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Study of Impact of Arterial/Venous Ratio in Optimizing Outcome of Hand Replantation Surgery at Zagazig University Hospitals

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ABSTRACT

Background: The number of anastomosed arteries and veins in replantation surgery of the hand is one of the most important factors in determining survival rate.

Objective: To evaluate the surgical and functional outcomes of replantation after injuries in the hand with different ratios of the repaired arteries and veins.

Patients and Methods: Twenty-one patients underwent replantation and revascularization procedures for hands and fingers amputation from April 2021 to the end of October 2021 in the Department of Plastic Surgery at Zagazig University Hospitals. According to arterial/venous (AV) ratio in optimizing replantation they were grouped into 3 groups, group I AV ration < 1 vein, group II: AV ration = 1 vein, group III: AV ration > 1 vein and they were followed up for more than six months

Results: There were a statistically significant increase in total active range of motion (TAM) degree among Group III compared to Group I and II. Regarding Chen criteria, there was a statistical significant increase in frequency of class I among Group III compared to Group I and Group II. There was a statistically significant –ve correlation between A/V ratio and TAM degree among the studied cases. Also, there was a statistical significant +ve correlation between A/V ratio and Chen criteria, two-point discrimination (2PD), and Q dash among the studied cases.

Conclusion: All hand surgeons should be able to perform digital replantation. A successful vessel anastomosis ensures the viability of the replanted portion of the body.

Keywords: Arterial/Venous Ratio, Replantation.

INTRODUCTION

Traumatic amputations are among the most serious types of hand injuries, and they are most commonly caused by high-energy trauma in young, healthy people. These injuries are often life-altering and necessitate multiple surgeries, prolonged hospitalization, missed work, and other financial and emotional sufferings [(1)].

Surgeons who perform replantation and revascularization of post-traumatic amputations have helped to preserve the quality of life for amputees since the first successful limb replantation reported by Ronald Malt in 1964. As microsurgery has improved in recent years, reattaching a severed hand has become a common procedure in medical facilities around the world. Surgeons' growing experience and expanding knowledge have allowed the success rate for replantation to rise to 80-90 percent [(2)].

Replantation of digits that have been amputated can restore both their function and appearance. To put it another way, patients who have had their fingers successfully replanted have better long-term health and well-being than those who have had their fingers amputated in revision [(3)]. Anastomosed arteries and veins have a significant impact on a patient's survival rate in replantation surgery, so repairing as many as possible is done to increase the likelihood of a successful outcome [(4)].

Starting from Zone III (distally) to Zone V (proximally), every hand amputation offers the possibility of replantation that is frequently superior to the available prosthetics [(5)]. Finger replantation failures are frequently caused by venous congestion or insufficiency. The most important predictor of success is surgical technique, not postoperative anticoagulation or leeching [(6)].

There are very few outcome studies concerning digital replantation. Most studies of digital replantation only have a level IV or Level V impact and more clinical trials are required to elevate the quality of the evidence. Future out-comes studies must also consider cost within studies so that the outcomes of digital replantation are considered in con-junction with economic burden on individuals and society [(7)].

Arabic Q-DASH is a valid and reliable measurement of upper extremity disorders for patients whose primary language was Arabic in Egypt; it can be used to track patient status and outcome sand to promote evidence-based practice[(8)]. Our results used as an alternative to the full DASH for assessing individuals with upper extremity disorders.

The aim of the present study was to evaluate the surgical and functional outcomes of replantation after injuries in the hand with different ratios of the repaired arteries and veins.

PATIENTS AND METHODS

This study was undertaken in the Department of Plastic Surgery at Zagazig University Hospitals. Twenty-one consecutive patients with 21 hands and finger underwent replantation and revascularization procedures

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from April 2021 to the end of October 2021 at this prospective interventional clinical trial.

Ethical consent:

An approval of the study was obtained from Zagazig University Academic and Ethical Committee (ZU-IRB#6729). Every patient or parent of child patient signed an informed written consent for acceptance of participation in the study. This work has been carried out in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki) for studies involving humans.

Inclusion criteria:

Complete or incomplete amputation of any part of hand, amputation at wrist level and distally, surgery performed at the tertiary hospital during the study period, and documentation of procedures and related data retrievable and complete

Exclusion criteria:

Medical co-morbidities that can affect anesthesia, healing, therapy or ability to cooperate with care, amputation above wrist level, and documentation of procedures and related data not available or not complete

Once the medical records of a patient have been located, data on the patient's characteristics (such as gender, race, age, and co-morbidities like diabetes mellitus and hypertension) and concurrent medications (such as anti-diabetic drugs (such as gliclazide and metformin) and antihypertensive drugs (such as calcium channel blockers or angiotensin converting enzyme inhibitors) as well as amputation characteristics (such as the level and type) were documented.

Total of 21 patients 19 males and 2 females, ages ranged from 4 to 53 years. Those patients enrolled with hands and fingers amputation and underwent replantation used computer-generated random numbers in sealed envelopes for allocation to one of the arms in a randomization procedure.

According to arterial/venous (AV) ratio in optimizing replantation, patients were classified into three groups:

- **Group I:** AV ration < 1 vein (n = 4), they were 4 males only with mean age was 37.75±13.82 years, ranged from 20 – 51 years, and median age 40 years.
- **Group II:** AV ration = 1 vein (n = 6), they were 6 males only with mean age was 30.33±9.63 years, ranged from 16 – 43 years, and median age 30.5 years.
- **Group III:** AV ration > 1 vein (n = 11), they were 9 (81.8%) males and 2 (18.2%) females with mean age was 24.73±14.19 years, ranged from 4 – 46 years, and median age 27 years.

Preoperative Replantation:

Patients who have had an amputation need to be stabilized and checked for life-threatening injuries as soon as possible in an emergency. Using sterile gauze moistened with normal saline, the amputated part should be wrapped and photographed so that other medical personnel can see it without re-exposing it. To determine the extent of the bone injury, radiographs were taken to evaluate the extent to which the comminution, intra-articular involvement, and bone loss had occurred.

Operative technique:

General anesthesia and tourniquets on the upper limb were used in most cases for the initial stages of surgery in most cases.

There were only so many venous anastomoses that could be made because of the state of the available veins at the time. There were times when only a single vein flap was possible, while other times it was more common to perform a double anastomosis unless the other vessel's condition was unsuitable or there was no suitable recipient vein.

1. Wash, debridement of the unhealthy tissues, and radical resection: Particularly in crush injuries were of vital significance. 500 ml of sterilized lactated Ringer's solution containing 80 mg of gentamicin was used to wash the amputated parts, these parts were then cautiously debrided under.
2. Magnification, shortening of the bone according to the necessity and bone destruction, enables primary vessels, nerves, and tendons restoration.
3. Exploration and identification of the tissues in the amputated segments and in the proximal portions was done systematically, vessels and nerves declared and marked with an 8/0 nylon suture.
4. Microsurgical evaluation of the vessels was achieved: Ribbon signs in the arteries denoted inappropriate fragment for repair. Any hurt to the intima required its excision. Minor hematomas on the arterial wall specified side branches avulsion. If these problems were present, suturing or resection of a segment was done. Subcutaneous hematomas on back aspect of fingers suggested the location of vein interruption. Dorsal venous arcades were recognized and used in repair.
5. Bone fixation and musculotendinous avulsion management: The cases were fixed by K wires, and in patients of amputation at the wrist joint we did our best to preserve certain joint task. Tendons were fixed to muscle bellies or tendon transfer to substitute avulsed tendon in avulsion amputation with total destruction of muscles.
6. Sutures of 4-0 polyproline (horizontal mattress) were used to repair the extensor tendons.
7. Flexor tendons repair: The flexor tendons were sutured with 3-0 polyproline using the suture method.

8. Repair of one or two veins: To decrease incidence of congestion.
9. Arterial reconstruction: Only in conjunction with bone shortening was primary arterial repair feasible. When fingers were replanted, superficial vein grafts from the front of the distal part of the same side forearm were used. The proximal end of the artery was used to establish blood flow prior to arterial anastomosis.
10. Venous reconstruction: After arterial anastomosis, primary end-to-end vein anastomosis of double number of the arteries, which had been anastomosed. Relocating marginally one end of a venous arcade present adjacent to wound was a noble answer in digital vein defects 2 cm or less.
11. Nerve reconstruction: Neurorrhaphy was done using epineural sutures to both median and ulnar nerve and their branches using 9/0 nylon suture.
12. Skin closure and drainage were done with light bandage; the hand was placed in a plaster splint in anticlaw position for 10-21 days.

The postoperative results as regard the form was evaluated as regard function the following points were evaluated:

1. The general performance of the patient using his replanted hand and his overall satisfaction by noting his work stability.
2. The recovery of flexor and extensor mobility of digits by measuring the total active motion.
3. The recovery of thumb opposition.
4. Recovery of sensitivity of the fingers supplied by median and ulnar nerve by using the 2-points discrimination test.
5. The ability to do daily activity by allowing the patient to hold objects of different shape and dimension, writing, picking up a coin and buttoning.
6. As a part of their testing, the patients who had undergone surgery returned for an interview with a patient-centered questionnaire and physical examinations of their range of motion.

Follow up: Follow-up of patients continued intermittently until postoperative 3-6 months.

Statistical analysis

The collected data were coded, processed and analyzed using the SPSS (Statistical Package for the Social Sciences) version 22 for Windows® (IBM SPSS Inc, Chicago, IL, USA). Data were tested for normal distribution using the Shapiro Wilk test. Comparison between three groups with quantitative data was done by ANOVA with post-Hoc Tukey HSD Test when the distribution of the data was found parametric. Kruskal-Wallis test was used with the nonparametric data. Spearman correlation coefficients were used to assess the correlations.Qualitative data were represented as frequencies and relative percentages. Chi square test (X^2) was used to calculate difference between two or more groups of qualitative variables. Quantitative data were expressed as mean ± SD (Standard deviation), median, and range. P value < 0.05 was considered significant.

RESULTS

Age and sex distribution were not statistically different between the groups studied **(Table 1).**

Table (1): Demographic data of the studied groups

Variable	Group I (AV ratio <1) (n=4)		Group II (AV ratio=1) (n=6)		Group III (AV ratio >1) (n=11)		KW	P
Age: (years) Mean ± SD Median Range	37.75±13.82 40 20-51		30.33±9.63 30.5 16-43		24.73±14.19 27 4-46		2.87	0.24
	No	**%**	**No**	**%**	**No**	**%**	**X^2**	**P**
Sex: Male Female	4 0	100 0	6 0	100 0	9 2	81.8 18.2	2.01	0.37

Table (2) shows that lesion levels and sides were not statistically different between groups studied.

Table (2): Level and side of lesion among the studied groups

Variable	Group I (AV ratio <1) (n=4)		Group II (AV ratio=1) (n=6)		Group III (AV ratio >1) (n=11)		χ^2	P
	No	%	No	%	No	%		
Level:								
T1	2	50	0	0	0	0	15.29	0.12
T2	1	25	2	33.3	2	18.2		
T3	0	0	1	16.7	4	36.3		
T4	0	0	3	50	3	27.3		
T3+4	0	0	0	0	1	9.1		
T5	1	25	0	0	1	9.1		
Side:								
Dominant hand	3	75	2	33.3	5	45.5	1.71	0.42
Not dominant hand	1	25	4	66.7	6	54.5		

Table (3) shows that ischemic time and the mechanism of lesion were not statistically different between the groups studied.

Table (3): Mechanism of injury and ischemic time among the studied groups

Variable	Group I (AV ratio <1) (n=4)		Group II (AV ratio=1) (n=6)		Group III (AV ratio >1) (n=11)		X^2	P
	No	%	No	%	No	%		
Mechanism:								
Avulsion	2	50	2	33.3	2	18.2	10.34	0.41
Blunt crushing	0	0	1	16.7	0	0		
Crushing	0	0	2	33.3	5	45.5		
Guillotine	1	25	1	16.7	2	18.2		
Locally crush	1	25	0	0	2	18.2		
Ischemic time:								
< 6 h	2	50	2	33.3	6	54.5	0.71	0.70
> 6 h	2	50	4	66.7	5	45.5		

Table (4) shows that there was no statistically significant difference in replanted part or follow-up time between the studied groups.

Table (4): Replanted part and follow up time among the studied groups

Variable	Group I (AV ratio <1) (n=4)		Group II (AV ratio=1) (n=6)		Group III (AV ratio >1) (n=11)		Sig. Test	P
	No	%	No	%	No	%		
Replanted part:								
Index	1	25	2	33.3	1	9.1	χ^2=7.31	0.84
Little	0	0	1	16.7	1	9.1		
Middle	0	0	1	16.7	1	9.1		
Ring	0	0	1	16.7	3	27.3		
Thumb	2	50	1	16.7	3	27.3		
Wrist	1	25	0	0	1	9.1		
Ring + little	0	0	0	0	1	9.1		
Follow up: (months)								
Mean ± SD	11.25±0.96		11.17±0.98		11.36±0.67		F=0.12	0.89
Range	10-12		10-12		10-12			

Table (5) shows that there was a statistically significant increase in total active range of motion (TAM) degree among Group III compared to Group I and II. Regarding Chen's criteria, there was a statistical significant increase in frequency of class I among Group III compared to Group I and Group II.

Table (5): Postoperative Chen’s criteria and TAM degree among the studied groups

Variable	Group I (AV ratio <1) (n=4)		Group II (AV ratio=1) (n=6)		Group III (AV ratio >1) (n=11)		KW	P
TAM: (degrees) Mean ± SD Median Range	76.75±31.97 87.5 30-102		86.33±29.23 89 34-120		100.55±22.55 103 49-132		**4.30**	**0.02***
	No	**%**	**No**	**%**	**No**	**%**	**X^2**	**P**
Chen grade: I II III IV	 0 1 2 1	 0 25 50 25	 1 2 2 1	 16.7 33.3 33.3 16.7	 5 4 2 0	 45.5 36.4 18.2 0	**9.13**	**0.04***

*: Significant

Table (6) shows that there was a statistically significant decrease in mean 2PD among Group III compared to Group I and II. Regarding Q dash, there was a statistical significant decrease in mean Q dash among Group III compared to Group I and Group II.

Table (6): Postoperative 2 point discrimination and Q dash score among the studied groups

Variable	Group I (AV ratio <1) (n=4)	Group II (AV ratio=1) (n=6)	Group III (AV ratio >1) (n=11)	KW	P
2 PD: (mm) Mean ± SD Median Range	7.75±3.3 7.5 4-12	5.67±2.42 5.5 3-10	4.91±1.7 5 3-8	**5.12**	**0.008***
Q dash: Mean ± SD Median Range	36.25±19.69 28.5 23-65	28.83±9.02 27.5 20-45	25.36±7.38 24 17-44	**4.02**	**0.03***

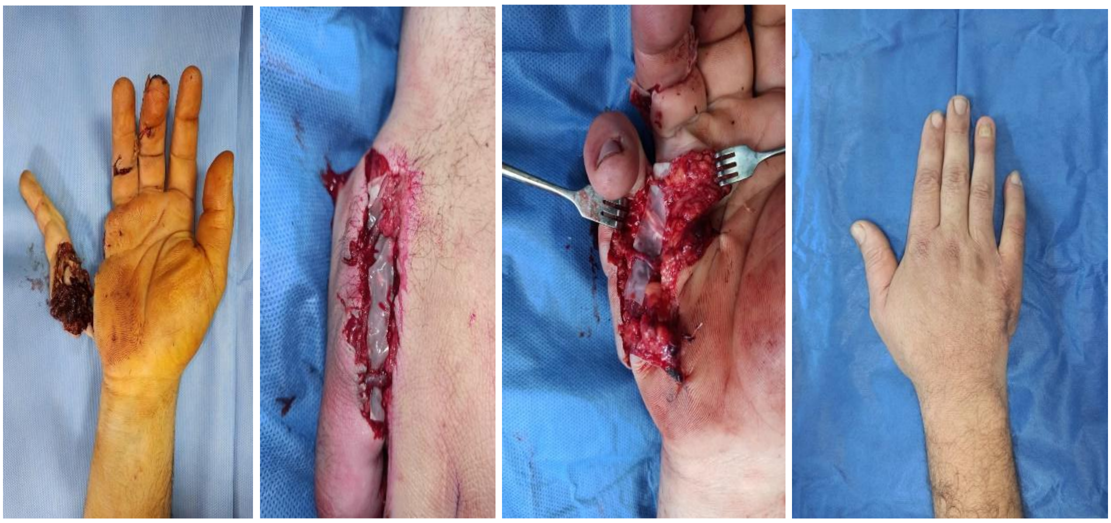
*: Significant

Table (7) shows that there was a statistically significant –ve correlation between AV ratio and TAM degree among the studied cases. Also, there were a statistical significant +ve correlation between AV ratio and Chen's criteria, 2PD and Q dash among the studied cases.

Table (7): Correlation between postoperative parameters and AV ratio among the studied cases

Variable	AV ratio (*n*=21)	
	r	***P***
TAM degree	-0.34	0.03*
Chen criteria	0.37	0.01*
2 PD (mm)	0.41	0.006*
Q dash	0.32	0.04*

*: Significant



(A) (B) (C) (D)

Figure (1): A: Nearly totally amputated right little finger, B: two dorsal veins were anastomosed, C: two volar arteries were anastomosed, D: 4 months follow up postoperatively

DISCUSSION

The extensive damage to vessels and nerves caused by avulsion and crush injuries makes them particularly problematic. Shortening of the extremity is required in cases where a crush is the primary cause of complex fractures of the forearm and carpal bones [(9)]. Replantation of amputated extremities has been considered an accepted technique, especially after the finest microsurgical technique added an important element in stopping arterial or venous occlusion [(10)]. In addition, the growing microsurgical and super microsurgical experience have permitted to replant several digits and digital parts that would be believed unachievable in the past [(11)]. As a result, many medical facilities are questioning the long-established guidelines for digital replantation described in classic texts [(12)].

The replantation of amputated digit has come to be a dependable method, with success rates stated to be more than 90% [(13)]. Venous insufficiency remains the commonest complication after replantation with stated incidence of 7-32% [(14)]. At the level of the wrist regarding vessel repair, two main arteries and their venae comitantes, and at least two subcutaneous veins, should be repaired. Venae comitantes of the radial and ulnar arteries seem small compared with subcutaneous veins but are capable of draining a significant quantity of blood [(15)]. Safety of any surgical procedure has the same importance of its efficiency, vein transfer is not only a simple procedure but it is also a safe one, as no general or vascular complication (congestion or ischemia) was developed in any patient due to vein(s) harvesting [(4)].

To date, however, few studies have evaluated functional outcomes following replantation. Therefore, the purpose of this study was to evaluate the surgical and functional outcomes of replantation after injuries in the hand with different ratios of the repaired arteries and veins and analyze the surgical techniques for microsurgical anastomosis. Additionally, identifying the possible early complications and compare the clinical results of anastomosing different numbers of arteries and veins anastomoses. Also, to give a reliable data about the different ratios of the repaired arteries and veins.

The current study included 21 patients who were treated with replantation of fingers and hands amputation. They were 19 males and 2 females whose ages ranged from 4 to 53 years. All patients presented with complete amputations at the level of finger, metacarpals or at wrist joint. All cases were due to sharp trauma. Two cases were bilateral, 4 cases involved the right finger, 5 cases involved the right hand, and 10 cases involved the left hand. In ten cases there was good preservation of the amputated parts with ischemia time about four to twelve hours, in the remaining eight cases preservation was bad with ischemia time of about six to nine hours. According to arterial/venous (AV) ratio in optimizing replantation, patients were classified into three groups: Group I: AV ration < 1 vein (n = 4), they were 4 males only with mean age was 37.75. Group II: AV ration= 1 vein (n = 6), they were 6 males only with mean age was 30.33. Group III: AV ration > 1 vein (n = 11), they were 9 (81.8%) males and 2 (18.2%) females with mean age was 24.73. Statistically, there was no significant difference between the studied groups in age or sex distribution.

Regarding the level and side lesions of amputation, the current study revealed that there were 50% of amputation level lesions in group I with T1, 33.3 % of patients in Group II with T2, and 36.3 % of patients in Group III with T3. The majority (75%) patients in Group I had lesions in the dominant hand, (66.7%) of patients in Group II and (54.4%) of patients in Group III had lesions in the non-dominant hand. Statistically, there was no significant difference between the studied groups regarding the level or side of the lesion.

With regard of mechanism of injury, the current study revealed that 50 % of patients in group I were avulsion, followed 33.3% of patients in group II were avulsion and other 33.3% were crushing and 45.5 % of group III also were crushing. Ischemia time is also important to know in order to determine treatment options. The majority (66.7 %) of patients in group II had ischemia time > 6 h, and 54.5% of group III had < 6 h. Statistically, there was no significant difference between the studied groups in mechanism of lesion or ischemic time

Our study was agreeing with the study of **Lima Neto *et al.*** [16] who conducted 50 reimplantation and 15 revascularizations. Patients were aged from 3-75 years with mean age 36 years. Two (4.4 percent) of the patients were females, while the other forty-three (95.6 percent) were males. 54 (83%) of the cases involved cutting injuries, three (4.6%) involved avulsion injuries, and eight (12.3%) involved crush injuries. Patients with lesions in the non-dominant hand were the most common (73.3 percent). There were no survivors after 7 hours, and only 9 hours of ischemia were recorded in fingers that were successfully reimplanted or revascularized by the researchers. Regarding the injured area of the fingers, 44 (67.7%) of the fingers were injured in Verdan zone 2, 14 (21.5%) in zone 1 and seven (10.8%) in zone 3. Six pure dislocations with no bone damage accounted for 28 of the fractures, while 31 were comminuted. Twenty-nine metacarpal fractures were found in the proximal phalanx, 10 on the medial side, and one on the distal side in the eight amputees. 10 fractured and dislocated at the interphalangeal level, and six at the distal level.

As studied by **Ahmad** [5] the success of replantation surgeries is influenced by the type of injury (crush avulsion or guillotine) and the length of time during which the organ was in an ischemic state. In terms of both success rates and functional outcomes, the type of injury is the most critical determinant.

Our findings agreed with the study of **El-Sherbiny *et al.*** [17]**,** who revealed that thumb opposition was possible in three cases with no difficulty, one case had difficulty while doing opposition and the remaining case had no thumb injury.

Regarding the evaluation of postoperative both Chen's criteria and total active range of motion (TAM) degree among patients with fingers and hands replantation, the current study revealed that there were a statistically significant increase in TAM degree among Group III compared to Group I and II. Regarding Chen criteria, there was a statistical significant increase in frequency of class I among Group III compared to Group I and Group II. These findings agreed with the study of **El-Sherbiny *et al.*** [17] who found the TAM for fingers apart from thumb was from 100 to 175 degree, these results mimic previous studies. Poor function of intrinsic muscles is still reported in most cases of transmetacarpal replantation either due to direct injury, ischemia or postoperative scarring. In our study there was impairment of intrinsic muscle function yet not to the degree to impair finger abduction and flexion of metacarpophalangeal (MP) joint.

The reported TAM of survived digits after transmetacarpal injuries has varied from 94 degree to 192 degrees. **Scott *et al.*** [18] and **Russell *et al.*** [19] reported total active motion for replanted fingers to be 120 degree and thumb MP and IP motion combined was 59 degrees.

Regarding the mean±standard deviation for postoperative 2-point discrimination (2PD) and Q dash score; the current revealed that, the mean 2PD sensation between the group I, II, and III were 7.75±3.3 mm with median 7.5- mm, and ranged between 2-12 mm in Group I, 5.67±2.42 mm with median 5.5- mm and ranged from 3-10 mm in Group II, versus 4.91±1.7 mm with median 5- mm and ranged from 3-8 mm in Group III respectively (p = 0.008). however, the mean Q dash were 36.25±19.69 with median 28.5 and ranged from 23-65 in Group I, 28.83±9.02 with median 27.5, and ranged from 20-45 in Group II versus 25.36±7.38 with median 24 and ranged from 17-44 respectively (p = 0.03). Therefore, there was a statistically significant decrease in mean sensation range of 2PD among Group III compared to Group I and II. Regarding Q dash, there was a statistical significant decrease in mean Q dash among Group III compared to Group I and Group II.

Cho *et al.* [20] observed 2PD test is the most used tool to measure sensory outcome after nerve repair. Tactile gnosia, the replanted segment's sensory function, is examined to determine that two nearby objects that come into contact with the skin are two distinct points of touch. Assessors typically use calipers to measure the distance between two points of contact, starting at a distance that is greater than expected and gradually decreasing in distance.

Cho *et al.* [20] reported for the thumb, index, other digits, palm, and dorsal metacarpal, the normal values are 2.5-5 mm, 3-5 mm, 4-6 mm, and 11 mm (7- 12 mm).

According to the correlation between postoperative parameters and arterio/venous (A/V) ratio; the current study revealed that, there was a statistically significant –ve correlation between A/V ratio and TAM degree among the studied cases. Also, there were a statistical significant +ve correlation between A/V ratio and Chen criteria, 2PD and Q dash among the studied cases. These correlations are similarly with the studies with **Salama *et al.*** [13]**, El-Sherbiny *et al.*** [17]**, Cho *et al.*** [20] **and Chen *et al.*** [21]**.**

CONCLUSION

All hand surgeons should be able to perform digital replantation. A successful vessel anastomosis ensures the replanted part's viability, while the quality of bone, tendon, nerve, and skin repair determines the replanted part's overall functional success if possible. All structures should be repaired at the time of the primary procedure, as secondary surgery is extremely difficult to perform. Enhancing the patient's sensation, reducing cold intolerance, and maximizing tendon motion should be the focus of future developments.

The nature of injury is the most important factor both in terms of success rates and functional results. Lengthy ischemia time somewhat declines the success rates of replantation. The indications and contraindications for replantation should be revised.

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