance showing nail bed defect of the right middle finger. The skin defect was about 1.5 × 1.5 cm. A reverse fasciocutaneous flap based on the dorsal branch of the proper digital artery at the distal phalanx (pedicle length, 1.1 cm; pedicle width, 0.6 cm) was required to cover the defect. At postoperative 3 days, the finger developed swelling and blistering (B) and dorsal views of the reconstructed finger 3 weeks postoperatively (C).

Figure 3. Preoperative appearance showing skin defect of the left index finger (A). The skin defect was about 2.0 × 1.8 cm. A reverse fasciocutaneous flap based on the dorsal branch of the proper digital artery at the proximal phalanx (pedicle length, 2.0 cm; pedicle width, 0.8 cm) was required to cover the defect. Postoperative view of the reconstructed finger 3 days after the operation (B), postoperative view of the reconstructed finger at extension (C) and flexion position (D) 4 months after the operation.

injury such as fractures and tendon injuries; 2) a defect greater than or equal to 1.5 cm in length. The exclusion criteria were: 1) injuries involving the donor sites or the course of the vascular pedicle; 2) a defect less than 1.5 cm in length; 3) a skin defect in the thumb; 4) patients had severe organic disease, such as diabetes and hypertension which may affect the flap survival; and 5) patients who had a history of smoking. The patients consisted of 29

males and 16 females. The mean age was 35.6 years old with a range from 17 to 51 years. There were 12 index finger, 13 middle finger, 12 ring finger and 8 little finger injuries. The defects were caused by machine crushing injuries (n = 14), electrical sawing injuries (n = 16), friction injuries (n = 8), thermal friction injuries (n = 2) and wound infections (n = 5). All patients had salvage surgery with a time delay after injury of 2 hours to 10 days. Among these cases, finger reconstruction using homodigital fasciocutaneous flap was performed in 13 patients, heterodigital fasciocutaneous flaps in 14 patients, dorsal metacarpal artery fasciocutaneous flap in 12 patients, and free venous flap in 6 patients. In this series, the minimum skin defect was 1.5 × 1 .5 cm, and the maximum defect was 2.0 × 2.5 cm. The distribution of age, gender, digital involvement, location of the defect, and length of flap used are shown in **Table 1**.

Designing flaps

Reverse fasciocutaneous flap from the dorsum of the middle phalanx of the finger: The flap was designed on the dorsum of middle or proximal phalanx of injured finger according to the rotating point and the pedicle lengthen (**Figure 1**). The line of the peak of the transverse striation between distal and proximal phalanx under digital flexion (median line of the finger side) was taken as the flap axis. 0.5-1.0 cm proximal to the distal interphalangeal joint was taken as the rotating point of articular branch. The midpoint of the middle phalanx was taken as the rotating point of dorsal branch of the proper digital artery at the middle segment of the middle phalanx. The pedicle width was about 0.5-0.8 cm.

Reverse fasciocutaneous flap based on the end dorsal branch of the proper digital artery: The flaps were designed on the dorsum of the middle phalanx of the injured fingers (**Figure 2**). The pivot point was located at the origin of the end dorsal branch of the digital artery. The proximal portion of the flap can reach to the proximal margin of dorsal stria of the proximal interphalangeal joint. The distal portion of the flap mainly located at the middle segment of the middle phalanx. The flap axis extended obliquely from the injured side to the opposite side. The flap size was designed slightly larger than the defect. The pedicle length and width was about 0.8-1.1 cm and 0.5-0.8 cm, respectively.

Reverse fasciocutaneous flap based on the dorsum of the middle phalanx of the finger: The flap was designed on the dorsum of proximal phalanx or the radial or ulnar side of the dorsum of the metacarpophalangeal joints according to the pivot point and pedicle length (**Figure 3**). Attention should be paid to avoid the dorsum of the metacarpophalangeal joints. The median line of the finger side was taken as the flap axis. 0.5-1.0 cm proximal to the proximal interphalangeal joint was taken as the rotating point of articular branch. The midpoint of the proximal phalanx was taken as the rotating point of dorsal branch of the proper digital artery at the middle segment of the proximal phalanx.

Reverse dorsal metacarpal artery fasciocutaneous flaps: The pivot point was located at the region of 1.5 cm proximal to the free edge of the finger web. The middle line of the adjacent metacarpal bone was taken as the flap axis. The mean pedicle width was about 0.8 cm. The anatomic depth reached to the superficial layer of the deep extensor tendon.

Anterograde heterodigital fasciocutaneous flaps: The pivot point was located at the region of 1.5 cm proximal to the free edge of the finger web. The junction of the lateral aspect and dorsal aspect of the median line of the finger side was taken as the flap axis. The anatomic depth was superficial aspect of the extensor digitorum. The median pedicle width was about 0.8 cm.

Free venous flaps: The donor sites of the free venous flaps were located at the volar aspect of the distal forearm. 1-2 veins were selected to run through the flaps longitudinally. The direction of blood flow was anterograde with no valve block. They may contain pure venous flap or arterialized venous flaps. The mean number of anastomoses was 3-5.

Flap harvesting

After thorough debridement, the recipient digital artery and nerve and the dorsal digital vein were identified and marked. Flaps based on based on the end dorsal branch of the digital artery was elevated carefully in a retrograde

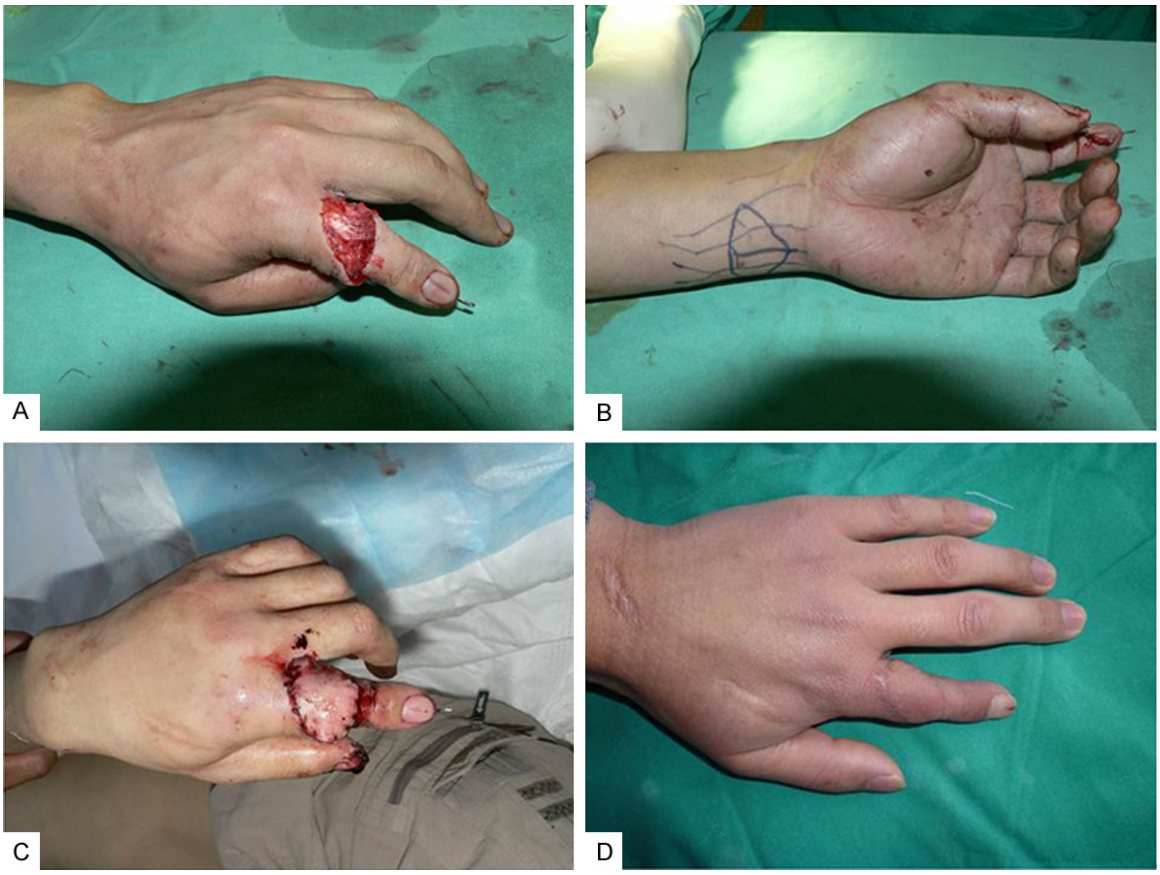

Figure 4. (A) Preoperative appearance showing skin infection of the proximal interphalangeal joint. The skin defect was about 2.5 × 2.0 cm. A free venous flap from the ipsilateral volar aspect of the distal forearm was used to cover the defect (B and C). The venous flap is designed in antegrade, flow-through fashion. Postoperative appearance of the reconstructed finger 6 months postoperatively showing the flap appearance was satisfactory (D).

pattern and separated at the superficial surface of the extensor aponeurosis. Dorsal digital veins was cut and ligated, leaving the distal end of the dorsal digital veins attached to the flap. The elevated flap was dissected bilaterally proximal to the rotating point. An opened tunnel was prepared for the transfer of the flap. The fascial tissue, approximating 0.5 cm in width and vascularized pedicle should be dissected simultaneously. Tourniquet was loosed after full flap elevation. If there was active flap bleeding, the flap can be transferred in a retrograde fashion to the wound of nail bed and dorsal distal phalanx. Interrupted suture was performed between the flap and wound margin. Attention should be paid to the location of the pedicle during flap transfer. It should not be angulated, tortuous or too tight. The tension of flap and wound margin during suture processing should be controlled to avoid vascular pedicle compression. The surrounding skin (approximate 0.5 cm) around the vascular pedicle was used to relieve the pressure of the pedicles. Full-thickness skin grafts were harvested from the palmar side of the forearm to cover the donor sites. Compression package was performed. The pattern of flap resection is similar between dorsal middle and proximal phalanx finger flaps. The difference was that the pedicle width of the middle phalanx can reach to 0.8-1.0 cm. The donor sites of the free venous flaps are usually from the volar aspect of the distal end of the ipsilateral forearm (**Figure 4**). Air tourniquet was temporarily used to facilitate direction and distribution of the local venous network. The most common patterns are H-pattern followed by Y-pattern and λ-pattern. The flap was then carefully elevated from the superficial layer of the deep fascia and the number of the anastomosis was 3-5. All flaps were transferred with antegrade flow, anastomosing the afferent vein to a digital artery or the efferent vein to a dorsal digital vein.

Postoperative management

After surgery, blood supply of each flap was monitored hourly for 7 days. The pedicle skin flaps were treated depended on the blood supply of flaps. For flaps with good blood supply, antibiotic was used to prevent postoperative infections. However, for flaps with poor blood supply, intravenous injection of low-molecular-molecular-weight dextran (500 ml twice daily for 3-5 days) and intramuscular injection of papaverine hydrochloride (30 mg/12 h for 7 days) was administered to ensure artery blood flow and improve blood circulation of flaps. When necessary, plaster support immobilization of the injured finger was performed.

Results

The follow-up period ranged from 3 to 36 weeks (mean period, 18 weeks). All flaps survived. Of the 17 patients treated with reverse homodigital fasciocutaneous flaps, 7 patients developed swelling in the distal portion of flaps. Of the 14 patients treated with heterodigital fasciocutaneous flaps, there were 11 cases with a retrograde pedicle and 3 cases with an anterograde pedicle. Of 8 patients treated with reverse dorsal metacarpal artery fasciocutaneous flaps, 3 developed mild swelling in the distal portion of flaps but survive well. Of the 6 patients treated with free venous flaps, 4 cases experienced venous congestion. No full-thickness graft necrosis was noted. All patients were satisfied with the functional results of normal extension and flexion of the digits and achieved good texture and appearance of the flaps. Most of the donor sites healed and became normal in texture and appearance about 3 to 8 weeks postoperatively, except for pigmentation.

Case reports

Case 1

A 27-year-old man suffered from a local red and hot swell wound of the right ring finger following knife injury and admitted to our hospital 3 days later due to no improvement in swelling. The patient was diagnosed with a skin purulent infection on the dorsum of the ring finger. The patient underwent local incision and drainage of the right ring finger and received intramuscular administration of cefoxitin (0.5 g twice daily) after bacterial culture. After obtaining a regression of red, hot swollen wound, the patient was treated by reverse heterodigital fasciocutaneous flap from the dorsum of the middle phalanx finger. The flap survived well 10 days postoperatively (c); at 4 months after the operation (d), the flap achieved a pleasing appearance and texture (**Figure 1**).

Case 2

A 20-year-old woman presented a nail bed defect of the right middle finger following the machine crushing. The patient underwent debridement of the right middle finger and treated with a homodigital fasciocutaneous flap based on the end dorsal branch of the proper digital artery under the brachial blockade. The flap developed blister 3 days after the operation but not impacting the flap survival. Blister rupture was noted 2 weeks after the operation, the flap survive well (**Figure 2**).

Case 3

A 51-year-old man sustained a machine crushing injury to the left index finger. Local skin defects was observed and treated by reverse perforator-based fasciocutaneous flap based on the dorsal branch of the proper digital artery. The flap survived the transfer completely. The flap exhibited a favorable appearance and texture; the finger grew well at 4 months after the operation (**Figure 3**).

Case 4

A 29-year-old man presented a skin defect of the left index finger following the punch press crushing. The defect included a damage of proximal interphalangeal joint, extensor tendon rupture, and skin damage. The patient underwent proximal interphalangeal joint arthrodesis, extensor tendon repair and was treated with a free venous flap from the ipsilateral volar aspect of the distal end of the forearm under the brachial plexus anesthesia for the coverage of the skin defect. The flap blister was observed 3 days after the operation but not impacting the flap survival. The blister flap recovered to normal 2 weeks after the operation. The flap exhibited a good appearance at the postoperative 6 month follow up (**Figure 4**).

Discussion

Coverage of the dorsal aspect of the fingers is difficult, especially when the soft tissue defect

is large and extensor apparatus and joints are involved [3]. Sensory return secondary to good coverage and appearance is the main complaint due to dorsal digits located at the nonfunctional region of the finger. Local flap reconstruction techniques has been predominately for covering small to moderate digital defects has established [4-6]. Massimo et al. [7] reported that dorsal branch of the finger has complete longitudinal arterial and venous network. Proximally from the middle level of the proximal phalanx, this network includes the terminal branches of the dorsal metacarpal artery, but distally from the first phalanx, the network contains numerous volar digital artery branches [8]. Dorsal digital artery cannot be used as the axial vessel of the dorsal digital flaps due to its short diameter. But the slender branches of the dorsal digital artery and the dorsal branches of the volar aspect of the proper digital artery developed rich anastomosing network on the dorsum of the digits. The anastomosing network can provide blood supply through narrow pedicle. Four of them located at the middle and the distal third of the proximal phalanx, the middle of the second phalanx and the level of the distal interphalangeal joint [9]. The four dorsal branches of the digital artery has constant anatomic structure and can be designed as the rotating point for local pedicled fasciocutaneous flaps or heterodigital pedicled fasciocutaneous flaps according to the requirement of wound repair.

Reverse fasciocutaneous flaps based on the distal dorsal branch of the digital artery used in our study was first reported by Kim et al [10]. In our study, 7 patients treated with reverse homodigital fasciocutaneous flaps based on the end dorsal branches of the digital artery developed swelling in the distal portion of flaps and small amount of blisters but not affect skin flap survival. No full-thickness neurosis was observed in these patients. Pedicle rotation angle of the heterodigital fasciocutaneous flaps based on the dorsal branches of the proper digital artery was far below the homodigital dorsal flaps. In this study, the surrounding skin (approximate 0.5 cm) around the vascular pedicle was used to relieve the pressure of the pedicles. After the removal of the flaps, full-thickness skin grafts were used to cover another side of the pedicles. After the operation, the flaps achieved good blood supply without obvious clinical manifestation of blood circulation disorder. Full-thickness skin grafts impact the pedicel in two ways: 1) covering the bare region of the pedicle which reduced the pedicle effusion and protect the pedicle vessels; 2) adjusting the graft length and width according to the distance of heterodigital interphalangeal joint and the flap location to take pressure off the pedicle. Anterograde heterodigital flaps can provide stable blood supply through ramus anastomoticus at finger web between proper palmar digital arteries and dorsal metacarpal arteries. In the present study, 14 patients treated with heterodigital fasciocutaneous flaps of which 3 cases were with an anterograde pedicle. These 3 patients achieved good blood supply after the operation. Postoperative incision scar did not affect the motion of fingers and finger web width.

The merits and demerits of the flaps in the study were as follows. Homodigital fasciocutaneous flap from the dorsal branch of the proper digital artery has the advantages of stable vascular position, adequate coverage of skin defects of middle and distal phalanx, good postoperative joint range of motion and not impairing the main vessels and disadvantages of large impact on arterial blood supply and venous return. Anterograde fasciocutaneous flap from the adjacent finger (Heterodigital) have the advantage of stable blood supply but the disadvantage of large scope of surgical stripping and rotating point crossing over the finger web which may affect the motion of digits and the finger web width. Heterodigital fasciocutaneous flap from the dorsal branch of the proper digital artery has the advantages of (1) limited scope of surgical stripping, (2) adequate coverage of skin defects of middle and distal phalanx and (3) not affecting the blood supply as compared to the dorsal homodigital flap and the disadvantages of prolonged pedicle due to the distance of adjacent fingers. In order to overcome the shortcoming, the flaps should be carefully designed preoperatively and attention should be paid to the distance and location of adjacent finger. Besides, the patients should be placed in a natural position. The patients in the present study were all placed in a natural position and had no immediate and long term of restricted joint movement. The length-width ratio of the flaps in this group can reach to 6:1 with no abnormal blood supply.

The venous flap first introduced by Nakayama et al [11] is highly regarded in microsurgical and reconstructive surgeries in recent years, especially in the reconstruction of hand and digit injuries [12]. Venous flap is that the blood circulation of the flap is supported by the vein system regardless of blood properties and blood flow direction within the veins. Besides, blood flows from the artery to arteriole, blood capillary, venule, and vein under normal physiological condition will not exist at the early stage of flap. In this study, 6 patients underwent skin defect repair using free venous flap. The donor sites were the volar aspect of the ipsilateral forearm. There are 3 cases of arterialized venous flap and 3 cases of pure venous flap. Of the 3 patients treated with arterialized venous flap, 2 cases survive well and the remaining developed venous congestion and recovered 2 weeks postoperatively. Long term follow up showed the flaps had a good appearance. The 3 patients treated with pure venous flap had a small amount of blisters and restored to normal 3 weeks postoperatively. No full-thickness necrosis was noted. Long term follow up showed no discomfort in appearance and motion in patients. The venous flaps had the advantages of 1) simple surgical dissection and 2) thin flap; and the advantages of 1) being non-physiological flaps, 2) demanding experienced vascular suture techniques, and 3) prolonged surgical time compared to the pedicle flaps. Therefore, the free venous flaps used in the study were inferior to the other types of flaps.

Conclusion

Multiple options are available for the repair of skin defects on the dorsum of the digits. Besides, the use of a reverse heterodigital fasciocutaneous flap based on the dorsal branch of the proper digital artery was a simple, safe, and less invasive regimen for repairing dorsal digital skin defects.

Acknowledgements

This work was supported by a grant from National Natural Science Foundation of China (2013m542572).

Disclosure of conflict of interest

None.

Address correspondence to: Xuecheng Cao, Department of Orthopedic and Traumatic Surgery, General Hospital of Jinan Military Command, No. 25 Shifan Road, Tianqiao District, Jinan 250031, China. Tel: +86-15315002090; E-mail: caoxuecheng66@163.com

References

[1] Chen C, Tang P and Zhao G. Direct and reversed dorsal digital island flaps: a review of 65 cases. Injury 2014; 45: 2013-2017.

[2] Lassner F, Becker M, Berger A and Pallua N. Sensory reconstruction of the fingertip using the bilaterally innervated sensory cross-finger flap. Plast Reconstr Surg 2002; 109: 988-993.

[3] Wavreille G, Cassio JB, Chantelot C, Mares O, Guinand R and Fontaine C. Anatomical bases of the second toe composite dorsal flap for simultaneous skin defect coverage and tendinous reconstruction of the dorsal aspect of the fingers. J Plast Reconstr Aesthet Surg 2007; 60: 710-719.

[4] Huang YC, Liu Y and Chen TH. Use of homodigital reverse island flaps for distal digital reconstruction. J Trauma 2010; 68: 429-433.

[5] Mishra S and Manisundaram S. A reverse flow cross finger pedicle skin flap from hemidorsum of finger. J Plast Reconstr Aesthet Surg 2010; 63: 686-692.

[6] Tan O. Reverse dorsolateral proximal phalangeal island flap: a new versatile technique for coverage of finger defects. J Plast Reconstr Aesthet Surg 2010; 63: 146-152.

[7] Bene MD, Petrolati M, Raimondi P, Tremolada C and Muset A. Reverse dorsal digital island flap. Plast Reconstr Surg 1994; 93: 552-557.

[8] Kojima T, Tsuchida Y, Hirase Y and Endo T. Reverse vascular pedicle digital island flap. Br J Plast Surg 1990; 43: 290-295.

[9] Pelissier P, Casoli V, Bakhach J, Martin D and Baudet J. Reverse dorsal digital and metacarpal flaps: a review of 27 cases. Plast Reconstr Surg 1999; 103: 159-165.

[10] Kim KS, Yoo SI, Kim DY, Lee SY and Cho BH. Fingertip reconstruction using a volar flap based on the transverse palmar branch of the digital artery. Ann Plast Surg 2001; 47: 263-268.

[11] Nakayama Y, Soeda S and Kasai Y. Flaps nourished by arterial inflow through the venous system: an experimental investigation. Plast Reconstr Surg 1981; 67: 328-334.

[12] Woo SH, Kim KC, Lee GJ, Ha SH, Kim KH, Dhawan V and Lee KS. A retrospective analysis of 154 arterialized venous flaps for hand reconstruction: an 11-year experience. Plast Reconstr Surg 2007; 119: 1823-1838.