



Replantation of the total skin-only avulsions of fingers

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Abstract

Background Skin-only avulsion is a particular type of avulsion surgery. In this type of injury, tendons, bones, and joints maintain their integrity. In this report, we aimed to report the promising results of replantation in seven fingers with total skin-only avulsions.

Methods From 2007 to 2015, 6 patients with a mean age of 34.6 (20–52) who underwent replantation surgery for total skin-only avulsion injuries distal to metacarpophalangeal (MP) joint were evaluated according to the injury type, etiology, level of repair, and the repaired structures.

Results Seven fingers of 6 patients were evaluated. The mean repaired artery and vein number were 1.5 (1–2) and 3.8 (3–5), respectively. The mean percentage of partial necrosis in the three fingers and an amputated finger was 25.70%. Three fingers survived completely, whereas three developed partial necrosis which were managed by debridement and full thickness skin grafting. Mean static and dynamic two-point discriminations were 6 mm and 3.83 mm, respectively. The mean ROM degree of PIP/IP joints and DIP joints was 74.1 (60–85) and 56.6 (40–70) degrees, respectively. The mean follow-up was 28.3 months (24–36).

Conclusions Skin-only avulsions are a particular type of avulsion injury and very challenging to treat. In order to avoid from the partial necrosis due to the vascular deprivation of perforating branches of the proper digital artery, we recommend repairing both arteries in this type of avulsion. Skin-only replantation results can be successful when several technical details are observed.

Level of evidence: Level V, therapeutic study.

Keywords Amputation · Avulsion · Replantation · Skin-only

Introduction

Finger replantation is a challenging microsurgical procedure, and the main factors that determine success are the type of injury and the number of anastomosed vessels [1]. Degloving injuries, a type of injury rarely observed, are one of the most problematic areas of reconstructive surgery.

Replantation surgery is technically more difficult because this type of amputation occurs in the pull out–breakout style.

The presentation of degloving injuries is extensive, from avulsions involving only the skin to complete amputations. Urbaniak classified the avulsion injuries as (I) adequate circulation, (II) inadequate circulation, and (III) degloving/complete amputation [2]. Kay et al. divided class II injuries in two according to the skeletal injury. Also, complete amputation was defined as class IV injury [3]. One of the critical steps in this type of amputation is the detection of appropriate vessels within the amputate. Kayalar et al. indicated that replantation is not possible if the vessels remain on the finger rather than the amputate [4]. Among these types of avulsion injuries, skin-only finger avulsions are a particular type. In skin-only finger avulsion, the skin and subcutaneous tissue are amputated, while the tendons are still attached to the subcutaneous tissue. In this type of degloving injury, the digital arteries and the subcutaneous perforator arterial system are distracted and injured. Therefore,

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repair of a single digital artery does not guarantee the survival of the whole amputated [4–6].

Kerschhagl et al. reported a case with circumferentially degloved thumb which resulted with partial skin necrosis, and they discussed that the circumferentially degloving injuries are rare and difficult to treat [7]. Because the isolated soft tissue envelope, the success rate of replantation of these injuries is low [7].

The replantation indications for avulsion-type amputations were expanded, including avulsion injury with complete degloving of dorsal and palmar skin and vessels [8, 9]. Despite this expansion, avulsion injuries have relatively low rates of successful replantation. According to a meta-analysis, the replantation success of avulsion injuries was 66.3%, whereas clean-cut injuries were 91.4% [10]. Because the replantation of skin-only avulsion injuries has a complicated surgical technique, many surgeons accept the failure from the beginning of the surgery. However, these avulsions can be replanted successfully by taking care of a few technical details.

In this report, we aimed to report the promising results and surgical technique of replantation in seven fingers with total skin-only avulsions.

Patients and methods

From 2007 to 2015, 6 (1 female, 5 male) patients who underwent replantation surgery for total skin-only avulsion injuries distal to metacarpophalangeal (MP) joint were considered for enrollment in this retrospective report. Pure skin and subcutaneous injuries without involvement of tendon or bone were included to the report. All operations were performed by the same surgical team consisting of two hand surgeons. Avulsion injuries other than skin and subcutaneous tissue were excluded from the report. All procedures followed were in accordance with the ethical standards of the local institutional review board, and informed consents were obtained from all patients for being included in the study.

Surgical technique

All the procedures were performed under regional anesthesia. Amputated fingers were examined under a microscope following the standard debridement procedure. Digital arteries, nerves, and available dorsal and volar veins on the amputate are marked with 8/0 nylon sutures. All those structures are marked on the patient's finger(s) as well. Extra incisions to explore the amputate were avoided. Marked digital arteries of the amputate are injected with saline solution to verify if there is any venous return; thus, arterial injuries at the distal segments are evaluated. Vessel

anastomoses were performed using 10/0 nylon sutures whereas nerve repairs were performed using 8/0 or 9/0 nylon sutures. All the vessels were repaired without vein grafts. Minimal distal phalangeal tuft shortening was performed in two fingers to avoid excessive tension on the anastomoses and vein grafts.

All the patients received prophylactic antibiotic (cephazolin sodium, 1 g, intravenously), subcutaneous low molecular weight heparin (5000 U/day), and dextran 10% infusion (500 cc/24 h). Patients were hospitalized on an average of 8.2 days (7–10 days).

Passive range of motion exercises were started at the third week in all fingers.

Evaluation

All patients' injury mechanism, level of injury, the initial surgery, secondary procedures (if needed), rehabilitation protocol, follow-up time, complications, and range of motions (ROM) regarding interphalangeal joints distal to the level of injury were recorded. Partial necrosis percentage was measured with area calculation of Image J software (National Institutes of Health Bethesda, MD, USA). Semmes–Weinstein monofilament test (SW), static two-point discrimination (STP), and dynamic two-point discrimination (DTP) tests' results at 6th month follow-up are obtained and analyzed.

Results

Six patients, with a mean age of 34.6, whose mean follow-up length was 28.85 months (24–36 months), were evaluated. All patients had an avulsion injury. Seven fingers were replanted. Three thumbs, 2 index fingers, 1 ring finger, and 1 small finger were the amputated fingers. The level of injuries was MPJ (metacarpophalangeal joint), ($n = 3$); PP (proximal phalanx), ($n = 3$); and PIPJ (proximal interphalangeal joint), ($n = 1$). Skin-only replantations were performed for all amputates. The mean repaired artery, vein, and nerve numbers were 1.5 (1–2), 3.8 (3–5), and 1.2 (1–2), respectively. Bilateral digital arteries were repaired in 4 fingers, whereas 3 fingers underwent single digital arterial repair. Both volar and dorsal veins were anastomosed in all fingers. Two volar veins in 2 fingers and one volar vein in 5 fingers were anastomosed. Bilateral digital nerves were repaired in two fingers, and unilateral digital nerve was repaired in five fingers.

Three fingers survived completely, whereas three developed partial necrosis which were managed by debridement and full thickness skin grafting. The three patients' mean percentage of skin necrosis was 25.70% (14.44–50%). One patient's (case 6) index finger middle and distal phalanx

skin underwent circumferential skin necrosis. Patient rejected to have a groin flap procedure; therefore, a PIP joint level amputation was performed.

Physiotherapy was interrupted for 2 weeks for patients who underwent debridement and skin grafting due to partial necrosis of the skin; it was resumed after wound healing.

According to the Semmes–Weinstein test, 2 fingers tested normal (green), 3 had diminished light touch (blue), and 1 had diminished protective sensation (purple).

Mean static and dynamic two-point discriminations were 6 mm (3–9 mm) and 3.83 mm (3–5 mm), respectively.

Mean flexion and extension degree of PIP/IP joints were 80 and 5.8, respectively. The mean ROM values of PIP/IP joints were 74.1 (60–85). Mean flexion and extension degree of DIP joints were 60 and 3.3, respectively. The mean ROM values of DIP joints were 56.6 (40–70) degrees. The mean follow-up was 28.3 months (24–36) (Table 1).

Case reports

Case 1. 36-year-old male worker who had amputations on ulnar three fingers due to a crush injury (Fig. 1a). Long and ring fingers were treated with stump revisions and skin grafts taken from the amputates, while little finger underwent a replantation surgery (Fig. 1b). Two arteries, 1 volar vein, and 3 dorsal veins were repaired (Fig. 1c–e). In the postoperative 12th day, skin necrosis was determined on the ulnar side of the little finger which is limited with the midphalanx level (Fig. 1h). After the replantation, acceptable cosmetic and sensorial results were obtained (Fig. 1i, j). The patient was followed up for 25 months.

Case 2. 20-year-old female worker sustained to a right thumb skin only amputation by a roller (Fig. 2a). Avulsed thumb skin was replanted; 2 arteries, 1 volar vein, and 2 dorsal veins were anastomosed during the procedure (Fig. 2b, c).

2 weeks after the initial surgery, skin necrosis was developed on the thumb which is limited with the dorsum of the proximal phalanx (Fig. 2e). After debridement the skin defect closed with skin grafting. Acceptable functional and esthetic results were obtained (Fig. 2f, g). The patient was followed up for 36 months.

Case 3. 42-year-old male worker who had left thumb and index finger skin only amputations through MPJ by a hand drill underwent skin-only replantation procedure (Fig. 3a–c). Two arteries, 2 volar veins, and 3 dorsal veins were repaired for thumb, and 1 artery, 1 volar vein, and 2 dorsal veins were repaired for the index finger (Fig. 3d, e). 7 days after the initial surgery, a circumferential necrosis was determined on the index finger which is limited with the distal phalanx (Fig. 3g, h). Patient rejected the groin flap for salvage, and the finger was amputated through PIPJ (Fig. 3i). For the thumb, cosmetically and functionally acceptable results were obtained (Fig. 3j, k). The patient was followed-up for 32 months.

Discussion

The type of injury is the most important predictor of survival and functional results [11]. In the literature, most papers found that replantation of sharp amputations provides significantly better results than crush and avulsion injuries [10, 12]. However, the desired survival and functional results can be obtained in the replantation of avulsion injuries.

Skin-only avulsions are a particular type of avulsion injury and very challenging to treat. Technically speaking, replantation of these injuries differs from the replantation of amputates containing tendons and bone. Tendons, bones, and joints maintain their integrity in total skin-only amputations; digital nerves and the vessels are the only structures to be repaired.

Table 1 Patients’ demographics, characteristics of amputations, and sensorial and functional results

CASE	AGE	Finger	Level of repair	A	V	N	Secondary procedures	Follow-up (months)	SW	STP	DTP	IP/PIP ROM	DIP ROM	Complications
1	36	Small	PIPJ	2	4(1 V,3D)	1	Skin grafting	25	blue	7	4	0/85	0/60	Partial necrosis
2	31	Index	PP	2	4(1 V,3D)	1	–	24	blue	7	4	5/90	10/50	–
3	20	Thumb	MPJ	2	3(1 V,2D)	2	Skin grafting	36	green	5	3	10/70		Partial necrosis
4	27	Thumb	PP	1	4(2 V,2D)	1	–	27	blue	5	4	0/75		–
5	52	Ring	PP	1	4(1 V,3D)	1	Skin grafting	26	purple	9	5	10/80	0/70	Partial necrosis
6a	42	Thumb	MPJ	2	5(2 V,3D)	2	–	32	green	3	3	10/80		–
6b	42	Index	MPJ	1	3(1 V,2D)	1	Amputation through PIPJ	32						Circumferential necrosis

SW, Semmes–Weinstein monofilament test; STP, static two-point discriminations; DTP, dynamic two-point discriminations; N, nerve repair; A, arterial repair; V, venous repair



Fig. 1 a 36-year-old male worker who had amputations on ulnar three fingers due to a crush injury, ulnar three fingers' amputation (dorsal view). b Long and ring fingers were treated with stump revisions and skin grafts taken from the amputates, while little finger underwent a replantation surgery; left long, ring, and little finger amputations (volar

view). c–e Different vein repairs during replantation. f and g Immediate result after surgery. h In the postoperative 12th day, skin necrosis was determined on the ulnar side of the little finger which is limited with the midphalanx level. i After the replantation, acceptable cosmetic and sensorial results were obtained. j Follow-up at postoperative 4th month

Besides, if the skin of the amputate involves extra skin cuts, digital vessels and nerves may have injuries in multiple segments which should be examined in detail. In cases where the distal end of the digital artery cannot be examined, a multiple segment arterial injuries should be suspected, and venous backflow must be verified using saline injection through an

appropriate size angiocaths at the exposed arterial stoma; thus, more distal arterial injuries can be diagnosed [13, 14].

In this report, we observed that skin-only amputations have lower vascular bed injury compared with the other avulsion amputations. This may be due to the difference between the levels of energy causing the amputation. The

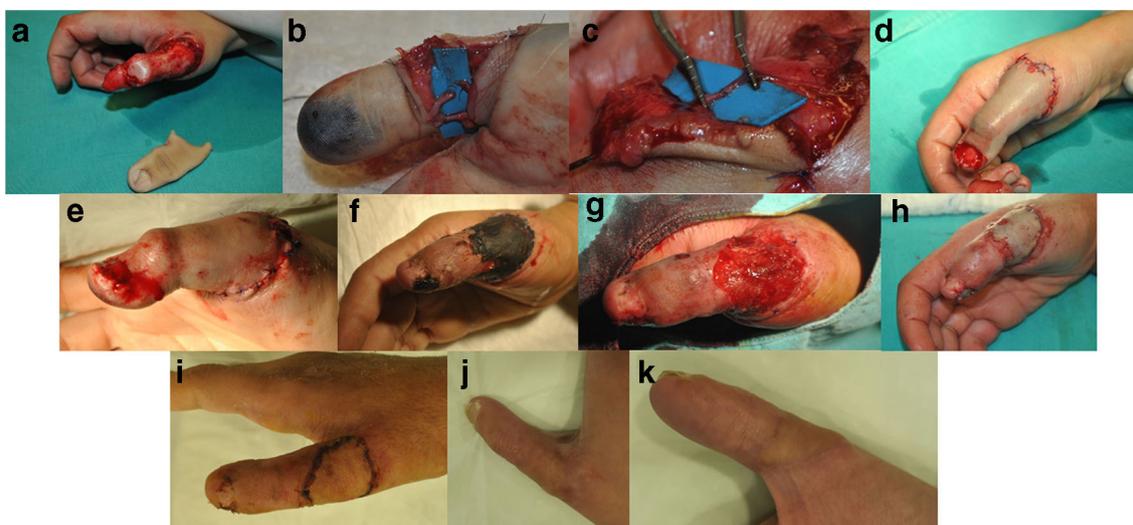


Fig. 2 a 20-year-old female worker sustained to a right thumb skin only amputation by a roller, right hand skin only amputation through MPJ. b Ulnar side digital artery and nerve repair. c Repair of a volar vein. d Immediate result after the surgery. e Partial skin necrosis developed

2 weeks after replantation. f After the debridement of the skin necrosis. g Immediately after the skin grafting. h 10 days after skin grafting. i and j Follow-up at postoperative 26th month, acceptable functional and esthetic results were obtained

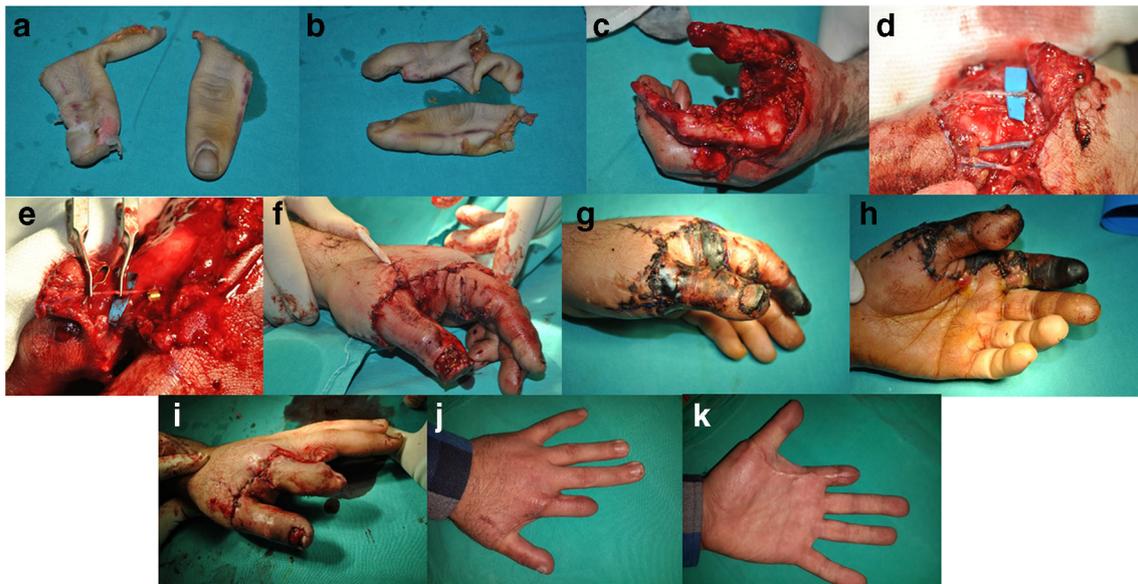


Fig. 3 **a** and **b** 42-year-old male worker who had left thumb and index finger skin-only amputations through MPJ by a hand drill; left thumb and index finger skin-only amputations through MPJ. **c** All components of the fingers other than the skin and subcutaneous tissue is intact. **d** and **e** Vein repairs during replantation. **f** Immediate result after surgery. **g** and **h** 7 days after the initial surgery, the circumferential necrosis was determined on

index finger which is limited with the distal phalanx. **i** Amputation through PIPJ (patient rejected the groin flap for salvage). **j** Follow-up at postoperative 22nd month (dorsal view), cosmetically and functionally acceptable results were obtained for the thumb. **k** Follow-up at postoperative 22nd month (volar view).

skin-only avulsions are subjected to lower-density energy, and the type of trauma is a superficial traction. Almost all the standard ring avulsion cases require long vein grafts or arterial transposition from the adjacent finger and reconstructions following a long-segment arterial debridement [13]. However, in this report, we determined that none of the skin-only avulsions required vein grafts or long-segment arterial debridement. We were able to anastomose all the digital arteries in our skin-only amputation cases, whereas only two cases required minimal distal phalangeal tuft shortening to overcome the vein graft requirement. Vein grafts require another surgical incision, two another anastomoses, and prolonged surgical time. Vein grafts, however, are standard entities in replantation surgery and are not challenging for surgeons with sufficient microsurgical experience. In such cases, the need for vein grafting is much less than conventional ring avulsions, because the vein defect is either absent or very small. Bone shortening should not be considered superior to vein grafts; however, in anastomoses made possible by shortening not exceeding the tuft portion in 2 patients, both prolongation of the surgical time and 2 separate anastomoses were avoided. These shortenings are those that do not compromise finger length, finger function, and bone integrity and are very minimal and included only a small part of the ungual tuberosity, and neither of

these cases suffers from loss of function nor cosmetic deficiency.

Surgical dissection is one of the most important steps in the surgery of avulsion-type amputations. Conventional avulsions may need more dissection inside the subcutaneous tissue to expose the tendon, artery, nerve, and especially the veins. We recommend minimal dissection in the amputated part in skin-only avulsions; thus, meticulous surgical dissection in this type of amputation is almost not necessary. Only examination under microscope or very minimal dissection in order to expose adequate artery, vein, and nerve parts is sufficient. If necessary, amputate can be examined by making inside out like gloves.

Digital arteries have their anastomoses at the proximal, middle, and distal phalanges [15]. Radial and ulnar digital arteries anastomose just dorsal to the flexor tendon. Skin-only avulsions involve the digital arteries but not those arterial anastomoses. Therefore, both ulnar and radial digital arteries should be repaired in skin-only avulsions. Even though in cases where both arteries are anastomosed and cases where one of them is anastomosed, subacute partial skin necrosis may occur. Some of that necrosis may heal secondarily, and some may need skin grafting. In this report, partial skin necrosis was present in 2 of the 3 patients with single artery repair, and both were repaired with skin grafting. Besides the digital arteries' anastomoses, the

vascular deprivation of perforating branches of the proper digital artery may cause partial necrosis of the finger skin in one region of the finger. The vascular deprivation of the perforating branches of the proper palmar digital arteries and the dorsal branches of the proper digital arteries are responsible for the partial necrosis. Thus, it is recommended to repair the two digital arteries in skin-only avulsion injuries. Skin necrosis may have many reasons, most of which is the arterial deprivation. However, partial necrosis indicates that there is insufficiency in the proper digital arteries' branches rather than arterial insufficiency in the proper digital arteries themselves. One of the other reasons for the partial skin necrosis is the severity of the injury; especially the status of the amputate and whether the perforator vessel remains intact are the main entities for the success of the replantation and these may define the partial necrosis. Apart from the perforator-dependent reasons, postoperative wound dressings may be one of the partial necrosis reasons. In the postoperative period, depending on bleeding, the dressing material becomes occluded with dried blood and compresses the replanted amputate. Therefore, circulation may be partially impaired. For this reason, we make a loose dressing and change this dressing frequently in the early days.

Venous repair is as important as the arterial anastomoses in amputations [16]. Volar vein repair, in addition to the multiple dorsal vein repairs, will increase the success rate [17]. In this report, 3 veins were repaired in two patients, 4 veins were repaired in four patients, and 5 veins were repaired in one patient. Six of the seven replanted fingers following total skin-only amputations survived and had good functional outcomes. This result was attributed to the number of vein anastomosis; thus, repairing both volar and dorsal veins is recommended.

One of the critical steps in this type of amputation is the detection of appropriate vessels within the amputate. Replantation is not possible in these cases if the vessels remain on the finger rather than the amputate [4]. For vessel exploration, in cases where it is needed, it may be appropriate to perform the amputate by inverting it like a glove finger instead of making extra skin incisions. In these cases, the aim should be two arteries and maximum number of vein repairs if possible.

Three partial necroses required skin grafting procedures, whereas one finger was amputated at the PIP joint level due to patients' preference. There are few publications on secondary procedures after replantation. In the literature, the secondary procedure rate after finger replantation was found to be about 50%, and these procedures are often soft tissue coverage [18]. In this report, skin grafting was performed in 3 of 6 fingers which resulted in success, and the

secondary procedure rate was found to be compatible with the literature.

If possible, the repair of 2 digital nerves has been advocated. Because of multiple levels of injury to most fingers or because the digital nerve was not suitable for coaptation, in this series, single digital nerve repair was performed for 5 fingers. The 2 fingers where both digital nerves were repaired resulted with the green monofilament pressure sensation. However, no green monofilament pressure sensation results in the monofilament test of the other 5 fingers. This indicates that the repair of the 2 digital nerves is more successful. We recommend the 2 digital nerve repairs in possible cases.

Skin-only avulsions do not require bone or tendon repair. This will reduce the surgery time and will allow an early range of motion exercises which will reduce the tendon adhesions.

In 1981, Zhong-Weia et al. indicated that the replantation indications are relative and dynamic and they will change with the technology and microsurgical experiences [19]. Indeed, the indications for replantation have changed and expanded in recent years. In addition to certain indications such as child, thumb, multiple fingers, and single finger distal to the flexor digitorum profundus insertion, palm, and more proximal levels, it is now recommended to decide the indication for replantation by taking into account factors related to the patient, injury, and environment [20]. Replantation indications can be expanded, and an avulsion injury may become a replantation indication according to the physical and occupational demands, social factors, and cultural and personal values.

Other surgical alternatives in skin-only avulsions injuries are flap reconstructions for skin defects. These options could be interpolation flaps like groin flap or chest flap, modified cross-finger flaps, heterodigital flaps, and radial forearm perforator flaps [21–23]. The use of flaps may help to preserve the finger length. However, the replantation of an avulsed skin will provide better results because those flap options may end up with fingers having a rough appearance, senseless, and impaired motor activity due to bulky soft tissue cover compared to replanted fingers, especially when using tube flaps [4]. Therefore, it is recommended that replantation should be considered initially, and other flap options may be considered if the replantation failed.

Almost all the standard ring avulsion cases require vein grafts following a long-segment arterial debridement. However, it is determined that none of the skin-only avulsions required vein grafts or long-segment arterial debridement. We associate it with the type of avulsion. Conventional avulsion-type amputations are more severe

and high-intensity injuries, while skin-only avulsions are more superficial and of lower intensity. Total skin-only avulsions occur after lower density, superficial traction forces in which bone and tendons remain unaffected, making the skin-only avulsions even more specific than other avulsion injuries. Compared with the composite of avulsion injuries, arterial intimal injuries may be limited in skin-only avulsion injuries. This is attributed to the low-density traction force of the trauma. Therefore, as in the classical avulsion-type amputation, there is no severe intimal damage to the artery. The absence of severe arterial damage allows limited debridement, often end-to-end anastomosis, and the need for vein grafting is relatively reduced compared to classical avulsion amputations. Therefore, it is suggested that the digital arteries should be repaired primarily or after minimal distal phalangeal tuft shortening and without using venous grafts [14].

In conclusion, skin-only avulsions are a particular type of avulsion injury. Decision-making and treating the skin-only avulsions are challenging. Replantation surgery gives the best result both cosmetically and functionally if amputated part contains suitable vessels. In contrast to the replantation results in conventional avulsion injuries, replantation results can be successful in skin-only avulsions when several technical details are observed. In such amputations, the presence of a suitable vessel in the amputate should be examined, and replantation should be attempted if an appropriate vessel is found, because replantation is superior to all alternative methods such as flap or skin graft, and those alternatives should be considered for failed replantations. In addition, there is always the possibility to use these alternatives if skin loss occurs. In order to avoid from the partial necrosis due to the vascular deprivation of perforating branches of the proper digital artery, we recommend repairing both arteries in this type of avulsion. Replantation should be considered as the first step for skin-only avulsions.

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Resources and supervision: Berkan Mersa.

Compliance with ethical standards

Conflict of interest All authors declare that they have no conflict of interest.

Ethical approval All study was conducted in accordance with the Helsinki Declaration, and the study was approved by Yenyuzuyl University Review Board and Ethical Committee.

Informed consent Was obtained from all patients for being included in the study

Patient consent Patients provided written consent for the use of their images.

References

1. Chaivanichsiri P, Rattanasrithong P (2006) Type of injury and number of anastomosed vessels: impact on digital replantation. *Microsurgery* 26:151–154
2. Urbaniak JR, Evans JP, Bright DS (1981) Microvascular management of ring avulsion injuries. *Hand Surg Am* 6:25–30
3. Kay S, Wermert J, Wolff TWJ (1989) Ring avulsion injuries: classification and prognosis. *Hand Surg Am* 14:204–213
4. Kayalar M, Güntürk ÖB, Kaplan İ, Sügün TS, Ademoğlu Y (2017) Techniques and survival incidence for revascularization of degloved fingers. *J Hand Surg Eur Vol* 42:946–951
5. Adani R, Busa R, Castagnetti C, Castagnini L, Caroli A (1998) Replantation of degloved skin of the hand. *Plast Reconstr Surg* 101:1544–1551
6. Adani R, Busa R, Tarallo L, Castagnetti C (2004) Update on replantation of degloved skin of the hand. *Plast Reconstr Surg* 114:1228–1332
7. Kerschhagl M, Larcher L, Mattiassich G, Prantl L (2019) Replantation of a circumferentially degloved thumb in an occupational crush injury – a case report and review of the literature. *Clin Hemorheol Microcirc* 71:403–414
8. Adani R, Marcoccio I, Castagnetti C, Tarallo L (2003) Long-term results of replantation for complete ring avulsion amputations. *Ann Plast Surg* 51:564–568
9. Sears ED, Chung KC (2011) Replantation of finger avulsion injuries: a systematic review of survival and functional outcomes. *J Hand Surg Am* 36:686–694
10. Dec W (2006) A meta-analysis of success rates for digit replantation. *Tech Hand Upper Extrem Surg* 10:124–129
11. Waikukul S, Sakkarnkosol S, Vanadurongwan V, Un-nanuntana A (2000) Results of 1018 digital replantations in 552 patients. *Injury* 31:33–40
12. Prucz RB, Friedrich JB (2014) Upper extremity replantation. *Plast Reconstr Surg* 133:333–342
13. Molski M (2007) Replantation of fingers and hands after avulsion and crush injuries. *J Plast Reconstr Aesthet Surg* 60:748–754
14. Ozerkan F, Ada S, Bora A, Kaplan I, Ademoğlu Y (1995) Eight years experience in crush and avulsion type finger amputation. *Microsurgery* 16:739–742
15. Schmidt HM, Lanz U (2004) *Surgical anatomy of the hand*. Georg Thieme Verlag, Stuttgart, p 267
16. Pederson WC (2001) Replantation. *Plast Reconstr Surg* 107:823–841
17. Mersa B, Kabakas F, Pürisa H, Özçelik IB, Yeşiloğlu N, Sezer I, Tunçer S (2014) Advantages of using volar vein repair in finger replantations. *J Plast Reconstr Aesthet Surg* 67:63–67
18. Yu J-C, Shieh S-J, Lee J-W, Yu JC, Shieh SJ, Lee JW, Hsu HY, Chiu HY et al (2003) Secondary procedures following digital replantation and revascularisation. *Br J Plast Surg* 56:125–128

19. Zhong-Wei C, Meyer VE, Kleinert HE, Beasley RW (1981) Present indications and contraindications for replantation as reflected by long-term functional results. *Orthop Clin North Am* 12:849–870
20. Pet MA, Ko JH (2019) Indications for replantation and revascularization in the hand. *Hand Clin* 35:119–130
21. Çoban YK, Öcük Ö, Bekircan K (2017) Wrapping degloved fingers with a distal-based radial forearm perforator flap: a repair method for multiple digital degloving injury. *Ulus Travma Acil Cerrahi Derg* 23:525–527
22. Demiri EC, Dionyssiou DD, Biskiniotis I, Papadimitriou D (2007) Reconstruction of a degloved finger with a heterodigital reverse dorsal digitometacarpal flap. *Scand J Plast Reconstr Surg Hand Surg* 41:42–44
23. Gopalakrishna A (2014) Avulsion amputation of the ring finger managed by double cross finger flap: 25 years follow-up. *Indian J Plast Surg* 47:444–446

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