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Free Radial Forearm Flap for Near Total Degloving Finger Reconstruction

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Background: Total circumference degloving injury of the digits usually results in a large cutaneous defect with tendinus structure and bone and joint exposure. A thin and adequately sized flap is required when revascularization is not possible to resurface the defect, restore the finger function, and prevent amputation. **Materials and Methods:** In this report, we present our experience on reconstruction of total circumferential degloving injury on the digits using free radial forearm (RF) flaps in 6 patients. Between February 2006 and January 2011, 6 male patients with circumferential degloving injury of 6 digits underwent reconstruction with the free RF flaps. The average flap size was 15.8×7.1 cm. Donor sites were covered with split-thickness skin graft (STSG). **Results:** All of flaps survived completely and donor sites healed without complications. The mean follow-up period was 22 months. A maximum Kapandji score (10/10) was seen in 2 cases with crushed thumbs. All patients could achieve good key pinch and grasping functions. All skin flaps showed acceptable static 2-point discrimination with an average of 10.2 mm (range, 8–12 mm) and adequate protective sensation. Patient satisfaction for resurfaced digits averaged 9.3 (range, 9–10 mm) on a 10-points visual analogic scale (VAS). **Conclusion:** In conclusion, the free RF flaps were thin and did not interfere with finger movements. The patients could attain smooth finger contours and acceptable function results after reconstruction. This method may be a valuable alternation for reconstruction of total circumference avulsion injury of the digits.

Key words: degloving digit injury, free radial forearm flap, sensate flap

INTRODUCTION

Complete degloving injury of the finger, which is a class III injury according to the Urbaniak classification[1], could be difficult to manage because of a lack of appropriate tissues that can be used to cover denuded tendons, pulleys, and phalangeal bones, as well as structurally intact joint capsules. Smaller size defects may be treated by simpler procedures, such as secondary intention healing, delayed closure, or skin grafting.[2,3] Larger soft tissue defects would be treated with a pedicled or free flap, especially when poorly vascularized structures are exposed.[4] Due to development of microsurgical procedures, free flaps have been introduced for large defect reconstruction of total circumference degloving injury of the digits. Although several methods are used to manage this type of injury in order to preserve function and prevent deformities, none provide an ideal solution to the problem because the unique prehensile finger skin with loops and whorls on the fingerprint. Free RF flap is a valuable surgical option when only a thin layer of vascularized tissue, including the fascia for tendon glide, is required. The purpose of this paper is to present our experience on reconstruction of the total circumference degloving injury on the digits using free RF flaps in 6 patients.

PATIENTS AND METHODS

Between February 2006 and January 2011, free RF flaps were used for resurfacing extensive posttraumatic skin envelope circumferential loss of digits in 6 patients, including the thumb injury in 2 patients, and the index finger injury in 4 patients. Three degloved digits were

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Table 1 Summary of Patient Data

Patient	Sex/ Age (yr)	Co-morbidity	Defect Location	Flap Size (cm^2)	Neurorrhaphy	S-2PD (mm)	Protective Sensation (>1yr)	Flap Ulcer (>1yr)	Flap survival	Follow-up (m)
1	M/22	None	Right index	17x9	Y	10	Y	N	Survived	47
2	M/48	None	Left index	19x4.5	N	11	Y	N	Survived	35
3	M/28	None	Left thumb	18x8	Y	12	Y	N	Survived	23
4	M/53	Type 2 DM	Right index	15x8	N	12	Y	N	Survived	14
5	M/20	None	Right index	17x7	Y	8	Y	N	Survived	7
6	M/33	None	Right thumb	9x6	Y	8	Y	N	Survived	6
Average	34			15.8x7.1		10.2				22

M=male; yr=year; m=month; DM=diabetes mellitus; HTN=hypertensive; N=no; Y=yes; S-2PD=static two-point discrimination

injured in traffic accidents; the other three digits were injured while the patients worked with a machine. All patients were male, with an average age of 34 years (range, 20–53 years). Only 1 patient (patient 4) had a medical co-morbidity, who had type 2 diabetes mellitus and took regular oral anti-hyperglycemic agents. After admission, debridement and wound care were performed to clean the wound base for subsequent reconstruction with free flaps.

All of wounds had skin and soft tissue defects with tendon and bone exposure that could not be healed by second intention or be closed primarily. The average area of the defects for free flap reconstruction was approximately 15.8×7.1 cm. In all cases, the radial artery and adjacent superficial subcutaneous veins in the snuffbox were used as the recipient vessels. The donor sites were all covered with STSG. Four sensate RF flaps were performed (Table 1). To reconstruct the recipient digit sensation, the superficial branch of radial nerve was reanastomosed to proximal end of RF flap radial nerve. The Kapandji classification[5] was used for the evaluation of basic hand function after reconstruction surgery of thumb.

RESULTS

All of flaps survived completely, and the wounds and donor sites healed without complications. Follow-up period ranged from 6 to 47 months (mean, 22 months). Two patients, who underwent thumb reconstruction (patients 3 and 6) achieved opposable basic hand function (grade 10 of Kapandji classification[5]). Compared to the normal side, the average of key pinch was 98.6% and grasping was 96.9%. The mean range of motion of the thumb interphalangeal joint was 80°. The proximal interphalangeal joint of the index finger had a range of motion from 80° to 85° (mean 82.5°), and the distal interphalangeal joint had a range of motion from 65° to 70° (mean 67.5°) .

Four sensate RF flaps provided glabrous skin of reconstructed digits that was sensate, stabile, and durable, with a static 2-point discrimination of 8 to 12 mm (mean, 9.5 mm). Static 2-point discrimination for the other 2 patients ranged from 11 to 12 mm (mean, 11.5 mm) (Table 1). However, the patients with sensate flaps did not show better static 2-point discrimination than that of patients with nonsensate flaps when analysis by an independent samples t-test ($p = 0.15$). The protective sensation was restored within 1 year in patients with nonsensate flaps.

Case reports

Case 2

A 48-year-old man suffered from a degloving injury of his left index finger due to crushed by an roller machine accident; the finger showed complete loss of the skin envelope at the level of the metacarpophalangeal joint (Figure 1A). The degloved skin envelope could not be replanted, and the patient did not want to use the cutaneous part of the second toe wrap-around flap. Therefore, after debridement, a free RF flap, 19×4.5 cm in size, was raised from his right forearm and was transferred to cover the exposed bones and tendons of the index finger (Figure 1B,C,D). The arterial pedicle was anastomosed end-to-side to the radial artery at the anatomical snuffbox, and the venous pedicle was end-to-end anastomosed to the venae comitantes of the radial artery. The donor site was

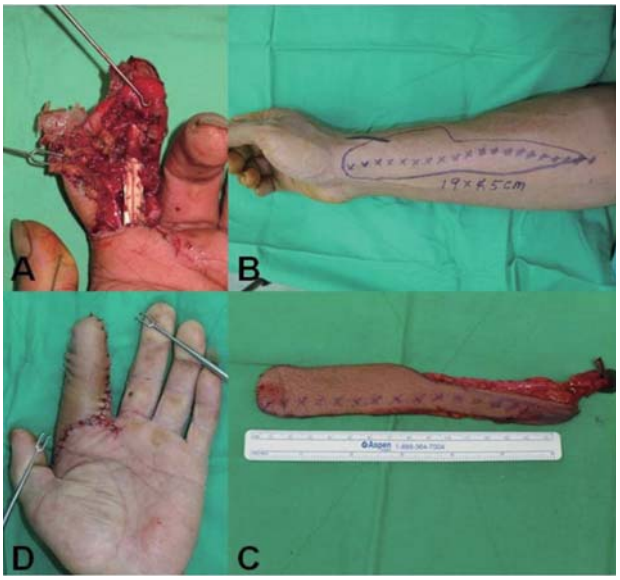

Fig. 1 Preoperative view of complete circumferential skin loss of the left index with intact tendon and bone (A). The free RF flap was outlined over the right forearm (B,C). Intraoperative view of the resurfaced index finger (D).

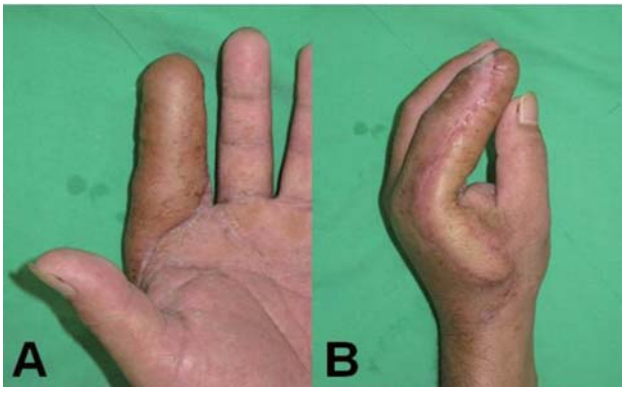

Fig. 2 At 6-month follow-up, the index recovered acceptable appearance (A) and range of motion (B).

covered with split-thickness skin graft. The postoperative course was uneventful, and the patient was discharged on the tenth day. Six months later, the patient showed a good contour and achieved basic hand function (Figure 2). The range of active motion of the proximal interphalangeal joint of the index finger was 0^{o} to 80^{o}, whereas that of the distal interphalangeal joint was 0^{o} to 65^{o}. Compared to the normal side, the recovery of key pinch was 93% and grasping was 96%. The static 2-point discrimination value of fingertip in this patient was 11 mm.

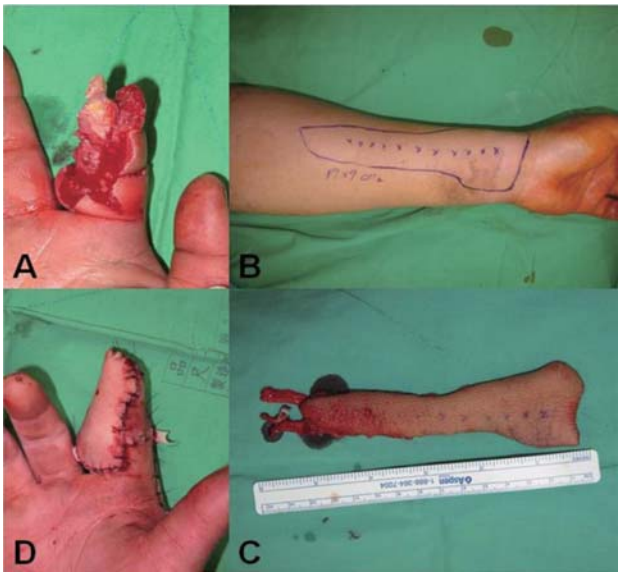

Fig. 3 Preoperative view of extensive soft tissue defect of the right index with intact tendon and bone (A). An 17×7 cm free RF flap was required to cover the defect (B,C). Intraoperative view of the resurfaced index finger (D).

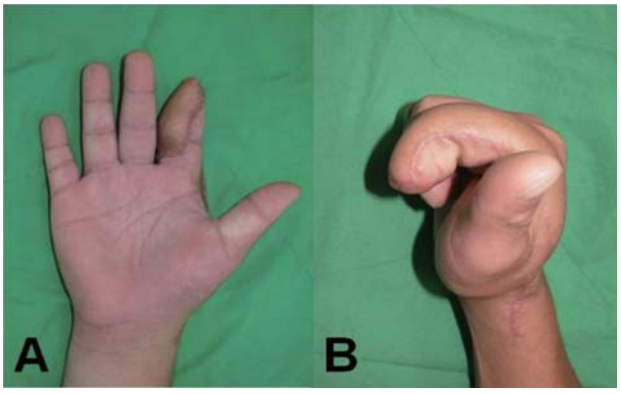

Fig. 4 At 9-month follow-up, the index recovered acceptable appearance (A) and range of motion (B).

Case 5

A 20-year-old man suffered from a traumatic degloving injury of his right index finger, when his dominant hand was caught in a rotating machine. The defect was circumferentially at the level of the metacarpophalangeal joint and the tendon, bone, and joint coverage was preserved (Figure 3A). Therefore, after debridement, a 17×7 cm free RF flap was raised and then transferred to cover the defect. The arterial pedicle of flap was anastomosed end-to-side to the radial artery at the distal forearm and the venous pedicle was end-to-end to the venae comitantes of the radial artery (Figure 3B,C,D). The do-

nor site was covered with a split-thickness skin graft. The postoperative course was uneventful. Nine months later, the patient showed a good contour and achieved basic hand function (Figure 4). The range of active motion of the proximal interphalangeal joint of the index finger was 0^o to 85^o, whereas that of the distal interphalangeal joint was 0^o to 70^o. Compared to the normal side, the recovery of key pinch was 99% and grasping was 96.8%. The static 2-point discrimination value in this patient was 8 mm.

DISCUSSION

Traumatic soft tissue defects of the finger are encountered frequently. Reconstruction of a denuded finger with exposed intact functional bone and tendon poses a difficult problem in hand surgery because of the scarcity of muscle and skin in this region. Although the avulsed skin should be used for wound coverage when possible[6], however, the tissues and vascular structures are usually traumatized that replantation is not feasible. Although many methods are available for managing this type of injury while preserving function and lessening deformities, no ideal procedure exists at present. The general consensus among hand surgeons is that prompt coverage of raw areas and early motion exercise are the key factors in successful treatment of avulsed fingers.

The ultimate goal in this situation is to provide the best functional and aesthetic outcomes with the least donor site morbidity. Therapeutic options include primary closure, skin grafting, local flaps, and free tissue transfer. Circumferential stripped fingers with circulatory disturbance constitute an unfavorable bed for skin grafts. In addition, skin grafting is not usually considered because of problems associated with wound contraction, non-gliding of tendons directly under skin grafts, and avascular necrosis of the distal bones. Although local flaps, such as palmar advancement flaps, homo- or hetero-digital flaps, cross finger flaps, or dorsally based dorsal hand flaps, offer the main advantage of “replacing like with like”, their use are limited by the size and location of the defect and are not always suitable.[7,8,9]

Reconstruction of digital defects can be performed using distant pedicle flaps from the groin, trunk, or contralateral arm.[10,11,12] This method requires that the injured hand must be attached to the distant body part for at least 2 weeks, which usually causes joint stiffness after prolong immobilization. The other disadvantage of this technique is that the flaps are bulky and require multiple, staged defatting procedures. Free flaps offer flexibility in size, shape, and positioning and do not add donor site morbidity to the injured hand. Although free flap is technically more demanding, they offer a favorable cosmetic result and is superior to local options.

Options of free flap donor site are include the PIOA flap[13,14], RF flap[15], AMT flap, MSA flap, dorsalis pedis flap[16,17], and lateral arm flap;[18,19] other options specifically for the thumb are the great toe hemi-pulp to thumb transfer[20], the wrap around toe flap[21], and the great toe wrap-around flap combined with the second toe medial flap.[22] The PIOA flap is thin, pliable, and can be used as a sensory flap for small-to-moderate defects. It has a good skin color to match the skin color of the digits, but it is not always reliable due to anatomical variations and possible partial necrosis.[13,14] The AMT flap has a longer vascular pedicle and allows simultaneous flap harvest, but it has a relatively bulky appearance and is not always reliable because of no AMT perforators in up to 20% cases.[23]

The MSA flap is reliable as a sensory flap for small-to-moderate defects, but it also has a relatively bulky appearance with a short pedicle.[24] There were two case series focus on total circumferential degloving injury in the digits in literature at present by using the lateral arm flap, but the founctional result was seldom satisfactorily due to the bulkiness of the flap and the short vascular pedicle.[18,19] The dorsalis pedis flap, first reported by O’Brien and Shanmugan in 1973[25], is broad and long enough to cover vulnerable parts easily. However, this flap causes high donor site morbidity, such as pain over the donor site when wearing open toed sandals, and yields unacceptable cosmetic results. The same complicatons were also observed in the wrap-around flaps.[20,21,22]

The free RF flap was first used in patients with degloving injuries of the fingers, described by Adani et al. in 1995.[26] This method allowed early mobilization and preservation of reasonable mobility of the metacarpophalangeal joint and the proximal interphalangeal joints, and resulted in good key pinch power and prehension in all patients. The RF flap is a thin flap, which is pliable, always reliable, easy to design and harvest, and can be used as a sensory flap for moderate-to-large defects. It also matches the skin color of the digits well and allows two-team operation. Although it can be designed as either distally based flap or free flap, venous congestion in the distally based RF flap resulting in partial flap compromise has been encountered and described in the literature.[27,28] Free RF flap is easily tailored to fit the defect and covers the finger tip without marginal necrosis.[30,31] The disadvantages of the RF flap are that sacrifice of a major artery is necessary and the donor site is left with an unsightly scar.[29] The reasons of choosing RF flap including the

large, thin, pliable, easy performing and good functional results. The procedures of flap design and anchoring should be noticed including complete coverage of defect, adequate tension, nerve protection and the direction of scar formation. The micro-ICU monitoring of flap, finger and web extension splint, quitting of smoking, Kentamin administration and earlier rehabilitation were performed in post-operative care.

In our report, nerve repair was performed as much as possible, unless the patient had suffered severe avulsion with a long segment of nerve defect. Four patients received sensate flap reconstruction with the superficial sensory nerve being incorporated into the flap. However, results of the static 2-point discrimination test (flap distal end) were not significant different between the sensate and nonsensate groups during the follow-up period. There were many sensory recepters with the most cloudy density nerve ending within the fingers. The regeneration of nerve sensation of fingers was not only from the sensory nerve repair. The residual nerve fibers could inosculate into the flap gradually. There was no significant difference of nerve regeneration in two groups. The severe crushed finger might be repair as a sensate flap because preserving less soft tissue and nerve endings. In fact, protective sensation was restored within 1 year in patients with nonsensate flaps (Table 1). In our series, the patients could return to their daily work with the sufficient finger sensation without insensate ulceration on flap during long term follow up. Therefore, the monofilament test was not routinely used for sensate flap test and it could not be checked in this kind of flaps due to difficult regeneration of light-touch nerve endings. The cold intolerance was not found due to adequate arterial inflow of RF flaps.[4,6,8,30]

As to functional results, a relatively normal range of motion could be obtained after free RF flaps reconstruction because intact tendons and bony structures were preserved after degloving injury of the digits. The mean range of motion of the thumb interphalangeal joint was 80^{o}. The range of motion of the proximal interphalangeal joint of the index finger was from 80^{o} to 85^{o} and that of the distal interphalangeal joint was from 65^{o} to 70^{o}. Moreover, the functional outcomes of power of grasp and key pinch were satisfactory and recovered to more than 90% of the normal uninjured side.

In conclusion, our experience showed that the free septocutaneous flaps can be used for resurfacing the defect, restoring acceptable finger function, and preventing amputation for near total circumferential degloving injury of digits. The results of the static 2-point discrimination test were not significantly different between sensate and nonsensate flap groups during one year follow-up period. The RF flap is an alternative choice for resurfacing the degloving injury of digits due to thin and pliable qualities, long pedicle, reliable perforator, easy to design and harvest, and need two-team approach.

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FINANCIAL DISCLOSURE

None of the contributing authors have any conflicts of interest, including specific financial interests and relationships and affiliations relevant to the subject matter or materials discussed in the manuscript.

DISCLOSURE

All authors declare that this study has no conflict of interest.

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