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Reconstruction of complex nail matrix defect using the homodigital reverse fasciocutaneous flap

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Abstract

Reconstruction of complex and severe nail matrix defects with the exposure of bone, tendon or joint continues to be challenging for the surgeon. We present our experience using the homodigital reverse laterodorsal fasciocutaneous flap in the reconstruction of complex nail matrix defects.

Six patients (7 fingers) of complex nail matrix defects with the exposure of bone, tendon or joint were treated with the homodigital reverse laterodorsal fasciocutaneous flap based on the dorsal branches of the proper digital artery. In this study, the composite tissue defect size ranged from $1.0 \times 1.5\,cm^2$ to $1.3 \times 2.5\,cm^2$. All 6 patients participated in follow-up.

All flaps survived well, and no complications were found postoperatively. The mean size of the flaps was $1.4 \times 2.4\,cm^2$ (range, 1.2×2.0–$1.5 \times 3.0\,cm^2$); the mean follow-up period was 8 months (range, 4–15 months); patients' average time to get back to their former jobs was 4.3 weeks (range, 3–6 weeks) postoperatively. All patients were satisfied with the appearance and functional outcomes of the fingers.

The homodigital reverse laterodorsal fasciocutaneous flap based on the dorsal branches of the proper digital artery is an ideal surgical method to reconstruct the complex and severe nail matrix defect.

Abbreviations: DIP = distal interphalangeal, MHQ = Michigan Hand Outcomes Questionnaire, MP = metacarpophalangeal, PIP = proximal interphalangeal, ROM = range of motion.

Keywords: homodigital fasciocutaneous flap, nail bed, nail matrix defect, reconstruction, soft tissue defect

1. Introduction

Fingers are important functional and cosmetic tools for human beings to touch and perceive the external world, so there is a high incidence of finger injuries, especially for manual labors. Reconstruction of complex and severe nail matrix defects with the exposure of bone, tendon or joint continues to be challenging for the surgeon. Moreover, wound coverage is of great importance for preserving the function and appearance of the injured finger.

Currently, the treatment for this complex lesion is rarely reported in the literature. The reconstructive objectives of this complex lesion should include low risk of flap necrosis, maintenance of interphalangeal joint flexibility, minimal donor-site morbidity, the existence of cold-resistance, low hospitalization expense and quick return to previous occupational jobs. Skin or nail matrix grafting alone is not enough to reconstruct this complicated tissue defect because of its exposure of bone and tendon. Common reconstructive methods are regional flaps and free composite tissue transfers.[1–6] However, these surgical methods are not reliable and possess a variety of postoperative morbidities at the donor sites.[7–9]

The homodigital reverse laterodorsal fasciocutaneous flap, first reported by Bertelli and Pagliei,[10] is an axial fasciocutaneous flap based on the dorsal branches of the proper digital artery, which provides soft-tissue reconstruction of a volar defect using the laterodorsal skin of the injured finger. Since then, the homodigital reverse laterodorsal fasciocutaneous flap has been widely applied in the reconstruction of the injured fingers with small- to medium-sized defects, such as the fingertip and pulp.[11–13] However, reconstruction of the complex nail matrix defect using this flap is rarely described in the literature.

The aim of this study was to evaluate the reliability of the homodigital reverse laterodorsal fasciocutaneous flap for the reconstruction of complex nail matrix defects. The excellent postoperative outcomes make us believe that this flap would be useful in the therapy of similar patients in the future.

2. Patients and methods

Our study was approved by the Ethics Committee of the First Hospital of Jilin University and written informed consent was also obtained from all patients. From March 2014 to October 2016, a total of 6 patients (7 fingers) with complex nail matrix defects were investigated in this study. The inclusion criteria were described as follows:

1) Patients had complex nail matrix defects with exposure of bone and tendon, including fractures or tendon injuries;

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2) The size of defect (including nail matrix, nail bed, and skin) was greater than or equal to $1.0 \times 1.5\,cm^2$. The major reasons of these inclusion criteria are as follows.

First, the complex nail matrix defects always involve various soft tissue defects and exposure of bone and tendon, but the reconstruction of this injury is rarely reported. Second, for the small-size defect of nail matrix, skin or nail matrix grafting is enough to reconstruct this soft tissue defect. Therefore, the reconstruction of the complex nail matrix defects measuring greater than or equal to $1.0 \times 1.5\,cm^2$ was investigated in this study so as to provide relevant clinical experience. The exclusion criteria were given below:

1) Injuries involved the donor site or the vascular pedicle;
2) A nail matrix defect was located in the thumb;
3) Patients had serious organic diseases, such as hypertension or diabetes which could influence the flap survival.

The major reasons of these exclusion criteria are as follows. First, if injuries involve the donor site or the vascular pedicle, this flap will not be used because of the destruction of the blood circulation. Second, because the vascular anatomical characteristics of thumb are different from that of the other 4 fingers, the thumb defects are excluded in this study in order to unify the evaluation standard in the design and application of the reverse homodigital fasciocutaneous flap. Moreover, for the reconstruction of dorsal thumb defects with nail involvement, the dorsoulnar flap or the kite flap represents a feasible and satisfactory solution.[14–16] Finally, because serious organic diseases, such as diabetes, could influence hemodynamics of distal extremities and cause poor blood circulation, the probability of flap survival may decline. To summarize, the above 3 kinds of situation are excluded. All patients were male, and the mean age was 37.7 years old (range, 23–50 years old). They were all involved in manual activities (electrical sawing injuries, 4 cases; machine crushing injuries, 2 cases).There were 5 middle finger injuries and 2 ring finger injuries. The defect size ranged from $1.0 \times 1.5\,cm^2$ to $1.3 \times 2.5\,cm^2$. In all subjects, the reconstruction was performed using the reverse homodigital fasciocutaneous flap based on the dorsal branches of the proper digital artery. All 6 patients (7 fingers) participated in follow-up.

2.1. Surgical technique

The operation is performed using a tourniquet under regional anesthesia. Thorough debridement is essential, and the repairs of phalanx fracture or tendon injury should be achieved before the reconstruction of the soft tissue defect. Subsequently, the flap is designed and harvested according to the size and shape of the nail matrix and skin defects (Fig. 1). The dorsal skin damage of the distal interphalangeal (DIP) joint is estimated to design the pedicle of the flap. If the damage does not affect the course of the dorsal branch of the proper digital artery at the level of the DIP joint, the pivot point of flap is located at the origin of that branch (b1 branch, Fig. 1); If the damage affects that branch, the pivot point of flap is marked at the origin of the dorsal branch of the proper digital artery at the level of the middle phalanx (b2 branch, Fig. 1). The distance between the proximal margin of the wound and the pivot point serves as the length of the pedicle of the flap. When the pivot point of the flap is located at b1 branch or b2 branch (Fig. 1), the length of the flap is between the proximal interphalangeal (PIP) joint and the DIP joint, and between the metacarpophalangeal (MP) joint and the middle segment of the middle phalanx of the digit, respectively. The cutaneous veins of the flap should be protected when incising the skin. Meanwhile, the incision depth should reach the paratenon around the extensor tendon (avoid damaging the paratenon) except the vascular pedicle corner, where only the skin is incised. To prevent pedicle compression and postoperative venous crisis, an opened tunnel is applied for the transfer of the pedicle. Complete haemostasis is carried out after the tourniquet release. Then, the flap is sutured loosely over the defect region and a full-thickness skin graft is performed to cover the donor site with tie-over dressing.

2.2. Postoperative management

Postoperative flap care and subjective monitoring were performed for the first 5 postoperative days. Low-molecular-weight heparin calcium, as an anticoagulation agent, was administrated subcutaneously for 3 days postoperatively. The flap color, temperature and capillary refill were observed carefully in order to predict any blood circulation changes of flaps. The dressings were changed 1 time per day for the first 3 postoperative days, and then once every 2 days. Appropriate antibiotics were administered concomitantly. Active range-of-motion exercises were permitted for patients without associated fracture or tendon injury with the help of physical therapy from the third postoperative day. The internal fixations were removed 3 to 4 weeks postoperatively, followed by functional rehabilitation program.

2.3. Evaluation of outcomes

We evaluated outcomes for the appearance of the reconstructed fingers, flap sensation, active mobility of hand joints, and patient satisfaction with hand function. Hand appearance included color matching, scar and deformity. The Vancouver scar scale was used to evaluate the scar. The flap sensation was assessed by detecting the pain and touch sense of flaps. Active motion of hand joints was measured with a goniometer at the postoperative follow-up. For the flap from the middle phalanx, the mobility of the DIP and PIP joint was measured. For the flap from the proximal phalanx, the PIP and MP joint mobility was measured. The active range of motion (ROM) of the reconstructed finger was compared to that on the opposite

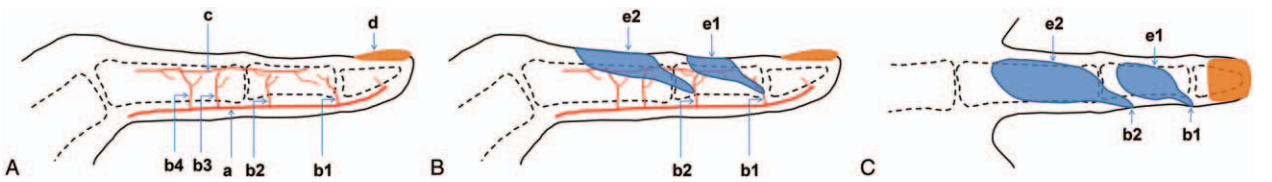

Figure 1. Schematic diagram showing the homodigital reverse laterodorsal fasciocutaneous flap. (A) The laterodorsal artery network of the finger: a, the proper digital artery; b (b1, b2, b3, b4), the 4 major dorsal branches of the proper digital artery; c, the dorsal digital artery; d, nail. (B and C) The homodigital reverse laterodorsal fasciocutaneous flap can be harvested at the proximal phalange (e2) or middle phalange (e1), and their pivot points are located at the origin of b2 and b1 branches, respectively.

Table 1

Patients' detailed clinical characteristics and prognoses.

Case	Sex	Age (years)	laterality	Defect location	Defect type	Associated injury	Phalanx and tendon exposure	Flap size (cm^2)	Flap outcome	Time return to work (weeks)
1	Male	50	Left	Middle finger	B	PD and TI	Yes	1.5×3.0	CS	6
				Ring finger	A	None	Yes	1.2×2.0	CS	
2	Male	23	Right	Middle finger	A	PD and TI	Yes	1.2×2.0	CS	4
3	Male	47	Left	Ring finger	A	PD and TI	Yes	1.5×2.5	CS	4
4	Male	36	Left	Middle finger	A	None	Yes	1.4×2.2	CS	3
5	Male	42	Right	Middle finger	B	PD	Yes	1.5×2.3	CS	4
6	Male	28	Left	Middle finger	A	TI	Yes	1.4×2.6	CS	5

A, the area of nail matrix and nail bed defects less than 1/2 of the total area of nail matrix and nail bed. B, the area of nail matrix and nail bed defects more than or equal to 1/2 of the total area of nail matrix and nail bed. CS = complete survival, PD = phalanx defect, TI = tendon injury.

side. A value $P < .05$ was regarded as statistically significant. To further estimate patient satisfaction with hand function, the Michigan Hand Outcomes Questionnaire (MHQ) was achieved.

3. Results

All flaps survived well, and no skin graft necrosis was observed. The mean size of the flaps was $1.4 \times 2.4\,cm^2$ (range, 1.2×2.0–$1.5 \times 3.0\,cm^2$). All 6 patients (7 fingers) were followed up, and the mean follow-up period was 8 months (range, 4–15 months). No complications were found postoperatively, such as venous congestion, haematoma or infection. Patients' average time to get back to their former jobs was 4.3 weeks (range, 3–6 weeks) postoperatively. Patients' detailed clinical characteristics and prognoses are shown in Table 1.

There were many advantages for the flaps, including rich blood supply, good texture, and appropriate thickness, which avoided thinning or other revisions. Moreover, color matching of the flap in the reconstructed region was normal in all patients. All incisions healed well without significant scars, especially in the perionychium (Vancouver scar scale score. 0–3). No obvious nail deformity was observed for the reconstructed fingers. For the flap from the middle phalanx, the mean ROM of the DIP and PIP joints was similar to that of the opposite side. For the flap from the proximal phalanx, no significant difference was observed in the ROM of the PIP and MP joints between the reconstructed finger and the contralateral side. According to the MHQ, 5 patients were strongly satisfied with the function of the reconstructed fingers (score 5). The remaining 1 patient was satisfied with the function (score 4).

Furthermore, we found that the restoration of pain and touch sense was achieved in our series at 12 months after surgery. For the patient with 4 months follow-up, the return of sensibility to prick pain could be detected, but the sense of touch was not acquired obviously. All patients reported no donor-site pain, and no signs of extensor tendon adhesion were observed at the donor sites in our series. On the whole, all patients were satisfied with the appearance and functional outcomes of the fingers.

3.1. Case 1

A 50-year-old male patient presented with complex nail matrix defects of left middle finger and ring finger following electrical sawing injury. There was a $1.3 \times 2.5\,cm^2$ soft tissue defect (complete nail matrix and nail bed defects) of the middle finger and a $1.0 \times 1.5\,cm^2$ soft tissue defect (about 1/4 of nail matrix and nail bed defects) of the ring finger (Fig. 2A and B). The

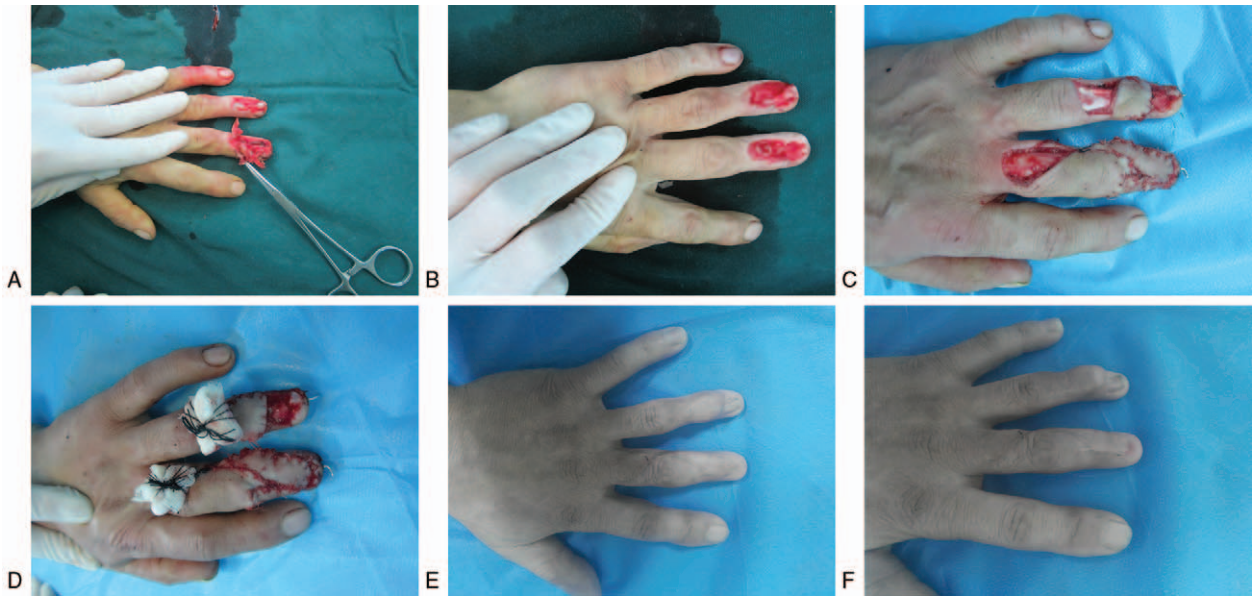

Figure 2. Case 1. (A and B) Complex nail matrix defects with exposure of bone, tendon and joint. (C) The homodigital reverse fasciocutaneous flap was designed and harvested. (D) The skin defects of the donor sites were covered with full-thickness skin grafts. (E and F) Images taken 15 months after reconstruction.

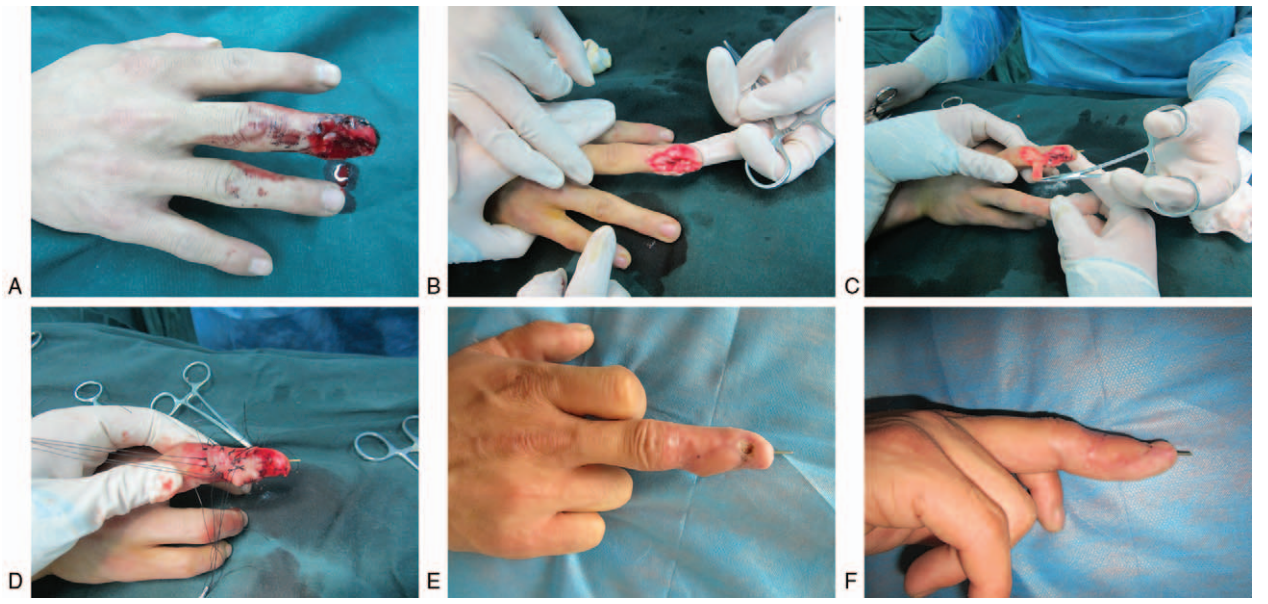

Figure 3. Case 2. (A and B) Soft tissue defect (including nail matrix) and phalanx defect. (C) The homodigital reverse fasciocutaneous flap was harvested and transferred into the defect. (D) The defect of the donor site was covered with full-thickness skin grafting. (E and F) Results at 4 weeks after the operation.

concomitant bone defect of the DIP joint and the extensor tendon end defect of the middle finger resulted in the arthrodesis of the DIP joint. The homodigital reverse fasciocutaneous flaps were designed for both middle and ring fingers with different flap pivot points according to the size and shape of the defects (Fig. 2C). Then, the flaps were harvested and rotated to cover the above defects. The flap size of the middle finger was $1.5 \times 3.0\,cm^2$, and that of ring finger was $1.2 \times 2.0\,cm^2$. The skin defects of the donor sites were covered with full-thickness skin grafts from the ipsilateral upper arm (Fig. 2D). The wounds achieved primary healing, and the flaps survived well with rich blood supply. The patient was contented with the appearance and function of the reconstructed fingers and returned to his original job at 6 weeks postoperatively. Figure 2E and F show the outcome at 15 months postoperation.

3.2. Case 2

A 23-year-old male patient sustained an electrical sawing injury to his right middle finger, presenting with soft tissue defect (including nail matrix, nail bed and skin) and phalanx defect (Fig. 3A). After debridement, about a $1.0 \times 1.6\,cm^2$ soft tissue defect with exposure of the distal phalanx and tendon was observed (Fig. 3B). A $1.2 \times 2.0\,cm^2$ size flap, whose blood supply originated from the dorsal branch of the proper digital artery at the level of the DIP joint, was designed, harvested and transferred into the defect (Fig. 3C and D). The defect of donor site was covered with full-thickness skin grafting. Both the flap and grafting exhibited a pleasing appearance (Fig. 3E and F). Moreover, the patient returned to his former work 4 weeks after the operation.

4. Discussion

During nail matrix reconstruction, both function and aesthetics should be taken into consideration. Traumatic nail matrix defect is always accompanied by a variety of injuries, involving other tissue defects (nail bed and skin), phalangeal fracture or tendon rupture. Therefore, the reconstruction of this complex lesion is challenging. So far, however, there are rare reports about how to repair and reconstruct this composite tissue damage in the literature.[1–6] Moreover, the outcomes of these methods are not reliable, and many postoperative morbidities might occur at the injury and donor sites.[7,9,17]

Skin or nail matrix grafting alone is not enough to reconstruct this complex tissue defect due to its exposure of bone and tendon.[18,19] Major reconstructive methods are regional flaps and free composite tissue transfers. One of the regional flaps is the homodigital reverse digital artery island flap, which may produce cold intolerance as a result of sacrificing 1 digital artery.[1] Another regional flap, the cross-finger flap, requires a 2-stage surgical procedure along with the related risk of interphalangeal joint stiffness, especially in the elderly.[20] The vascularized nail flap is a common free tissue transfer technique generally used for nail reconstruction. However, many patients refuse this surgical method because of its various disadvantages, including long operation time, great damage to the donor site, high risk of failure, and high hospitalization expenses.[9,20] It is noteworthy that most of the patients suffering from these complicated lesions are manual labors, so the reconstruction should be a simple, safe and cost-effective surgical method with a minimal morbidity. To optimize the results of the reconstructed finger, 6 patients (7 fingers) with complex nail matrix defects were treated with the homodigital reverse laterodorsal fasciocutaneous flap, which is based on the dorsal branches of the proper digital artery.

The homodigital reverse laterodorsal fasciocutaneous flap is a simple and practical method, which is strongly recommended for clinical application, because no necrosis of the flap in this study is noted; furthermore, this flap can achieve the purpose of reconstruction for the complex nail matrix defect in a single-stage process, which not only avoid sacrificing the digital artery but also reduce cost and time to get back to work. We propose

that the donor site is similar to the distal dorsum skin of the finger in texture, and it can be harvested from either the middle phalange or the proximal phalange according to the size and shape of the defects. Moreover, this flap can provide enough tissue coverage even if the complex lesion involves a complete defect of nail matrix and nail bed. Therefore, this 1-stage local flap is preferred because of the lower hospital cost, lager tissue coverage, and shorter disability time.

The homodigital reverse fasciocutaneous flap has rich blood supply from the dorsal branches of the proper digital artery, and its supply is the links between the proper digital artery and the dorsal digital artery. The dorsal branches of the proper digital artery have 4 major branches, which arise at the level of the middle and distal one-third sites of the proximal phalange, in the middle phalange site, and at the level of the DIP joint site.[13,19,21] Flap venous congestion is regarded as a major postoperative complication.[22] The venous flow of this flap is drained mainly through the subcutaneous venous network, and the associated superficial venous trunk plays an important role, which results in no or little venous congestion.[19] In our cases, an appropriate skin strip over the pedicle was preserved to protect the subcutaneous veins and avoid pedicle compression after flap transfer, thus leading to excellent venous drainage. No significant venous congestion occurred in our series, and all flaps survived well.

Because sensory return of flaps for the reconstruction of the distal dorsal finger defects is less important than that of the fingertip and the pulp, the non-innervated homodigital reverse fasciocutaneous flap was performed in our study.[23] However, it is worth noting that the protective sensory recovery was achieved in our series at 12 months after surgery. Besides, the return of sensibility to prick pain could be detected at 4 months follow-up, contributing to the protection of the flap. Therefore, the homodigital fasciocutaneous flap without nerve reconstruction is sufficient to produce stable postoperative results.

There were no serious postoperative donor-site complications in our study. Though extensor tendon adhesion and skin graft contracture are inevitable, these complications can be overcome by early functional exercises with the help of physical therapy.[24] The donor-site scar was not conspicuous at the homodigital dorsum, which was considered acceptable for the salvage reconstruction of the complex nail matrix defect.

Our study shows that the homodigital reverse fasciocutaneous flap is a preferred surgical method of the reconstruction of large and complex nail matrix defects. Before determining the operative scheme, we should assess the size and location of the injury, the flap blood supply, and patient's requirements. The homodigital reverse fasciocutaneous flap is unable to be used for the nail matrix defect caused by an electric burn or severe crushing injury, which affect the microcirculation of the injured finger. Moreover, advanced age, peripheral vascular disease or heavy smoking history also limits the use of this flap.[25] In spite of its above limitations, the homodigital reverse fasciocutaneous flap should be considered first when reconstructing the complex nail matrix defect.

5. Conclusion

The homodigital reverse laterodorsal fasciocutaneous flap, which is based on the dorsal branches of the proper digital artery, has many advantages, including simple and safe dissection, reliable blood supply, good aesthetic results, and excellent function outcomes. This flap is an ideal surgical method to reconstruct the complex and severe nail matrix defect.

Author contributions

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Methodology: Xiucun Li.
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Writing – original draft: Yang Liu.
Writing – review & editing: Laijin Lu.

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