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Replantation of Finger Avulsion Injuries: A Systematic Review of Survival and Functional Outcomes

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Abstract

Purpose—Recent studies presenting functional outcomes after replantation of finger avulsion injuries have challenged the historic practice of performing revision amputation for all complete finger avulsion injuries. The aim of this study is to conduct a systematic review of the English literature of replantation of finger avulsion injuries to provide best evidence of survival rates and functional outcomes.

Methods—A Medline literature search yielded 1398 studies using keywords of traumatic amputation or replantation with limitation to humans and finger injuries. Inclusion criteria required that studies meet the following requirements: (1) primary data are presented; (2) the study includes at least five cases with either complete or incomplete finger avulsion injuries at or distal to the metacarpophalangeal joint; (3) the study presents survival rates, total active arc of motion (TAM), or static two-point discrimination (2PD) data; (4) data for incomplete and complete avulsions are reported separately; (5) patients are treated with microvascular revascularization or replantation. Survival rates, TAM, and 2PD data were recorded and a weighted mean of each was calculated.

Results—Thirty-two studies met the inclusion criteria. Of these 32 studies all reported survival outcomes, 13 studies reported TAM (MCP+PIP+DIP), and 9 studies reported sensibility. The mean survival rate for complete finger and thumb avulsions undergoing replantation was 66% (n=442). The mean TAM of complete finger avulsions after successful replantation was 174 degrees (n=75), with a large number of patients in the included studies having arthrodesis of the DIP joint. The mean 2PD in patients after replantation was 10 mm (n=32).

Conclusions—We found that functional outcomes of sensibility and range of motion after replantation of finger avulsion injuries are better than what is historically cited in the literature. The results of this systematic review challenge the practice of performing routine revision amputation of all complete finger avulsion injuries.

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Keywords

finger amputation; finger avulsion; hand surgery outcomes; replantation; revascularization; systematic review

Advances in microsurgery have made salvage of amputated fingers a commonly performed procedure. Survival of replanted digits has become fairly reliable, with survival rates estimated to be 80 – 90 percent in the literature (1–3). However, replanting a digit having sufficient function has proven more difficult to achieve. For this reason, indications and contraindications for patients who are reasonable candidates for the procedure continue to evolve to exclude those with anticipated poor functional outcome.

Avulsion amputations are a particularly difficult problem to treat due to the extent of damage sustained by skin, nerves, and vessels. As surgeons continued to push the boundaries of microsurgery, novel techniques were proposed to manage the difficulties of salvaging avulsed digits. Reconstruction of vessels with long vein grafts (4,5), venous flow-through flaps (6), or transfer of vessels from adjacent fingers (7,8) enhanced survival of the avulsed digit. Several classification systems (9–11) have evolved to categorize patients according to anticipated treatment and functional outcome (Table 1).

With the exception of replantation of avulsed thumbs, which have undisputed functional advantage, the functional benefit of replanting avulsed fingers when compared to revision amputation remains a controversial issue. Avulsion injuries are commonly cited as having poor functional outcomes after replantation (1,3,12–14), especially in the case of complete amputation or when there is damage to the proximal phalanx or the PIP joint (4,9,15–17). Urbaniak has advocated for revision amputation to treat complete finger avulsion injuries (9,14). However, recent studies presenting functional outcomes after replantation of finger avulsion injuries have challenged this recommendation, with some authors achieving reasonable total active motion (TAM) approaching 200 degrees or greater after replantation of digital avulsion injuries (4,5,15,18–20).

Systematic reviews are especially useful in synthesizing information from studies with small sample sizes, as is the case for replantation of complete finger avulsion injuries. The aim of this study is to conduct a systematic review of the English literature of replantation of finger avulsion injuries to provide best evidence of survival rates and functional outcomes. A secondary aim was to compare functional outcomes after replantation of finger avulsion injuries to outcomes after repair of zone II flexor tendon injuries and digital nerve repair. Review of functional outcomes after these two procedures offers a baseline to which we can compare outcomes after replantation of finger avulsion injuries. We hypothesize that replantation of complete finger avulsion injuries will have acceptable outcomes that challenge the traditional practice of routinely performing revision amputation for all patients with this injury type.

MATERIALS AND METHODS

A Medline literature search, conducted in August 2010 yielded 1398 studies using keywords of traumatic amputation or replantation with limitation to humans and finger injuries. Although this systematic review is aimed at the evaluation of outcomes related to complete avulsion injuries of fingers, our literature search also included the separate review of thumb avulsion injuries and incomplete avulsion injuries to provide comparison outcomes of groups for whom replantation or revascularization is routinely performed. These outcomes were compared to those obtained for finger avulsion injuries when possible. Inclusion criteria required that studies meet the following:

1. Primary data are presented.
2. The study includes at least five cases with either complete or incomplete avulsion injuries of thumbs or fingers at or distal to the metacarpophalangeal (MCP) joint. For example, if a study had five patients in the complete avulsion group and three patients in the incomplete avulsion group, the incomplete avulsion data were excluded from analysis. Incomplete avulsion injuries are termed revascularizations, incomplete amputations, subtotal amputations, Kay class II and III (and subtypes) and Urbaniak class II avulsion injuries in the literature; complete avulsion injuries are termed replantations, complete amputations, Kay class IV, and Urbaniak class III avulsion injuries in the literature.
3. The study presents survival rates, total active arc of motion (TAM), or static two-point discrimination (2PD) data; survival rates and 2PD data were noted from both finger and thumb avulsions and the data were separated from one another when possible.
4. Patients were treated with microvascular revascularization or replantation.

The following studies or data were excluded from the analysis:

1. Studies were excluded if the data for incomplete and complete avulsion injuries were not reported separately.
2. TAM data were excluded from studies if the data from finger and thumb avulsion injuries were not reported separately due to differences in normal TAM between the digits.
3. TAM data were excluded if arc of motion was not able to be translated to a measurement in degrees through reported TAM in degrees or percent normal of TAM. TAM is defined in this study to be MCP+PIP+DIP joint motion (minus extensor lag), in which normal TAM is assumed to be 270 degrees.
4. 2PD data were excluded if not reported as a continuous variable in millimeters. Thus, studies that only presented data in a range of 2PD were excluded because of inability to uniformly compare across several studies.

All abstracts were reviewed to determine if inclusion and exclusion criteria were met. If no abstract was published or if the abstract did not have sufficient information to determine eligibility, the full-length manuscript was reviewed. Survival rates, TAM, and 2PD data were recorded from each study meeting criteria for inclusion in the systematic review. A weighted mean for each outcome based on sample size of each study was calculated. Separate analysis was performed for complete and incomplete avulsion injuries.

We reviewed the literature to compare TAM outcomes after zone II flexor tendon repair and 2PD outcomes after digital nerve repair to the outcomes obtained in this systematic review. Studies reporting outcomes of zone II flexor tendon repair were identified through a Medline literature search using keywords of tendon injuries, zone II, and zone 2. Studies were included if TAM was reported on a continuous scale in degrees or percentage of normal. If studies reported TAM of PIP+DIP joint motion (excluding MCP joint motion), 90 degrees was added to the total to include MCP joint motion to allow comparison to finger avulsion injury outcomes that included motion of all three finger joints. Studies reporting outcomes of digital nerve repair were identified through a Medline literature search using keywords of peripheral nerves and finger injuries. Studies used for comparison were included if they reported static 2PD in millimeters as a continuous numerical outcome. There was substantial variability in scales used to report TAM and 2PD after zone II flexor tendon repair and digital nerve repair in the literature. Thus, the studies included were limited to those reporting outcomes on a continuous scale to allow for pooling of data and direct comparison to outcomes of finger avulsion injuries. Weighted means of TAM and 2PD data based on sample sizes of each study were calculated to compare to functional outcomes obtained from this systematic review of finger avulsion injuries.

RESULTS

Thirty-two studies of finger avulsion injuries met the inclusion/exclusion criteria and reported survival outcomes (Figure 1) (4–7,9–11,[15]–17,19,21–41). We extracted TAM data from 13 studies (4,5,9–11,[15]–[17],[19],23,33,34,39), and we extracted static 2PD data from 9 studies (4,5,9,11,15–17,34,39). All studies that reported TAM and 2PD data also reported survival outcomes. Thus, the papers reporting functional outcomes were included within the group of 32 studies that also reported survival outcomes. The mean survival rate for complete finger and thumb avulsion injuries undergoing replantation was 66% (n=442) (Table 2). As a comparison, the mean survival rate for incomplete avulsion injuries undergoing revascularization was 78% (n=349). When the thumb and finger avulsion outcomes were able to be separated from one another, the weighted mean survival for replantation of finger avulsion injuries was 78% (n=134), whereas the weighted mean survival of replantation of thumb avulsion injuries was 68% (n=82).

None of the eligible studies reported TAM for thumb avulsion injuries, thus the data from this systematic review only represents TAM after replantation of finger avulsion injuries. The mean TAM of complete finger avulsion injuries after successful replantation was 174 degrees (n=75) (Table 3). As a comparison, the mean TAM of incomplete finger avulsions after successful revascularization was 199 degrees (n=115). Many patients undergoing replantation also had arthrodesis of the DIP joint. Table 3 indicates the number of patients with DIP joint arthrodesis in each study when reported. Patients having DIP joint arthrodesis were included in the TAM data presented in the individual studies. Thus, these patients were included in the pooled TAM in the systematic review. The mean 2PD in patients after replantation of complete avulsion injuries was 10 mm (n=32), and 8 mm (n=29) after revascularization of incomplete avulsion injuries (Table 4).

Review of the literature to compare outcomes after zone II flexor tendon repair yielded nine studies (42–50) with a weighted mean TAM of 229 degrees (n = 730) (Table 5). Eight of the nine studies reported TAM as PIP + DIP joint motion. Thus, for the purpose of comparison to TAM for finger avulsion injuries, which included MCP + PIP + DIP joint motion in all of the included studies, MCP joint motion was assumed to be 90 degrees for the purpose of providing a uniform definition of measurement. Studies reporting 2PD outcomes after digital nerve repair showed a mean 2PD of 13 mm (n=112) in three studies (51–53) (Table 6).

DISCUSSION

This systematic review of finger avulsion injuries showed survival outcomes that were predictable, with avulsion injury replantations having lower overall survival rates (66%) than the approximated 80 – 90% survival (1–3) for finger replantation in general. Also not surprising were the lower survival rates of thumb avulsion injuries (68%) due to the well accepted practice of attempting more technically difficult replantation with thumb avulsion injuries, where the condition for replantation may be less favorable. When we reviewed studies in which data from replantation of finger avulsion injuries alone were able to be analyzed apart from thumbs, we found that the mean survival of complete finger avulsion replants is 78% and begins to approach expected survival of replantations in general.

This systematic review found that functional outcomes after replantation of finger avulsion injuries are better than what is generally referred to as being “poor” by many experts (1,3,12,13). Urbaniak et al. (14) concluded that the general practice of replanting complete avulsion injuries results in compromised hand function. However we found this not to be the case in all situations. The ASSH grading of results of TAM for tendon repair categorizes an excellent result as 100%, good result as 75 – 99%, fair result as 50 – 74%, and poor result as <50% of the TAM of the corresponding contralateral digit (54). Mean TAM for repair of complete and incomplete finger avulsion injuries (174 and 199 degrees respectively) are both classified as fair according to ASSH TAM scoring system, which is worse than TAM outcomes expected after zone II flexor tendon repair (229 degrees); whereas zone II flexor tendon repairs are expected to be classified as good on average. However, a large number of finger avulsion injuries occur such that the skin is avulsed between the PIP joint and the base of the finger, but the bony injury or amputation occurs distal to the PIP joint, often at the DIP joint (15). With avulsion injuries of this type, arthrodesis of the DIP joint is nearly always performed. When reported, we found that 23 of 30 patients with complete avulsion injury had DIP joint arthrodesis in five studies. Also, 47 of 139 patients with incomplete or complete avulsion injury had DIP joint arthrodesis in three studies. Thus, at first glance the mean TAM of 174 degrees obtained with replantation of complete finger avulsion injuries seems to be a fair result. However, considering a large number of patients have two joint fingers, the outcome becomes more acceptable and functional. Sensibility outcomes show that replantation of finger avulsion achieves protective sensation and similar outcomes to digital nerve repair.

The results of this systematic review challenge the historic practice advocated in the literature of performing routine revision amputation of all complete finger avulsion injuries (9). Similarly, the recommendation supported by some authors (4,15,34) of performing revision amputation for all avulsions at or proximal to the PIP joint should also be approached with caution. In this systematic review we found virtually no functional outcomes data to compare avulsion injuries proximal and distal to the PIP joint. Several studies included in this review did not attempt replantation on any patients with injury proximal to the FDS insertion (4,15,34). Only two studies (16,23) explicitly stated that replantation was attempted on a total of four patients having complete avulsion injuries involving the proximal phalanx or PIP joint. The remainder of the studies did not specify the number of patients undergoing replantation, if any, who had injury proximal to the FDS insertion (5,9,19,33). In addition, studies by Kay et al. (10) and Sanmartin et al. (33) each reported no functional difference based on the level of injury in relation to the PIP joint. On the other hand, a study by Urbaniak et al. (14) reported poor range of motion with replantation of complete avulsion injuries whether or not the amputation was proximal or distal to the FDS insertion, but the sample size of patients with finger avulsion injuries included only five patients total. However, Urbaniak’s study was excluded from this systematic review because range of motion was reported based on pulp to palm distance rather than degrees of TAM.

This systematic review has several limitations. Data were pooled from multiple studies of varying quality with regard to detail of outcomes reported. Not enough studies reported the location of injury, thus all complete avulsion injuries with and without skeletal injury to the proximal phalanx and PIP joint were pooled in this analysis. Similarly, there are a variety of techniques that were used to perform revascularization. Several studies used more than one technique from one patient to another in the cohort (19,33,34), with few studies using the same technique on all patients reported (4,5,15,16), and several studies did not describe the technique used (9,10,23). Lastly, the results of the study could be biased toward having better results published in the literature than what may be achieved in routine clinical practice due to publication bias and due to these centers having more experience with difficult replantations.

The collective outcomes obtained from this systematic review can aid surgeons and patients in treatment decision-making for finger avulsion injuries. The included studies show that replantation of finger avulsion injuries does not equate to saving a nonfunctional finger, and the combined results may be acceptable and preferable to some patients and surgeons. We recommend attempting replantation of complete finger avulsion injuries with a preserved PIP joint and FDS tendon insertion. In addition, we recommend revision amputation with skeletal injury at or proximal to the PIP joint in patients who are unwilling to accept a likelihood of a poor functional result. However, we caution surgeons that there is little published evidence to support the later recommendation and there is a future need for studies that present functional data according to level of skeletal injury.

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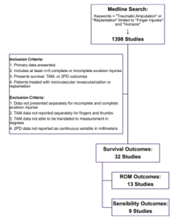

Figure 1.
Finger avulsion injury systematic review study selection based on inclusion/exclusion criteria.

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Table 1

Finger Avulsion Injury Classification Systems

Urbaniak Classification	
I	**Avulsion injuries with adequate circulation**
II	**Incomplete avulsion injuries with inadequate circulation**
III	**Avulsion injuries with complete degloving or amputation**
Kay Classification as Modified by Adani	
I	**Avulsion injuries with adequate circulation**
II IIa IIv	**Incomplete avulsion injuries with inadequate arterial or venous circulation, without skeletal injury** Arterial circulation inadequate only Venous circulation inadequate only
III IIIa IIIv	**Incomplete avulsion injuries with inadequate arterial or venous circulation, with fracture or joint injury present** Arterial circulation inadequate only Venous circulation inadequate only
IV IVp IVd	**Avulsion injuries with complete degloving or amputation** Complete avulsion injuries with amputation proximal to FDS insertion Complete avulsion injuries with amputation distal to FDS insertion

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Table 2

Survival Outcomes for Complete and Incomplete Avulsion Injuries

Complete Avulsion Injuries[§]	Thumbs		Fingers		Combined	
	n	survival	n	survival	n	survival
Obrien 1976	-	-	-	-	17	0.06
Isaacs 1977	-	-	-	-	5	0.40
Biemer 1979	7	1.00	5	1.00	12	1.00
Boeckx 1981	-	-	5	0.40	5	0.40
Urbaniak 1981	-	-	7	0.71	7	0.71
Cheng 1984	13	0.92	1	1.00	14	0.93
Tsai 1984	-	-	7	0.86	7	0.86
Waterhouse 1986	-	-	-	-	7	0.00
Bieber 1987	28	0.29	-	-	28	0.29
Foucher 1988	-	-	-	-	11	0.55
Kirwan 1988	-	-	-	-	16	0.83
Goldner 1989	8	0.75	8	0.75	16	0.75
Kay 1989	-		22	0.73	22	0.73
Van der Horst 1989	-	-	9	0.78	9	0.78
Cheng 1991	26	0.88	4	1.00	30	0.90
Yamano 1993	-	-	-	-	29	0.66
Beris 1994	-	-	13	0.62	13	0.62
Kim 1996	-	-	-	-	21	0.76
Waikakul 2000	-	-	-	-	51	0.51
Akyurek 2002	-	-	7	0.86	7	0.86
Adani 2003	-	-	7	0.86	7	0.86
Sanmartin 2004	-	-	28	0.79	28	0.79
Karaoguz 2006	-	-	-	-	26	0.81
Brooks 2007	-	-	-	-	10	0.50
Hyza 2007	-	-	6	1.00	6	1.00
Brooks 2008	-	-	5	1.00	5	1.00

Complete Avulsion Injuries[§]	Thumbs		Fingers		Combined	
	n	survival	n	survival	n	survival
Hasuo 2009	-	-	-	-	33	0.61
Mean for Complete Avulsion Injuries[‡]	**82**	**0.68**	**134**	**0.78**	**442**	**0.66**
Incomplete Avulsion Injuries[§]	**Thumbs**		**Fingers**		**Combined**	
	n	**survival**	**n**	**survival**	**n**	**survival**
Obrien 1976	-	-	-	-	12	0.58
Biemer 1979	19	0.74	6	1.00	25	0.80
Wilgis 1980	-	-	8	0.63	8	0.63
Urbaniak 1981	-	-	9	1.00	9	1.00
Nissenbaum 1984	-	-	5	1.00	5	1.00
Waterhouse 1986	-	-	-	-	9	0.56
Bieber 1987	11	0.18		-	11	0.18
Kirwan 1988	-	-	-	-	22	0.45
Kay 1989	-	-	22	0.86	22	0.86
Van der Horst 1989	-	-	12	1.00	12	1.00
Weil 1989	-	-	6	0.83	6	0.83
Adani 1995	-	-	6	1.00	6	1.00
Adani 1996	-	-	13	0.77	13	0.77
Waikakul 2000	-	-	-	-	89	0.79
Sanmartin 2004	-	-	47	0.83	47	0.83
Karaoguz 2006	-	-	-	-	13	1.00
Brooks 2007	-	-	-	-	40	0.88
Mean for Incomplete Avulsion Injuries[‡]	**30**	**0.53**	**134**	**0.87**	**349**	**0.78**
Mean for All Avulsion Injuries[‡]	**112**	**0.64**	**268**	**0.82**	**791**	**0.71**

[§] studies listed in chronological order

[‡] weighted averages based on sample size of each study

Table 3

Total Arc of Motion Outcomes for Complete and Incomplete Avulsion Injuries

Complete Avulsion Injuries§	**n**	**TAM* (degrees)**	**SD**	**# Patients with DIPJ Fusion**
Boeckx 1981	2	79	7	not reported
Urbaniak 1981	3	145	not reported	not reported
Tsai 1984	6	163	23	6/6
Kay 1989	13	182	22	15/25**
Beris 1994	7	152	not reported	4/7
Akyurek 2002	6	200	10	6/6
Adani 2003	6	200	21	4/6
Sanmartin 2004	22	173	22	21/75**
Brooks 2007	5	174	not reported	11/39**
Hyza 2007	5	195	17	3/5
Mean for Complete Avulsion Injuries ‡	**75**	**174**		
Incomplete Avulsion Injuries §	**n**	**TAM* (degees)**	**SD**	**# Patients with DIPJ Fusion**
Urbaniak 1981	9	206	not reported	not reported
Nissenbaum 1984	5	240	18	not reported
Kay 1989	12	193	28	15/25**
Weil 1989	5	224	not reported	not reported
Adani 1996	10	243	26	not reported
Sanmartin 2004	39	189	not reported	21/75**
Brooks 2007	35	190	not reported	11/39**
Mean for Incomplete Avulsion Injuries ‡	**115**	**199**		
Mean TAM* for All Avulsions ‡	**190**	**189**		

§studies listed in chronological order

*TAM = total arc of motion

‡weighted averages based on sample size of each study

**DIPJ fusion includes patients at start of study in both complete and incomplete subgroups combined (study did not reported separately)

Table 4

Sensibility Outcomes for Complete and Incomplete Avulsion Injuries

Complete Avulsion Injuries§	**n**	**2PD*** **(mm)**	**SD**
Urbaniak 1981	3	12	not reported
Tsai 1984	6	9	5
Beris 1994	7	9	not reported
Akyurek 2002	5	9	3
Adani 2003	6	14	2
Hyza 2007	5	9	not reported
Mean for Complete Avulsion Injuries‡	**32**	**10**	
Incomplete Avulsion Injuries§	**n**	**2PD*** **(mm)**	**SD**
Urbaniak 1981	9	10	not reported
Nissenbaum 1984	5	6	not reported
Weil 1989	5	6	not reported
Adani 1996	10	9	3
Mean for Incomplete Avulsion Injuries‡	**29**	**8**	
Mean 2PD* **for All Avulsion Injuries**‡	**61**	**9**	

§studies listed in chronological order

*2PD = two-point discrimination

‡weighted averages based on sample size of each study

Table 5

Total Arc of Motion Outcomes for Zone II Flexor Tendon Repairs

Author§	**n**	**TAM*** **(degrees)**	**SD**
Strickland 1980			
Mobilized group	24	213	not reported
May 1992			
Kleinert group	46	228	33
Passive group	39	223	38
Four finger group	34	249	21
Silfverskiold 1992			
All patients	35	226	35
May 1993			
Kleinert group	47	229	32
Passive group	49	220	37
Four finger group	49	242	25
Silfverskiold 1993 (May)			
All patients	41	242	23
Silverskiold 1993 (July)			
All patients	154	221	not reported
Silfverskiold 1994			
All patients	53	247	17
Baktir 1996			
Early motion group	47	227	31
Kleinert group	41	220	35
Hoffman 2008			
Lim/Tsai group	50	231	not reported
Kessler group	21	213	not reported
Combined Mean TAM* **for Zone II Tendon Repairs**‡	**730**	**229**	

§studies listed in chronological order

*TAM = total arc of motion

‡weighted averages based on sample size of each study

Table 6

Sensibility Outcomes for Digital Nerve Repairs

Author[§]	**n**	**2PD**[*] **(mm)**	**SD**
Buncke 1972	20	8	7
Poppen 1979	49	16	11
Sullivan 1985	43	11	5
Combined Mean 2PD[*] **for Digital Nerve Repairs**[‡]	**112**	**13**	

[§]studies listed in chronological order

[*]2PD = two-point discrimination

[‡]weighted averages based on sample size of each study