Treatment of Defects on the Volar Surface of the Finger using the Dorsal Digital–metacarpal Flap Versus the Free Medial Plantar Artery Flap: A Comparative Study

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Research article

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Abstract

Background

Few cases are reported on the treatment of defects on the volar surface of the finger, and its utility for digital resurfacing remains unclear. This study compared the outcomes of the free medial plantar artery flap (MPAF) and dorsal digital–metacarpal flap (DDMF) in finger reconstruction.

Methods

This cohort study was conducted on 24 patients who had soft-tissue defects on the volar side of the finger from March 2014 to March 2017. The patients were divided into the following 2 groups: the MPAF group and the DDMF group. The operative time as well as complications, including flap necrosis, graft loss, infection, paresthesia, donor-site morbidity, and two-point discrimination (2-PD) were carefully recorded. The Michigan Hand Outcomes Questionnaire (MHQ) was applied to conduct follow-up assessment.

Results

After more than 12 months of follow-up, the results were significant. In terms of overall function, MPAF was superior to DDMF ($p < 0.005$).

Conclusion

The MPAF and the DDMF are available and reliable for reconstruction of the volar surface of the finger; however, the MPAF offers better functional outcomes with a lower frequency of postoperative complications.

Background

Soft-tissue defect on the volar surface of the finger is a highly common situation in daily life. “Replacement of like with like” has become a key principle for plastic surgery techniques used in soft-tissue defect coverage.

The palmar surface of the hand has highly specialized skin that has its own structural characteristics with good sensibility and ability to restore skin stability to resist friction; therefore, this must be considered in the reconstruction. Several methods have been reported in previous studies, such as skin graft, cross finger flaps, local flap transfer, and free flaps. Each can meet wound coverage requirements; however, none of these methods is perfect.

Dorsal digital–metacarpal flap (DDMF) is a simple and easily available option for digital reconstruction[1, 2]. Following the first description of the dorsal metacarpal artery flap (DMAF) by Holevich[3], Foucher and Brauna improved it and designed a sensate island flap raised on the first DMAF with its concomitant veins and a sensory branch of the superficial radial nerve in 1979[4]. It then became popular and was used for reconstruction of soft-tissue defects of the hand because it enabled not only covered the wound defect and provided robust blood supply, but also has relatively fewer technical requirements.

Plantar skin is glabrous and thick, with solid anchorage to the deep structures, similar to the palmar skin. Shanahan et al[5]. first started the use of the medial plantar sensory flap to solve the problem of heel defects early in 1979. Subsequently, Oberlin et al[6]. demonstrated that it provided stable, pliable, durable, innervated, glabrous, and non-hairy skin. This is a relatively ideal supply area to the palmar. Moreover, with significant advances in microsurgery, it is not technically challenging to design free flaps based on the medial plantar artery.

Although some methods have been used to resurface whole palm defects and thumb contractures, the number of cases remains small and its utility for digital resurfacing remains unclear. The purpose of this study was to compare the outcomes of the free medial plantar artery flap (MPAF) and DDMF on the volar surface defects for finger reconstruction to provide better treatment suggestions.

Methods:

This cohort study was designed according to the guidance of the Helsinki declaration and approved by Jilin University, China (license number: SCXK (Ji) 20140084).This cohort study wasconducted on patients with soft-tissue defects on the volar surface of the finger because of trauma from March 2014 to March 2017,all patients signed the informed consent. For all the patients, full history was recorded and detailed clinical examination and radiography were performed to assess the skeletal effects and arterial duplex scanning to assess the vascular pattern of the hand.

Those who had systematic diseases, including diabetes mellitus, vascular sclerosis, and peripheral vascular disease, those who could not withstand long-time operation, and those who had a positive smoking history were excluded from this study, along with those with bad local conditions. Patients were notified about the merits and demerits of each method and themselves made the choice. Simultaneously, written informed consent was obtained from all the participants.

Total 24 patients were enrolled in the study with an average age of 38.9 years (20–65 years); 18 subjects were men (75%), and 6 were women (25%). All skin and soft-tissue defects were caused by trauma. The defects were localized at the volar surface of the finger with exposed flexor tendons. The patients were divided into the following 2 groups: the MPAF group and the DDMF group; all procedures were performed by a single surgeon. The locations were as follows: thumb, 7; index finger, 4; middle finger, 4; and ring finger, 9. Among of them, 13 had only skin and soft-tissue defects, and the other 11 fingers (MPAF: 6 cases/DDMF: 5 cases) had nerve defects/injury. The nerve was repaired applying different methods

(MPAF: nerve bridging, DDMF: flap with neurovascular bundle or proper digital dorsal nerve was anastomosed with the digital nerve). Demographic patient data is presented in **Table 1**.

A survey was conducted at least 12 months after the surgery to investigate the operative time and complications, including flap necrosis, graft loss, infection, paresthesia, and donor-site morbidity that were carefully recorded. The Michigan Hand Outcomes Questionnaire (MHQ)[7] was applied to assess patient satisfaction with the result for all patients. The questionnaire consists of five domains, including hand function, activities of daily living, work performance, aesthetics, and satisfaction with hand function. It was scored on a scale from 0–100 (0 = worst result, 100 = best result). In particular, the aesthetic appearance (full appearance, soft texture, color consistent with the finger volar skin, and pigmentation) of the injured hand was measured with a cosmetics score (0 = worst cosmetic result, 10 = best cosmetic result). Differences between independent parametric variables were assessed with t-test for independent samples. Probabilities of < 0.05 were considered to indicate significance.

Surgical method/technology:

The wound was subjected to radical debridement before reconstruction because most cases were those of trauma. Necrotic tissue was removed, and antibiotic therapy was administered on the basis of microbiology results until the local wound bacterial culture confirmed the absence of infection. Thereafter, flap and nerve bridging were performed to repair the soft tissue and nerve defects in the second stage.

The operation was performed under general anesthesia or nerve block. The pneumatic tourniquet was applied to provide a bloodless field. Surface marker measurement and pre-operative photography was completed; antibiotics were injected intravenously before tourniquet application.

The MPAF is located in the non-weight-bearing area of the plantar on both sides of the axis and behind the head of the metatarsal bone. The size and shape of the flap can be designed and dissected as per the wound size, but generally cannot be $> 4 \times 8$ cm[8,9]. The medial plantar artery and the medial plantar nerve can be identified between the abductor hallucis and flexor digitorum brevis. The flap was then elevated at the superficial muscle membrane of the abductor halluces and isolated from the distal to the proximal direction. The medial plantar artery was anastomosed with the digital proper arteries or the common palmar digital arteries; the dorsal veins of the finger or palm were anastomosed with the accompanying vein of the plantar metatarsal artery. In order to ensure that the flap was sensate, the branches supplying the flap were isolated and teased out from the main trunk of the medial plantar nerve. The proximal and distal ends of the flap nerve should be sutured with the proper digital nerve. The donor site of the flaps was primarily grafted with a split-thickness skin graft. **Fig 1.**

The DDMF was located between the metacarpals and with rotation point located at the proximal phalanx level. It was designed on the intermetacarpal spaces as an ellipse centered over the dorsal metacarpal arteries (DMA) that were ligated at the proximal margin of the flap. The flap was elevated in the interosseous fascial plane. The pivot point of the flap was located at the mid-point of the proximal

phalanx where the proximal dorsal branch of the digital artery anastomoses with the dorsal digital artery. It can be transferred to the defect through an open tunnel, and the secondary defect was closed primarily or with skin graft. **Fig 2.**

Statistical Analyses:

The data are presented as the mean ± standard error of the mean values. The incidence of complications, functional outcomes, and other qualitative parameters were compared using the Fisher's exact test. The mean operative time between the two groups and other quantitative were analyzed using the t-test. The level of significance was set at $p < 0.05$.

Results:

The follow-up time ranged from 12–18 months (mean 14.6 months). No significant differences were present between the two groups in the terms of age, sex, etiology, nerve injury, or site and size of the defect. Despite infection in several patients, none developed necrotic flaps after dressing changes and anti-infection treatment.

For all the patients, the donor site had no serious complications, such as flap necrosis and graft loss, except for a relatively unsightly scar; however, they showed an uneventful course of recovery and good graft outcome. Even those with MPAF healed well or had callus formation, and experienced no adverse effect on walking. Although in DDMF, one case had a complication of hyperplastic scar contracture decreasing the range of motion, it improved normal through rehabilitation.

Complete weight bearing occurred significantly earlier in the DDMF (3–5 days) group than in the MPAF (9–12 days) ($P < 0.05$). The defect size, either MPAF or DDMF, was comparable for the wound in the finger ($P > 0.05$) (Table 2). The largest flap was 2 × 4 cm, and the smallest was 2 × 1 cm. There was a significant difference in the operative time; the MPAF group had a significantly longer operative time than the DDMF group (117 ± 5.0 min vs. 73 ± 3.9 min; $p < 0.001$).

Table 1 General statistics:

Variable	MPAF Group (N = 12)	DDMF Group (N = 12)	P Value
Age(y)	38.4 ± 2.4	39.2 ± 3.8	NS
Sex			NS
Male	8	10	
Female	4	2	
Defect site			NS
thumb	3	4	
index finger	2	2	
middle finger	2	2	
ring finger	5	4	
Nerve defect	N = 6	N = 5	NS
Thumb	0	0	
Index finger	1	1	
Middle finger	1	1	
ring finger	4	3	
Defect size (cm^2)	3.9 ± 1.9	3.8 ± 1.7	> 0.005

MPAF: medial plantar artery flap; DDMF: dorsal digital–metacarpal flap; NS: not significant; Data presented as mean ± standard error of the mean or n.

Table 2
outcomes data:

Variable	MPAF Group (N = 12)	DDMF Group (N = 12)	Normal finger	P Value
Operative time (min)	117 ± 5.0	73 ± 3.9		< 0.001
Weight-bearing time (d)	10 ± 0.94	4.0 ± 0.74		< 0.001
2PD nerve injury	5.4 ± 1.41 (n = 6)	6.3 ± 0.25 (n = 5)		< 0.001
(mm) uninjury	4.55 ± 0.27 (n = 6)	4.7 ± 0.20 (n = 7)		= 0.439
P Value	P < 0.001	P = 0.001		
Aesthetics score	8.7 ± 0.5	7.3 ± 0.6	10	< 0.001
MHQ score	86.48 ± 2.52	78.22 ± 3.06	100	< 0.005
Overall function	10 (83.3)	1 (8.33)		0.001
Excellent	2 (16.7)	11 (91.67)		
Good	0	0		
Poor				
2-PD: two-point discrimination. MHQ: Michigan Hand Outcomes Questionnaire				
Data presented as mean ± standard error of the mean.				

The two-point discrimination (2-PD) test, On an average, there was no significant difference between the uninjured cases of the two groups (p = 0.414), both of which were better than the injured cases (P < 0.05). However, there were obvious differences between the injured cases; the results of MPAF were superior to those of DDMF (P = 0.004).

The aesthetics (complete appearance, soft texture, color consistent with the finger volar skin color, and no pigmentation) and MHQ results were included in the evaluation of overall functional recovery. After more than 6 months of follow-up, the MPAF group was closer to the normal side and had a higher cosmetic score than the DDMF group(P < 0.001).

The overall function was graded as excellent, good, or poor. We defined the criteria for excellent results as survival of the flap and average MHQ score ≥ 85 without complications; survival of the flap with an average MHQ score 60–84 and minimum complications were the criteria for good results. A result was considered poor when an alternative reconstructive procedure was required or the average MHQ score was < 60. In the MPAF group, 10 patients had excellent results, and 2 had good results. In the DDMF group, 1 patient had excellent results, and 11 had good results. The improvement in the functional outcome was greater in the MPAF group than in the DDMF group (P < 0.005).

Discussion:

Hand trauma accounts for about 12% of all trauma cases and is the most common reason for emergency treatment, accounting for about 1/5 of all emergency patients[10, 11]. The results of defect coverage are closely related to the patient's quality of life, functional recovery, and appearance. The difficulty is in following the key principle of "like with like". Both, the appearance and functionality need to be considered.

The volar surface of the finger has a particular structure and characteristics, such as thickness and toughness with poor mobility, poor flexibility, thick cuticle layer, and absence of hair follicles. Although with the development of flap surgery, several repair methods have been developed, the number of cases remains small and its utility for digital resurfacing is yet to be fully clarified. Currently, DDMF[12, 14] and free MPAF[15, 22]are commonly used. In order to understand which method is superior and provides better treatment outcomes, we compared the outcomes of the two methods (DDMF and MPAF) to evaluate the effects.

According to the anatomy of finger and the defect size, Morrison WA and Yang KM found that MPAF can be designed and dissected less to than 4 × 8 cm.[8, 9] Backhach et al[16] and Pelissier et al [17] also reported that DDMF with a large donor site can allow total coverage of digital skin defects. Thus, both DDMF and MPAF can resolve moderate-size defects. In this study, the largest defect was 2 × 4 cm, and the smallest was 2 × 1 cm. There was no significant difference between the two groups ($P > 0.05$).

The operative time was significantly longer in the MPAF group than in the DDMF group (117 ± 5.0 min vs. 73 ± 3.9 minutes; $p < .001$), both of which were performed by a single surgeon. In a similar comparative study, Wael Hussein Mahmoud found that the surgery duration was longer in the medial plantar flap than in the distally based sural artery flap (90–130 min vs. 60–100 min). This could be explained by dissection of the medial plantar flap and micro-technique that make the process difficult[18, 19]. Although microsurgery is commonly performed in clinical practice with the development of technology and equipment, it has the limitation of being tedious and technically demanding. In contrast, DDMF with neurovascular bundle offers reliable blood supply and is relatively simpler in terms of technique without vascular anastomosis.

In our series, recovery of sensation in the flap was measured using a static 2-point discrimination (2-PD) test[20]. On an average, there was no significant difference between the uninjured cases in the two groups ($p = 0.414$), both of which were better than the injured cases ($P < 0.05$). However, there were obvious differences between the injured cases in the two groups; the results of MPAF were superior to those with DDMF ($P = 0.004$). Similarly, Yang D had reported in 2001 that DDMF as a retrograde flap is not sensitive, except in rare cases where the proper digital dorsal nerve was anastomosed with the digital nerve[21, 22]. However, unlike our findings, Qi-Shun Huang reported no significant difference between bridging cases and uninjured cases,and both of them better than those were sutured no tension when using the MPAF to repair defects of palm volar skin[23].

Donor-site morbidity following harvest of the flap is another issue that cannot be ignored while evaluating the overall functional effect. We found that the donor site defect can be closed directly leaving only one linear scar on the dorsum of the hand in DMAF. In contrast, it needed a skin graft for resolution in DDAF and MPAF. Hyperpigmentation and hypertrophic scarring are common complications[24] after full thickness skin grafting that creates a gross mismatch in color and affects metacarpophalangeal joint motion. The aesthetic result is potentially inferior in ethnic groups with darker pigmented skin. However, the donor site of the MPAF is located on the non-weight-bearing position of the foot in contrast to that for DDAF that has the obvious advantage of concealment without affecting the function of the foot. According to follow-up questionnaire, patient satisfaction was significantly better with MPAF than with DDMF, especially among young female patients, even if only one linear scar was left for DMAF. Moreover, if the flap is oversized and extends proximally over the metacarpophalangeal joint, it may decrease the range of motion because of hyperplastic scar contracture. Although in our series, there was one case with a similar situation; the patient showed improvement through rehabilitation. However, there was no dysfunction in MPAF except local pigmentation, consistent with previous reports by relevant scholars[23].

Conclusions

In sum, the MPAF and the DDMF are available for reconstruction of the volar surface of the finger. Irrespective of the technical requirements, DDMF, it is a single-stage procedure and has a wide arc of flap transposition, thus preventing the need of a free flap[25]. MPAF is an ideal donor site and can resolve the nerve defects. Although postoperative recovery of hand function mainly depends on trauma, other conditions were excluded, and the repair of skin and soft tissue and nerve defects were compared. We found that MPAF offers better functional outcomes with a lower frequency of postoperative complications.

The limitations of the study include a small sample size, lack of random treatment allocation, and biases associated with the surgeon assessing the outcomes. Thus, larger, prospective, randomized, blinded studies are required to better ascertain the efficacy of the outcomes.

Abbreviations

MPAF: medial plantar artery flap; DDMF: dorsal digital–metacarpal flap; 2-PD: two-point discrimination; MHQ: Michigan Hand Outcomes Questionnaire.

Declarations

Ethics approval and consent to participate

This study was approved by the Research Ethics Committee of the Second Hospital of Jilin University.

Availability of data and materials

All data generated or analyzed during this study are included in this article.

Competing interests

The authors declare that they have no competing interests.

Consent for publication

We have obtained the written consent for publication from all featured patients.

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Authors' contributions

All authors have intellectually contributed to this manuscript. QL wrote the manuscript. WG analyzed and interpreted the data. WQ and XO confirmed the results. RL and HT reviewed the notes and edited the document. All authors read and approved the final manuscript.

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Figures

Figure 1

MPAF method. (A) A 45-year-old man with post-traumatic soft-tissue defect of the thumb after debridement. (B) Harvesting of MPAF. (D) Intraoperative photography showed neurovascular anastomosis. (D,E) Postoperative photograph showing wound healing of the flap and skin graft.

Figure 2

DDAF method (A) A 42-year-old man with post-traumatic necrosis of the distal segment of the right thumb. (B) Harvesting of the DDAF. (C,D) The wound was covered immediately, and the donor site was covered with a split-thickness skin graft. (E) Postoperative photograph shows wound healing of the flap and skin graft.