First dorsal metacarpal artery flap with dorsal digital nerve with or without dorsal branch of the proper digital nerve produces comparable short-term sensory outcomes

Shi-Ming Feng1,2†, Jia-Ju Zhao1†, Filippo Migliorini3*, Nicola Maffulli4,5,6 and Wei Xu1*

Abstract

Background: The first dorsal metacarpal artery flap, including dorsal digital nerves with or without dorsal branches of the proper digital nerves, can be used to reconstruct thumb pulp defects with good results. However, it is still unclear whether there are differences in the sensory outcomes between preserving or not preserving the dorsal branches of the proper digital nerves.

Methods: This retrospective cohort study included 137 thumb pulp defect patients who underwent first dorsal metacarpal artery flap reconstruction procedure from October 2015 to June 2019. Patients were divided into two groups according to whether the dorsal branches of the proper digital nerves were preserved. In the non-preservation group (n = 80), the dorsal digital nerves were included in the flap for sensory reconstruction. In the preservation group (n = 57), the dorsal digital nerves and the dorsal branches of the proper digital nerves of the index finger were included in the flap. The stump of the proper digital nerves in the defect was coaptated to the donor nerves of the flap using the end-to-end fashion. At the last follow-up, static two-point discrimination, Semmes–Weinstein monofilament scores, pain, cold intolerance of the reconstructed finger, and patient satisfaction in both groups were compared.

Results: All patients were followed up for at least 17 months. No significant differences were found regarding pain of thumb pulp, static two-point discrimination, Semmes–Weinstein monofilament score, cold intolerance in the injured finger, and patient satisfaction. The non-preservation group presented slightly shorter operative times (p < 0.05).

Conclusion: There are no differences at 2 years in postoperative clinical outcomes when dorsal digital nerves are used to reconstruct flap sensation regardless of preservation of the dorsal branches of the proper digital nerves in the first dorsal metacarpal artery flap.

© The Author(s) 2021. Open Access This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article’s Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article’s Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit http://creativecommons.org/licenses/by/4.0/. The Creative Commons Public Domain Dedication waiver (http://creativecommons.org/publicdomain/zero/1.0/) applies to the data made available in this article, unless otherwise stated in a credit line to the data.
Background

The first dorsal metacarpal artery flap is currently the first choice for the treatment of thumb pulp defect [1–3]. Restoration of the sensory function of the thumb pulp is a major challenge for hand surgeons. The superficial branches of the radial nerve, which divides into the dorsal digital nerves, or the dorsal branches of the proper digital nerves of the index finger are the most commonly used nerves with the first dorsal metacarpal artery flap to restore the sensation of the thumb pulp (Fig. 1) [4–6].

In thumb pulp reconstruction with the first dorsal metacarpal artery flap, it remains unclear whether preserving the dorsal branches of the proper digital nerve at surgery is advantageous. To our knowledge, no report demonstrates whether dorsal branches of the proper digital nerve preservation produced superior outcomes to non-preservation procedures in first dorsal metacarpal artery flap with dorsal digital nerves.

We compared the clinical outcome between dorsal branches of the proper digital nerve preservation and non-preservation in terms of thumb function, sensory outcomes, and patient satisfaction.

Methods

Patient selection

This investigation was a retrospective cohort study evaluating the clinical results of the patients undergoing modified first dorsal metacarpal artery flap for thumb pulp reconstruction with or without dorsal branches of the proper digital nerves of the index finger. Our institutional ethics review boards approved the study. All patients provided a signed informed consent as well as consent under the Health Insurance Portability and Accountability Act to participate in this study. Inclusion criteria were: (1) thumb pulp defect patients underwent modified first dorsal metacarpal artery flap; (2) the dorsal digital nerves (superficial branches of the radial and ulnar nerves of the index finger) were included in the flap with or without the dorsal branches of the proper digital nerves of the index finger; (3) complete surgical and follow-up data; and (4) follow-up time was not less than 17 months. Exclusion criteria were: (1) combined multi-finger injury; (2) combined thumb fracture or tendon rupture; and (3) previous finger injury or surgery on the affected hand, or secondary finger injury during the follow-up period.

Patients’ information

From October 2015 to June 2019, 252 consecutive patients with a thumb pulp defect underwent modified first dorsal metacarpal artery flap by a senior surgeon with extensive experience in hand surgery. A total of 115 patients did not meet the inclusion criteria and were excluded. The common reasons for exclusion were thumb bone fracture (n = 54), thumb tendon injury (n = 30), multi-finger injury (n = 22), and secondary finger injury during the follow-up period (n = 9). A total of 137 thumb pulp defect patients undergoing modified first dorsal metacarpal artery flap were enrolled into the current study according to the above inclusion and exclusion criteria.

The patients selected the surgical procedure according to their own wishes after communicating with the doctor. Among the recruited 137 patients, 80 underwent modified first dorsal metacarpal artery flap carrying dorsal
digital nerves of the index finger and the other 57 were treated with modified first dorsal metacarpal artery flap carrying dorsal digital nerves and dorsal branches of the proper digital nerves of the index finger. The two groups were comparable in terms of sex, age, defect area, flap size, and follow-up time (Table 1).

### Surgical techniques

**Preservation group:** The flap was designed according to the shape and size of the thumb pulp defect. On the dorsum of the proximal phalanx of the index finger, the flap was raised along its margins. The integrity of the superficial branch of the radial nerve was maintained. The superficial branch of the radial nerve in the pedicle and an 8-mm-wide strip of subcutaneous tissue around the pedicle were preserved. The ulnar dorsal branch of the index finger of the superficial branch of the radial nerve (dorsal digital nerve) was raised with the flap. The dorsal branches of the proper digital nerves of the index finger were incised, with its integrity maintained in the flap. Through a subcutaneous tunnel, the raised flap was transferred to the wound, with the dorsal digital nerve and dorsal branches of the proper digital nerves of the index finger coaptated to the stump of the proper digital nerves in the wound in end-to-end fashion (Fig. 2).

**Non-preservation group:** The flap was designed and raised as was the case in the preservation group. The superficial branch of the radial nerve was preserved in the flap and pedicle. The ulnar dorsal branch of the index finger of the superficial branch of the radial nerve (dorsal digital nerve) was raised with the flap and coaptated to the stump of the proper digital nerves in the wound in end-to-end fashion. The dorsal branches of the proper digital nerves of the index finger were not carried with the flap. The wound was covered with the flap without tension (Fig. 3).

### Postoperative management

After surgery, the injured hand was placed above heart level to reduce possible flap venous congestion. Flap circulation was monitored closely for at least 24 h. The patients routinely received antibiotics and oral nonsteroidal anti-inflammatory drugs for 3 days after the procedure. On the second day after the surgery, patients were instructed to carry out early isometric exercise of forearm muscles. A splint was applied on the thumb to allow the flap to settle. Two weeks after the surgery, the splint was removed, and gentle mobilization started.

### Evaluation of outcomes

The patients were informed that they would be examined in the future when they were discharged. The appearance of the reconstructed finger and the donor site were assessed using the Michigan Hand Outcomes Questionnaire (MHQ) [7]. The sensory outcomes of the flap were evaluated using the static two-point discrimination (2-PD) [8] and Semmes–Weinstein monofilament (SWM) scores [9]. The visual analogue scale (VAS) was used to evaluate the pain of the injured and donor fingers. The results of the VAS score were
divided into three degrees (mild, moderate, and severe) corresponding to three ranges (0–3 cm, 4–6 cm, and 7–10 cm). Cold intolerance of the flaps was measured using the self-administered Cold Intolerance Severity Score questionnaire (the maximum score is 100; grouped into 0–25, 26–50, 51–75, 76–100, corresponding to mild, moderate, severe, and extreme severity, respectively) [10]. All measurements were undertaken by the same experienced hand surgeon who was blinded to the procedure performed.

Statistical analysis
The SPSS 19.0 statistical software (SPSS, Inc., Chicago, IL, USA) was used for analysis. The measurement data (e.g., VAS, 2-PD, SWM, and MHQ), in each group before and after surgery, as well as between two groups after surgery, were compared and analyzed using the t test (symmetric distribution) or the Mann–Whitney test (asymmetric distribution). Pearson Chi-square test was used to evaluate associations among nominal categorical variables. Significance level was set at 5%, and \( p < 0.05 \) was considered statistically significant. The \( \alpha \) value was set as 0.05 given the univariate comparisons before and after surgery. A post hoc power analysis was performed.

Discussion
Thumb pulp plays a fundamental role in grip by virtue of its specialized covering. Various surgical techniques are available for thumb pulp reconstruction [11–15]. Length preservation and sensory recovery are the main factors taken into consideration when selecting reconstruction procedures [16].

Local pedicled flaps are the most commonly used. V–Y advancement flaps provide good tissue coverage and sensory restoration and are used for defects less than 1.5 cm long [17]. For longer defects, neurovascular pedicle flaps are suitable alternatives [18]. However, the original injury might involve the dorsal arteries and cause dorsal skin and nail bed necrosis. An innervated cross-finger flap is an alternative technique for large and complex thumb
pulp defect reconstruction, though it requires 2–3 weeks of immobilization and a further surgery [19]. The first dorsal metacarpal artery flap is the most commonly used flap to repair the thumb pulp defect. The conventional first dorsal metacarpal artery flap carrying the superficial branch of the radial nerve has proven useful in the restoration of the sensation of the thumb pulp. Ege et al. [20] studied 21 patients who underwent thumb pulp reconstruction using the first dorsal metacarpal artery flap based on radial nerve-sensitive branches on the dorsum of the second metacarpal and proximal phalanx. In their study, 2-PD of the reconstructed thumb pulp was 10.8 mm (range 8–20). Wang et al. [21] reconstructed thumb pulp defects using the first dorsal metacarpal artery flap carrying the dorsal branches of the proper digital nerves of the index finger in 25 patients who recovered an average static 2-PD of 7.1 mm (range 5–11 mm) [23]. However, the nerve dissection and coaptation required longer operative time compared to conventional technique.

The dorsal digital nerve is commonly used in island flap to cover finger defects. Previous studies showed that the diameter of the dorsal digital nerve at the metacarpophalangeal joint level was 0.8–1.8 mm [24], and the diameter of the proper digital nerve at the thumb interphalangeal joint level was 1.1–1.5 mm [25]. Therefore, coaptation of the dorsal digital nerve to the proper digital nerve in an end-to-end fashion could, at least in theory, provide a better axonal regeneration pathway. To the best of our knowledge, however, there is no definite answer regarding which nerve to select when performing the first dorsal metacarpal artery flap procedure. To achieve better static two-point discrimination and shorter operative time, we raised the dorsal digital nerves in the flap and made them the sensory nerves of flap without the dorsal branches of the radial and ulnar proper digital nerves of the index finger.

| Variable                          | Preservation group (n = 57) | Non-preservation group (n = 80) | p*     | Power‡ |
|-----------------------------------|-----------------------------|---------------------------------|--------|--------|
| Operative time, min               | 97.46 ± 9.50                | 74.34 ± 10.67                   | <0.001 † |        |
| Hospital stay duration, days      | 4.53 ± 1.18                 | 4.59 ± 1.20                     | 0.767 † | 0.173  |
| 2-PD of pulp, mm                  | 6.67 ± 1.26                 | 6.89 ± 1.22                     | 0.306 † | 0.135  |
| SWM of pulp, g                    | 3.91 ± 0.38                 | 3.85 ± 0.44                     | 0.433 † |        |
| Cold intolerance                  |                             |                                 | 0.637†  |        |
| No                                | 37 (64.9%)                  | 55 (68.8%)                      |        |        |
| Mild                              | 20 (35.1%)                  | 25 (31.2%)                      | 0.222‡  |        |
| VAS (pain of thumb pulp)          | 0.00 (0.00–1.00)            | 0.00 (0.00–1.00)                |        |        |
| Patient satisfaction              | 4.75 ± 0.43                 | 4.81 ± 0.39                     | 0.416‡  | 0.132  |
| Donor site pain                   |                             |                                 | 0.892‡  |        |
| No                                | 40 (70.2%)                  | 57 (71.2%)                      |        |        |
| Mild                              | 17 (29.8%)                  | 23 (28.8%)                      |        |        |

*A value *p* < 0.05 was set as statistically significant
† t test
§ Pearson χ² test
‡ Power is computed to reject the null hypothesis of equal means
& Mann–Whitney test
pulp reconstruction provides no obvious mid-term clinical advantage if the dorsal digital nerves were carried in the flap. Although normal sensation in the thumb pulp is not restored, the present study shows that the outcomes of our patients are superior to those previously reported in studies which did not contain dorsal digital nerves. Our technique provides improved thumb pulp sensation. We are aware that an average follow-up of 2 years may be considered relatively short. However, the outcomes of surgery would have stabilized, and recovery effected by then. We suggest that dorsal digital nerve repair should be performed, if possible, when using a first dorsal metacarpal artery flap.

This study has several strengths. First, to our knowledge this is the first study to report the clinical outcomes of the dorsal branches of the proper digital nerves of the index finger in the modified first dorsal metacarpal artery flap. Second, it carefully assessed postoperative sensory function, pain, and patient satisfaction. Third, it recruited a representative large sample of patients. Likewise, several limitations should also be noted. For example, first, the present investigation is retrospective: We are aware of the fact that such study design introduces biases which are difficult to control despite accurate surgical technique and appropriate statistical analysis. Second, results may vary if larger samples are considered, though the present is one of the largest comparative studies of its kind. Increasing the length of follow-up may influence negatively the results, though we are not aware that this has occurred in similar studies, which have shown that, by two years after the index procedure, recovery has stabilized. Third, the measuring method might not comprehensively assess all aspects of the clinical outcomes.

Conclusions

Compared with first dorsal metacarpal artery flap carrying only dorsal digital nerves for thumb pulp reconstruction, the first dorsal metacarpal artery flap carried dorsal digital nerves and dorsal branches of the proper digital nerves of the index finger offers no mid-term advantages in clinical outcomes, such as static 2-PD, SWM, cold intolerance in the injured finger, and patient satisfaction. The modified first dorsal metacarpal artery flap innervated by the dorsal digital nerves represents a useful and reliable procedure for thumb pulp reconstruction with satisfactory flap sensation, appearance, and satisfactory function, with acceptable donor site morbidity.

Abbreviations

MHQ: Michigan Hand Outcomes Questionnaire; 2-PD: Two-point discrimination; SWM: Semmes–Weinstein monofilament; VAS: Visual analogue scale; DDN: Dorsal digital nerves; DBPDNs: Dorsal branches of the proper digital nerves; SBRN: Superficial branch of the radial nerve; PDNs: Proper digital nerves; FDMA: First dorsal metacarpal artery.

Acknowledgements

None.

Author contributions

ZJL performed the follow-up experiments. NM, FM, and XW gave the experiment guidance during this study and revised this paper critically for important intellectual content. FSM analyzed and interpreted the data and were major contributors in writing the manuscript. All authors read and approved the final manuscript.

Funding

Open Access funding enabled and organized by Projekt DEAL. This study was supported by Grants from the Natural Science Foundation of China (No. 81874008) and the Soochow Program of Health Talent Training (No. GWS2019010).

Availability of data and materials

The datasets generated during and/or analyzed during the current study are available throughout the manuscript.

Declarations

Ethical approval and consent to participate

The study was approved by the Clinical Research Ethics Committee of the Xuzhou Central Hospital. Informed consent was obtained from all subjects and/or their legal guardian(s).

Consent for publication

All patients signed the consent to publish their data.

Competing interests

Prof. Nicola Maffulli is Editor-in-Chief of the Journal of Orthopaedic Surgery and Research.

Author details

1 Department of Orthopaedics, The Second Affiliated Hospital of Soochow University, No. 1055, the Sanxiang Road, Suzhou 215004, Jiangsu, People’s Republic of China. 2 Department of Orthopaedics, Xuzhou Central Hospital, Xuzhou Clinical College of Xuzhou Medical University, Xuzhou 221009, Jiangsu, People’s Republic of China. 3 Department of Orthopaedics, Trauma, and Reconstructive Surgery, RWTH University Hospital Aachen, Pauwelstraße 30, 52074 Aachen, Germany. 4 Department of Musculoskeletal Disorders, Faculty of Medicine and Surgery, University of Salerno, Salerno, Italy. 5 Guy Hilton Research Centre, School of Pharmacy and Bioengineering, Keele University, Stoke-on-Trent, Staffordshire ST4 7QB, England. 6 Centre for Sports and Exercise Medicine, Barts and The London School of Medicine and Dentistry, Mile End Hospital, 275 Bancroft Road, London E1 4DG, England.

Received: 27 October 2021 Accepted: 10 November 2021

Published online: 18 November 2021

References

1. Small JO, Brennen MD. The first dorsal metacarpal artery neurovascular island flap. J Hand Surg Br. 1988;13:136–45.
2. Ratcliffe RJ, Regan PI, Scerri GV. First dorsal metacarpal artery flap cover for extensive pulp defects in the normal length thumb. Br J Plast Surg. 1992;45:544–6.
3. Ghoraba SM, Mahmoud WH. Outcome of thumb reconstruction using the first dorsal metacarpal artery island flap. World J Plast Surg. 2018;7:151–8.
4. Chen C, Zhang X, Shao X, Gao S, Wang B, Liu D. Treatment of thumb tip degloving injury using the modified first dorsal metacarpal artery flap. J Hand Surg Am. 2010;35:1663–70.
5. Checciucci G, Galeano M, Zucchini M, Zampetti PG, Ceruso M. Reverse flow first dorsal metacarpal artery flap for covering the defect of distal thumb. Microsurgery. 2014;34:283–6.
6. Delikonstantinou IP, Gravvanis AI, Dimitriou V, Zogogiannis I, Douma A, Tsoutsos DA. Foucher first dorsal metacarpal artery flap versus littler heterodigital neurovascular flap in resurfacing thumb pulp loss defects. Ann Plast Surg. 2011;67:119–22.

7. Chung KC, Hamill JB, Walters MR, Hayward RA. The Michigan Hand Outcomes Questionnaire (MHQ): assessment of responsiveness to clinical change. Ann Plast Surg. 1999;42:619–22.

8. Crosby PM, Dellon AL. Comparison of two-point discrimination testing devices. Microsurgery. 1989;10:134–7.

9. Kimata Y, Uchiyama K, Ebihara S, et al. Comparison of innervated and noninnervated free flaps in oral reconstruction. Plast Reconstr Surg. 1999;104:1307–13.

10. Lannau B, Bilel J, James IB, et al. Long-term patency of primary arterial repair and the modified cold intolerance symptom severity questionnaire. Plast Reconstr Surg Glob Open. 2015;3:eSS1.

11. Yuan C, Liu H, Zhang H, Wang T, Gu J. Reconstruction of thumb pulp defects using free lateral great toe flaps. J Hand Surg Am. 2021;46(421):e1–7.

12. Toros T, Gurbuz Y, Kelesoglu B, Ozaksar K, Sugun TS. Reconstruction of extensive pulp defects of the thumb with a radial-based pedicled flap from the index finger. J Hand Surg Eur. 2018;43:1036–43.

13. Liu H, Regme S, He Y, Hou R. Thumb tip defect reconstruction using neurovascular island pedicle flap obtained from long finger. Aesthetic Plast Surg. 2016;40:755–60.

14. Chi Z, Song DJ, Tian L, Hu FH, Shen XF, Chim H. Reconstruction of combined thumb amputation at the metacarpal base level and index amputation at the metacarpal level with pollicization and bilateral double toe composite transfer. J Plast Reconstr Aesthet Surg. 2017;70:1009–16.

15. Bjedov S, Ježić I, Bulić K. Reconstruction of a thumb defect following subungual melanoma resection using Foucher’s flap. Acta Dermato-Venereol Croat. 2019;27:51–2.

16. Mak MC, Ho PC, Chow EC, Liu B, Tse WL. Neurovascular island flap for pulp and nail augmentation in thumb duplication reconstruction: a surgical method with long-term follow-up. J Hand Surg Am. 2021;46(340):e1–8.

17. Díaz LC, Vergara-Amador E, Fuentes Losada LM. Double V-Y flap to cover the fingertip injury: new technique and cases. Tech Hand Up Extrem Surg. 2016;20:133–6.

18. Shen XF, Yin F, Wang J, et al. Reconstruction of Wassel IV-D radial polydactyly with a boot-shaped neurovascular island flap: a consecutive series of 91 thumbs. J Plast Reconstr Aesthet Surg. 2020;73:1801–5.

19. Lim JX, Chung KC. VY advancement, thenar flap, and cross-finger flaps. Hand Clin. 2020;36:19–32.

20. Ege A, Tuncay I, Ercetin O. Foucher’s first dorsal metacarpal artery flap for thumb reconstruction: evaluation of 21 cases. Isr Med Assoc J. 2002;4:421–3.

21. Wang H, Chen C, Li J, Yang X, Zhang H, Wang Z. Modified first dorsal metacarpal artery island flap for sensory reconstruction of thumb pulp defects. J Hand Surg Eur. 2016;41:177–84.

22. Keramidas E, Rodopoulou S, Metaxotos N, Panagiotou P, Ikonomou T, Ioannovich J. Reverse dorsal digital and intercommissural flaps used for digital reconstruction. Br J Plast Surg. 2004;57:61–5.

23. Feng SM, Sun QQ, Cheng J, Wang AG, Li CK. Superficial radial nerve transection improves sensory outcomes in first dorsal metacarpal artery flaps. Plast Reconstr Surg. 2017;140:558–64.

24. Zhang X, Shao X, Ren C, Zhang Z, Wen S, Sun J. Reconstruction of thumb pulp defects using a modified kite flap. J Hand Surg Am. 2011;36:1597–603.

25. Wang Z, Zhang X, Liu Z. A microsurgical anatomic study of the digital neurovascular bundle. Chin J Clin Anat. 1988;6:129–31.

Publisher’s Note
Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.