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The Use of Microsurgeon Tool Box to Improve Outcomes in Avulsed Finger Replantation

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Abstract

Background: Traumatic finger avulsion amputation is considered one of the most challenging emergency procedures in the field of hand surgery. The good preparation of variable different situation that may be faced by the surgeon in that critical condition is important issue.

Objective: Trying to solve chalenges associated with replantation of amputed fingers.

Patients and Methods: During the period from March 2020 to October 2023, 17 cases were included in this prospective study presented with traumatic avulsion amputation of their finger underwent replantation. Different scenarios of the trauma necessitate the presence of different solutions.

Results: This study was performed on 17 patients, 11 males (64.7%) and 6 females (35.3%) with mean age (27.18±14.16) year. Commonly involved finger was thumb (36.8%). Trauma by revolving machines in 13 cases (76.5%) and heavy blunt objects in 4 cases (23.5%). Average ischemia time were 3 hours of them 11 cases (64.7%) were cold ischemia, and 6 cases (35.3%) were warm ischemia.

Conclusion: The procedure of replantation of traumatic finger avulsion amputation has multiple difficulties to the hand surgeon. The surgical decision must be tailored according to the condition faced during surgery. An accepted final outcome can be achieved even in the most difficult scenario with good surgical preparation.

Key Words: *Avulsion – Degloving.*

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Ethical Committee: The study was approved by ethical committee of Ain Shams University code (IRB 00000379) at January 2020.

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Introduction

Traumatic degloving injuries of fingers is characterized by tendon avulsion from musculotendinuos junction and torn off neurovascular bundles at different levels from amputation site. So, this kind of injuries considered as contraindication of replantation **[1]**.

Despite finger avulsion is not life-threatening condition, but it may lead to major functional disability and has bad psychological effect **[2]**.

Literatures conclude that finger avulsion injuries dad bad outcomes regarding viability as well as function **[3]**.

The Success of replantation of amputated finger can be affected by multiple factors, as the injury level, surgeon skills, mode of trauma, amputated part preservation, the number of finger amputation in the same individual, surgical equipment, associated comorbidities, delay, patient age, gender and smoking **[4-8]**.

According to Urbaniak classification of finger amputation, grade III with complete degloving or amputation are considered the most challengeable **[9]**.

So in this study we try to solve these challenges by preparing our tool box by different solutions to a variety of problems we may find.

Patients and Methods

17 patients were included in this prospective study at the Department of Plastic, Burn and Maxillofacial Surgery, Ain Shams University, Cairo, Egypt, during the period between 2020 and 2023 presented by avulsion type amputation of fingers. We include all patients with traumatic finger amputation avulsion of any age and sex fit to general or

regional anesthesia. Poly-trauma patients with major associated comorbidities were excluded from the study.

The study was approved by ethical committee of Ain Shams University code (IRB 00000379) at January 2020.

Surgical procedures:

Two simultaneous teams, the 1st acted on the amputated part, and the 2nd team explored the amputated stump. Both teams did; irrigation and debris removal followed by identification of all structures (tendons, digital neurovascular bundles).

Then the sequence of replantation was performed as follows:

1- Bone fixation: Most of cases were fixed by single K wire as this modality of fixation allowed easier manipulation of the finger throughout the intervention, but sometimes we used 2 K wires to give more rigid fixation and prevent finger rotation. Also, 1ry joint arthrodesis might be performed, but we prefer to undergo the arthrodesis at later stage giving chance for normal joint mobility first according to our own protocol.

2- Tendon repair: Repair of both flexor and extensor tendons were performed primarily by both core and epitendinous sutures, usually we repaired FDP only. In cases with avulsed tendons we performed tenodesis. Also, tendon transfer was an option in some cases.

3- Digital artery repair: Because digital artery may be too short, thrombosed or even crushed or avulsed and may leaving a large gap so trimming was done first then we performed either direct anastomosis with or without using vein graft to same or contralateral bundle (crisscross anastomosis) or digital artery anastomosis into radial artery with vein graft.

4- Digital vein anastomosis: Always followed digital artery anastomosis in order to assess replant vascularity and enhance venous congestion to facilitate venous anastomosis. We usually perform at least two dorsal veins and in some cases we might use vein grafts with two or three tributaries. Also vein transposition might be performed in some cases.

5- Digital nerves repair: If short or severely damaged we might perform neurolysis to get more length. End to end nerve repair to the same bundle or contralateral bundle (crisscross repair) or into superficial radial nerve was performed. Also end to side nerve repair might be used either into contralateral nerve or digital nerve of nearby digit with the use of neve graft.

6- Wound closure performed primarily and meticulously to avoid ischemia or congestion of the operated finger. Loose dressing was performed with application of splinting in the resting position. Other options of skin closure that can be used like skin grafting or local flaps.

We usually try to perform all what the finger needs in the primary surgery to decrease the chance of auxiliary intervention later on.

Postoperative medications and follow-up:

1- Monitoring of replanted finger was performed on hourly basis during day 1, then every 2 hours in day 2 and every 6 hours during the remaining hospital stay period as regard vascularity using capillary refiling test.

2- Finger salvage: In case of finger ischemia reoperation might be performed according to operative situation during 1ry surgery. In case of finger congestion, we used to perform either scratching of the nail bed with application of heparinized saline soaked-gauze, leech in some cases or operative exploration if needed.

3- Anticoagulant: Low molecular weight heparin was used in all patients for at least 1 week postoperatively at the prophylactic dose according to age and body weight according to clinical pharmacy adjusted doses.

4- Fluid intake: Adult IV fluids of 120ml / hour in the 1st 3 days that tapered into 100ml / hour in the following 2 days then become 80ml / hour in the following two days then shifted to oral intake. Type of fluid used is Ringer or normal saline. In children's the rate of fluid intake adjusted with pediatric ICU physician usually ranged from 50-80ml/hour according to body weight and child age.

Fluid chart was used in every patient to avoid fluid overload complications.

5- After discharge from hospital patients were followed-up in our OPC to assess wound healing and detect any postoperative complication.

6- At 2 weeks' sutures removed and at 4 weeks' splint and k wires removed after clinical assessment of bone healing then physiotherapy initiated.

7- Patients were assessed on monthly interval for:

• Assessment of finger motility using Strickland evaluation system **[10]** at 6 and 12 weeks post-operatively. Where range of motion of the injured fingers in relation to normal finger range of motion were evaluated using standard goniometer. By detecting total active movement (TAM) of proximal and distal interphalangeal joints which subdivide the range of motion into excellent (85-100), good (70-84), fair (50-69) and poor (<50) in comparison of contralateral digit as shown in Table (1).

• Assessment of sensation at 3 and 6 months by 2-point discrimination test which classify sensation into normal (less than 6mm), fair (6-10mm), poor (11-15mm), protective when only one point was perceived and anesthetic where points are not perceived **[11]**.

• Subjective assessment of patient's overall satisfaction of hand function and restoration of pre-morbid activity was performed using quick DASH questionnaire **[12]**.

Fig. (1): 45 years old male with avulsed right thumb (A), 3 weeks post-operatively (B).

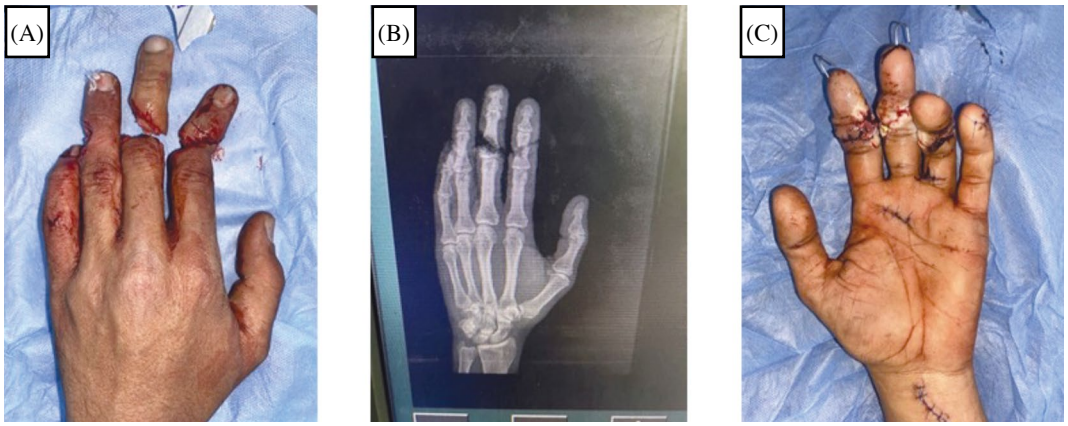

Fig. (2): 30 years old male patient with 3 digits crushed avulsion by heavy blunt object pre-operative (A), X-ray showing comminution of the bone (B), 1 month postoperative (C).

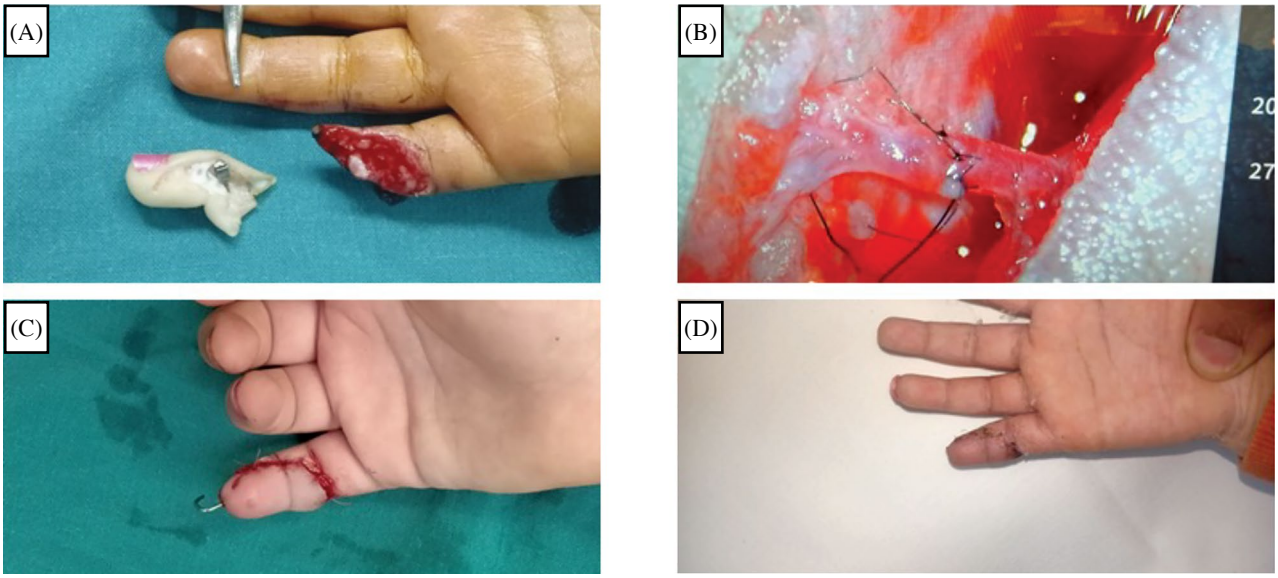

Fig. (3): 5 years old female child with avulsed type amputation of left little finger (A), Intra operative arterial repair (B), Immediate post-operative (C), 1 month post-operative (D).

Fig. (4): 52 years old male heavy smokers with avulsed type amputation of left thumb pre-operative (A,B), intraoperative with marking and harvest of vein graft (C, D), immediate post-operative (E), and 3 months post-operative (F).

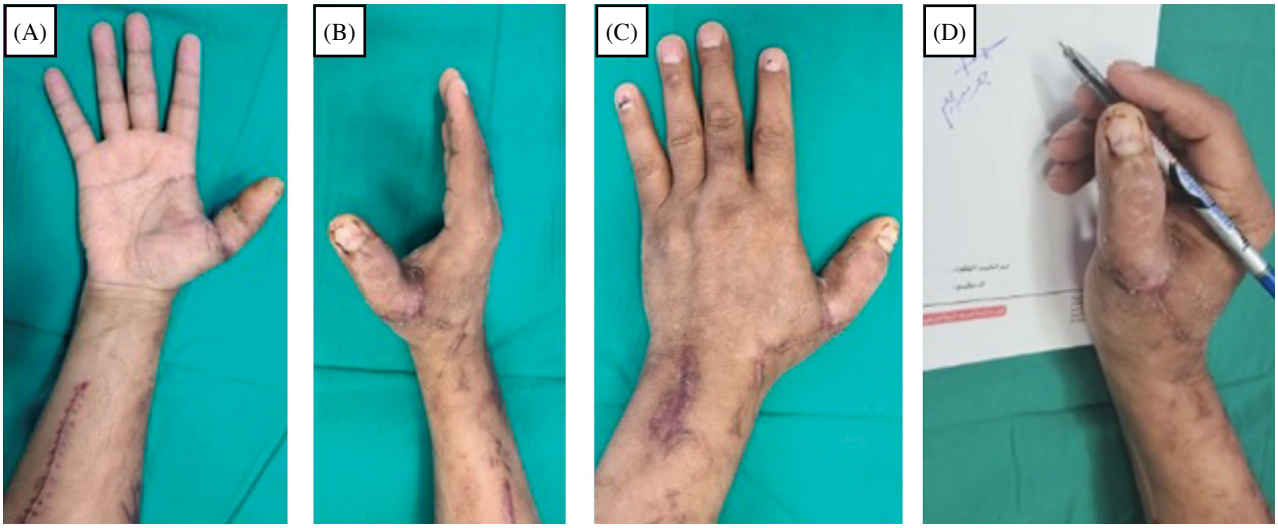

Fig. (5): 50 years old male heavy smokers with avulsed type amputation of right thumb with delayed 6 months post-operative after completeness of physiotherapy and full scar maturation (A, B, C) showed full recovery of hand function (D).

Table (1): Strickland evaluation system **[10]**.

Score	Original Strickland (TAM / 175) (%)	TAM (PIP + DIP flexion minus extensor loss) (degree)
Excellent	85-100	>150
Good	70-84	125-149
Fair	50-69	90-124
Poor	<50	<90

Results

This study was performed on 17 patients, 11 males (64.7%) and 6 females (35.3%) with a mean age (27.18±14.16) years. 16 patients had single digit affection (94.1%) with only one patient with multiple digits affected (5.9%). Commonly involved finger was thumb (36.8%) followed by index finger (26.3%). Trauma by revolving machines in 13 cases (76.5%) and heavy blunt objects in 4 cases (23.5%). Average ischemia time were 3 hours of them 11 cases (64.7%) were cold ischemia and 6 cases (35.3%) were warm ischemia. (Table 2).

We use our tool box as follows: (Table 3)

1- We performed Bone shortening of 0.5 to 1cm in 15 fingers (78.9%) and more than 1cm in only 4 fingers (21.1%) followed by bone fixation by single K wire in 14 fingers (73.7%) and by 2 K wires in 5 fingers (26.3%) and we did not need to perform 1ry joint arthrodesis in any finger of this study.

2- As regard tendon repair we performed 1ry tendon repair in 17 fingers (89.5%) and tenodesis in only 2 fingers (10.5%) which were totally avulsed from their bony attachment when no chance of 1ry repair was available.

3- Following trimming of digital artery we tried first to repair digital artery to digital artery (same bundle) which was successful in 12 fingers (63.2%) without the need of interposition of vein graft, and in one case (5.3%) with the aid of vein graft. But in the other 6 fingers we performed instead transposition of digital artery into radial artery with vein graft in one finger (5.3%), or into contralateral bundle in 4 fingers (Without vein graft) directly and in only one finger (5.3%) with interposition of vein graft.

4- Regarding digital veins repair we tried to perform direct dorsal venous anastomosis of at least 2 veins which were successful in 15 fingers (78.9%) but sometimes this was not feasible so instead we harvested vein graft after venous mapping with 2 tributaries in one finger (5.3%) and with three tributaries in two fingers (10.5%) or vein transposition which was performed in only one finger (5.3%).

5- Digital nerve repair was performed thereafter by different modalities the most commonly used was end to end repair to the ipsilateral nerve of fingers (68.4%) or to contralateral digital nerve in 2 fingers (10.5%) and in only one finger to superficial radial nerve (5.3%). When end to end nerve repair was not possible we tried to perform end to side repair with the aid of nerve graft into contralateral digital nerve (crisscross) which was performed in 2 fingers (10.5%) or into nearby digit in only one finger (5.3%).

Table (2): Patient's data and demography of the trauma.

	No. of cases = 17 No. of fingers = 19 F
Age:	
Mean ± SD	27.18±14.16
Range	5 – 52
Sex:	
Female	6 (35.3%)
Male	11 (64.7%)
Profession:	
No worker	5 (29.4%)
Manual work	12 (70.6%)
Smoking:	
Non-smoker	7 (41.2%)
Smoker	10 (58.8%)
Associated co-morbidities:	
No	14 (82.4%)
Yes	3 (17.6%)
Hand dominance:	
Right	16 (94.1%)
Left	1 (5.9%)
Level of amputation:	
MPJ	5 (26.3%)
PIP	8 (42.1%)
DIP	6 (31.6%)
Affected finger:	
Little	2 (10.5%)
Index	5 (26.3%)
Middle	2 (10.5%)
Ring	3 (15.8%)
Thumb	7 (36.8%)
Mode of trauma:	
Revolving	13 (76.5%)
Machine	4 (23.5%)
Place of Occurrence:	
Home	5 (29.4%)
Work	12 (70.6%)
Ischemia time (hours):	
Median (IQR)	3 (2-5)
Range	1-7
Preservation:	
Warm	6 (31.6%)
Cold	13 (68.4%)

Table (3): Different options that may be used (Tool box).

Structure	Tool box	Tool box		Number = 19 fingers	
Bone	Shortening	0.5-1cm		15	78.9%
		>1cm		4	21.1%
	Fixation	Single K wire		14	73.7%
		2 K wires		5	26.3%
		1ry arthrodesis		0	0.0%
Tendons	1ry repair			17	89.5%
	Tenodesis			2	10.5%
	Tendon transfer	Immediate		0	0.0%
		Delayed		0	0.0%
Digital artery anastomosis (Following trimming)	Digital to digital (same bundle)	With vein graft		1	5.3%
		Without vein graft		12	63.2%
	Transposition	Into radial artery with vein graft		1	5.3%
		Into contralateral bundle (crisscross)	With vein graft	1	5.3%
			Without vein graft	4	21.1%
	Direct repair			15	78.9%
Digital vein anastomosis (Following trimming)	Vein graft after venous mapping	2 tributaries		1	5.3%
		3 tributaries		2	10.5%
	Vein transposition			1	5.3%
Digital nerve repair	End to end	Same bundle		13	68.4%
		Contralateral nerve (crisscross)		2	10.5%
		Superficial radial nerve		1	5.3%
	End to side	Contralateral nerve (crisscross) with nerve graft		2	10.5%
		Nearby digit with nerve graft		1	5.3%
Wound closure	1ry			19	100.0%
	Skin graft			0	0.0%
	Flap coverage			0	0.0%

6- Finally, skin closure, we tried our best to trim unviable skin edges and perform meticulous direct skin closure in all fingers even with small skin defects may be left to heal by 2ry intention but local flaps like 1st dorsal metacarpal artery flap or even skin graft may be alternate options for skin closure.

Follow-up of replanted fingers were done on two stages:

- 1st stage (1ry assessment) early follow-up (1st week) which was concerned with finger vascularity which was performed by capillary refilling and show that 16 fingers were with maintained vascularity (84.21%) on the other hand 3 fingers with impaired vascularity (15.97%) of them 2 fingers due to venous congestion and single finger was due to arterial ischemia.
- 2nd stage (2ry assessment) late follow-up (3-6 months) which was subdivided into objective and subjective assessment. Objective assessment of both sensory recoveries by 2-point discrimination test that show overall average improvement (9-14mm) at 3 months that improved to (6-8mm) at 6 months **[11]**.

The results of sensory improvement by 2 points discrimination test after six months showed dramatic improvement as compared by 3 months' evaluation as shown in Table (5).

Active Range of motion in comparison to other finger according to Strickland evaluation system that show 5 cases (29.4%) were excellent, and 7 cases (41.2%) were good, and two cases (11.8%) with fair hand function **[10]**.

Subjective assessment of patient's overall satisfaction of hand function showed that all patients were satisfied from the results of replanted fingers. Also as regard restoration of premorbid activity which was performed using quick DASH questionnaire showed that 13 (76.5%) of our patients returned back to their premorbid activity and 1 (5.9%) was unable to resume his work or need to change his occupation. Unfortunately, 3 (17.6%) patients were missed our long term follow-up **[12]**.

Table (4): Primary assessment (early follow-up of replanted finger vascularity) and secondary assessment (delayed long term follow-up) of finger motility.

Score	No. of cases = 17 No. of fingers = 19 F
Early Follow-up (1st week)	
Vascularity by capillary refilling:	
Maintained	16 (84.22%)
Total loss (congestion	2 (10.52%)
Total loss (Ischemic)	1 (5.26%)
Late follow-up (3-6 months) Objective assessment 2 point discrimination test	
After 3 months (mm):	
Mean ± SD	11.88±1.59
Range	9 – 14
After 6 months:	
Mean ± SD	6.94±0.77
Range	6 – 8
Range of motion and power of hand grip in comparison to other finger and hand:	
Missed	3 (17.6%)
Fair	2 (11.8%)
Good	7 (41.2%)
Excellent	5 (29.4%)
Subjective assessment	
Return to premorbid:	
No	1 (5.9%)
Yes	13 (76.5%)
Missed	3 (17.6%)
Overall patient satisfaction:	
Satisfied	19 (100.0%)

Table (5): Improvement of sensory recovery.

2 Point discrimination test	After 3 months	After 6 months	Difference	Test value•	*p*-value	Sig.
	No. = 19	No. = 19	Mean ± SD			
Mean ± SD	11.88±1.59	6.94±0.77	-4.93±1.24	–15.971	0.000	HS
Range	9 – 14	6 – 8				

p-value >0.05: Non significant.
p-value <0.05: Significant.
p-value <0.01: Highly significant.
•: Paired *t*-test.

Discussion

In spite of the multiple technical difficulties and the possible risks of replantation of avulsed fingers as multiple injury level of all structures. Also because of individuals with amputated fingers were subjected to bullying and social withdrawal **[7]**.

We should prepare ourselves with different planes and back-up alternative, to overcome these challenges.

We worked as two separate teams to avoid boring and shortening the time of operative replantation which consistent with the concepts of Nanda et al. **[13]**.

One of the most important factors of encouraging results is good patient selection which not only improve outcomes but also decrease risks on poorly selected candidates. So in our study we excluded Poly-trauma patient with major associated comorbidities like Waikakul et al., who also exclude patients with associated injuries or chronic diseases **[14]**.

One of these major challenges is the separation of digital artery intima with exposure of highly thrombogenic tunica media with increase possibility of post anastomosis thrombosis **[15]**. To overcome this technical difficulty, a thorough dissection and trimming of the injured edges of digital vessel must be done in all cases, which may lead into shortening of vessel ends and impossible direct repair. Hence the value of using a tool box and chose suitable option like arterial transposition or interposition of vein graft.

In cases with venous congestion, re-exploration usually still an option but because we had performed most of suitable repairing options during 1ry surgery so unfavorable outcomes might be resulted. Also unsettled Inflammatory process from 1ry surgery, leading to friable vessels which makes re-anastomosis much more difficult. So, conservative management by scratching of nail bed with application of heparinized gauze, or the use of leeches may be suitable.

This was consistent with the results of Buntic RF and Brooks D who performed only digital artery anastomosis and allow temporary venous drainage until establishment of peripheral circulation **[16]**.

Baudet and others mentioned the efficacy of Leech therapy in management of venous congestion but multiple difficulties like the necessity for strict monitoring for the required drainage and refusal by many patients **[17,18]**.

The overall survival rate of replanted fingers in our study was (84.22%).

Which differ from the success rate of 50.9% in case of replantation of degloved fingers reported by Waikakul et al. **[14]** which may be attributed to multiple alternative solutions in our tool box.

Although smoking history have resulted in higher failure rate in finger replantation, this effect was not evident in our study group **[19-22]**.

Ischemia time didn't affect survival rate in our study which might be due to two separate teams acted together which accelerated the surgical progress, also no cases with ischemia time more than 24 hours were included. This was consistent with the results of Wei and colleagues who reported successful replantation of amputated fingers after prolonged ischemia **[23]**.

The active Range of motion in comparison to other finger and hand in our study was excellent in (29.4%), good in (41.2%) and fair in (11.8%) according to Strickland evaluation system **[10]**.

Which was comparable with the studies Holmberg et al. (1996) reported a mean active range of movement in replanted fingers was 84% when compared to healthy digits **[24]**.

In the Blomgren et al. (1998) study they also found the mean active range of motion in replants was about 46% as that of contralateral digits, and in case of thumb was only 19% compared to other thumb **[25]**.

Urbaniak et al., mentioned a mean ROM of 206° in avulsed finger replantation **[9]**.

Also, Adani et al., stated that after ring avulsion the mean ROM was 185° **[26]**.

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