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ORIGINAL PAPER

Limitation of microdissected thinning in free anterolateral thigh flap for hand reconstruction

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Abstract

Background Hand defects, especially complex defects involving tendon or bone exposure, are challenging to reconstruct. With the limited size and options of local flaps, the free-thinned anterolateral thigh (ALT) flap remains an excellent choice. However, many authors have described thinning procedures differently, leading to inconsistent outcomes. We present our clinical experience of immediate thinning ALT flaps depending on the anatomical structure of the perforator.

Materials and methods Between 2007 and 2021, we used a free ALT flap in 42 cases to cover hand defects after crushing and friction injuries, burning and burn scars, and animal bite wounds. There were 38 males and 4 females; the mean patient age was 31.2 years. Thinning procedure was performed in all flaps. The primary and microdissected thinning procedure was performed for 35 single flaps and 7 chimeric flaps, including 14 flaps for the fingers (29%), 4 flaps for the palm (8%), 12 flaps for the hand dorsum (24%), and 19 flaps for combined areas (39%).

Results The mean flap thickness was 18.6 (11–30) mm before defatting and 6.0 (3–12) mm after defatting, an approximately 65% reduction. The retained fascia island around the perforator was ≤ 1 cm in 73.5% of cases, 2–3 cm in 18.4%, and the remaining 8.1% had a fascia size ≥ 4 cm. The incidence of a well-survive flap was 93.9%. Three cases had partial to total necrosis. None of the patients required a secondary defatting procedure.

Conclusion Every case has a perforator pattern after running through the fascia, which allows surgeons to choose the appropriate thinning method. Perforators that run parallel to the superficial fascia are not good candidates for thinning. Instead, the thinning process should be performed with more perpendicular perforators.

Level of evidence: Level IV, therapeutic study

Keywords Primary thinning · Microdissection · Free ALT flap · Hand reconstruction · Microsurgery · Case series

Introduction

Hand soft-tissue defects caused by different injuries, including trauma, infection, burns, post-burn sequelae, and snake bites, require coverage to recover function and satisfy esthetic results. Since the skin of the hands is very thin and supple, the ideal reconstructive material for hand defects should be similar in texture and thickness to that of the recipient site [1]. With simple soft-tissue defect reconstructions, skin grafting is best for hand function recovery [2]. However, to reconstruct exposed functional structures such as tendons, bones, and blood vessels in the hand, surgeons can use either a pedicled flap or a free flap [3–5]. The versatile anterolateral thigh (ALT) flap is a safe and reliable solution for defects that need skin coverage and reconstructive procedures. Nevertheless, the ALT flap sometimes becomes

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undesirable for soft-tissue defect reconstruction of the hand because it is too thick [6, 7]. Although secondary thinning procedures can improve esthetic outcomes, delayed rehabilitation may harm functional outcomes. Kimura introduced the thinning method in 2003 and successfully applied it to the reconstruction of soft tissue defects of the hand [8, 9]. However, authors have described the thinning procedures used for the ALT flap differently, leading to inconsistent outcomes [10, 11]. In addition, a safe thinning operation has yet to be reported based on anatomical research. As a result, the procedure remains challenging for surgeons to reconstruct body defects, especially soft tissue defects of the hands. We retrospectively evaluated 78 cases using ALT flaps for the upper extremities, including 42 cases using thinned ALT flaps for the hands. We present our clinical experience performing ALT flap thinning procedures by analyzing successful reconstructive surgeries.

Materials and methods

Data from a case series of 42 consecutive patients who underwent thinned ALT-free flap reconstruction from July 2007 to September 2021 were analyzed retrospectively. There were 38 male and 4 female patients, with an average age of 31.2 ± 11.6 (range 14–63) years. The average BMI was 20.82 ± 2.63 (range 15.85–28.62). Eight male patients had a smoking history. The hand defects resulted from crush and friction injuries (22 patients), burning and burn scars (13 patients), and animal bite wounds (7 patients). Skin defects were observed in all cases, including exposed tendons in 33 cases (78.6%), exposed bone in 26 cases (61.9%), tendon lacerations in 9 patients (21.4%), and bone defects in 7 cases (16.7%). The average skin defect area was 79.4 (range 15.7–197.9) cm^2, including 51.4 (range 23.6–75.4) cm^2 on the hand dorsum, 43.79 (range 15.7–93.5) cm^2 in the finger area, and 104.6 (range 35.3–197.9) cm^2 in combined areas (dorsal and palmar, dorsal and finger, and dorsal and wrist).

Operative technique

All flaps were harvested in a similar manner. The perforator vessels were checked using handheld Doppler imaging, which only shows where the point of the perforator comes to the skin paddle. A skin incision was made on the medial side of the skin flap. Dissection to the subfascial plane (fascia lata) was performed until the descending branch and perforators of the lateral circumflex femoral artery (LCFA) were identified. After that, the perforators were dissected retrogradely, according to their origin. Skin islands with independent perforators were elevated based on the size of the skin defect. Using magnifying loupes, we identified the branching of each perforator as it penetrated the superficial fascia. If the perforator permitted only one or two branches to cross directly into the subfascial layer, we retained a fascial island of less than 1 cm or removed the fascial layer altogether. Subsequently, we performed flap thinning via microdissection of the entire skin flap. If the perforator had one perpendicular branch and one branch that ran parallel to the fascial surface, we retained a fascial island that measured approximately 2–4 cm along the path of the parallel branch. We then thinned the remaining skin flap by microdissection. In cases where the branches of the perforator only ran parallel to the fascia, a more extensive skin island of 4–6 cm was retained. Simultaneously, the remaining flap underwent a primary thinning procedure (Fig. 1). The thinning procedure was performed before the pedicle resection [11]. In the primary thinning method, the fat between the superficial and fascia lata was removed by blunt scissors, and subdermal vessels were conserved. Furthermore, the procedure

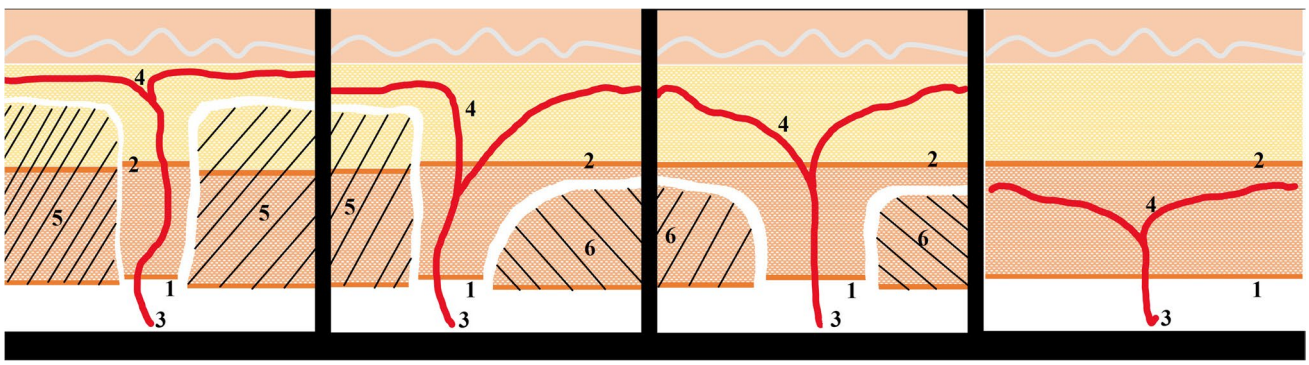

Fig. 1 Illustration of the technique. **A** The perforator branches that go perpendicularly toward the skin can be subject to microdissected thinning. The fascia island retains 1–2 cm. **B** The perforator branches with one side perpendicular and the other going diagonally. Primary thinning is applied to the diagonal side, and microdissected thinning is to another side. The fascia island retains 2–4 cm around the perforator. **C** The perforator branches diagonally to both sides through the superficial fascia and can be only primarily thinned. The fascia island is left around 4–6 cm. **D** The perforator branching below the superficial fascia is no candidate for thinning

was started from the periphery to the center. A fascia island around the perforator of the intended size was retained, and the thickness of the flap was reduced to approximately 8–12 mm. Following the primary thinning, a microdissected procedure was performed. Under a surgical microscope, the thinning procedure was done by removing the fat lobules lying deep in the superficial fat layer, preserving as many blood vessels as possible at that level. With microdissection thinning, the flap thickness was reduced to approximately 3–7 mm, which was suitable for reconstructing the impaired areas of the hand.

We independently chose two perforators for the chimeric flap, both from the descending branch. The thinned ALT flap was elevated, and the pedicle was clipped from the descending branch of the LCFA. Finally, the flap was transferred to the recipient site for reconstruction. The flap pedicle was anastomosed in an end-to-end or side-to-end manner to the radial, ulnar, or proper digital arteries. The skin defect was subsequently covered with a thin skin-paddle flap. The donor site was closed primarily or with a skin graft if primary closure was not possible. The flaps were monitored frequently within the initial 2-day postoperative period. Repairs were performed soon if an obstruction was suspected. Patients were discharged after approximately 10 days, and the flap survival, contour, and donor site were recorded. The range of motion dramatically improved at the routine follow-up, with a well-contoured and good esthetic result.

Our study still has some limitations, such as the bias in collecting data from the previous file and the patient's personal experience during the interview.

Results

The 49 thinned ALT flaps from 42 patients included in this study were used to cover defects in different parts of the hand. There were 35 single flaps and 7 chimeric flaps, including 14 flaps for the fingers (29%), 4 flaps for the palm (8%), 12 flaps for the hand dorsum (24%), and 19 flaps for combined areas (39%). The width of the skin paddle flap ranged from 3 to 14 cm (average, 7.8 cm), and the length ranged from 5 to 26 cm (average, 13.7 cm). The flap pedicle length was 8.9 cm (range, 5–14). The fascia island size around the entry of the main perforator into the flap was 1 cm in 36 flaps, 2–3 cm in 9 flaps, and > 4 cm in 4 flaps. The mean flap thickness before defatting was 18.6 (range, 11–30) mm, and it decreased to an average of 6.0 (range, 3–12) mm after defatting, representing a reduction of approximately 65%. Thirty cases (61.2%) of arterial anastomoses were end-to-end, and the remainder was end-to-side. Flap characteristics are presented in Tables 1 and 2. The donor flap area was closed directly in 32 patients (76.2%). One flap (2.38%) had total necrosis due to a missing vein in the pedicle. Two flaps had partial necrosis of up to 50%, requiring flap debridement, and two flaps had a small amount of ischemia at the flap's distal end that required no intervention. The incidence of a well-survive flap was 93.9%. After 1–8 years of follow-up, the patients were satisfied with the functional and esthetic results. The finger's range of motion (ROM) ranges from 20–80° at the MCP joint, 25–85° at the PIP joint, and 20–50° at the

Table 1 Characteristics of anterolateral thigh flap in hand reconstruction

Areas (n)	Flap width (cm)	Flap length (cm)	Areas (cm^2)	Result		
	Average, range	Average, range	Average, range	Total necrosis	Partial necrosis	Total survive
Finger (14)	6.6 (3–11)	12.0 (6–24)	138 (23–354)	1	1	12
Dorsum (12)	8.3 (7–22)	15.0 (7–22)	222 (65–414)	-	1	11
Palmar (4)	6.6 (3–11)	9.7 (5–13)	87 (23–150)	-	-	4
Mixed (19)	8.4 (4–14)	14.4 (5–26)	220 (31–449)	-	2	17
Total (49)	7.8 (3–14)	13.7 (5–26)	189 (23–449)	1	4	44

Table 2 Thinning results

Thinning methods (n)		Primary thinning (19)		Microdissection (30)		Total (49)	
		Average	Range	Average	Range	Average	Range
Flap thickness (mm)	Before	17.5	11–30	19.3	11–30	18.6	11–30
	After	7.0	4–12	4.9	3–8	6.0	3–12
	Percentage (%)	41.1	22–58	27.0	12–41	34.0	12–58
Fascial island size (n)	< 1 cm	9		27		36	
	2–3 cm	6		3		9	
	> 4 cm	4		0		4	

DIP joint. The ROM of the thumb was 10–35° at the MCP joint and ranged from 0-–40° at the IP joint. Some of the patients' results are presented in Figs 2, 3, 4, and 5. None of the patients required defatting.

Discussion

Complex hand injuries involve complicated lesions caused by skin and soft tissue defects that expose underlying critical

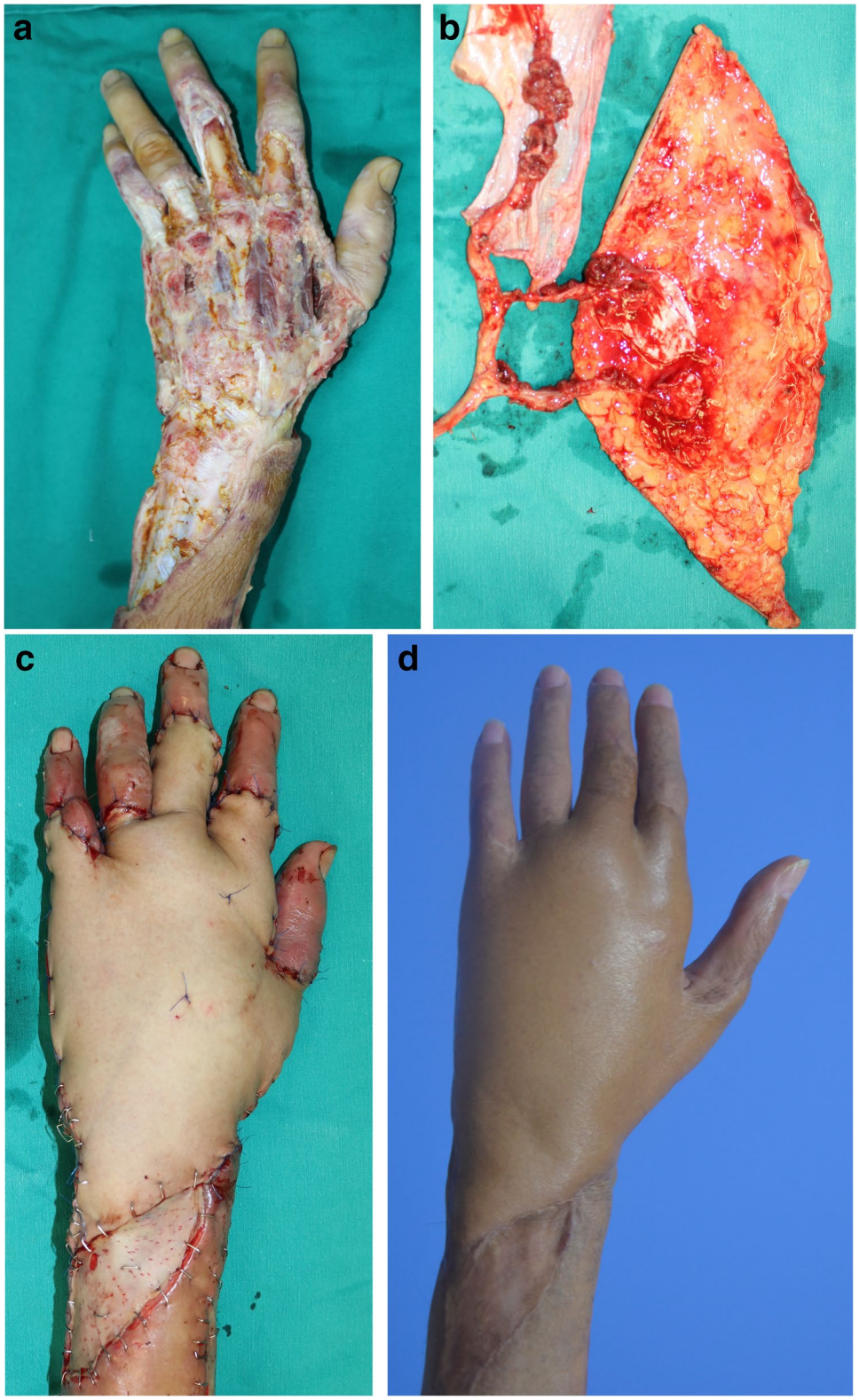

Fig. 2 Chimeric thinned ALT flap for reconstruction of the hand and finger dorsum and extensor tendons. **A** A 62-year-old male patient suffered a tilapia fish injury with a complete laceration of the extensor tendon and dorsum of the left hand. **B** An 11 × 23 cm chimeric ALT flap is thinned from 1.7 to 0.6 cm (microdissection), including two perforators and a fascial island of 2 × 4 cm. The fascia lata flap with a perforator. **C** Postoperative result with the hand dorsum and wrist covered. Extensor tendons of the index and middle fingers are reconstructed, with skin grafting in the forearm. **D** A satisfactory result is obtained at the 2-year follow-up

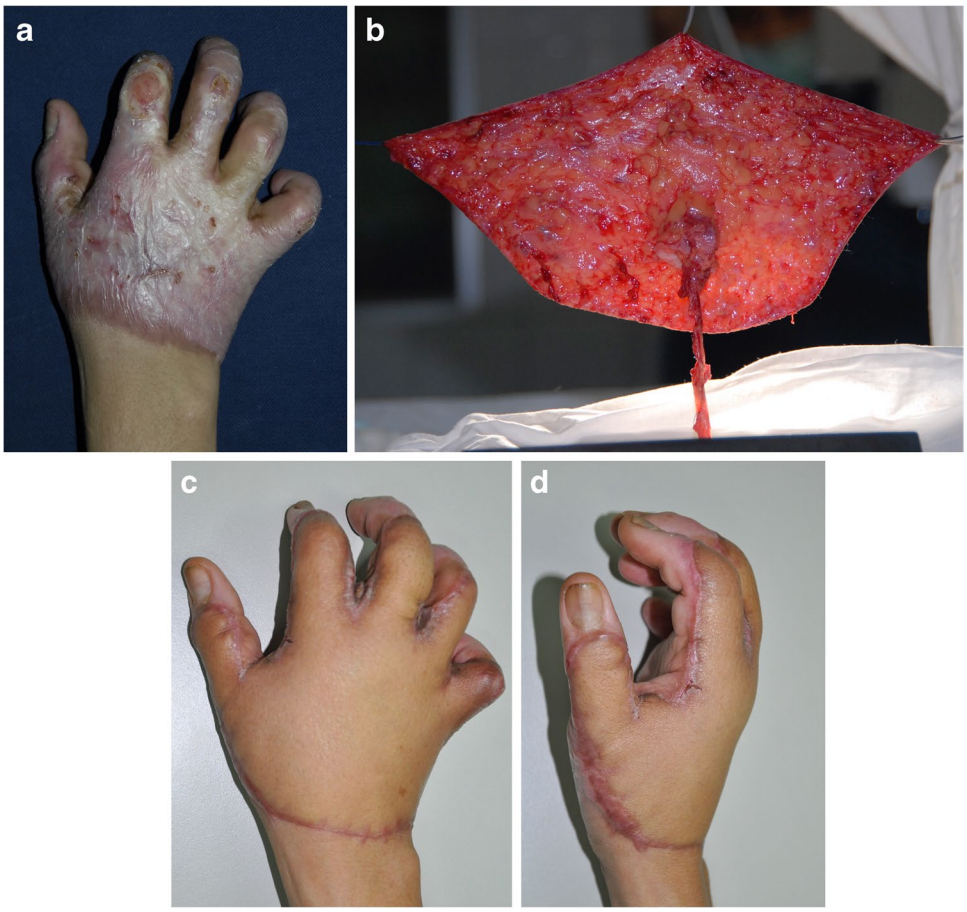

Fig. 3 Thinned ALT flap for reconstruction of the hand and finger dorsum. **A** A 43-year-old male patient presents with severe scar contracture on the right dorsal hand and fingers after a gas burn 4 months previously. **B** An 18 × 14 cm, approximately 3-mm thick, ALT flap with one perforator; the remaining fascial island size is 1 × 1 cm, and the flap is tailored into five parts at the distal end. **C** and **D** At the follow-up after 8 months, the flap showed total survival as well as improved esthetics and hand function

structures such as tendons and bones. The reconstruction of complex hand injuries needs to maximize both functional and esthetic outcomes, which requires good coverage and the provision of a gliding bed with an additional blood supply and a thin surface. Free flaps can include various tissues, such as cutaneous, fascia, muscle, or bone components, suitable for different hand defects [12–14]. Based on the clinical literature, ALT flaps have become favorable, with many variants that can be used for hand reconstruction. Few reports of the ALT flap have focused on the reconstruction of the upper extremities and even less on complex hand defects [6, 7, 15–17]. The main drawback of this flap is that it is relatively bulky because of the excessive thickness of the subcutaneous layer. After soft tissue defect reconstruction, bulky flaps can result in esthetically unacceptable outcomes and poor function. Kimura et al. first reported the technique of thinning the ALT flap, which can be thinned to approximately 3–4 mm by removing the adipose layer between the fascia lata and superficial fascia or under the subcutaneous layer. The subcutaneous vascular network can entirely nourish the thinning flaps [18, 19]. Many authors have used a thinned ALT flap to cover defects of the head, neck, or extremities [20–22]. The process of safely performing flap thinning has been studied by several centers worldwide, but it remains unresolved [10, 23–25]. Most authors have suggested leaving a small amount of adipose tissue of approximately 2 cm around the perforating vessel or using a flap with a small size to ensure good vascularity in the thin flap and reduce the incidence of necrosis in the distal end of the flap. Some authors have even suggested widening the adipose area around the perforating vessels; however, they have not mentioned when to expand it for flap survival. There has been no conclusion regarding whether the incidence of flap necrosis is related to residual fat around the perforating vessel, especially considering the form of the perforating vessels that run through the superficial fascia [26–28].

Little research has been conducted on how the perforator divides after passing through the superficial fascia. Kimura et al. divided perforator flaps into three types according to the path of the perforators in the adipose tissue [19]. Dissecting through the deep fascia and identifying the ramifications of the perforating vessels in the pre-thinning process enables an understanding of the branching of the perforating vessels below this layer. The success of thinning is not related to whether the perforator vessel is a transmuscular or transseptal vessel.

In our experience, we found three types of perforator branching, similar to the Kimura classification. The first type of perforator penetrates straight to the superficial

Fig. 4 Chimeric ALT flap for reconstruction of the left hand. **A**: A 33-year-old male patient completely lost the skin in the palm and part of the hand dorsum due to a workplace accident. **B** Thinned ALT flap, approximately 4-mm thick, is used as a chimeric flap. A flap measuring 14 × 18 cm covers the palmar defect, and another flap of 8 × 12 cm covers the thenar area and hand dorsum. **C** and **D** Two months after the operation, the flaps are well vascularized with good motor function and an appropriate thickness

fascia and then branches perpendicularly beneath the fascia. With this type, the entire fascia and adipose tissue layer around the perforator can be surgically removed without damaging the vessels supplying the subdermal plexus. In our study, there were 30 flaps (73.5%) with this type of perforator. We could entirely microdissect the flap, which guaranteed its vascularization.

The second type consists of a perforator that branches on the surface of the deep fascia on only one side and then passes obliquely to the superficial layer. For this type, we retained the deep fascia and open portion around the perforator branch until the vessel entered the superficial layer of the skin flap. Therefore, the remaining fascia had a width of approximately 2–3 cm, and the length depended on the vessel's position entering the superficial fascia layer. With this type, we can perform microdissection or primary thinning; the fascia island is larger than that in the first type. When there were two or more perforators in the flap, we kept all of the fascia between perforators and disregarded whether there were any vena comitantes in one of those two.

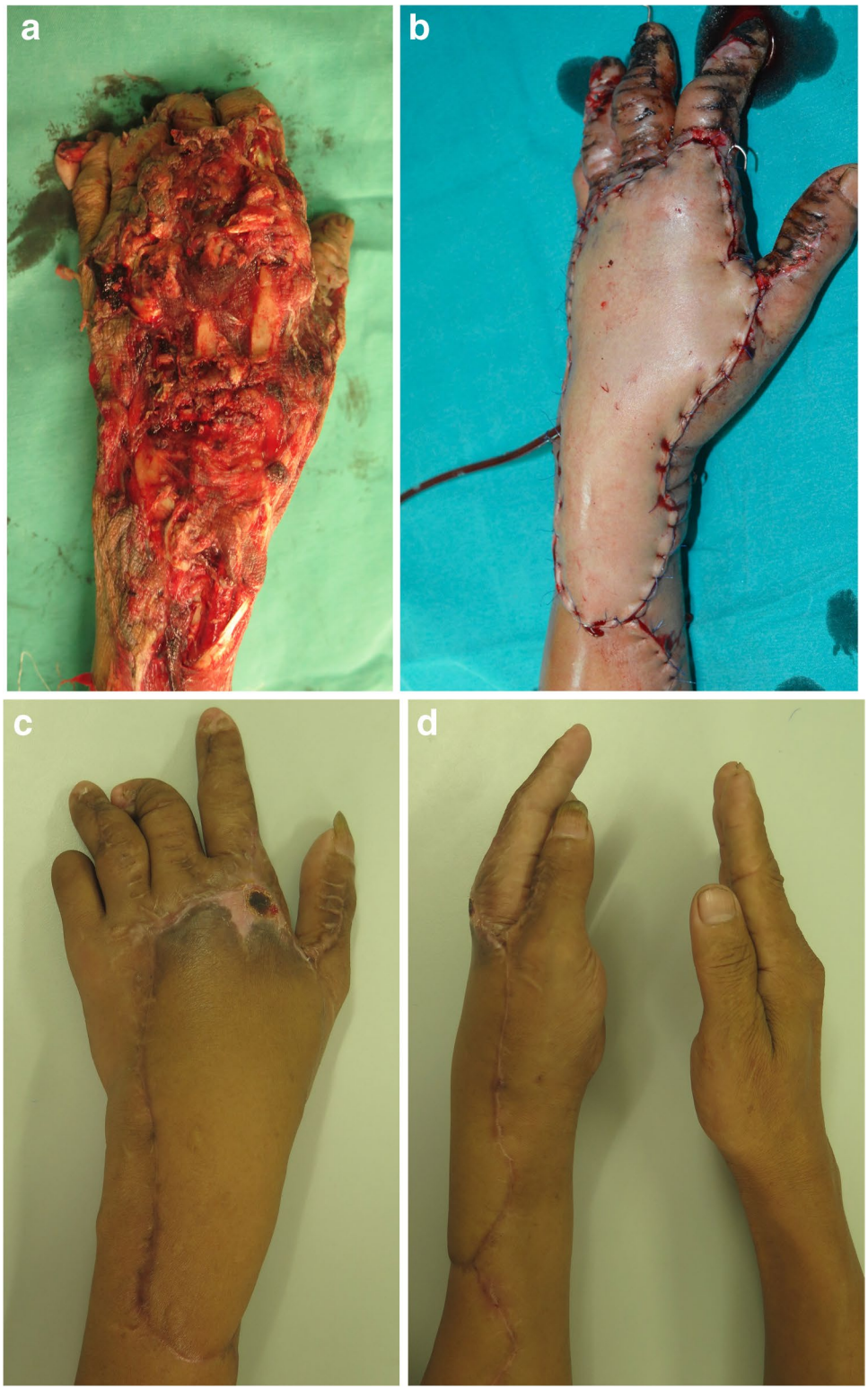

Fig. 5 Reconstruction of a complex hand injury with thinned ALT flap. **A** A 51-year-old male patient with a skin defect in the left hand and wrist dorsum and laceration of the dorsal extensor tendons. **B** A 12 × 28 cm ALT flap with two perforators is thinned primarily from 10 to 5 mm. A 4 × 6-cm fascia island is retained around the perforators. **C** and **D** Result after three months. A part of the distal end (2 cm) exhibits necrosis, which is left for secondary intention healing

The third type is the perforator, which branches to both sides after passing through the deep fascia. These vessels run parallel to and above the deep fascia. In this study, there were only four flaps (8.1%) of this type, and we preserved approximately 4 cm in width and 6–8 cm in length of the deep fascia on both sides. This allowed the preservation of vessels running to the distal end of the flap.

With this third type of perforator, we did not perform microdissection and only performed the primary thinning procedure. In our study, two cases of partial necrosis at the

distal end of the flap were in the third type of Kimura classification. One flap had a perforating vessel originating from the distal end of the descending branch, and the remaining was derived from the transverse branch of the LCFA. Even though these flaps preserved a large 4 × 6 cm fascia island around the perforator, ischemia was still present at the distal end. In addition, two flaps with an increased length of 18–26 cm, which underwent microdissection thinning, showed 2–3 cm of ischemia at the distal end. This can be a consideration when choosing a flap to thin—the more extended the flap size, the riskier the flap thinning. In one case of total necrosis, it was re-explored and did not have a vein in one of the perforating vessels. This usually occurs when two closed perforators are present in a single-skin paddle. All these cases exhibiting complications happened in the early period of our study, and this incidence is similar to the overall complication rates in other systematic reviews. Agostini et al. reported a 4.1% partial loss and 2.5% total loss, and Arakelyan et al. reported partial and complete flap losses of 8% and 6%, respectively [10, 29]. There was no significant influence of the thinning method on the presence of flap complications ($p = 0.067$). The flap oversizing, the distal origin of the perforator, and the perforator that runs parallel to the fascia may reduce the thinned flap's vascularization.

In our study, with the primary thinning technique, the flap can be thinned to approximately 7.0 mm; meanwhile, the microdissected method can reduce the thickness to an average of 4.9 mm. Our results are similar to those of other 3–12 mm reports, with an average of 4.2 mm after thinning [10]. The thinned skin paddles are compatible with the dorsal hand and even digit defects, which still achieve good esthetic and functional outcomes. Thinning of the ALT flap does not necessarily require the whole flap to be thinned evenly but depends on the purpose of the flap reconstruction. We decided which part of the flap needed thinning based on the position of the defect. In finger reconstruction flaps, microdissection thinning of the entire flap is required to create a finger pattern and achieve good finger movement. Skin flaps covering the dorsal side need to be thinner (usually 3–4 mm) than those covering palmar defects (5–8 mm). In addition, finger and hand palmar flaps must be thinner and smaller than those in mixed defects. However, in degloving finger injuries, the survival of the thinned flap is much worse than that of the other types. Vascularization of the thinned flap depends significantly on the surface of the damage, which is usually poor in degloving injuries. The results of 49 thinned flaps used to cover the defects of the hand manifested a success rate of 95.9%. The follow-up function of the hand after thinned ALT reconstruction shows that the color of the flap is similar; moreover, the flap is compatible with the surrounding skin, and the flexion and extension of the hand are guaranteed. This emphasizes the value of using the thinned ALT flap in hand defect reconstruction, especially in large and complex defects.

Conclusions

The thinned anterolateral thigh flap is suitable and adaptable to the reconstruction of soft tissue defects of the hand, which requires compatible thin tissue to guarantee function and aesthetics. Every case has a perforator pattern after running through the fascia, which allows surgeons to choose the appropriate thinning method. Our experience indicates that perforators that run parallel to the fascia are not good candidates for thinning. The thinning process, both primary and microdissection, is safer when the perforator runs perpendicularly, and this perforator pattern also helps to increase vascularization, even in larger ALT flaps.

Author contribution Trần Thiết Sơn: performed the operation and conceptualization, writing, editing, and supervision; Phan Tuấn Nghĩa: performed the operation, writing—review and editing; Phạm Thị Việt Dung: performed the operation; Vũ Hồng Chiến: performed the operation, data curation, and formal analysis; Tạ Thị Hồng Thúy: performed the operation; Nguyễn Hữu Trọng: performed the operation.

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Declarations

Ethics approval This study was performed in line with the principles of the Declaration of Helsinki. This study was approved by our institution's Research Ethics Committee (136/QĐ-ĐHYHN).

Consent to participate Informed consent was obtained from all the participants included in the study.

Consent for publication The authors affirm that human research participants provided informed consent to share their data and publish their images.

Conflict of interest Trần Thiết Sơn, Phan Tuấn Nghĩa, Phạm Thị Việt Dung, Vũ Hồng Chiến, Tạ Thị Hồng Thúy, and Nguyễn Hữu Trọng declare no conflict of interest.

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