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ORIGINAL ARTICLE

Reconstruction of dorsal hand and finger defects with reverse radial fasciocutaneous forearm flaps

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Abstract
Objectives To evaluate the midterm outcome and the degree of satisfaction of patients who underwent reconstruction of dorsal hand and finger defects with reverse flow radial fasciocutaneous forearm flaps and to test whether or not this is a reliable method which can be applied without the need for microsurgery.
Patients and methods Eleven patients were admitted with post-traumatic complex hand defects and treated by reconstruction with reverse flow radial fasciocutaneous forearm flaps from January 2010 to May 2013. The patient demographics, size of the hand and finger defects, and complications were recorded. The functional status of each of the patients was evaluated using the quick disabilities of the arm, shoulder and hand (DASH) scoring system, and patient satisfaction was assessed using Likert scores.
Results The patients comprised nine males and two females with a mean age of 30.7 ± 9.7 years. The mean follow-up period was 18.4 ± 5.2 months. The average defect size was 41 ± 14.3 cm^2. None of the patients had circulation defects caused by the sacrifice of the radial artery. The mean quick DASH score was determined as 30.2 ± 15.3. The Likert patient satisfaction evaluation was good in one patient, and very good in ten patients. All flaps survived well with only two complications; superficial skin necrosis occurred at the suture site in one patient and venous insufficiency occurred in the other patient. Both complications recovered with secondary healing following wound debridement.
Conclusions The reverse-flow radial forearm flap is a reliable method in the management of dorsal defects of the hand and does not require micro-surgical techniques.

Keywords Surgical flaps · Forearm injuries · Dorsal hand injuries · Dorsal finger injuries · Radial forearm flaps

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Introduction

Skin defects occur in many hand injuries. When soft tissue defects over the bone, tendon, nerve or joint have been closed with primary sutures, flap surgery should be performed to ensure a functional hand with tissue entirety [1]. While small defects can be closed with local transposition flaps, reconstruction of larger defects should be performed using distant flaps, free flaps or pedicle flaps. Although the application of distant flaps is a useful method, it may be uncomfortable for the patient and several operations may be required. Free flaps provide excellent soft tissue coverage and allow for early rehabilitation, but they have the disadvantages of an extended operation time, and requirements for special equipment and micro-surgery training [2, 3].

Pedicle flaps may be taken from both the distal and proximal pedicles, and there is no need for microvascular anastomosis during the defect reconstruction [4–7].

The aim of this retrospective study was to evaluate the midterm clinical and functional results of 11 patients who underwent reconstruction using reverse flow radial forearm fasciocutaneous flaps for hand and finger dorsal complex

defects due to avulsion injuries. We also evaluated whether this method can be reliably applied without micro-surgery.

Materials and methods

We retrospectively examined patients who presented to the Emergency Department of Selcuk University with soft tissue defects due to dorsal hand and finger trauma and who underwent reconstruction with reverse flow radial forearm flaps from January 2010 to May 2013. Approval for this study was granted by the Selcuk University Medical Faculty Ethics Committee.

The patients' follow-up data were obtained from hospital records and face-to-face interviews. The general demographic characteristics of the patients, the mechanism of trauma, the location and size of the defect, accompanying fractures or other injuries and the development of postoperative complications were recorded. The functional and aesthetic results at the final follow-up were evaluated and recorded. The quick disabilities of the arm, shoulder and hand (DASH) scoring system were used for functional evaluation [8]. Patient satisfaction was evaluated with a 5-point Likert scale [9].

All transferred flaps were fasciocutaneous island flaps. Each flap was moved together with the radial artery and associated radial vein. The smallest flap was 6 × 3 cm, and the largest was 10 × 8 cm. All the operations were performed by the same surgeon (M.A.A.).

Surgical technique

The Allen test was used to evaluate preoperative hand circulation, and the result was negative in all patients. In patients with crush injuries and advanced oedema, the status of the two dominant arteries of the hand was evaluated with Doppler ultrasonography. An axillary block anaesthesia was applied to three patients and the remaining patients underwent general anaesthesia. Upon completion of preoperative planning appropriate to the defect and flap design, dissection was performed with a tourniquet in place. The first incision extended to the muscle fascia, passing through the skin and fascia. By advancing between the deep fascia and muscle fascia, the surgical wound entrance was created below the radial artery from the edges of the flexor carpi radialis and brachioradialis tendons.

The superficial sensitive branch of the radial nerve was carefully preserved. The radial artery was cut by tying the branches which connected to deep tissues. The artery was cut from the proximal aspect by tying the radial artery. The radial artery flap was raised as a fasciocutaneous island in such a way as to be centred. An incision was made along the pedicle up to 2 cm proximal of the distal wrist line. Pedicle dissection was completed with the island flap from proximal to distal without damaging the pedicle. Flap circulation was checked by opening the tourniquet. By passing under the prepared skin bridge from the wrist level as far as the defect, the flap was adapted to the defect area. Attention was paid not to compress the vascular pedicle below the skin bridge. Small donor areas with a narrow width such as 4 cm underwent primary closure, and wider defects were closed with a full thickness skin graft (Fig. 1).

Results

This study included 11 patients (nine males, two females) with a mean age of 30.7 ± 9.7 years (range 11–55 years). The mean follow-up period was 18.4 ± 5.2 months (range 12–36 months). The patients' demographic characteristics, type of injury and concomitant injuries are summarised in Table 1. The time to surgery, flap dimensions, accompanying surgical procedures, complications, follow-up period, quick DASH scores and patient satisfaction scores are summarised in Table 2.

With respect to complications, superficial skin necrosis developed at the flap edge in one patient. Superficial skin necrosis associated with venous insufficiency in the flap developed in one patient and recovered after a single session of debridement (Fig. 2). No impaired circulation associated with the tying of the radial artery was observed in any patient. Edema which developed in the early postoperative period was brought under control with elevation and started to decrease within approximately 7–10 days. There was no flap loss in any patient.

Discussion

Satisfactory results were obtained in all the patients who underwent reconstruction of soft tissue defects of the dorsal of the hand using reverse flow radial forearm fasciocutaneous flaps. Superficial skin necrosis developed in the flap edge in only one patient. Venous congestion was determined in one patient, and this was treated with debridement only. There was no flap loss in any patient, and satisfactory cosmetic results were obtained in all patients. According to the results of this study, the application of reverse flow radial forearm flaps is a reliable method in the treatment of hand defects.

In a study by Chen and Li [10] in which hand skin defects of 42 cases were treated with reverse flow terminal radial artery forearm fasciocutaneous flaps, it was reported that satisfactory cosmetic and functional results were obtained in 18 cases. Ayad [11] compared the use of reverse flow radial

Fig. 1 **a** A 55-year-old patient with an industrial accident injury. **b** Preoperative planning. **c** Flap preparation. **d** Flap rotation. **e** Postoperative flap location. **f** Postoperative donor area. **g**, **h** Clinical appearance at follow-up

forearm flaps ($n = 4$), distant pedicular groin flaps ($n = 7$) and anterolateral thigh flaps ($n = 3$) in hand injuries and reported good survival of all the flaps. However, in the reconstruction of complex hand injuries, reverse flow radial forearm and free anterolateral thigh flaps were reported to be superior to distant pedicular groin flaps. In that study, although the number of patients to whom radial forearm flap was applied was low, it is important as a clinical study comparing different types of flaps. Similarly, the results of reconstruction with radial forearm flap in dorsal surface finger injuries in the current study also determined that flap survival was good. In addition, patient satisfaction was evaluated in

Table 1 Patients' demographic characteristics of the patients, type of injury and accompanying defects

Case no	Gender	Age	Mechanism of injury	Location of the injury requiring flap	Injury size (cm)	Accompanying upper extremity injuries
1	M	21	Firearm injury	Over the metacarpal	5 × 6	2nd metacarpal fracture, 3 extensor compartment tendon injury
2	M	41	Traffic accident	Dorsal 3rd, 4th, 5th metacarpal	8 × 5	4–5–6 extensor compartment injury
3	M	13	Firearm injury	Dorsal metacarpal	9 × 7	Tendon defect in the 3rd, 4th extensor compartment
4	M	33	Traffic accident	Dorsal hand over 4th, 5th metacarpal	9 × 5	Widespread skin abrasions on the forearm and arm
5	M	55	Industrial accident	Dorsal 2nd, 3rd finger after 2nd finger polarisation insufficiency	7 × 4	Loss of correction in the 2nd metacarpal + implant failure
6	M	11	Industrial accident	Dorsal metacarpal	7 × 5	Amputation of the 2nd finger at the level of the mid phalanx and of the 3rd and 4th fingers at the MP joint
7	M	38	Industrial accident	Dorsal 2nd, 3rd, 4th, 5th metacarpal	10 × 8	Extensor tendon defect in the left wrist and exposure of 2nd, 3rd, 4th, 5th metacarpals. Total amputation of the right wrist.
8	F	48	Traffic accident	Dorsal PIP joint and 4th finger MP joint	6 × 3	Fracture within the proximal phalanx segmentary joint + extensor tendon defect
9	F	32	Traffic accident	Dorsal 2nd, 3rd, 4th, 5th metacarpal	10 × 7	Amputated 2nd, 3rd, 4th, 5th fingers not suitable for replantation
10	M	30	Industrial accident	Distal and volar of 1st finger distal phalanx	6 × 3	Thumb crushed at the level of the distal phalanx amputated and not suitable for replantation
11	M	16	Firearm injury	Dorsal 4th, 5th metacarpal	6 × 4	4th, 5th metacarpal proximal fracture + 2nd, 3rd, 4th finger digital nerve injury + 2nd, 3rd, 4th finger FDP defect

the current study, and patients were found to be satisfied with the cosmetic results. As patient satisfaction was not researched in the Ayad [11] study, it is not possible to comment in terms of patient cosmetic satisfaction with radial forearm flaps and other flaps.

The reasons for our choice to use reverse flow radial forearm flaps in our clinic were the suitability of colour and size of these flaps, the possibility of transferring thin, hair-free tissue; the ability to perform surgery in one session; and no requirement for micro-surgical anastomosis, thus providing the opportunity to start mobilisation and physiotherapy in the early postoperative period. Several advantages of reverse flow radial forearm flaps include pliability, flexibility and reliability of results [12, 13].

Radial forearm flaps are extremely suitable for reconstruction of not only hand and wrist injuries but also for defects in the head and neck regions. However, there are some disadvantages to these flaps, the most significant of which is that one of the main arteries of the hand is sacrificed [12, 14]. In addition, when the defect in the area from which it has been taken cannot be closed primarily, it is necessary to close the donor site with a skin graft and from a cosmetic aspect, this is a disadvantage [12, 15]. However, in the current study, no complications were determined related to these disadvantages.

In a recent review at a third stage centre, which compared free tissue transfers, six types of free flap were used on 1,051 patients: fasciocutaneous radial forearm (53 %), osteocutaneous radial forearm (16 %), rectus abdominis (11 %), fibula (10 %) anterolateral thigh (7 %) and latissimus dorsi (2 %). No statistically significant difference was determined between the flaps when evaluated in respect of donor site results [16]. Sinclair et al. [17] applied DASH scoring to 60 patients following surgery with free radial forearm osteocutaneous or fasciocutaneous flap, and in the results, a minor level of donor site morbidity or donor site complication was determined by the patients. In the current study, the donor site required closure with full thickness skin graft in seven (63.6 %) patients and primary closure was made in four (36.4 %) patients. All the patients, whether closure was made primarily or with full thickness skin graft, were pleased with the cosmetic results.

One of the most important points in the success of reverse flow radial forearm flaps is the continuation of appropriate blood flow in the arm. In this respect, it is recommended that the Allen test or Doppler flow studies should certainly be applied preoperatively [18]. Non-circulation in either the ulnar or radial artery is a clear contraindication for the use of a flap, because the most feared complication of radial forearm flaps is acute hand ischaemia which may develop associated with the sacrifice of the

Table 2 Time to surgery, flap dimensions, accompanying surgical procedures, complications, follow-up period and patient satisfaction scores

Case no.	Time to surgery (days)	Accompanying surgical procedures	Flap complications	Follow-up period (months)	Quick DASH score	Patient satisfaction	Donor site closure
1	8	1. Fixation with K-wire 2. Iliac bone graft + K-wire fixation, tendon reconstruction + skin graft	–	22	34.1	Satisfied	Full skin graft
2	21	1. K-wire fixation + tendon repair 2. Debridement 3. Debridement	–	18	13.6	Very satisfied	Full skin graft
3	23	1.Tendon repair	–	12	20.5	Very satisfied	Full skin graft
4	1	–	–	12	2.3	Very satisfied	Primary closure
5	90	Iliac wing bone graft + K-wire fixation	–	18	22.7	Very satisfied	Primary closure
6	Same day	Debridement + incomplete closure	–	24	38.6	Very satisfied	Full skin graft
7	Same day	Debridement + extensor tendon transfer to distal metacarpal	–	36	75.0	Very satisfied	Full skin graft
8	Same day	Debridement + bone fixation with mini-screw + extensor tendon reconstruction with PL graft	Skin necrosis over the flap	12	2.3	Very satisfied	Primary closure
9	1	Debridement + reconstruction with flap	–	12	59.1	Very satisfied	Full skin graft
10	Same day	Amputation skeleton stripped and fixed with K-wire + osteoplastic reconstruction	–	24	20.5	Very satisfied	Full skin graft
11	Same day	Debridement + digital nerve repair with graft + K-wire fixation + tendon repair	Skin necrosis around the flap	12	43.2	Very satisfied	Primary closure

radial artery. Although there are very few cases reported in literature and this is a very rare complication, relative hypoperfusion may continue, demonstrated by cold intolerance [19–21]. The Allen test, which is a cheap, quick and non-invasive method used to ensure hand perfusion and evaluate dual arterial flow, is the first test preferred in the determination of the risk of distal ischaemia after the sacrifice of the radial artery. If the Allen test result is abnormal, vascularisation should be evaluated again with Doppler ultrasonography. Although arteriography is expensive, and despite the risks of serious complications such as arterial occlusion, renal failure, haematoma, intimal damage and anaphylactic reactions due to contrast, it is still accepted as the ideal technique in the evaluation of arterial anatomy, clarity and collateral between the radial and ulnar arteries [22]. In the current study, the Allen test was negative for all the patients. Ischaemia did not develop in any patient, and no patient had complaints of cold intolerance during the follow-up period. In this respect, the reverse flow radial forearm flap operation can be accepted as a low-risk operation in terms of ischaemic complications in patients with a negative Allen test. The complication of superficial skin necrosis was observed in two patients, one on the flap and one around the flap, but there was no flap loss in any patient.

There is a tendency for venous congestion to develop with the use of reverse-flow radial artery flaps because the venous drainage of these flaps is weak [23]. There is no advantage to the use of a dual venous drainage system even though a superficial and deep venous drainage system was recommended by Liu et al. [24] to prevent complications associated with venous drainage, and it has been reported that the use of only a superficial venous drainage system on patients does not affect flap survival. Similarly, in another study, venous congestion developed in 13 of 178 radial forearm fasciocutaneous flaps; 11 of these 13 cases of venous congestion occurred in the first 72 h. Nine of these 13 flaps were saved and four were lost. In that extensive study, the main reasons for venous insufficiency were defined as an inappropriate pedicle length or mechanical obstruction because of the shape, insufficient venous drainage, compression or a kink in the vein [25]. In the current study, venous congestion in the flap developed in one (9.0 %) case and this was treated with debridement only.

The main limitation of the current study is its retrospective design and relatively small number of the cases. Due to the study design, we primarily focused on the reverse radial forearm flap. Since different techniques (i.e. free flaps and pedicle flaps) were only reserved for selected patients who were not included in the current study and the

Fig. 2 **a**, **b** A 48-year-old female patient with a traffic accident injury. **c** Preoperative planning. **d** Flap preparation. **e** Postoperative flap location. **f** Postoperative superficial necrosis of the flap postoperatively. **g**, **h** Secondary healing after debridement

scarce number of these aforementioned groups, we did not have the opportunity to compare different flaps. However, it is important that the cosmetic satisfaction of the patients was evaluated as well as functions.

In conclusion, despite some disadvantages such as evident donor site scars, the application of reverse flow radial forearm fasciocutaneous flaps should be kept in mind as a very good alternative in hand reconstruction. Advantages

of this flap include a very well-developed vascular structure, the ability to be prepared at appropriate sizes, providing mobilisation and physiotherapy in the early period, and it can be applied in a single session without the need for microsurgery and has very good aesthetic adaptation to the hand and wrist area. Further prospective, randomised, controlled studies with greater numbers of patients researching patient functional and cosmetic satisfaction with reverse flow radial forearm fasciocutaneous flaps. Such research will provide more objective data regarding the advantages and disadvantages of these flaps.

Conflict of interest None.

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