



End to side nerve repair in avulsion amputations

Fatih Kabakas¹, Muhammed Besir Ozturk²

ABSTRACT

In avulsion amputations, replantation is challenging because the structures, such as the skin, veins, nerves, and tendons are extensively damaged. Various techniques have been described for avulsion amputations with nerve defects. If the nerve is avulsed from the main body and the proximal nerve stump cannot be located, nerve transfers, neurovascular island flaps, or end-to-side (ETS) nerve repair are reasonable options. ETS nerve repair involves the coaptation of the distal stump of the transected nerve to the side of the donor nerve. ETS nerve repair has been described as an alternative technique in cases where the proximal nerve stump cannot be located, but literature regarding the use of this technique in avulsion amputations is extremely limited. In this study, we performed replantation in three patients with avulsion amputations of nine digits. We present the long-term outcomes of these nerve repair procedures in this study.

Key words: *Neurosurgical procedures, reconstructive surgical procedures, nerve transfer, terminolateral nerve repair, nerve defect reconstruction*

Introduction

In avulsion amputations, replantation is challenging because the structures, such as the skin, veins, nerves, and tendons are extensively damaged. Functional outcomes may be poor, even if successful replantation can be performed in this type of amputation [1-3].

Various techniques, such as nerve grafts, veins grafts, synthetic circuits, nerve transfers, and neurovascular island flap procedures have been described for avulsion amputations with nerve defects [4-7]. If the nerve is avulsed from the main body and the proximal nerve stump cannot be located, nerve transfers, neuro-

vascular island flaps, or end-to-side (ETS) nerve repair are reasonable options [8]. ETS nerve repair involves the coaptation of the distal stump of the transected nerve to the side of the donor nerve. ETS nerve repair has been described as an alternative technique in cases where the proximal nerve stump cannot be located, but literature regarding the use of this technique in avulsion amputations is extremely limited.

In this study, we performed replantation in three patients with avulsion amputations of nine digits. In these patients, all the digital nerves were avulsed from the main body and there were no proximal nerve

Author affiliations : ¹ IST-EL Microsurgery and Rehabilitation Group, Istanbul, Turkey ² Department of Plastic and Reconstructive Surgery, Medeniyet University, Goztepe Training and Research Hospital, Istanbul, Turkey

Correspondence : Muhammed Besir Ozturk, MD, Department of Plastic and Reconstructive Surgery, Medeniyet University, Goztepe Training and Research Hospital, Istanbul, Turkey. email: muhammedozturk@msn.com

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stumps available for nerve repair. We performed ETS nerve repair of the digital nerves in these patients using the median and ulnar nerves. We present the long-term outcomes of these nerve repair procedures in this study.

Material and Methods

A total of nine digit replantations (one thumb and two partial hand amputations) in three patients between 2013 and 2017 were included in this study. All the amputations were avulsion amputations, and there were no proximal nerve stumps for primary nerve repair. All the digital nerves were repaired via ETS nerve repair to the median and ulnar nerves. The patients were evaluated with the Semmes–Weinstein monofilament test and the static two-point discrimination test for sensory outcomes in the postoperative second year by the same physiotherapist. Any complications were noted.

Surgical Technique

All patients operated by the same surgeon, under axillary block anesthesia and with an arm tourniquet. After appropriate debridement and bone shortening, the bones were fixed, and the tendons, arteries, and veins were repaired via routine replantation. The ends of the nerves were microscopically examined, and the nerves were shortened until the distal intact nerve fascicles were visible. The nerves were withdrawn proximally without any tension. The epineural window was

opened to the median nerve in the carpal tunnel in the patient with thumb amputation and to the median and ulnar nerves at the level of the wrist in the two patients with partial hand amputations. The procedures were performed as proximally as possible without any tension. When planning the epineural windows at the wrist level to the ulnar and median nerves, attention was paid to the nerve topography for localization of the sensory fascicles. During epineural window opening, the donor nerve axons were protected to avoid laceration. The ETS nerve repair procedures were performed on the proximal main nerve bodies with 8/0 polyamide sutures. In cases where tendons were avulsed from the muscles, tendons were reinserted into the muscle, or primary tendon transfers were performed.

Results

There were no partial or complete replantation failures in the nine digits. The patient who underwent thumb replantation regained complete sensory function on both sides of the thumb at the follow-up. There was no sensory return in one of the patients who underwent partial hand replantation. In the second patient who underwent partial hand replantation, there was no sensory return in the third digit, a loss of protective sensation in the second and fourth digits, and a decreased mild touch in the fifth digit. The nerve repair

Table 1. Patient data.

Patient	Age (years)	Follow-up (months)	Nerve lesion	2PD (mm)	Semmes-Weinstein	Smoking
Case 1	44	72	thumb	4mm	Normal light touch	-
			Digit 2	>15 mm	Loss of protective sensation	
Case 2	43	36	Digit 3	>15 mm	unresponsive	-
			Digit 4	>15 mm	Loss of protective sensation	
			Digit 5	7mm	Diminished light touch	
Case 3	48	29	Digit 2	>15 mm	unresponsive	+
			Digit 3	>15 mm	unresponsive	
			Digit 4	>15 mm	unresponsive	
			Digit 5	>15 mm	unresponsive	

results of the patients are summarized in Table 1.

Case 1. The patient underwent an avulsion amputation of the thumb at the level of proximal phalanx, and the common digital nerve was avulsed from the median nerve. There was no proximal digital nerve stump visible. The common digital nerve was repaired via ETS anastomosis through the epineural window opening to the median nerve. In postoperative year two, full sensory function returned (Figure 1).

Case 2. The patient was admitted for avulsion amputation of the 2nd, 3rd, 4th and 5th finger at the level of metacarpal neck. The digital nerves appeared to be fully avulsed from the median and ulnar nerve bodies. There were no proximal digital nerve stumps visible under the microscope, and all nerves underwent ETS anastomosis to the median and ulnar nerves at the level of the wrist. Sensation in the third digit did not return, and there was a loss of protective sensation in the second and fourth digits and a decreased mild touch in the fifth digit in the second year (Figure 2).

Case 3. Another patient was admitted for avulsion amputation of the 2nd, 3rd, 4th and 5th finger at the level of metacarpal neck. The digital nerves appeared to be fully avulsed from the median and ulnar nerves. There were no proximal nerve stumps for the digital nerves, and all nerves underwent ETS anastomosis to the median and ulnar nerves at the level of the wrist. No sensory return was observed in the postoperative second year evaluation (Figure 3).

Discussion

In avulsion amputations, replantation is challenging due to substantial damage to the vessels, skin, and nerves. Functional results after replantation in avulsion amputations have generally been reported to be poor [1-3,9]. Some authors recommend routine revision amputations due to poor functional results in amputations proximal to the proximal interphalangeal joints [10-12]. Although the skin remains intact after successful revascularization, possible poor function may include total hand function impairment [6]. We performed one

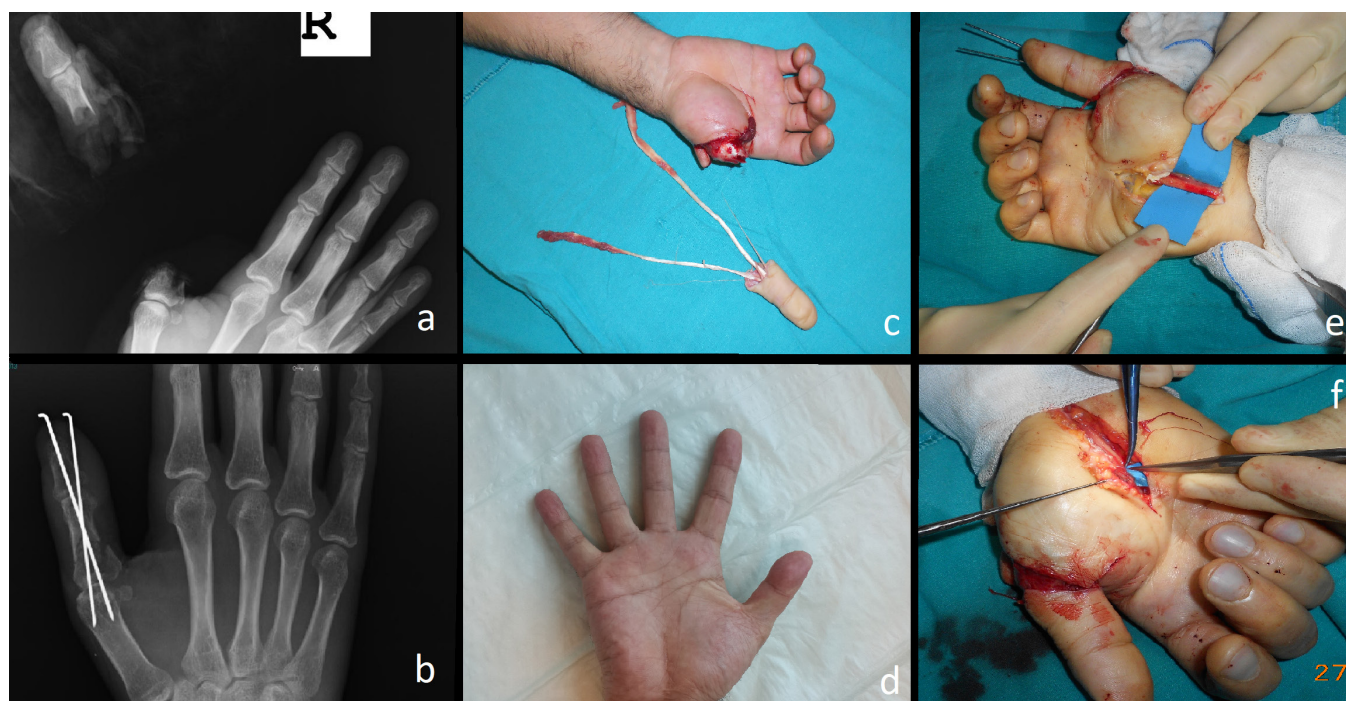


Figure 1. A,B) Preoperative and intraoperative x-rays of the 44 years old male with avulsion amputation of the thumb at the level of proximal phalanx. C) Preoperative picture of the patient. D) Intraoperative picture of the patient shows that the common digital nerve of the thumb was avulsed from the median nerve without proximal nerve stump. E) The common digital nerve of the thumb was sutured end to side to the median nerve. F) Postoperative 2nd year picture of the patient with full sensory recovery of the thumb on both sides.

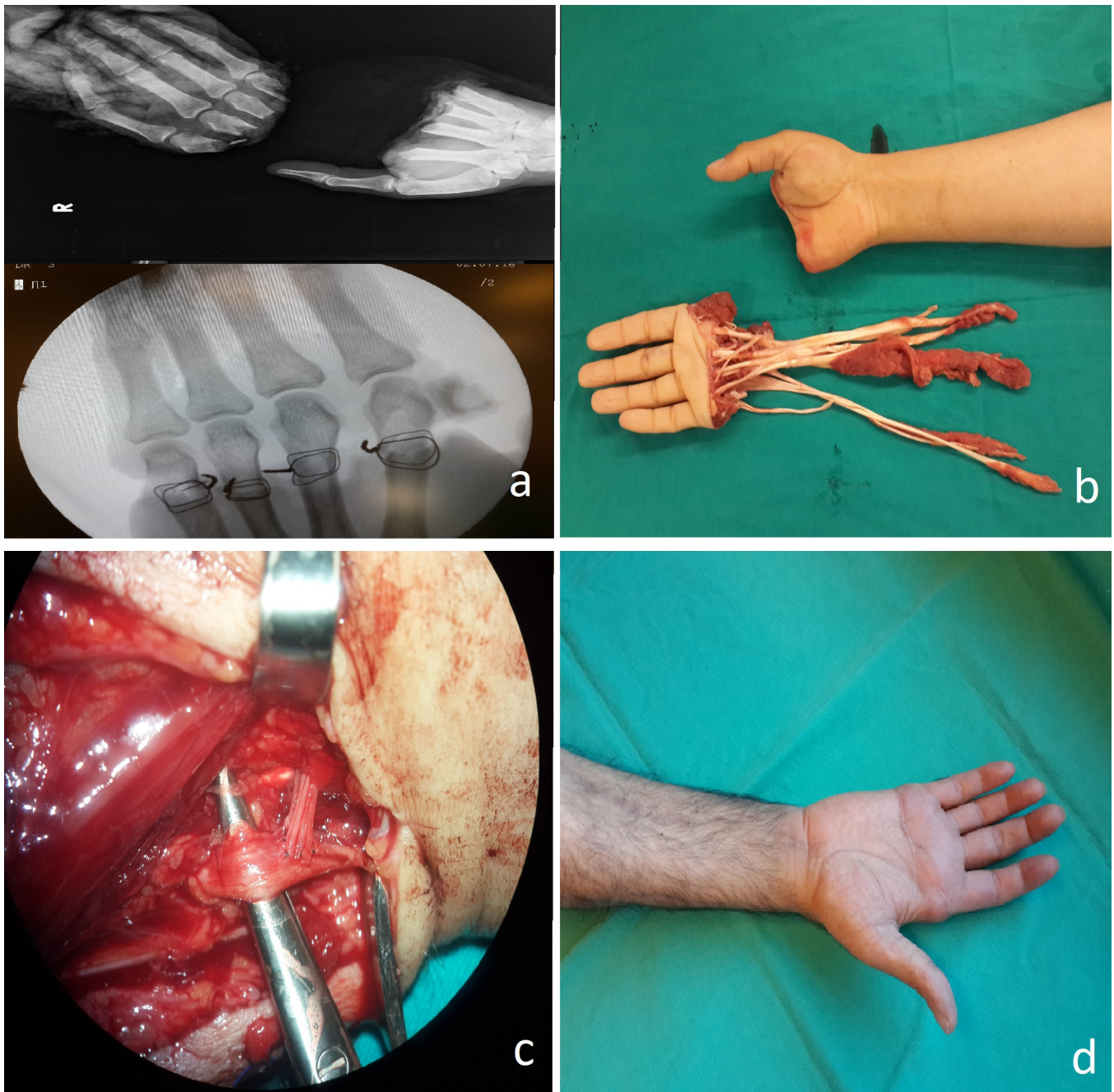


Figure 2. A) Preoperative and intraoperative x-rays of the 45 years of old male patient with amputations of the 2nd, 3rd, 4th and 5th digits at the level of the metacarpal neck. B) Preoperative picture of the patient. C) Digital nerves of the 4th and 5th fingers were sutured end to side to the ulnar nerve and digital nerves of the 2nd and 3rd fingers were sutured end to side to the median nerve. D) Postoperative 2nd year picture of the patient.

thumb replantation in one case and partial hand amputations in two cases. In these cases, attempting replantation was necessary due to severe functional loss.

The sensation after replantation is poor in avulsion amputations [11]. In a systematic review, two-point discrimination was 10 mm for complete avulsion am-

putations and 8 mm for incomplete avulsion injuries after revascularization [13]. In a study by Sanmartin et al., 105 patients with ring avulsion amputations were evaluated. They found poor results for nerve repair procedures in all patients who underwent primary nerve repair and nerve repair with a nerve graft or a vein graft.

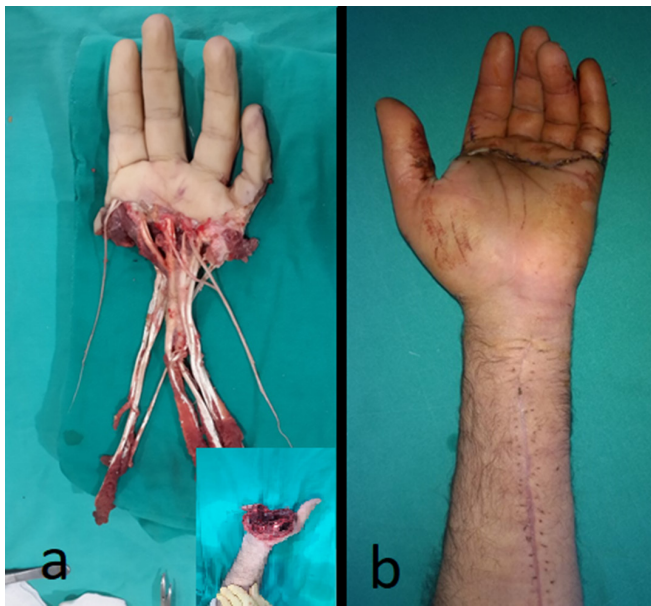


Figure 3. A) Preoperative pictures of the patient with amputations of the 2nd, 3rd, 4th and 5th digits at the level of the metacarpal neck. B) Postoperative 9th months picture of the patient.

In their study, 66% of the patients who underwent primary nerve repair had a two-point discrimination greater than 8 mm [14]. The damage caused by avulsion injuries may extend beyond the damage observed with light microscopy and may be responsible for these poor results [15].

In our study, the nerve repair results in nine digit replantations were evaluated in three patients who underwent avulsion amputations. All the nerves were repaired by the ETS nerve repair technique. In the second year of follow-up, one patient had no sensory return; one patient had complete sensory return; and one patient had no sensory return in one digit, two-point discrimination of 7 mm (diminished light touch) in one digit, and two-point discrimination of > 15 mm (loss of protective sensation) in two digits. The results were unpredictable.

ETS nerve repair involves coaptation of the distal stump of the transected nerve to the lateral wall of the donor nerve. ETS nerve repair was first described by Letievent in 1873, and many clinical and experimental studies were performed in the following years [16,17]. However, this technique was subsequently abandoned

in the following years, likely due to the use of non-microsurgical instrumentation and techniques. In 1992, Viterbo reintroduced this technique with experimental and clinical studies and showed the effectiveness of this technique [8,18,19]. To repair a nerve in patients without available proximal nerve stumps by anatomically and functionally preserving the donor nerve is an impressive technique [20]. This technique has been shown to provide nerve fiber regeneration to the distal nerve stump via collateral axonal sprouting from the Nodes of Ranvier of the donor nerve [21,22].

There are several publications that demonstrate successful sensory return of the median, ulnar, and radial nerves after ETS nerve repair procedures in the upper extremity [23-26]. However, publications showing the results of ETS nerve repair procedures in the palmar digital nerves are limited. Mennen et al. repaired palmar digital nerves in five cases in a series of 56 ETS nerve repair procedures. They reported successful results in four cases and partially successful results in one case [27]. Voche et al. repaired the traumatic nerve defects of palmar digital nerves in 10 patients with the ETS nerve repair technique. They found a mean static two-point discrimination of 9.1 mm (range 6-12 mm) in a long-term follow-up [28].

The results of ETS nerve repair in finger amputations are much more limited in the literature. Frey et al. performed ETS repair of the digital nerves to the median nerve in an avulsion amputation in a 13-year-old patient. The radial digital nerve was repaired end-to-end, while the ulnar digital nerve was repaired ETS to the median nerve, and the bilateral static two-point discrimination was 3 mm, which is similar to that of the thumb replantation we performed [29]. Pelisser et al. presented the results of ETS nerve repair in six patients, four of whom were amputations. In this study, the average two-point distinction was 10 mm (range 8-12 mm) [30]. However in our study we observed a wide distribution of nerve repair results, and the results were unpredictable. Although the demographic characteristics of the patients

were similar, patient-specific factors, such as severity of the avulsion trauma and smoking history, may have affected these unpredictable results as well.

In cases of nerve defects where nerve repair cannot be performed primarily, nerve repair using a nerve autograft is the standard technique [30]. In the case of defects between 3 and 5 cm, synthetic and autogenous non-nervous conduits are also an option [31,32]. Nerve transfers or neurovascular island flaps may be alternative treatment options where no proximal nerve stumps can be located for nerve repair, but donor site morbidity is an important issue in these cases [7]. ETS nerve repair may offer surgeons an alternative option without donor site morbidity [33]. In our study, all the nerves were injured via complete avulsion from the main trunk, and there were no proximal nerve stumps available to perform primary repair or nerve grafting. Especially in thumb avulsion amputations, nerve transfer from the third digit is a good option [7]. We achieved full sensory return in the case that involved thumb amputation. ETS nerve repair does not require cortical adaptation, and the lack of donor site morbidity can be considered an advantage over nerve transfer.

The relatively few patients and the lack of a control group were the main limitation of this study. However, it should be considered that even if our clinic is a replantation center, the numbers of such cases are quite limited.

In this study, the results obtained by the ETS repair technique in avulsion amputations were unpredictable. Further studies with a greater number of cases may clarify the indication for the use of ETS nerve repair in avulsion amputations.

Conflict of interest statement

The authors have no conflicts of interest to declare.

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