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# One-stage reconstruction of complex soft tissue defects in the hands using multidigit, chimeric, lateral arm, perforator flaps



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## KEYWORDS

Lateral arm flaps;  
Multidigit injury;  
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**Summary Purpose:** To describe our experience using microsurgically fabricated, multilobed, chimeric, lateral arm (LA) flaps to reconstruct hand injuries with complex, multidigit, soft tissue defects and to evaluate the morbidity and esthetic and functional outcomes of the donor sites.

**Methods:** We performed a single center, retrospective analysis of 21 patients with hand wounds treated from October 2013 to February 2016. All patients underwent reconstruction using multilobed, chimeric, free, LA flaps. A self-reported questionnaire was used to assess donor site morbidity and satisfaction with the esthetic and overall functional result. Outcome measures were the Disabilities of the Arm, Shoulder and Hand (DASH) score, static 2-point discrimination score, and visual analogue scale.

**Results:** The study included 21 patients (20 males and 1 female), with an average age of 32.14 years (range 18–45 years), who sustained traumatic injuries in road traffic accidents ( $n=2$ ) or industrial devices ( $n=19$ ). The average DASH score was  $28.25 \pm 2.3$ , the average 2-PD score was  $7.20 \pm 1.30$ , and the average visual analogue scale (VAS) was  $0.38 \pm 0.40$ . All 21 patients had sensory disorders at the donor site. Postoperative donor site complications comprised wound

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dehiscence ( $n=1$ ) and hematoma ( $n=3$ ). The patient-rated satisfaction score for the donor site was  $5.40 \pm 0.90$ , and 70% of the patients would undergo the same surgery again.

**Conclusion:** Microsurgical fabrication of multilobed, chimeric, LA flaps can exhibit sensory recovery and minimal pain but may cause hematoma and sensory disorders at the donor site. The flaps are a viable alternative for the reconstruction of complex, multidigit, soft tissue defects of the hands.

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## Introduction

Multidigit, high-energy hand injuries are challenging for orthopedic and reconstructive surgeons. Appropriate therapy should preserve the esthetic appearance, provide sensate coverage without pain in important regions, and minimize donor site morbidity.<sup>1</sup> Primary wound closure of the donor is required for good esthetic and functional results.<sup>2-4</sup>

Current reconstructive options for complex hand injuries include skin grafts, free flaps, and pedicle flaps (including abdominal and groin flaps).<sup>5-10</sup> These cases require multistage procedures and prolonged splinting to enable free tissue transfer and neovascularization.<sup>11,12</sup> Extensive tissue defects have been covered using free fabricated tissue transfers based on a single pedicle from different vascular systems, offering freedom in the flap setting for complex wounds.<sup>13-17</sup> In traumatic and reconstructive cases, the anterolateral thigh flap is a popular free flap because of its ease of dissection and versatility, but the biggest drawback is the thickness of the flap.<sup>18</sup>

The lateral arm (LA) flap has been widely applied in hand wound reconstruction because of its convenient dissection and high survival rate.<sup>19-21</sup> In addition, the LA flap is thin, pliable, and conforms well to the texture of the hand. In the conventional LA flap method for resurfacing multidigit skin defects, multidigit wounds were combined and covered during the first stage, and the fingers were then divided in the second stage.<sup>22,23</sup> Compared with the conventional LA flap method for multidigit defects, the multilobed LA flap method avoids a second finger-division surgery, results in good sensory return, and enables early mobilization of the fingers, which may shorten the recovery period. However, despite the increasing popularity of multilobed LA flaps, there is a lack of studies assessing the morbidity of the donor site<sup>19,24-25</sup> and the sensory return of the multilobed LA flaps.

The purpose of the present study was to describe our experience using microsurgical fabrication and multilobed flaps from the LA for one-staged reconstruction of multidigit hand injuries and to evaluate the morbidity and esthetic and functional outcomes of the primarily closed donor sites.

## Materials and methods

From October 2013 to February 2016, a total of 21 patients (20 males and 1 female) with a mean age of 32.14 (range 18-45) years with complex two-dimensional defects in the hands underwent reconstructive procedures that included chimeric LA flap transfer. The mechanisms of injury were

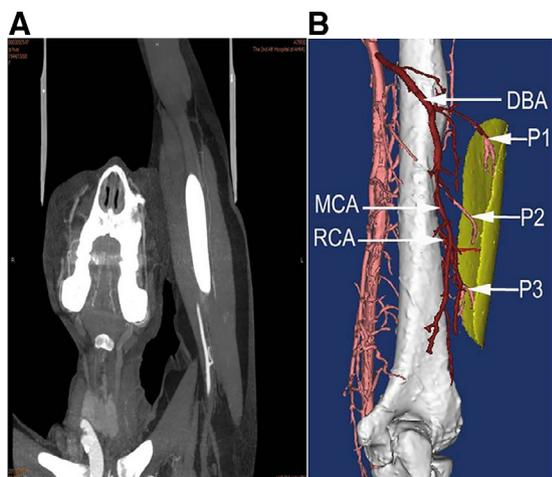
traffic accidents ( $n=2$ ) and industrial injuries ( $n=19$ ). The area of the soft tissue defects ranged from  $8 \times 4 \text{ cm}^2$  to  $11 \times 6 \text{ cm}^2$  (mean,  $8.62 \times 5 \text{ cm}^2$ ). No thumbs were amputated because of trauma. Study approval was granted by the local ethics committee, and informed consent was obtained from each patient.

The subjective donor site morbidity and satisfaction with the esthetic and functional results were assessed by the patients themselves using a self-made, nonstandardized questionnaire. The degree of satisfaction was rated on a scale from 0 to 10 points (0-2 points=poor, 3-5 points=moderate, 6-8 points=good, 9-10 points=excellent). Upper extremity function was assessed using the Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire, which is rated on a scale ranging from 0 to 100, with a higher score indicating a greater degree of disability.<sup>26</sup> The pre- and postoperative ranges of motion of the joints proximal and distal to the donor site (the shoulder and elbow joint) were assessed by physical examination with photographic and video documentation. At final follow-up, sensory restoration of both flap islands was measured using the static 2-point discrimination (2PD) test.<sup>27</sup> The pain at the recipient site was evaluated by the VAS. All outcomes were reported by the same follow-up group, who were blinded to the surgical procedures.

## Operative technique

### Flap design

Upper extremity computed tomographic angiography (CTA) images were procured on a dual source, 64-slice, multidetector, CT scanner (Siemens, Germany). The surgeon first carefully scrutinized the handheld Doppler ultrasonographic and CTA images in the axial plane to identify suitably positioned cutaneous perforators from the posterior radial collateral artery (PRCA) (Figure 1A). A virtual 3D perforator plan and flap delineation of the 3D model were then created preoperatively (Figure 1B). The patient was placed under general anesthesia, and all nonviable tissue and chronic granulation tissue of the wound were debrided. The flap dimensions were planned with the aid of a paper template of the defect. A line was drawn from the insertion of the deltoid to the lateral epicondyle, corresponding to the lateral intermuscular septum between the triceps and brachialis muscles in the uninjured upper limb. In accordance with the shape of the wound and the distance between the wounds over the hand, multilobed skin flaps



**Figure 1** Location of the posterior radial collateral artery (PRCA) perforators. (A) Coronal computed tomographic angiographic image showing the PRCA and its perforator. (B) Three-dimensional reconstruction of the perforators and design of the lateral arm flap. BA, brachial artery; DBA, deep brachial artery; RCA, radial collateral artery; MCA, medial collateral artery; P1, perforator of the deep brachial artery; P2-P3, perforators of the radial collateral artery.

were designed to include the perforators of the descending branch of the PRCA in the upper limb.

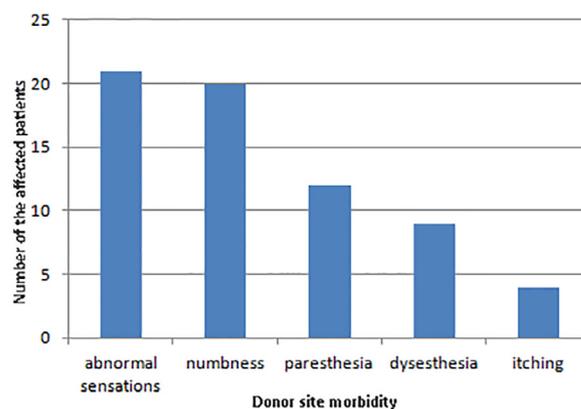
### Flap dissection

Flap elevation was performed from the posterior to the anterior side of the upper arm. It was verified that each flap was supplied by at least one perforator. The skin flaps were tailored such that the point where the perforator entered the skin was located at the proximal part of each flap. Each lobulated flap was isolated from below the deep fascia, while conserving the superficial veins and cutaneous nerves of the flap. The posterior cutaneous nerves of the arm were identified in all patients. The flap was then dissected in a retrograde manner along the PRCA. The effective vascular pedicle length between the flaps and the trunk pedicle length were documented.

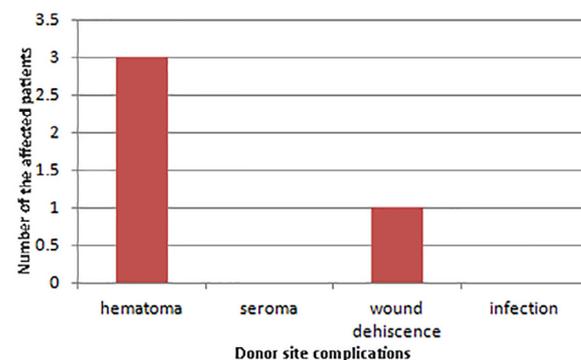
### Anastomoses of blood vessels and nerves

Innervation of the multidigit, chimeric, LA flap was evaluated by coaptation of the branches of the posterior cutaneous nerve of the arm in each island to each of two different palmar dorsal cutaneous nerves at the recipient site. The descending branch of the PRCA was anastomosed to the dorsoradial branch of the radial artery in an end-to-end fashion in all cases.

The postoperative monitoring techniques included evaluation of color, capillary refill, surface temperature, presence of bleeding, and skin graft adherence. The flaps were monitored frequently, especially in the initial postoperative period, as emergency exploration and repair must be performed soon after the occurrence of obstruction.



**Figure 2** Donor site morbidity of the multidigit, chimeric, lateral arm, perforator flaps, consisting of abnormal sensations, numbness, paresthesia, dysesthesia, and itching.



**Figure 3** Postoperative donor site complications of the multidigit, chimeric, lateral arm, perforator flaps, consisting of infection, seroma, hematoma, and wound dehiscence.

## Results

Patient characteristics are displayed in [Table 1](#). The mean chimeric flap size was  $9.05 \times 5.19 \text{ cm}^2$  (range,  $8 \times 4 \text{ cm}^2$  to  $11 \times 6 \text{ cm}^2$ ). The mean operation time for flap harvesting was 2.3 hours, and mean hospital stay was 14.1 days. The donor sites of the LA flaps were directly closed in all patients.

All patients were followed up postoperatively for an average of 18 months (range, 10-32 months). All flaps survived. There were no flap ischemia and/or venous congestion in any patient. The mean DASH score was  $28.25 \pm 2.30$ , the mean static 2PD score was  $7.20 \pm 1.30$  (range, 5-11 mm), and the mean VAS for pain was  $0.38 \pm 0.40$  (range, 0-3). Patient-rated satisfaction with the esthetic and functional outcome was  $5.40 \pm 0.90$  points (range, 1-10 points). Of the 21 patients, 15 (70%) stated that they would choose to undergo the same flap surgery again. The donor site morbidity consisted of abnormal sensations, numbness, paresthesia, dysesthesia, and itching ([Figure 2](#)). Early donor site complications consisted of infection, seroma, hematoma, and wound dehiscence ([Figure 3](#)).

**Table 1** Summary of patient information.

Case no.	Age/sex	Etiology	Finger amputation (n)	Flap size (cm <sup>2</sup> )	AROM elbow (°)	Flap survival
1	20/M	Crush injury	None	10 × 5	0-135	Complete
2	21/M	Crush injury	None	11 × 6	0-140	Complete
3	41/M	Crush injury	None	9 × 5	0-130	Complete
4	18/M	Crush injury	None	9 × 4	0-135	Complete
5	45/F	Crush injury	None	10 × 5	0-130	Complete
6	26/M	Crush injury	1	8 × 6	0-140	Complete
7	29/M	Crush injury	None	10 × 4	0-125	Complete
8	32/M	Crush injury	None	9 × 6	0-130	Complete
9	34/M	Motor vehicle accident	None	8 × 4	0-135	Complete
10	35/M	Crush injury	None	11 × 4	0-125	Complete
11	43/F	Crush injury	None	10 × 6	0-130	Complete
12	37/M	Crush injury	2	9 × 4	0-135	Complete
13	45/M	Crush injury	None	10 × 5	0-130	Complete
14	39/M	Motor vehicle accident	None	9 × 5	0-135	Complete
15	44/M	Crush injury	None	8 × 5	0-120	Complete
16	21/M	Crush injury	None	8 × 6	0-130	Complete
17	26/M	Crush injury	None	7 × 6	0-135	Complete
18	25/M	Crush injury	None	9 × 5	0-125	Complete
19	29/M	Crush injury	None	10 × 6	0-135	Complete
20	30/M	Crush injury	1	8 × 5	0-130	Complete
21	35/M	Crush injury	None	9 × 6	0-140	Complete



**Figure 4** A 37-year-old male with a crush injury to the right hand. (A) Intraoperative view showing irregular and serious soft tissue defects measuring  $3 \times 3 \text{ cm}^2$  on the middle finger and  $3 \times 4 \text{ cm}^2$  on the index finger. (B, C) Intraoperative view of the multilobed, chimeric, free, lateral arm flaps. (D) Intraoperative photographs revealing the flaps that were placed *in situ*. (E) The donor site was directly closed. (F, G) The well-healed wound at 1-month postoperatively.

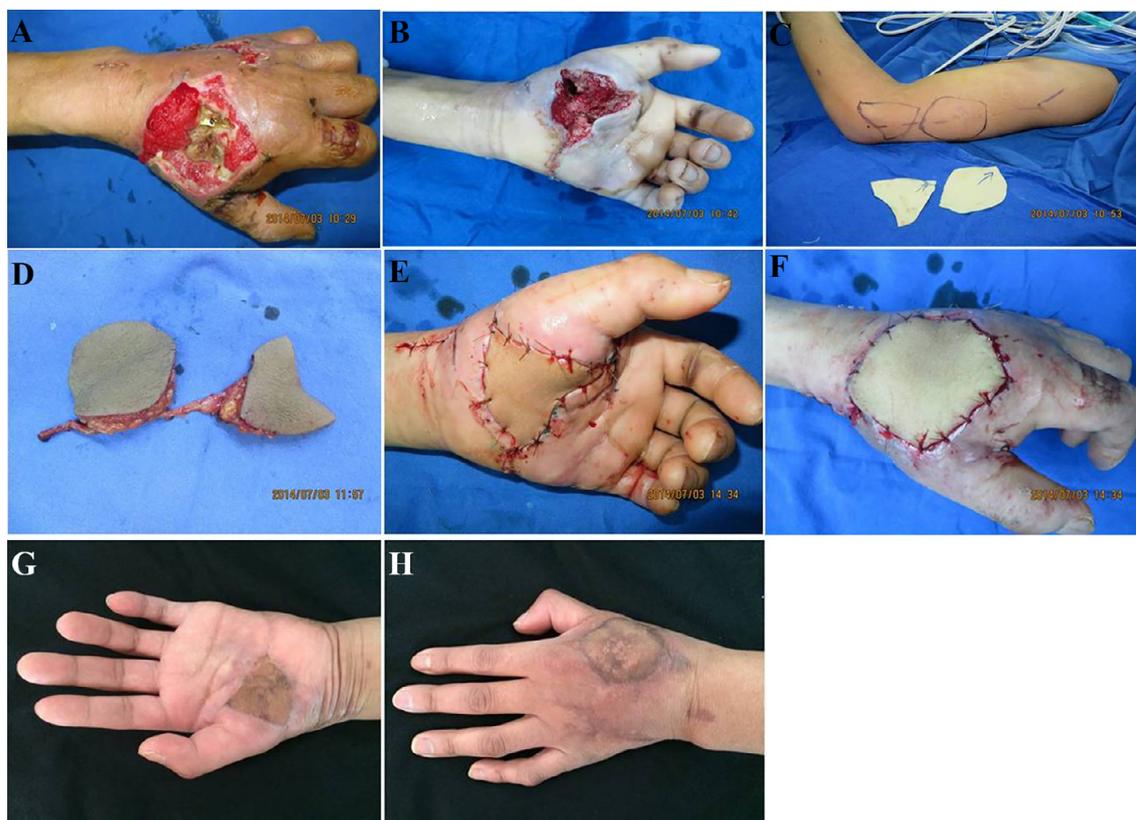
## Case reports

### Case 1

A 37-year-old male sustained a crush injury to the right hand. He presented with irregular and serious soft tissue defects measuring  $3 \times 3 \text{ cm}^2$  on the middle finger and  $3 \times 4 \text{ cm}^2$  on the index finger (Figure 4A). After meticulous debridement, one-stage reconstruction was performed with innervated, multilobed,  $4 \times 4 \text{ cm}^2$  and  $4 \times 5 \text{ cm}^2$  chimeric, LA perforator flaps (Figure 4B and C). The donor site was primarily closed. The recipient vessels were the radial artery and cutaneous vein (Figure 4D). Early mobilization was apparent at 1 month postoperatively (Figure 4E and F).

### Case 2

A 20-year-old male sustained a crush injury to the left hand in a factory accident. He presented with irregular and extensive soft tissue defects measuring  $4 \times 4 \text{ cm}^2$  on the dorsum of the hand and  $5 \times 4 \text{ cm}^2$  on the palm. In addition, the patient had previously undergone fixation of a second metacarpal fracture; the plate was exposed at the defect site, and the dorsal cutaneous nerve of the hand was ruptured (Figure 5A and B). After meticulous debridement, one-stage reconstruction was performed with innervated, multilobed,  $5 \times 4 \text{ cm}^2$  and  $5 \times 5 \text{ cm}^2$  chimeric, LA perforator flaps (Figure 5C and D). The donor site was primarily closed. The recipient vessels were the radial artery and cutaneous vein



**Figure 5** A 20-year-old male who sustained a crush injury to the left hand in a factory accident. (A, B) Intraoperative imaging demonstrated a massive soft tissue defect on the dorsum and palm of the left hand. In addition, a plate from a previous surgery was exposed at the defect site. (C, D) Intraoperative view of the multilobed, chimeric, free, lateral arm flaps. (E, F) Intraoperative view after final insertion of the flaps. (G, H) The result was satisfactory at 11 months postoperatively.

(Figure 5E and F). A branch of the posterior cutaneous nerve of the arm was coapted to the superficial radial nerve at the defect site. Early mobilization was apparent at 11 months postoperatively (Figure 5G and H).

## Discussion

In cases with complex, multidigit, soft tissue defects in the hands, it is challenging to obtain adequate coverage of the exposed regions while achieving minimal donor site morbidity. When choosing the appropriate flap donor site, surgeons must consider the size, thickness, color, and texture of the harvest site. The LA flap is extensively used for the reconstruction of complex defects of the upper extremities.<sup>28</sup> However, when using the classic LA flaps, it is difficult to repair digital, irregular, and ring-like soft tissue defects in the hands. Furthermore, postoperative donor site morbidity must also be considered. The characteristics of the potential donor sites have been previously studied in detail. The present study reports the feasibility of one-stage reconstruction of complex hand wounds using multilobed, chimeric, free LA flaps and evaluated the morbidity and esthetic and functional outcomes of the primarily closed donor sites.

In the present study, the chimeric flaps were designed in accordance with the size and characteristics of the

recipient site. Our standard preoperative assessment procedure already consists of CTA and hand-held Doppler flowmetry to evaluate the vascular anatomy; this information is then used to create a virtual 3D perforator plan, as CTA can accurately determine the location and course of the perforators, and identify any vascular anomalies.<sup>29</sup> The distal LA flap has valuable advantages over the classic LA flap, such as a longer pedicle, less bulk, and decreased sensory loss at the donor site, without significantly affecting elbow function.<sup>30</sup> Although some authors have reported that the most common donor site problems of the LA (such as hypesthesia and a broad scar) are infrequent and minor,<sup>31</sup> all 21 of the present patients had abnormal sensations at the donor site. One study reported that sensory disturbance at the donor site occurred in 61.4% of patients.<sup>32</sup> Another study reported that a broad scar occurred in 75% of 37 patients<sup>33</sup>; however, 24 of 37 patients reported a “good” esthetic outcome at the donor site.<sup>33</sup> In contrast to these results, the patients in our study rated the esthetic result as “moderate,” although there were no dog-ear malformations at the donor site. One study reported that wound dehiscence occurred in 20% of 20 patients<sup>34</sup>; however, only one patient experienced wound dehiscence at the donor site in our study.

The present retrospective study revealed that patients with visible scars reported low levels of satisfaction. This may be because the scar is in the patient’s direct field of vision or because of the characteristics of the donor site. The

dermal thickness and soft tissue elasticity depend mainly on the patient's age and the thickness of the subcutaneous tissue.<sup>34</sup> Minimization of pain is reportedly more important than sensory recovery, as pain can cause severe psychological and physical morbidity.<sup>35</sup> The average VAS for pain in our study was relatively low, and most patients had no pain postoperatively. As a comprehensive and direct metric evaluation, the DASH score is very important in the evaluation of hand surgery.<sup>34</sup> The mean DASH score in the present study indicated a favorable functional outcome in the affected upper extremity.

The use of free flaps has several advantages in soft tissue reconstruction of hand wounds. The free LA flap provides up to 6 × 11 cm<sup>2</sup> of soft tissue coverage, which is ideal for small wounds of the distal extremities that cannot be closed primarily. The palm is a region in which sensate reconstruction is considered mandatory. In the present study, reconstruction with innervated flaps achieved a good mean static 2PD score, indicating adequate sensory restoration. The accuracy of the preoperative ultrasonographic identification of the perforators ensures that the designs of smaller skin flaps result in optimal reconstruction. However, caution should be used when guiding microsurgeons during the learning curve to minimize the risks of such techniques. The techniques described in the present series were performed by senior surgeons in a mature team of microsurgeons with extensive experience in the field.

The main limitation of the present study is the small sample size; outcomes may vary in other or larger cohorts. Future studies will ideally be comparative, randomized, and blinded to better ascertain the efficacy of different flaps.

## Conclusion

Multilobed, chimeric, free LA flaps can be used to reconstruct complex, multidigit hand wounds, resulting in sensory recovery and minimal pain. While free flap dissections can often be time-consuming and complex procedures, the LA flaps can be dissected quickly and with relative ease. Complications included hematoma and sensory disorders at the donor site. Although the present study included a small sample, it shows that the LA flap is a viable alternative to other flaps previously described for multidigit hand wounds.

## Conflict of interest

The authors declare that they have no competing interests.

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