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ARTICLE

Reverse homodigital dorsal wraparound flap for reconstruction of distal thumb

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ABSTRACT

Reconstruction of degloving injury or amputation of distal thumb with no indication of replantation has always been a challenging problem for hand surgeons. In this study, a reverse homodigital dorsal wraparound flap innervated by the dorsal digital nerve was devised to repair degloving injury or amputation of distal thumb in 20 consecutive cases. In nine cases of thumb amputation, we skeletonized the phalanxes of the amputated part as a free cortical bone with Kirschner wires. All flaps survived uneventfully. The radiographs showed bone healing in all the patients of thumb amputation within 6 weeks postoperatively. At final follow-up, the appearance of the reconstructed thumb was acceptable and flap sensation and range of joint motion were satisfactory. This flap is a simple and reliable alternative method for degloving injury or amputation of distal thumb when replantation is impossible and patients refuse to donate tissues from toes.

Type of study/level of evidence Therapeutic IV.

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KEYWORDS
Reverse homodigital dorsal flap; thumb reconstruction; degloving injury; amputation; wraparound flap; distal thumb

Introduction

Due to the thumb being the most important digit for hand function, degloving injury or amputation of distal thumb must be reconstructed or replanted as soon as possible [1]. Replantation, if possible, should be the first choice of treatment [2]. In this study many cases were not suitable for replantation because of the seriousness of the injury. In these cases, it is mandatory to perform an appropriate procedure to regain thumb function. Since Morrison et al. [3] first described the great toe wraparound flap, this procedure has often been applied to repair degloving injury or amputation of the thumb [4–9]. These techniques can provide good function and appearance with the preservation of digit length. However, some patients, especially women, refused to donate toe tissue. As such, other procedures should be considered. The reverse homodigital dorsal flap first reported by Brunelli [10], is a common-choice technique for reconstructing extensive dorsal or pulp loss of the thumb in-clinic. This flap has reliable arterial perfusion with simple procedure and inconspicuous donor-site morbidity [11–13]. Anatomical studies have demonstrated that there are two constant arteries, the dorsoradial and dorsoulnar arteries on the dorsal surface of the thumb which are accompanied with sensory branches of the superficial radial nerve [14–16]. The two arteries have consistent anastomoses with the volar proper digital arteries (PDAs) at the level of the middle third and neck of the proximal phalanx. Furthermore, there is also a vascular arcade at the proximal nail fold connecting the two dorsal digital arteries. On the basis of anatomical findings, we covered the soft-tissue defect of degloving injury or amputation of distal thumb using a reverse homodigital dorsal wraparound (RHDW) flap innervated by the dorsal digital nerve (DDN) and skeletonized the distal phalanx of the amputated part with a single Kirschner wire (Figure 1).

The aim of our study was to present our clinical experience of thumb reconstruction with this flap.

Patients and methods

The study was approved by the ethics committees of participating hospitals. All patients signed informed consent forms. All clinical investigations were conducted according to principles expressed in the Declaration of Helsinki.

From June 2014 to March 2018, a total of 20 cases of degloving injuries (11 cases) and amputations (9 cases) of distal thumb in 20 patients, were treated by the RHDW flap. The patients included 12 men and eight women with a mean age of 39 years (range, 25–62 years) at surgery. There were 15 right and five left thumbs involved. The mechanisms of injury were avulsion ($n = 12$) and crush ($n = 8$). Flap transfer and skeletonizing distal phalanx of the amputated part was performed in 8 cases of amputation. The left cases of amputation were repaired by the RHDW flap with arthrodesis of the interphalangeal (IP) joint. Three cases of degloving injury combined with distal phalanx fracture were reconstructed by the RHDW flap and internal fixation with one or two Kirschner wires. The size of soft-tissue defects ranged from 2.0 cm to 4.3 cm (mean, 3.3 cm) in length and 1.8 cm to 2.3 cm (mean, 2.1 cm) in width. The flaps ranged in dimension from 2.0×2.3 cm to 2.6×4.7 cm (mean, 2.4×3.6 cm). Emergency reconstructions were performed within 8 h after injury on all patients by the same hand surgeon (H. W.). The demographic characteristics of the patients are summarized in Table 1.

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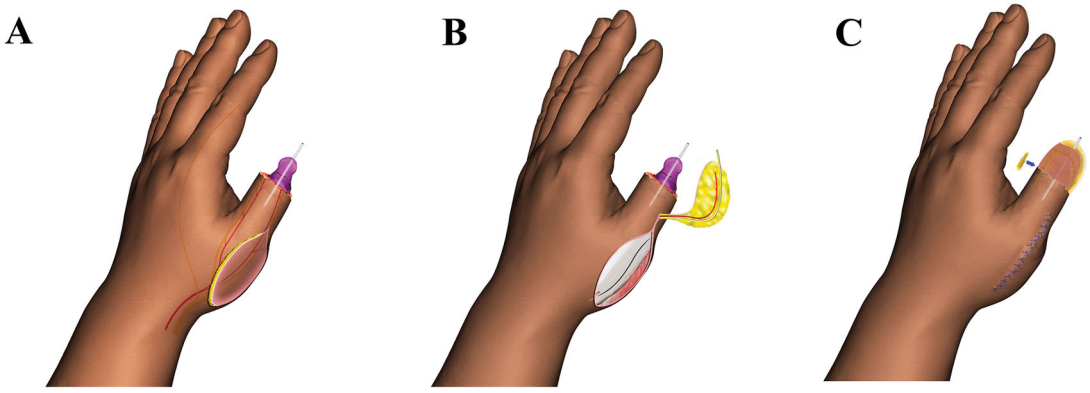

Figure 1. (A) The amputated phalanx is skeletonized with a single Kirschner wire. (B) The soft-tissue defect of distal thumb is covered using the RHDW flap innervated by the DDN. (C) The DDN innervating the RHDW flap is coaptated to the volar PDN.

Table 1. Demographic details of the 20 patients.

Case	Age (y)/ Sex	Side	Cause	Type of Inury	Defect Size (cm × cm)	Flap Size (cm × cm)
1	36/W	Right	Avulsion	Degloving	1.9 × 3.0	2.2 × 3.3
2	42/M	Left	Avulsion	Degloving	2.1 × 3.4	2.4 × 3.7
3	31/M	Right	Crush	Amputation	2.0 × 3.5	2.3 × 3.8
4	48/M	Right	Avulsion	Degloving	2.2 × 2.8	2.5 × 3.1
5	28/M	Right	Crush	Amputation	2.2 × 4.0	2.5 × 4.4
6	40/W	Right	Avulsion	Degloving	1.8 × 2.0	2.0 × 2.3
7	33/W	Left	Crush	Amputation	2.0 × 3.3	2.3 × 3.6
8	51/M	Right	Avulsion	Degloving	2.2 × 3.8	2.6 × 4.1
9	25/M	Right	Crush	Degloving	2.0 × 3.0	2.3 × 3.3
10	41/W	Left	Avulsion	Amputation	1.9 × 3.4	2.2 × 3.7
11	30/M	Right	Avulsion	Amputation	2.3 × 3.5	2.6 × 3.9
12	47/W	Right	Avulsion	Amputation	2.0 × 2.7	2.3 × 3.0
13	36/M	Right	Crush	Degloving	2.3 × 3.8	2.6 × 4.1
14	34/W	Left	Avulsion	Degloving	1.9 × 2.8	2.2 × 3.3
15	62/M	Right	Crush	Amputation	2.3 × 3.0	2.6 × 3.3
16	40/M	Left	Avulsion	Amputation	2.2 × 3.3	2.5 × 3.6
17	42/M	Right	Avulsion	Degloving	2.3 × 4.3	2.6 × 4.7
18	36/W	Right	Crush	Degloving	2.0 × 3.6	2.3 × 3.9
19	55/W	Right	Crush	Degloving	2.1 × 3.5	2.4 × 3.8
20	31/M	Right	Avulsion	Amputation	2.2 × 3.0	2.5 × 3.3
Mean					2.1 × 3.3	2.4 × 3.6

In this study, patients who met the following criteria were included: (1) degloving injury of distal thumb with exposed bone; (2) amputation of distal thumb with no indication of replantation; (3) refusal to toe transfer; (4) necessity to preserve thumb length; (5) patient less than 65 years of age; (6) asking for single-stage procedure. Excluded criteria were as follows: (1) injury in donor site of the harvested flap; (2) thumb defect <1.2 cm or >5 cm in the longitudinal axis; (3) associated proper digital nerve (PDN) avulsion of thumb proximal to the head of the proximal phalanx; (4) consent to toe transfer.

Surgical technique

Surgery was carried out under a brachial plexus anesthesia with the aid of tourniquet control, loupe magnification and an operating microscope. Preoperatively, the courses of the dorsoradial and dorsoulnar arteries of the thumb were identified with a Doppler probe. During debridement, bone periosteum of the amputated phalanx was left *in situ*. The amputated phalanx was fixed to the stump with a single Kirschner wire or integrated to the distal IP joint with two crossing Kirschner wires (Figures 2(A, B), and 3(A)). The bone periosteum was sutured between the amputated phalanx and the proximal stump. Distal phalanx fracture of degloving injury was treated with internal fixation by one or two Kirschner wires.

The flap was tailored on the dorsoradial or dorsoulnar surface of the first metacarpal bone according to the location of soft tissue defect (Figures 2(C), and 3(B)). When necessary, the flap in the longitudinal axis was extended to the level of the anatomic snuffbox. The flap was harvested in a proximal to distal direction along the course of the dorsoradial or dorsoulnar arteries in the subfascial dissection plane. The flap should be slightly larger than the defect due to skin retraction. The pivot point was often at the level of the middle third or neck of the proximal phalanx, where the dorsal digital artery had one anastomoses with palmar PDA. At the proximal end of the flap, the branch of the superficial radial nerve was identified to innervate the flap. A cutaneous tail near the pedicle was reserved to avoid the pedicle compression after rotation of the flap. A 1.0-cm-wide subcutaneous pedicle was dissected including at least one subcutaneous vein to ensure venous outflow [17]. The flap was transferred to the recipient site by open tunnel and wrapped around the soft-tissue defect. With the aid of the operating microscope, the DDN innervating the flap was coaptated to one or both of the volar PDNs in all cases using 10-0 nylon microsutures. The donor site and the pedicle can be closed primarily in some cases (Figure 2(D)). In other cases, we recovered the open pedicle with full-thickness skin graft obtained from the inner arm area (Figure 3(C)).

Postoperatively, the thumb was elevated above the heart level to minimize flap swelling. Flap viability was monitored by visual observation of the flap color, capillary refilling and temperature for at least 3 days. The thumb was immobilized with a protective splint for 4 to 6 weeks until the radiographs showed bone union. Thereafter, the Kirschner wire was taken out and active mobilization of the thumb was conducted with the aid of a physical therapist for about 6 weeks.

Evaluation of outcomes

Data assessments were performed by an experienced hand surgeon (B.W.), level 5 according to Tang and Giddins [18]. At the final follow-up, mobility of the thumb including range of motion (ROM) of the metacarpophalangeal (MCP) and IP joints and web span (WS) [19] was measured using a goniometer. WS was measured when the thumb was in maximal abduction with the volar surface of the hand flat on the table. These results except Case 5 which was performed arthrodesis of the IP joint, were compared with those of the contralateral thumb. Sensibility of the flap was

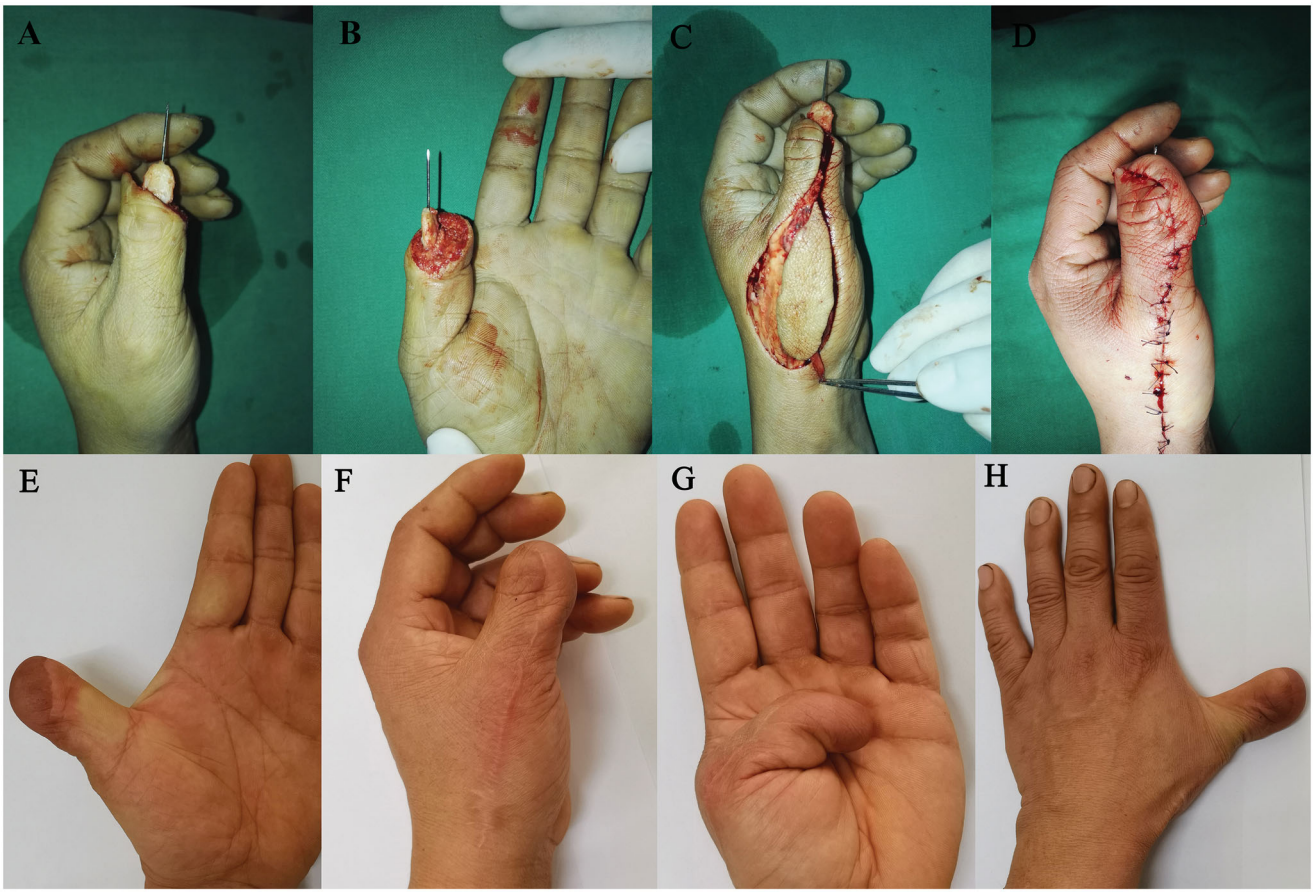

Figure 2. A 40-year-old man suffered amputation of distal thumb pulp defect. After debridement, the amputated phalanx was fixed to the stump with a single Kirschner wire. (A) Dorsal view. (B) Volar view. (C) The RHDW flap is harvested from the dorsoradial surface of the first metacarpal bone and innervated by the branch of the superficial radial nerve. (D) The donor site and the pedicle is closed primarily. (E) The volar appearance of reconstructed distal thumb 24 months after surgery. (F) The appearance of donor site 24 months after surgery. (G) Flexion of the thumb 24 months after surgery. (H) The mobility of the WS in the injured side 24 months after surgery.

measured using the Semmes-Weinstein monofilament (SWM) test [20] and the static 2-point discrimination (2-PD) test [21] and also compared with those of the contralateral side. The test points were at the volar center of the flap and corresponding location of contralateral thumb. Cold intolerance of the flap was assessed using the self-administered Cold Intolerance Severity Score questionnaire (CISS) [22]. The scores range from a minimum of 0 to a maximum of 100 and are grouped into 4 ranges (0–25, mild; 26–50, moderate; 51–75, severe; and 76–100, extremely severe). Pain in the reconstructed thumbs was also evaluated subjectively by the patients using a visual analogue scale (VAS). The VAS consists of a 10-cm line in a ruler ranging from 0 (no pain) to 10 (worst pain). The scores are rated as mild (1–3 cm), moderate (4–6 cm) and severe (7–10 cm).

Results

All 20 flaps survived uneventfully, without arterial insufficiency or venous congestion. Primary healing in the donor site was obtained in all cases. Two weeks after operation, all the flaps exhibited good blood circulation with a pink colour. Bone union was achieved at 4 to 6 weeks after surgery according to radiographic findings (mean, 5 weeks). All patients reported acceptance of the appearance of the reconstructed thumbs. No flap debulking was required and no bone resorption was demonstrated at late follow-up. All patients were followed up for a mean of 18 months (range, 12–30 months).

At final follow-up, the appearance of reconstructed distal thumb and the donor site were acceptable in all cases (Figures 2(E, F), 3(D, E)). The average ROMs of the MCP and IP joints of the injured thumbs were 58° and 70°, respectively (Figures 2(G), 3(F)). Mean values of the contralateral thumbs were 59° and 90°, respectively. There was no obviously abduction contracture of WS in the 20 cases (Figures 2(H), 3(G)). The mean value of WS in the injured side was 89° (range, 75°–95°) compared with 90° (range, 80° to 95°) in the contralateral side.

The average values of SWM and static 2-PD tests of the reconstructed thumbs were 3.81 g (range, 2.83 to 4.17 g) and 8 mm (range, 5 to 10 mm), respectively. On the contralateral side, the mean values were 2.53 g (range, 2.36 to 2.83 g) and 4 mm (range, 3–5 mm), respectively. The details of the sensibility and mobility on the injured and contralateral thumbs are listed in Tables 2 and 3.

There were no significant differences of the MCP joint of the thumb and WS between the bilateral sides ($p > 0.05$). Although there were significant differences between the value of IP joint of the bilateral thumbs ($p < 0.01$), the mean joint ROM of the injured thumb reached 78% of the contralateral side (Table 4). The mean values of SWM and static 2-PD tests of the reconstructed thumbs achieved 66% and 50% compared with those of contralateral sides.

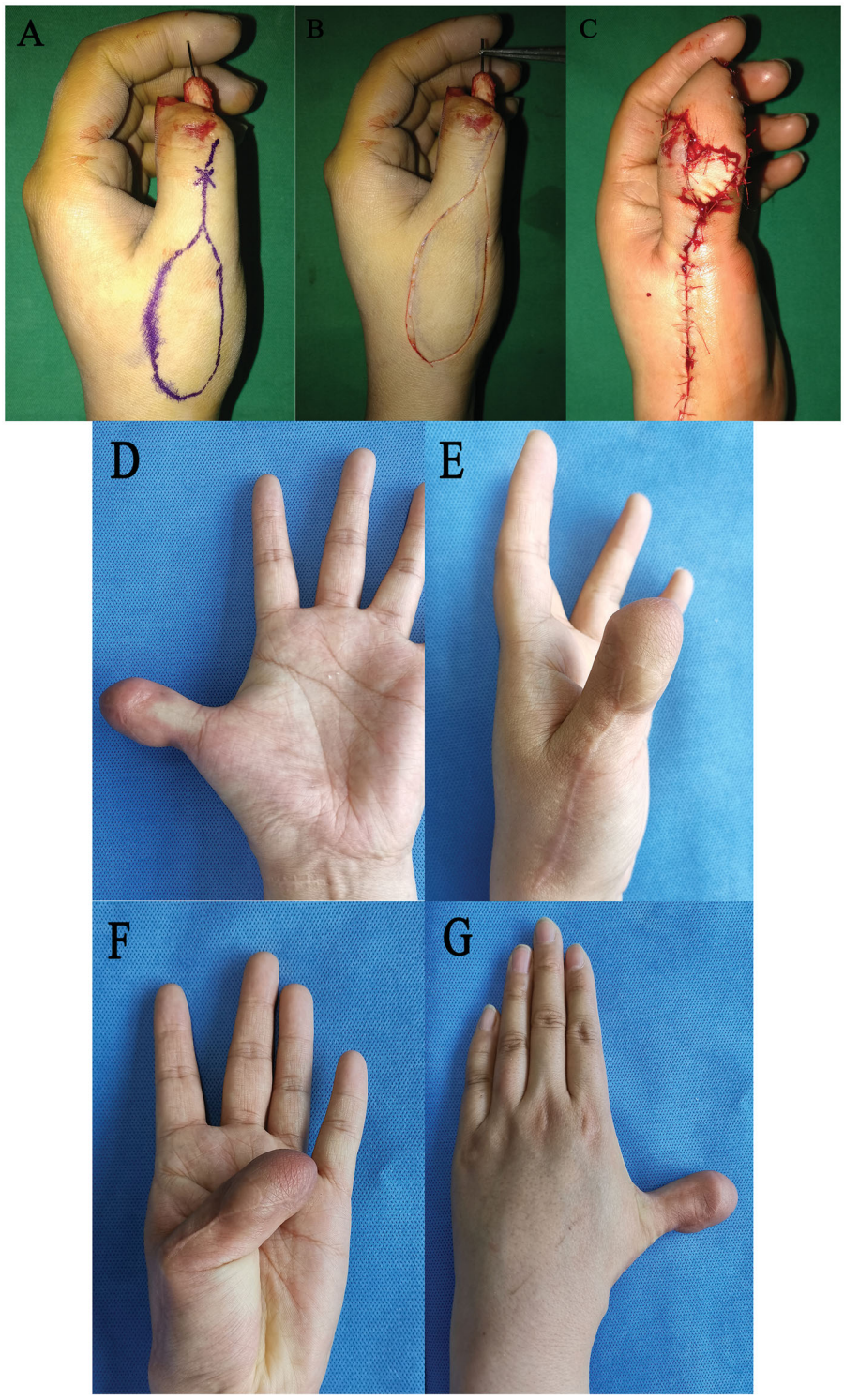

Figure 3. A 33-year-old woman suffered amputation of distal thumb pulp defect (A) The amputated phalanx was fixed to the stump with a single Kirschner wire and the RHDW flap was tailored on the dorsoradial surface of the first metacarpal bone. (B) The RHDW flap is harvested from the dorsoradial surface of the first metacarpal bone and innervated by the branch of the superficial radial nerve. (C) The pedicle was recovered by full-thickness skin graft obtained from the inner arm area. (D) The volar appearance of reconstructed distal thumb 20 months after surgery. (E) The appearance of donor site 20 months after surgery. (F) Flexion of the thumb 20 months after surgery. (G) The mobility of the WS in the injured side 20 months after surgery.

On the basis of the CISS, the scores of all flaps were less than 25, and all patients experienced mild cold intolerance. According to the VAS, 14 thumbs had no pain, and six suffered mild pain (Table 2). All flaps also obtained complete cortical reorientation on the distal thumb.

Discussion

Degloving injury or amputation of distal thumb with no indication of replantation usually causes serious functional loss of the hand. Free toe wraparound flap can be a good option for reconstructing

Table 2. Postoperative assessment of the injuried thumb at the final follow-up.

Case	Sensibility of the Flap SWM (g)/ 2-PD (mm)	ROM of MCP and IP Joint MCP/IP (°)	WS (°)	Cold Intolerance	Pain
1	3.61/7	60/75	92	5	0
2	4.08/9	52/70	90	0	0
3	3.84/8	60/80	90	0	0
4	3.84/9	55/65	85	10	1
5	3.61/7	60/0	90	0	0
6	3.84/8	60/80	95	0	1
7	2.83/5	60/75	90	0	0
8	4.17/10	52/60	85	10	0
9	3.61/7	62/80	95	0	2
10	4.08/9	57/70	90	0	1
11	3.84/8	58/75	93	10	0
12	4.08/9	53/71	90	15	0
13	3.84/8	65/66	90	5	0
14	3.61/7	60/70	92	10	0
15	4.17/10	46/50	75	20	2
16	3.61/8	55/75	90	0	0
17	4.08/9	60/60	90	0	0
18	3.84/8	59/72	88	0	1
19	4.08/9	60/65	85	20	0
20	3.61/7	60/75	91	0	0
Mean	3.81/8.1	58/70	89	5	0.4

SWM: Semmes-Weinstein monofilament test; 2-PD: two-point discrimination; ROM: range of motion; MCP: metacarpophalangeal joint; IP: interphalangeal joint; WS: web span.

Table 3. The outcomes of the contralateral thumb at the final follow-up.

Case	Pulp Sensibility of the Thumb SWM (g)/2-PD (mm)	ROM of MCP and IP Joint MCP/IP (°)	WS (°)
1	2.83/5	60/92	90
2	2.44/4	55/90	92
3	2.36/4	60/89	90
4	2.83/4	55/90	88
5	2.36/3	65/90	90
6	2.44/4	60/95	93
7	2.36/4	60/90	88
8	2.83/5	55/85	89
9	2.36/4	60/95	90
10	2.44/4	57/91	90
11	2.44/3	55/93	95
12	2.83/5	60/90	87
13	2.44/4	65/90	92
14	2.44/4	60/95	90
15	2.83/5	50/80	85
16	2.44/4	55/90	90
17	2.44/4	60/90	90
18	2.36/3	62/88	88
19	2.83/5	60/85	87
20	2.36/4	60/93	93
Mean	2.53/4.1	59/90	90

SWM: Semmes-Weinstein monofilament test; 2-PD: two-point discrimination; ROM: range of motion; MCP: metacarpophalangeal joint; IP: interphalangeal joint; WS: web span.

Table 4. The comparison results of thumb mobility.

Variable	Injured side	Contralateral side	p*
MCP (°)	58 (SD 4)	59 (SD 4)	$>0.05^{\dagger}$
IP (°)	70 (SD 8)	90 (SD 4)	$<0.01^{\dagger}$
WS (°)	89 (SD 4)	90 (SD 4)	$>0.05^{\dagger}$

MCP: metacarpophalangeal joint; IP: interphalangeal joint; WS: web span.
*A value of $p < 0.05$ was considered statistically significant.
†Paired-sample t test.

thumb function and appearance. However, obvious complications on the foot, including an ugly appearance, shortening of great toe, painful toe tip and skin ulceration with shoe wearing, make many patients refuse this procedure [7–9]. Furthermore, other important factors such as age, sex, job and other activities, also influenced patients choice of this procedure [23]. Thus, other good alterative methods need to be designed. Parmaksizoglu and Beyzadeoglu [24] used a composite osteocutaneous groin flap with a neurovascular island flap for reconstruction of the amputated thumb. This surgical procedure was reliable and simple with satisfactory function. However, it needs a third operation, which prolongs treatment and recovery times significantly. Chen et al. [25] reconstructed thumb tip degloving injury using a modified first dorsal metacarpal artery flap. The modified flaps were harvested from the dorsum of both the proximal and the middle phalanges of the index finger and supplied by the longitudinal vascular chain between the first dorsal metacarpal artery and dorsal branches of the PDA. However, this technique affects the appearance of the dorsum of the index finger and may compromise its mobility. Twin dorsal middle phalangeal finger flaps from the dorsums of the middle and ring fingers reported by Qi and Chen [26] is another method to repair degloving injury of the thumb. These flaps were dominated by the PDA and dorsal branch of the PDN with the PDN left *in situ*. The pulp sense of donor finger was retained. The disadvantages included that the flaps were taken from two healthy fingers, the common digital artery and two PDAs from the middle and ring finger were sacrificed and the dorsal aspect of the donor fingers had a deformity of contour with a slight numbness. A free wraparound chimeric radial collateral artery perforator flap is another effective option to reconstruct an amputated or degloving injury of the thumb [27]. This technique can reconstruct thumb loss with no major donor-site complications. There are however several shortcomings, including the variation of perforators, the requirement of prolonged operations and a high degree of microsurgical skill.

To shorten operative duration, reduce high-risk microanastomosis and minimize donor-site morbidity, we used an alterative procedure of the RHDW flap to salvage degloving injury or amputation of distal thumb in our series. This flap can provide well-vascularized skin, preservation of thumb length, one-stage operation, and donor and recipient sites at the same digit. Meanwhile, this procedure does not need excellent microsurgical techniques. The MCP joint and abduction of web space reached nearly normal level compared to the contralateral side. All patients returned to previous occupations satisfied with motor function.

For the selection of the donor site, we prefer the dorsoradial side of the first metacarpal bone due to its glabrous skin and the lower incidence of abduction contracture of WS in case of no early rehabilitation exercise as compared to the dorsoulnar side. If the proximal edge of the defect was closer to the ulnar side, the dorsoulnar flap was harvested. If the extensive soft-tissue defect could not be covered by the dorsoradial or dorsoulnar flap alone, the flap was extended to include both the dorsoradial and dorsoulnar arteries.

In our series, all nine cases of amputation of distal thumb displayed good bone healing without bone necrosis and resorption. This may be related to sufficient blood supply of the RHDW flap and retained periosteum of the amputated phalanx which can provide abundant osteogenic constituents to nourish the devitalized bone of the amputated part for skeletal reconstruction [17]. Because the devitalized bone was small and no more than the IP joint, the creeping substitution process from the proximal bone was easier than the amputated phalanx proximal to the IP joint [28]. Thus, we recommend that this technique is best applied to repair the amputation of distal thumb.

To improve the volar sense of the reconstructed thumb, we coaptated the DDN of the flap in all cases. Although normal sensation in the thumb pulp was not fully attained, the results in our study were slightly superior to those reported that did not repair the DDN of the flap [11,17]. The result may be due to the sensory test point of the flap near nerve anastomosis, so nerve recovery on the pulp can be easier and faster. Furthermore, nerve anastomosis can also significantly reduce the formation of painful neuroma of the digit [29]. Therefore, we suggest neurorrhaphy in all flaps.

At the donor site, the subcutaneous pedicle was preserved at least 1.0-cm-width to ensure vascular sufficiency. To avoid flap compression and vascular compromise, the pedicle in some cases were not closed primarily and resurfaced with full-thickness skin graft. During late follow-up, the grafted skin healed well and did not form scar contracture.

The major drawback of this procedure was the nailless appearance. Nevertheless, thumb appearance was acceptable for all patients and did not affect normal life and work. It is especially suitable for older patients. Another drawback was a slight numbness of the thumb dorsum. Other limitations of this study include small sample size, lack of a control group and sample was limited to those reluctant to prefer toe transfer.

Conclusions

Despite the aforementioned drawbacks, the RHDW flap innervated by the DDN provides a simple, safe, one-stage procedure at minimal donor-site cost for reconstruction of degloving injury or amputation of distal thumb, when replantation is not feasible and patients refuse to accept toe transfer.

Acknowledgements

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Ethical approval

Ethical approvals for report this cases were obtained from the ethical committee of The Second Hospital of Tangshan and North China University of Science and Technology. This study was completed in accordance with the Helsinki Declaration as revised in 2013.

Informed consent declaration

Written informed consent was obtained from the patients for their anonymized information to be published in this article.

Author contributions

Hui Wang wrote the first draft of the manuscript. All authors reviewed and edited the manuscript and approved the final version of the manuscript.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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