Study of Replantation and Revascularization of Limb and Its Parts

Aditya Damani[2], Priyank K.Katwala[2], Vinayak Lokare[3]

[1]Assistant professor, Department of Surgery, Rural medical College, Loni, Maharashtra,

[2]Associate Professor, Department of Plastic and Reconstructive Surgery, SBKSMI & RC, Sumandeep Vidyapeeth, Waghodia, Vadodara, Gujarat, [3]Consultant Plastic Surgeon, Sangli, Maharashtra

Abstract

Background: Traumatic amputations may be devastating and can result in irreversible functional and psychological problems in individuals who sustain them. With developmental advances in microvascular surgery, amputated body parts are now routinely attached in many centres across the world. Successful replantation of amputated digits may allow better appearance, better functional outcome and minimal pain to the patient.

Materials and Methods: This is Prospective observational descriptive study comprising of 20 cases with traumatic amputation of extremities and its parts treated with replantation and revascularization of part from October 2014 to February 2017. Nature of injury was classified by Yamano classification of amputation based on mechanism and severity of injury. Patients were evaluated by Chen & Quick DASH score.

Results: The viability of replanted part is guranted by a successful vessel anastomosis, while the quality of bone, tendon, nerve and skin repair will determine the overall functional success of replanted parts. Revascularisation procedures had overall better survival than replantation due to less complexity of procedure.

Keywords: *Replantation, Revascularization, digit amputation, Microvascular anastomosis.*

Introduction

The term replantation is defined as, the reattachment of a body part that has been totally severed from the body without any attachments. Revascularization is the repair or reattachment of a body part which is incompletely amputated from the body and requires vascular (arterial and/or venous) repair. (1)

Traumatic amputations may be devastating and can result in irreversible functional and psychological problems in individuals who sustain them. They occur in all age groups from the children to elderly. So it is imperative that the surgeon be both knowledgeable and meticulous in order to afford the best possible outcome. (2)

When an extremity or part has been severed, it is common desire of both the patient and the surgeon to achieve survival and functional use of replanted extremity.

With developmental advances in microvascular surgery, amputated body parts are now routinely attached.

The ultimate goal of replantation is to restore normal hand or finger function. Successful replantation of amputated digits may allow better appearance, better functional outcome and minimal pain.(3) The surgeon should guide the patient in making the decision by

Corrosponding Author:
Dr. Priyank K. Katwala
Associate Professor, Email: pkk_108@yahoo.co.in. (M) 9925224346. Address: Dr. Priyank Katwala, Associate Professor, Department of Plastic and Reconstructive Surgery, SBKSMI & RC, Sumandeep Vidyapeeth and Dhiraj Hospital, Waghodia, Vadodara.

explaining the risks involved and likely outcome, secondary procedures and prolonged rehabilitation after the procedure.

Materials and Methods

This research is Prospective observational descriptive study conducted in Department of Plastic Surgery, Government Medical College and Sir Sayaji General Hospital, Vadodara. It comprises of 20 cases with traumatic amputation of extremities and its parts treated with replantation and revascularization of part in Department of Plastic Surgery, Medical College Baroda and S.S.G. Hospital, from October 2014 to February 2017.

· Nature of injury was classified by Yamano classification of amputation based on mechanism and severity of injury. [4]

· Care of amputated part:-

1) Optimal – Part is wrapped in moist saline gauze and placed in waterproof plastic bag. Plastic bag is placed in ice.

2) Suboptimal – not following above mentioned standard care of amputated part.

Detailed clinical history and relevant clinical information were recorded and patients have been followed up regularly at 1 week, 1 month and 3 months.

Inclusion Criteria:

- Patients with traumatic injuries causing devascularization or amputation of limb and its parts presenting to S.S.G. hospital, vadodara.
- Patient who are medically fit for surgery

Exclusion Criteria:

- Patients with concomitant life threatening injuries.
- Severe crushing or avulsion injury of tissues.
- Multiple segmental injuries in amputated parts.
- Prolonged warm ischemia time (>9hrs).
- Patient who are medically unfit for surgery.
- Mentally unstable patients.

Surgical Technique:

Amputated part if not preserved in optimal condition, was wrapped in moist saline gauze and preserved in plastic bag and bag inserted in ice slurry. All partial and near total amputations were assessed for devascularizing injuries. Temporary splintage was given for all associated fractures while patient was transported to operating room. After ruling out all major injuries, if patient is stable for surgery was shifted to operating room.

Feasibility of replantation was judged by examining the amputated part under microscope. Debridement of unhealthy tissue was done and arteries, veins and nerves were identified and tagged with 8-0 nylon. Mid axial incisions were taken on volar and dorsal skin to explore the vessels.

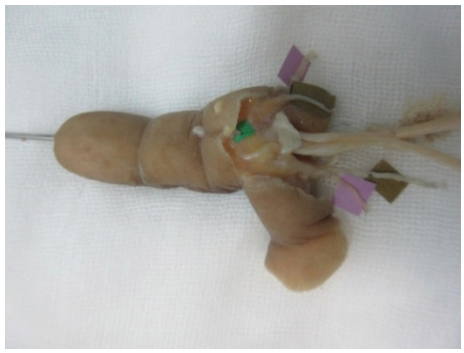

Figure 1(a) Volar aspect (For vessel exposure)

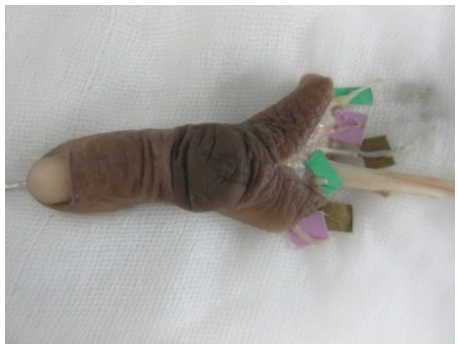

Figure 1(b) Dorsal aspect (For vessel exposure)

All patients except those mentioned in exclusion criteria were taken for surgery after informed consent from patient and relatives.

All cases of upper limb were done under brachial plexus block and single case of great toe amputation was done under spinal anaesthesia. Replantation surgery was done with two team approach, one team on amputated

part and other on extremity simultaneously.

Exploration and preparation of extremity was done under operating microscope (TAKAGI OM-10).

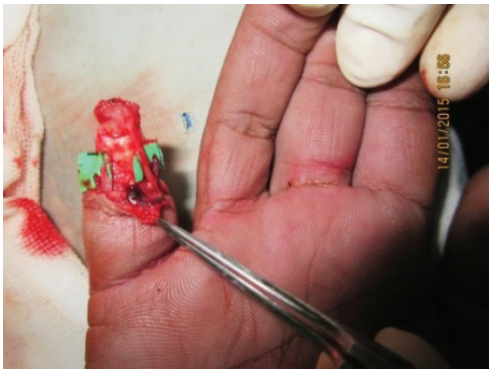

Figure 2- Preparation of amputed extremity

Depending on amount of soft tissue loss and condition of proximal and distal vessels amount of bone shortening was planned followed by bone fixation, tendon repair, vascular anastomosis and skin closure.

Bone fixation was done with vertical K-wire in all cases of distal amputations while in forearm amputation radius and ulna were fixed with plate and screws. Tendon repair was done with nylon 4-0 with modified Kessler's sutures and peripheral sutures with nylon 6-0. In zone 2 injuries only flexor digitorum profundus tendon was repaired.

Proximal artery was cut till pulsatile bleeding was seen.

Vascular anastomosis was done with nylon 10-0 round body micropoint needle using 3V S&T clamps for radial and ulnar arteries, 2V S&T clamps for common digital and digital vessels till middle phalanx level and 1V S&T clamps for digital vessels at distal phalanx level. Vessels were anastomosed end to end with simple sutures.(Fig. 3)

Figure 3- Showing end to end anastomosis between digital vessels

Heparin injection 1ml (5000IU) bolus followed by heparin drip (5000IU in 500 ml D5 @ 40ml/hr) was started before release of microvascular clamps.

If after proper debridement gap precludes primary repair then interposition vein grafts were used for anastomosis, which were harvested from volar aspect of forearm.[5].

Venous anastomosis was done after arterial anastomosis was found functional and bleeding seen from distal veins. Nerve repair was done with perineural repair technique with nylon 10-0. Skin closure was achieved with primary suturing with or without skin graft. Loose dressings were done with paraffin gauze. Cotton wool dressing was done over the limb. Cast was applied over the dressing, till above elbow maintaining elbow in 90 degree flexion. Limb elevation was given post operatively and adequate hydration was maintained. Heparin drip was continued postoperatively for 5 days. Complete bed rest was given for 5 days.

Smokers and tobacco chewers were advised to stop the habit in post operative period. Patients were monitored and complications such as bleeding, infection, wound dehiscence at surgical site, skin blackening and necrosis (complete or partial), if any, were noted. Post operatively change of dressing was done on day 5 in most of the patients. No case was re-explored. In case of complete necrosis of part, it was managed by shortening closure, debridement and dressings, skin grafting or flap closure.

On follow up, subjective patient evaluation (Quick DASH Score) and functional outcomes (Chen's criteria for functional outcome) were assessed at 3 months post operatively. Percentage total active motion of survived part was accessed as total active motion in fingers/limb compared to opposite normal finger/limb. Following moments of thumb were noted: flexion and adduction at 1st MCP joint and opposition with little finger, and were described as percentage of movement compared with normal opposite side. Sensory recovery was assessed subjectively and classified in complete, near complete, partial and no recovery, based on patient's response. [6],[7].

Results

Total 20 patients were taken in study from age 5 to 65 years out of which 4 were females and 16 were males. Commonest mode of injury was machine injury followed by injury by sharp object followed by road traffic accidents. Replantation was done in 9 (43%) patients and revasularization in 12 (75%) patients. One patient had two amputations (middle and ring finger) who underwent revascularization procedure for both amputations.

Out of 12 procedures of revascularization 7(58.3%) had near total amputation of part of which 1(14.3%) procedure had complete survival. Among 3 partial amputations 1(33.3%) had complete survival and 2(66.7%) had partial survival. Among two patients with deep incised wound with vascular compromise both patients had complete survival of distal part. In replantation procedures one patient had complete survival of distal part and rest were failure.

Mean warm ischemia time in cases of complete survival was 4.8 hours and in cases of failure was 3.9 hours.

Optimal care of amputated part during transportation was taken in only 3 (33%) cases.

In our study 9 (45%) patients were smokers out of which 6 (66.7%) had failure of surgery and 3 (33.3%) had complete survival of distal part. In non-smokers 7 (63.6%) had failure of surgery. Although percentage of failure was high in smokers, it was not statistically significant. (p value of 0.350).

Out of 20 patients 11(55%) had Yamano type 3 (crush avulsion injury), 7 (35%) had Yamano type 2 (crush cut injury) and 2(10%) had Yamano type 1 (clean cut injury). Of 13 patients who had failure 9(69.2%) patients had crush avulsion injury.[4] While only 2(15.4%) patients of crush avulsion injury had complete survival of part. One patient of clean cut injury had failure.

All patients had single amputation except one who had partial amputation of ring and middle fingers. Amputations were more common on right side of body and on upper limb. 16 (80%) patients had injury on right upper limb of body while only 3 (15%) patients on left upper limb. There was only one case of lower limb amputation at first metatarsophalangeal joint level. Out of 21 total amputations, thumb and little finger were equally affected 5 (23.8%) cases each while only one (4.7%) patient had devascularizing injury over middle finger and one had over palm/dorsum of hand.

Of 21 amputations, most common level of injury was at proximal phalanx with 8 (38%) cases. Out of 8 cases, 1 (12.5%) had complete survival and 2 (25%) had partial survival. 17 (81%) cases were distal to metacarpophalangeal joint level, 1 (4%) case was at metatarsophalangeal joint level and remaining 3 (14.28%) cases had injury proximal to metacarpophalangeal joint. 2 (9.5%) patients had major injuries proximal to wrist joint.

Mean time duration of surgery in failure cases was 7.08 hours while in cases of complete survival was 5.4 hours and 4.5 hours in cases of partial survival.

Thrombosis was most common complication in 16 (76%) patients. Out of 16 patients 9 (56%) had arterial thrombosis and 7 (44%) had venous thrombosis. Of these patients 2 (12.5%) had partial survival of part and rest were failure.

Out of 13(61.9%) procedures complicated with wound infection 9(69.2%) had failure, 2(15.4%) had complete survival and 2(15.4%) had partial survival. Haemorrhage was seen after 2 (9.5%) procedures. 1 (5%) patient who underwent revascularization of right ring finger had pulp atrophy of the digit.

Salvage procedures-- Shortening and closure was most common procedure for defect closure done in 9 (42.8%) procedures. 4(19%) distant flaps were done (2 groin and 2 abdominal flaps). Groin flaps were done for thumb reconstruction after failed procedure. Debridement and dressing and skin grafting were done in 2 (9.5%) cases each.

Functional recovery (Range of motion):

Functional evaluation of finger motion was done by percentage of total active motion. 4(80%) patients had percentage TAM more than 70%. One patient (20%) of middle finger revascularization who had partial necrosis of distal part had total active motion of 55%. Patient with successful revascularization at forearm had near

normal (90%) TAM.

Three patients with failed procedure for thumb replantation received reconstruction for thumb. Movements of thumb were measured in four patients of thumb amputation. All patients had adduction more than 70% while three patients had flexion restricted to 50-55% and one patient with thumb tip amputation (Tamai zone 2) had flexion of 95%. [8] All the patients were able to oppose thumb with little finger. **Chens** grade was measured for functional evaluation in 7 patients with part survival and two patients with thumb reconstruction with groin flap. Of 9 patients 3 (33%) were in grade 1, 5 (56%) patients in grade 3 and 1(11%) in grade 2. No patient had non functional limb (grade 4).[7]

Table 1- Quick DASH (Disabilities of arm, shoulder and hand) score:[6]

	N	Mean	Std. Deviation	Std. Error	95% CI for Mean		Mini-mum	Maxi-mum
					Lower Bound	Upper Bound		
Complete Survival	4	9.65	3.894	1.947	3.45	15.85	4	14
Partial Survival	2	26.10	4.808	3.400	-17.10	69.30	23	30
Failure	11	18.39	9.670	2.916	11.89	24.89	7	41
Total	17	17.24	9.373	2.273	12.42	22.06	4	41

Although the Mean Quick DASH score was more in partial survival cases, it was not statistically significant.

Table 2 - ANOVA test

ANOVA(analysis of variance) test was used for statistical correlation					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	402.002	2	201.001	2.803	.095
Within Groups	1003.759	14	71.697		
Total	1405.761	16			

Discussion

Age: Youngest patient in our study was 5 years old female with complete amputation at metatarsophalangeal joint of right great toe while eldest patient was 65 years old who sustained near total amputation of right thumb due to assault. Maximum numbers of cases (33%) were present in age group of 21 to 30 years.

In H. Venkatramini et al[9] series similar age distribution of cases was seen with maximum number of cases (33.34%) in age group of 21-30 years.

Sex: In our study there were 16 (80%) male patients and 4 (20%) female patients. In study done by Nadezhda Gavrilova[3] et al 86% cases were males and 14% females. In Mahajan[10] series only 6% cases were females.

It is because males are more outgoing and more prone to machine injury at work and road traffic accidents which are commonest causes of such amputations.

Mode of injury: Injury while working on machine was most common cause of injury in our study which was seen in 6 (30%) patients while road traffic accident

in 4(10%) cases. Assault with sharp object was in only 1 (5%) patient who sustained right thumb amputation.

Two most common injury mechanisms were similar in Njoku Isaac Omoke et al[11]series. Road traffic injuries were higher in their series. There were 30 (56%) road traffic accidents and 7 (13.2%) machine injury cases. Other modes of injury in there series were gunshot, explosives and collapsed building, 3 (5.7%) patients each. The difference may be because their series included all patients of traumatic amputations presented in their hospital, while we included only those cases that met our inclusion criteria for operative procedure.

In study done by Nadezhda Gavrilova et al[3] industrial machinery injury was most common mode of injury seen in 46% cases which is similar to our study.

Lack of awareness and safety measures may be the reason for more cases of machine injuries seen in our study.

Ischemia time: All patients presented to us early with mean warm ischemia time was 4.8 hours in 5 complete survival cases while it was 3.46 hours in 13 failure cases. Mean cold ischemia time was 2.3 hours. One patient who presented to hospital after 7 hours of ischemia time had partial survival after revascularization.

Site of injury: In our study thumb and index finger were most commonly amputated digits (53.8%), devascularizing injury at the level of metacarpal was seen only in 1 (4.7%) patient and major injuries were seen in 2 (9.5%) patients.

In study done by J.Q.L. Neto et al[12] also, thumb is the most commonly amputated digit. This may be because the thumb is the most important digit for pinch function and rarely the replantation/ revascularization of thumb is contraindicated.

Effect of tobacco and smoking: In our study of although percentage of failure was high (66.7%) in smokers but result was not statistically significant. There was no statistically significant correlation between tobacco chewing and failure of procedure.

Similar findings were obtained by Ji-Yin He et.al. [13] in their study of 149 replants. The study showed that use of cigarettes / tobacco did not affect the replantation outcome.

Vein graft: We did not find any significance between use of vein graft and survival of distal part, however study done by Jing Li et.al.[14] found statistical significance between use of vein graft and success of procedure.

Type of amputation and procedure done: We divided devascularizing injuries of limbs into 4 classes. Complete amputation (part completely separated from limb), near total amputation (part is attached to limb by a small skin tag), partial amputation (part is attached to limb with structures other than skin, with or without skin attachment) and deep incised wound.

Of complete amputations only 1(11.1%) replantation of little finger at middle phalanx level was successful. Among near total amputations 1(14.3%) patient with amputation at distal phalanx level was successful. There was no failure case in partial amputation and deep incised wound.

In study by N. Waterhouse[15], success rate was 61% in total amputations and 75% in subtotal amputations.

In our study 85% patients had severe crush injury and 55% patients had avulsion component. Replantation and revascularization was attempted in all cases presented and criteria for selection was not rigid.

81% cases in our study were distal to metacarpophalangeal joint involving digital arteries which are technically more demanding.

In 67% cases care of amputated part was suboptimal.

Mean time duration of surgery in failure cases was 7.08 hours which increased intraoperative ischemia time.

Replantation and revascularization procedures are technically demanding and there is longer learning curve.

Complications: In our study thrombosis occurred in 16 digits of which 9 (56%) had arterial thrombosis and 7 (44%) had venous thrombosis. Wound infection was seen in 13 (62%) patients. Two patients had reactionary haemorrhage, probably because of slippage of ligature, these patients were managed conservatively. One patient developed pulp atrophy in follow up. Skin grafting was

done as salvage procedure in 2 (9.5%) patients. Distant flaps (groin and abdominal) were done in 4 (19%) failed procedures, for thumb reconstruction. Shortening and closure was done in 9 (42.8%) procedures.

In N Waterhouse [15] series thrombosis was seen in 13 digits (31%) of which 11 (85%) had arterial thrombosis and 2 (15%) had venous thrombosis. local flaps (cross finger flap) were done in 2 (4.7%) digits. 2 (4.7%) digits had infection along track of k-wire. All patients had some degree of atrophy in fingers.

In N Waterhouse study, all cases of thrombosis were explored and they could salvage 2 cases from 13 cases of thrombosis. In our study we did not re-explore any case of thrombosis due to lack of patient willingness and motivation and it was difficult to manage re-exploration with limited human resources.[15]

Raja Sabapathy S et. al. [16] in their study of ring avulsion amputations found raw areas at wound margins in 6 (75%) patients who required split skin grafting. One patient had partial necrosis of volar skin managed by cross finger flap.

Total Active motion:

In 4 (80%) survived fingers, range of motion was >70% while only 1 (20%) patient had range of motion in 50-70%.

In Mahajan et al[10] study range of motion was >70% for 2(14.28%) cases and 50% in 4(28.67%) cases.

The reason for difference being we studied all devascularizing injuries i.e. both replantation and revascularization and in Mahajan et al study only replanted hand at wrist were studied.

We studied thumb function as flexion, adduction and opposition. All patients in our study had adduction >70%. One patient in our study having thumb tip amputation had flexion >70%. All patients were able to oppose thumb with little finger. In Mahajan et al[10] study opposition was >70% in 3 (21.42%) patients. Reason for difference may be because of preservation of 1st metacarpophalangeal joint in all patients of our study.

Chen classification: (Table 3 - Comparision with other studies)

Chen grade	No. Present series	B. Yaffe et al(17)	Sabapathy S.R et al(15)
Grade 1	3 (33%)	2 (33.33%)	3 (15%)
Grade 2	1 (11%)	2 (33.33%)	9 (45%)
Grade 3	5 (56%)	1 (16.67%)	6 (30%)
Grade 4	0 (0%)	1 (16.67%)	2 (10%)

In our study we included both major as well as minor amputations. Chen grade [8] was measured for both. No patient in our study had cold intolerance. Out of 9 patients three were treated by distant flaps, two with groin flaps for thumb reconstruction and 1 with abdominal flap for thumb tip reconstruction. Although %TAM and power was more but there were no sensations in the flap area and so were grouped in grade 3. Three (33%) patients had grade 1 function (excellent outcome), while no patient had non functional limb, grade 4 (poor outcome).

B. Yaffe et al series and Sabapathy SR series considered only major upper limb replant.

In B Yaffe et al series 2(33.3%) patients had excellent outcome and 1(16.67%) had poor outcome.

In Sabapathy SR series majority, 9(45%) patients had grade 2 (good outcome), while 2(10%) had non functional limb.

Quick DASH:

Quick DASH compares the postoperative result with the patient's functional competence in day to day activities.

Quick DASH score was calculated in 17 patients out of 20 as one patient was lost to follow up, in one patient 3 months follow up is still awaited and one patient had amputation of great toe.

In our study mean quick DASH score in cases of complete survival was 9.65, for failure cases it was 18.39, and in partial survival cases it was 26.1.

In study done by J.Dabernig et al[18] after successful replantation DASH Score achieved was 12.3. while in Hass F et al[19] Quick DASH score was 11.3. Findings were similar to our results. Quick DASH score of partial survival cases were high because it took longer time for wound to heal following partial necrosis of skin which delayed physiotherapy.

Conclusion:

Traumatic amputations were more common in young, working and economically productive age group, so successful replantation and revascularization procedures helps to reduce the financial burden on them.

First responders should be adequately educated regarding optimal care of amputated parts.

There are multiple factors to be considered for replantation and revascularization procedures. Preoperative selection includes ischemia time, contamination and care for preservation of part, avulsion and crushing injuries. Intraoperative management includes number of arteries, veins and nerve repaired, use of vein graft, bone shortening, anticoagulation and postoperative rehabilitation including physiotherapy, which independently influence the overall outcome of replantation and revascularization cases.

The viability of replanted part is guaranteed by a successful vessel anastomosis, while the quality of bone, tendon, nerve and skin repair will determine the overall functional success of replanted parts.

For thumb amputations, replantation and revascularisation is best option for thumb reconstruction and should be attempted in all cases.

Revascularisation procedures had overall better survival than replantation due to less complexity of procedure.

These procedures require specialized microsurgical skills and appropriate use of microvascular techniques, ultra-modern microscope, pneumatic drills and fine instruments for providing better results.

Well-developed replantation centre and multiple skilled replantation teams is need of modern time for assurance of good success rate.

Conflict of Interest: None

Funding: None

Ethical Approval: Ethical clearance for study was taken from ethical committe of Baroda Medical College, Vadodara before conducting this study.

Acknowledgments: We acknowledge the support and cooperation of all the residents and head of department of plastic surgery at Baroda Medical College and all patients included in this study.

Bibliography

1. J.Martin Walsh, Nancy Chee. Replantation. In Rebecca Saunders, Romina Astifidis et. al. editors. Hand and Upper Extremity Rehabilitation: A Practical Guide. St. Louis Missouri: Elsevier publication; 2006. p. 431-440.
2. Dimitrios Christoforou, M.D., Michael Alaia, M.D., and Susan Craig-Scott, M.D. Microsurgical Management of Acute Traumatic Injuries of the Hand and Fingers. Bulletin of the Hospital for Joint
3. Nadezhda Gavrilova, Aram Harijan,et al Pattrens of finger amputation and replantation in the setting of a rapidly growing immigrant population. Annals of Plastic Surgery • Volume 64, Number 5, May 2010.
4. Yamano Y. Replantation of the amputated distal part of the fingers. J Hand Surg Am 1985; 10:211-8.
5. Saha SS, Pandey A, Parwal C. Arterial segments as microvascular interposition grafts in venous anastomosis in digital replantations. Indian J Plast Surg 2015; 48:166-71.
6. The QuickDASH outcome Measure: Information for users [internet]. Toronto, Canada. Institute for

work and health: 2006. Available from: http://dash.iwh.on.ca/sites/dash/files/ downloads/quickdash_info_2010.pdf.

7. William W. Dzwierzynski. Replantation and revascularization Plastic Surgery: Peter C. Neligan third edition. Vol 6 (11) 227-249.
8. Susumu Tamai, M.D., Ph.D. History of Microsurgery. MICROSURGERY SUPPLEMENT Plast. Reconstr. Surg. 124: 282e, 2009. Tamai S. Twenty years' experience of limb replantation review of 293 upper extremity replants. J Hand Surg Am 1982; 7:549-56.
9. Venkatramani H, Sabapathy SR. Fingertip replantation: Technical considerations and outcome analysis of 24 consecutive fingertip replantations. Indian J Plast Surg 2011;44: 237-45. \
10. Mahajan RK, Mittal S. Functional outcome of patients undergoing replantation of hand at wrist level-7 year experience. Indian J Plast Surg 2013;46:555-60.
11. Njoku Isaac Omoke, Christian Onyebuchi Otu Chukwu et al. Traumatic extremity amputation in a Nigerian setting: patterns and challenges of care. International Orthopaedics (SICOT) (2012) 36:613–618.
12. José Queiroz Lima Neto, Alberto De Carli et al prognostic factors on survival rate of finger replantation. Acta Ortop Bras. 2015;23(1):16-8
13. Ji-Yin He, Shih-Heng Chen The Risk Factors for Failure of an UpperExtremity Replantation: Is the Use of Cigarettes/Tobacco a Significant Factor?
14. Jing Li,, Fingertip Replantation: Determinants of Survival. Plast. Reconstr. Surg. 122: 833, 2008.).
15. N WATERHOUSE A review of five years experience of digital replantation. Annals of the Royal College of Surgeons of England (1986) vol. 68
16. Raja Sabapathy S., Hari Venkatramani et. al. Replantation of ring avulsion amputations. Indian J Plastic Surg July-December 2003 Vol 36 Issue 2. 76-83.
17. Yaffe B, Hutt D, Yaniv Y, Engel J. Major upper extremity replantations. J Hand Microsurg 2009;1(2):63–67
18. J. Dabernig et al Evaluation outcome of replanted digits using the DASH score: Review of 38 patients. Int J Surg. 2006;4(1):30-6. Epub 2006 Feb 9
19. Haas F, Hubmer M et al Long-term subjective and functional evaluation after thumb replantation with special attention to the Quick DASH questionnaire and a specially designed trauma score called modified Mayo score.J Trauma. 2011 Aug;71(2):460-6.