Initial Management of Traumatic Digit Amputations: A Retrospective Study of Functional Outcomes

Ledibabari Mildred Ngaage, BA (Hons) Cantab[1], Dr. Georgette Oni, MD PhD FRCS (Plast)[2], Dr. Rudolph Buntic, MD[3], Prof. Charles Malata, BSc (HB), LRCP MRCS, FRCS (Glasg), FRCS (Plast)[2,4,5], Dr. Gregory Buncke, MD[3]

[1]School of Clinical Medicine, University of Cambridge, Cambridge, UK,

[2]Addenbrooke's Hospital, Department of Plastic Surgery, Cambridge, UK

[3]Buncke Clinic, Department of Microsurgery, San Francisco, USA

[4]Cambridge Breast Unit, Addenbrooke's Hospital, Cambridge University Hospitals NHS Foundation Trust, Cambridge, UK.

[5]Postgraduate Medical Institute, Faculty of Medical Sciences, Anglia Ruskin University, Cambridge & Chelmsford, UK.

Corresponding author: Ledibabari Mildred Ngaage, BA (Hons) Cantab

milliengaage@msn.com

Tel: (+44)7426761549

ABSTRACT

BACKGROUND: Traumatic amputation of one or more digits can have a serious detrimental effect on social and economic standings which can be mitigated by successful replantation. Little has been recorded on preoperative management before replantation and how this affects the outcomes of the replanted digit.

METHODS: A retrospective cohort study was conducted and data collected over an 18-month period. Three protocols for preoperative management were examined: minimal (basic wound management), complete Buncke (anticoagulation, dry dressing on amputate placed on indirect ice and absence of a digital block), and incomplete (any two or three criteria from complete Buncke in addition to the minimal) protocols. Data was collected on survival rate, secondary operations, and complication rate. Function was defined by sensation, range of movement, and strength.

RESULTS: 74 of 177 digits were replanted with an overall survival rate of 86.5%. The rates for minimal, incomplete and complete protocols were 95%, 87%, and 91%, respectively, and not significantly different. The complication rate was significantly different between the complete (20%) and minimal (60%) protocols (p=0.0484). Differences in sensation and grip strength were statistically significant between protocols (p=0.0465 and p=0.0430, respectively). Anticoagulation, no digital block and dry gauze all showed reduced complication rates in comparison to their counterparts.

CONCLUSION: The Buncke protocol, which includes anticoagulation, no digital block and

dry gauze, was found to significantly reduce the complication rate which suggests that it prevents compromise of tissue integrity. Significant differences were found between protocols for sensation and grip strength. A higher-powered study is needed to investigate the effects of preoperative management on complication rates and functional outcomes.

KEYWORDS: digit replantation, preoperative management, hand surgery, Buncke protocol

INTRODUCTION

The first successful digit replantation was performed in 1967 by Komatsu and Tamai[1], and with the advent of microvascular techniques now, nearly 50 years on, the success rate varies around 80%[2-4].

Indications for replantation and salvage are debated[5-7], and there is no formalised guideline on factors that recommend a digit to replantation rather than amputation[8]. However, there is a consensus on strong indications such as thumb amputations, multiple finger amputations, and children. Initial management can affect level of recovery and the functional ability the patient regains[9], making it an important variable in post-operative success. However, there is little data in the relationship between preoperative management and survival of the digit. Additionally, there are few standardised guidelines on initial management of an amputated digit[10,11]. The Advanced Life Trauma Support (ATLS) guidelines, remain the gold standard worldwide and are adopted as a consensus protocol (wash with saline, wrapped in wet gauze and placed on indirect ice). However, Azzopardi et al found that only 25% of UK doctors,

from junior doctors to consultants, could describe the correct procedure [12, 13]. Many of the papers that describe function and survival rate of replants do not detail the preoperative management so it is difficult to ascertain how often the ATLS guidelines are adhered to and if this has an impact on postoperative outcomes.

The Buncke protocol (rectal aspirin, dry dressing on amputate placed on indirect ice, and absence of a digital block, *Appendix 1*) has been in use for 30 years and this study aims to compare it to the ATLS protocol in terms of effect on digit survival and functional outcomes.

METHODS

Over an 18-month period from July 2013 to December 2014 inclusive, all traumatically amputated digits treated at the Buncke Clinic (San Francisco, California, USA) were recorded and included in this study. These included complex injuries, and incomplete amputations, and injury to multiple digits. Partial amputations were defined as insensate, immobile and devascularised digits with an intact skin bridge. Digits with intact neurovascular bundles and/or tendinous connections were excluded.

A cohort study was conducted through retrospective chart review. Details were collected on age, gender, mechanism of injury, injury level, associated injuries, non-replantable digits, reason for terminalisation (or completion of amputation), management of the digit prior to admission, survival of digit and failure of replantation. In severe avulsion injuries, bony level was taken at the level of injury; the Tamai classification [14] was used for distal amputations.

Information on management prior to admission was further analysed and divided into three

categories: minimal, incomplete and complete Buncke protocols. Table 1 shows the inclusion criteria for the minimal protocol and the complete Buncke protocol. The minimal protocol is based on acute assessment of the patient and basic wound management; these procedures were consistently performed for every patient with a hand injury. The minimal protocol is similar to ATLS but does not include the use of indirect ice recommended for ATLS. The incomplete protocol category was designated for any patient for whom two action points from the complete Buncke protocol were completed; all four points had to be performed to fulfil the complete Buncke protocol criteria. The incomplete protocol is similar to the ATLS guidelines, however includes additional variables, such as local anaesthetic block of the digit and anticoagulation, thus the ATLS guidelines were not able to as a comparator protocol.

The primary endpoints were survival, and complications. Secondary outcomes measured included secondary surgeries, time to return to work, and return of function, which was defined through three modalities: sensation, range of movement and power. These were measured directly through Semmes Weinstein monofilament testing, goniometry, grip strength and pinch strength.

Data were tabulated on a Microsoft Excel 2013 spreadsheet (Microsoft, Redmond, Washington, USA) and statistical analysis was performed with IBM SPSS Software (IBM Corp. 2016. IBM SPSS Statistics for Windows, Version 23.0. Armonk, NY: IBM Corp).

RESULTS

Preoperative characteristics

A total of 177 traumatic digit amputations in 126 patients were identified from July 2013 to

December 2014. The non-dominant hand suffered more traumatic amputations (58.8%) with the long digit amputated most often (22.6%, *Table 2*), however, the thumb was the most common replanted digit (29.7%, *Table 3*). The most common level of injury (*Table 4*) was the middle phalanx and proximal interphalangeal joint (35.1%); and this was true also for the replanted digits (*Table 5)*. However, the distribution of injury varied for terminalisation (completion of amputation) vs. replantation (*Figure 1*, *Figure 2).* Of the 61 patients with replanted digits, the majority (91.8%) were male (56 men versus 5 women). The age range was 2 to 72 years with a mean age of 36.6 years.

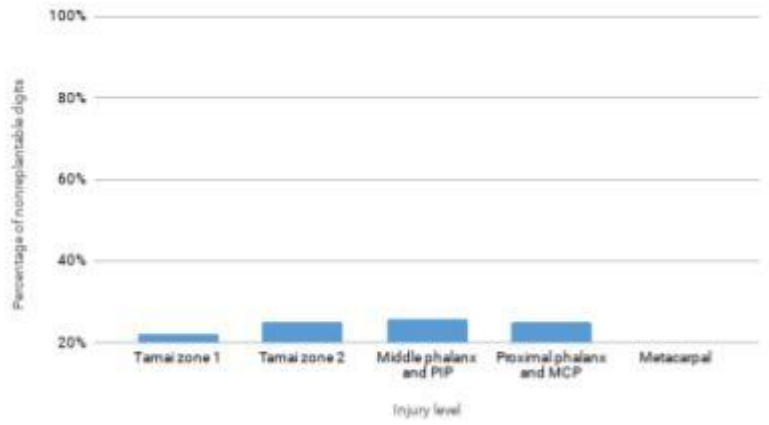

Figure 1. Level of injury in nonreplantable digits

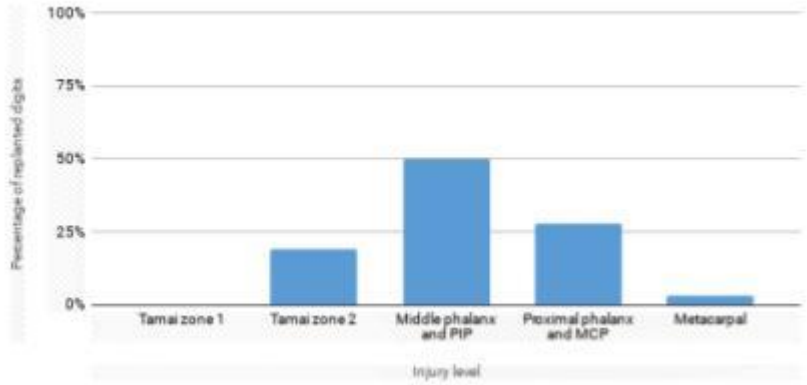

Figure 2. Level of injury in replanted digits

Of the amputated digits, 125 were total and 52 were partial amputations; of these 74 (41.8%) digits were replanted (55 total and 19 partial) (*Table 6, Figure 3).* Of the 103 digits (58.2%) not replanted, the decision to terminalise was made on admission in 60.2% of digits and intra-operatively after exploration of the digit in the remaining 39.8%. The reasons for terminalisation are listed in *Table 6, Figure 4*.

Figure 3. Intraoperative view of an incomplete amputation of the left thumb.

Figure 4. Intraoperative view of a non-replantable digit due to multilevel injury.

With regards to mechanism of injury, all blast injuries were terminalised, crush and avulsion injuries were also more likely to be terminalised, whilst more sharp injuries were replanted (*Table 8*). The most common mechanism of injury in minimal, incomplete and complete Buncke protocols was a sharp amputation at 84%, 57% and 64% respectively; avulsion injury occurred at 5%, 30% and 9% respectively; whilst crush injuries occurred at 11%, 14% and 27% respectively.

Two heterotropic digit replants were included in the study; the index finger was transplanted to the thumb site, and in another patient the small finger was transplanted to the index site.

Primary outcome (Table 9)

Follow up data on survival was available for all 74 digits and with an overall survival rate of 86.5% (*Figure 5*). Causes of failure included arterial insufficiency in five digits, and five from venous congestion. The mean time for failure of digit was 8.6 days (0 hours – 21 days). *Table 9* shows how survival rate varied for various patient and injury factors. The survival rate was not significantly different between the protocols (p=0.6149) (*Table 10*). Interestingly, of the surviving replanted digits, crush and avulsion injuries represented 12.5%, 39% and 40% in minimal, incomplete and complete Buncke protocols.

Figure 5. Intraoperative view of a replanted digit.

Follow up data on complication rates was available in 64 digits. The overall complication rate for these digits was 47% (31 complications occurred in 57 digits). For each protocol, the complication rate was found to be 20% in complete Buncke protocol, 50% in incomplete protocol, 60% in minimal protocol (*Table 11*). There was statistical significance between minimal and complete Buncke protocols (p=0.0484), but no significance between incomplete and complete Buncke protocols (p=0.0943).

When looking at complication subsets, there was a statistically significant difference in soft tissue (p=0.047241 overall) at a 95% confidence interval. Bone, tendon and nerve complications yielded no significance between protocols.

Secondary outcomes

Of the surviving digits, the average total number of operations was 1.91. On average those that underwent the Buncke protocol had a greater number of re-operations at 2.7 [1 - 4] total

operations, compared to incomplete 1.6 [1 – 4], and minimal 2.0 [1 - 7], although this was not significant at p=0.08721 and p=0.18758 respectively. *Figure 6* shows the number of reoperations, following initial replantation, for each protocol.

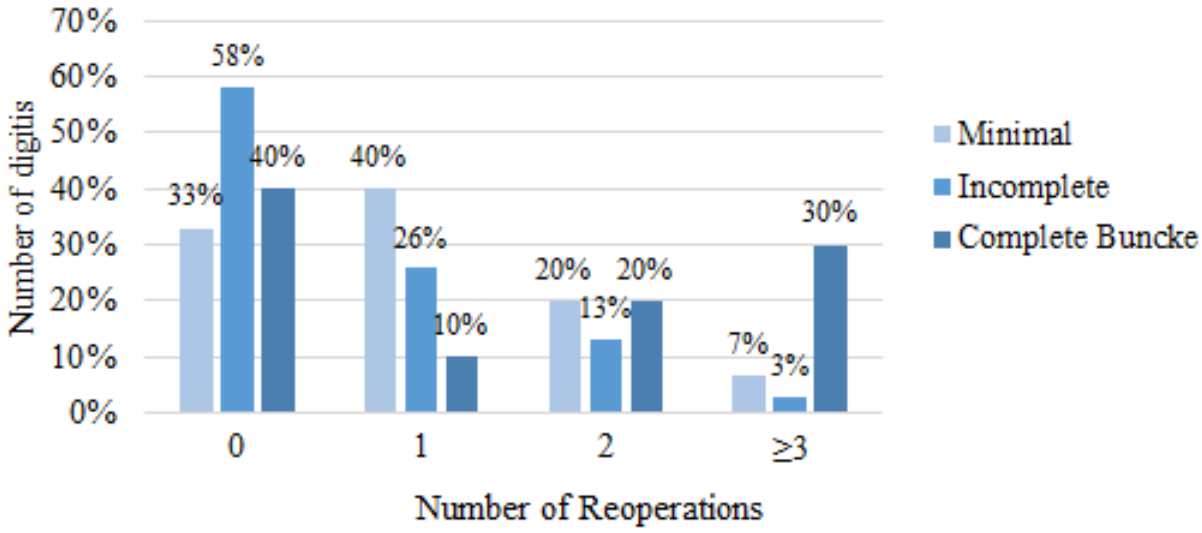

Figure 6. Number of reoperations versus protocols

Complete follow up date on functional outcomes was available in 46 of the 74 replanted digits (62.2%). In terms of functional outcomes, there was a significant difference between the three protocols (*Table 12*) for sensation and grip strength. Average time to return to work was 8.5 months and 13.3 months in those without workers' compensation and those with workers' compensation, respectively; this was significant at a 95% confidence interval (p=0.0168). Although, time to return to work did no differ greatly between the three protocols (*Table 12*). There was no significance between digits that suffered complications and digits that did not in functional outcomes (range of movement, sensation and grip strength with p=0.6330, p=0.8577, and p=0.3256, respectively).

Protocol Analysis

The Buncke protocol is made up of four different preoperative behaviours that differ from current standards. Additionally, the incomplete group represents a varied cohort (*Table 13*). In order to validate each aspect, digits were then regrouped into: preoperative anticoagulation, digital block and wet, dry or no gauze. Digits who had undergone direct ice (n=3) were excluded due to their high failure rate (67%, p=0.0426).

Table 14 shows the survival rates for the preclinical management did not differ significantly, aside from dry gauze (advised by the Buncke protocol) which had a significantly higher survival rate compared to digits who received wet gauze (p=0.0252).

When complication rates were compared between the preoperative parameters, there is an apparent reduction in complication rates for the Buncke protocol recommendations (anticoagulation, no digital block and dry gauze) (*Table 15, Figure 7*); although this did not reach significant levels.

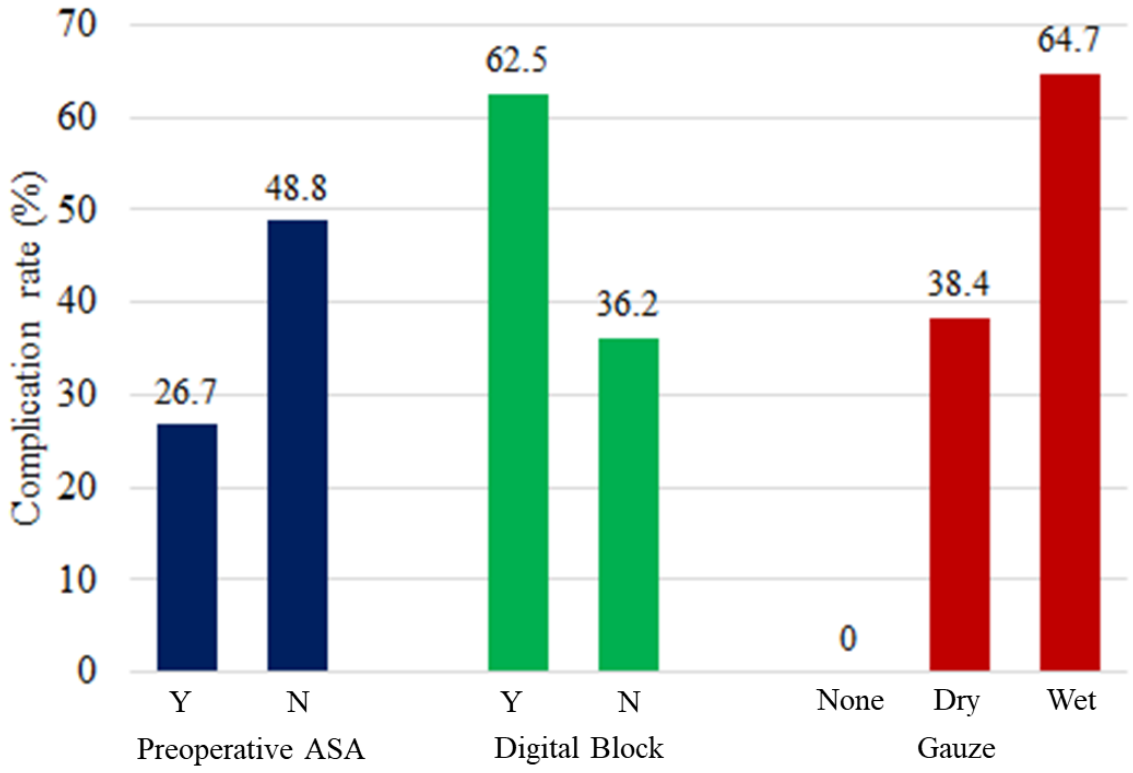

Figure 7. Complication rates versus preoperative management

DISCUSSION

The loss of digits can be a devastating and life-changing event, which not only results in disfigurement but the loss of function impacts almost every aspect of normal life. The hand provides fine motor function as well as a range of versatile grips. The thumb is responsible for 40% of overall hand function[15] and provides opposition, a highly important movement. Multiple finger injury results in loss of grip and thus power. Regaining these functions may prove vital to a patient's life as it can affect ability to work, daily activities of living and personal interactions.

Studies looking at the peri-operative management of the amputated digit and subsequent outcome for the patient are useful for guiding the surgeon for their day-to-day practice. In this study, there was an overall survival rate of 86.5%. Whilst this was slightly higher than that denoted in the literature[5,6]; it also demonstrated that survival did not vary significantly with preoperative factors. This may reflect evidence from previous studies which promote injury factors, such as mechanism of injury, and ischaemia time, as strong independent predictive factors for digit survival[16]. It is also suggesting that the postoperative management and surgical expertise influences the survival rate.

Influence of protocol

There was a significantly lower complication rate in the complete Buncke protocol versus the minimal protocol. When further reviewed, this revealed an increased incidence of soft tissue complications in both minimal and incomplete protocols versus the complete Buncke

protocol. This could be related to the preoperative handling of the digit because the Buncke protocol is designed to limit iatrogenic soft tissue insults, e.g. digital block is advised against to limit the disruption to the digit and the vessels therein. It is accepted that cooling an organ or digit is used to reduce metabolism and preserve the integrity of the appendage[3,17]; whilst duration of warm ischaemia has been shown to adversely affect outcomes[16]. However, the Buncke protocol goes one step further and advises against the use of saline and instead proposes dry gauze around the amputate. The rationale is that saline would cause too great a cooling of the digit due to its increased surface area to volume ratio, and faster rate of heat loss in liquids compared to air[18,19], and would therefore result in frostbite injury[20]. Direct ice caused a significantly higher failure rate which is inkeeping with literature[21].

In addition, anticoagulation remains a staple in postoperative management of replanted digits[22]. In these small vessels, formation of thrombi can completely occlude the lumen and impede inflow or outflow, thus compromising the digit. The Buncke protocol includes preoperative anticoagulation, which may help intraoperatively once blood flow is re-established[23,24]. Aspirin was the anticoagulation used in all cases but it may also aid replant outcomes via a different mechanism. There is discussion on whether aspirin may help prevent further ischemia in frostbite by blocking the inflammatory cascade[25].

These theories were further supported by the analysis of each individual preoperative behaviour which showed an increase in survival rate and reductions in complication rates for each component in the Buncke recommended management. Although significance was not reached, this may be due to the increased heterogeneity and influence of confounding factors in these subgroups, such as, those who received preoperative anticoagulation did not receive

identical management with respect to gauze and digital blocks, which also precluded the in-depth analysis of each individual variable. Inherent patient factors such as ASA grade may also have an influence on the outcome of microvascular success of the replant[26].

Crush and avulsion injuries compromise soft tissue and can lead to an association with a high complication rate and lower survival rate[6]. However, a large number of digits with crush/avulsion injury survived replantation. Further investigation is needed to determine if there is a variable within the protocol, such as anticoagulation, that may be linked to this effect on complication rate. An additional study to investigate the impact of the protocols on early versus late complications would be beneficial.

Secondary procedures

Further surgery is often needed to improve function. Secondary procedures include tenolysis, tendon grafting, osteosynthesis, free tissue transfers and bone grafts. Literature has reported a range of 1 to 4.5 for number of secondary surgeries, with an average total number of procedures as 2.84[27]. In our study, the number of total surgeries was not statistically significant for the protocols. As previously mentioned, crush and avulsion injuries often require more secondary procedures than sharp injuries[28]; this may account for the increase in total number of operations in the complete Buncke protocol, which also possessed the highest proportion of crush and avulsion injuries in surviving digits. The follow up period was also greater in the complete Buncke period. However, it is worth noting that all three protocols yielded a lower total number of surgeries than expected in the literature. The total number of procedures is dependent on follow up time and insurance company approval, which invariably confounded the results.

Functional outcomes

Statistical significance was only found in sensation and grip strength between the protocols. However, there were various limitations and confounding factors including, method of fixation, number of digits, and the digits involved. Arthrodesis was used in many replantations but this yields a range of motion of zero degrees and negatively affects strength of grip. In addition, this study did not limit data to single digit injury and included different digits; the resultant effect was that the small finger was compared alongside a thumb. However, we acknowledge that the loss of a thumb would have a more profound effect on function than the other. Multiple digit injury on the same hand would adversely affect grip and pinch strength more than in a single digit injury. The nature of the study means that we could not control for all confounding factors, known and unknown.

Limitations and further work

We acknowledge that there are limitations to this body of work. In addition to those already mention other limitations of this study include hand therapy, patient related factors and workers' compensation.

Performance bias was introduced by the variation in number of hand therapy sessions; hand therapy can improve functional outcomes but insurance companies determine the number of sessions. There was also increased heterogeneity in data (age, smoking status, injured digit, and number of digits injured), which makes drawing a firm conclusion difficult. The sample size was small, and as a result the study is underpowered so we must be cautious when interpreting data. Preoperative anticoagulation therapy is not a recognised step in current practice, and may have some beneficial effects as shown in this study. Before a decision can

be made on the benefit of including it within guidelines, more rigorous cohort studies using anticoagulation as the sole intervention with a greater sample size and reduced heterogeneity are needed.

Workers' compensation introduces an interesting third variable; our results show that those on workers' compensation take almost twice as long to return to work, as those without. There may be a psychological aspect involved; motivation is essential in medical recovery. Further cohort studies are needed before an association between workers' compensation and poor functional outcomes can be made.

CONCLUSION

This study has shown that with the Buncke protocol, which includes anticoagulation, no digital block and dry gauze, there was a significant reduction in complications following replant of an amputated digit. There was no significance found between protocols for survival rate and secondary surgeries with the exception of dry gauze versus wet gauze. Statistical significance was found in sensation and grip strength between the different protocols, however, there were many confounding factors. Given what has been shown so far, there is potential impact on future practice in improving replant outcomes. A higher-powered cohort with greater sample numbers is needed. In addition, further studies are needed to look at different variables within the Buncke recommended preoperative management and their effect on survival, complication rate and functional outcomes.

ACKNOWLEDGEMENTS

Thanks to the Scar Free Foundation for their generous funding, Dr Isak Godwin for *Figure 3*,

and Dr Andrei Odobescu for *Figure 5*.

CONFLICTS OF INTEREST

None.

REFERENCES

1. Komatsu S, Tamai S. Successful Replantation of a Completely Cut-off Thumb - Case Report. Plast Reconstr Surg. 1968;42(4):374-&
2. Sebastin SJ, Chung KC. A Systematic Review of the Outcomes of Replantation of Distal Digital Amputation. Plast Reconstr Surg. 2011;128(3):723-737
3. Yu H, Wei L, Liang B, Hou S, Wang J, Yang Y. Nonsurgical factors of digital replantation and survival rate A metaanalysis. Indian J Ortho. 2015;49(3):265-271
4. Medling BD, Bueno RA, Russell RC, Neumeister MW. Replantation outcomes. Clin Plast Surg. 2007;34(2):177-+
5. Chung KC, Alderman AK. Replantation of the Upper Extremity: Indications and Outcomes. J J Am Soc Surg Hand. 2002;2(2):78 - 93
6. Ma Z, Guo F, Qi J, Xiang W, Zhang J. Effects of non-surgical factors on digital replantation survival rate: a meta-analysis. J Hand Surg [Eur]. 2016;41(2):157-163
7. Soucacos PN. Indications and selection for digital amputation and replantation. J Hand Surg [Br]. 2001;26(6):572-581
8. National Institute for Health and Care Excellence. Fractures (complex): assessment and management. Manchester and London, UK; February 2016. NICE guideline (NG37)
9. Win TS, Henderson J. Management of traumatic amputations of the upper limb. Br Med J. 2014;348
10. Lloyd MS, Teo TC, Pickford MA, Arnstein PM. Preoperative management of the amputated limb. Emerg Med J. 2005;22(7):478-480
11. Anerican College of Surgeons. Advanced Trauma Life Support Guidelines. 8th edition. Chicago, IL, USA; 2011
12. Azzopardi EA, Whitaker IS, Laing H. Perceptions of correct preoperative storage and

transfer of amputated digits: a national survey of referring emergency departments. J Plast Reconstr Aesthet Surg. 2008;61(11):1418-1419

13. Oomman A, Tickunas T, Javed M, Yarrow J, Azzopardi E, Whitaker IS. Changes in Perceptions Regarding Correct Preoperative Storage and Transfer of Amputated Digits: A 5-year Follow-up. Microsurgery. 2014;34(1):76-77
14. Tamai S. 20 years Experience Of Limb Replantation - Review of 293 Upper Extremity Replants. J Hand Surg [Am]. 1982;7(6):549-556
15. Flatt A. Our thumbs. Baylor University Medical Center Proceedings. 2002;15(4):380-387
16. Breahna A, Siddiqui A, O'Connor EF, Iwuagwu FC. Replantation of digits: a review of predictive factors for survival. J Hand Surg [Eur]. 2016;41(7):753-757
17. Southard JH, Belzer FO. Organ Preservation. Annu Rev Med. 1995;46:235-247
18. Lotens WA, Vandelinde FJG, Havenith G. Effects of condensation in clothing on heat transfer. Ergonomics. 1995;38(6):1114–31
19. Farnworth B. A numerical-model of the combined diffusion of heat and water-vapor through clothing. Text Res J. 1986;56(11): 653–65
20. Fudge J. Exercise in the Cold: Preventing and Managing Hypothermia and Frostbite Injury. *Sports Health*. 2016;8(2):133-139
21. Partlin MM, Chen J, Holdgate A. The preoperative preservation of amputated digits: an assessment of proposed methods J Trauma. 2008;65(1):127-31
22. Buntic RF, Brooks D. Standardized Protocol for Artery-Only Fingertip Replantation. J Hand Surg [Am]. 2010;35A(9):1491-1496
23. Salemark L, Wieslander JB, Dougan P, Arnljots B. Effect of low and ultra low oral doses of acetylsalicylic acid in microvascular surgery: an experimental study in the rabbit. Scand J Plast Reconstr Surg Hand Surg. 1991;25(3):203–11

24. Bannister CM, Chapman SA. The influence of systemic aspirin on rat small diameter vein grafts: a scanning electron microscopic study. Surg Neurol 1980;13:99.
25. Heggers JP, Robson MC, Manavalen K, et al. Experimental and clinical observations on frostbite. Ann Emerg Med. 1987;16:1056–62.
26. Jubbal KT, Zavlin D, Suliman A. The effect of age on microsurgical free flap outcomes: An analysis of 5,951 cases. Microsurgery. 2017. doi: 10.1002/micr.30189
27. Wang H. Secondary surgery after digit replantation: Its incidence and sequence. Microsurgery. 2002;22(2):57-61
28. Waikakul S, Sakkarnkosol S, Vanadurongwan V, Un-nanuntana A. Results of 1018 digital replantations in 552 patients. Injury. 2000;31(1):33-40

FIGURE CAPTIONS

Figure 1. Level of injury in nonreplantable digits

Figure 2. Level of injury in replanted digits

Figure 3. Intraoperative view of an incomplete amputation of the left thumb.

Figure 4. Intraoperative view of a non-replantable digit due to multilevel injury.

Figure 5. Intraoperative view of a replanted digit.

Figure 6. Number of reoperations versus protocols

Figure 7. Complication rates versus preoperative management

TABLES

Table 1. Inclusion criteria for minimal, incomplete and complete Buncke protocols.

Minimal	Incomplete	Complete
● Analgesia ● Antibiotics ● Tetanus vaccine ● Pressure dressing on injured limb	Minimal plus: ● 2 - 3 points from the complete Buncke protocol	Minimal plus: ● Rectal aspirin ● No digital block ● Dry dressing on amputate ● Indirect ice for amputate or splint for incomplete amputate

Table 2. Digit vs. hand dominance in traumatic amputations

Digit	Dominant	Non-dominant
Thumb (*n* = 37)	43%	57%
Index (*n* = 39)	44%	56%
Long (*n* = 40)	35%	65%
Ring (*n* = 35)	46%	54%
Small (*n* = 26)	38%	62%
Total (*n* = 177)	41.2%	58.8%

Table 3. Digit vs. hand dominance in replantation

Digit	Dominant	Non-dominant
Thumb (*n* = 22)	41%	59%
Index (*n* = 15)	33%	66%
Long (*n* = 18)	28%	72%
Ring (*n* = 10)	40%	60%
Small (*n* = 9)	56%	44%
Total (*n* = 74)	37.8%	62.2%

Table 4. Level of injury in non-replanted digits (*n* = 103)

	Complete	Incomplete	Percent
Distal to nailbed (Tamai 1)	22	1	22%
Nailbed to DIP (Tamai 2)	20	6	25%
Middle phalanx and PIP	17	10	26%
Proximal phalanx and MCP	12	14	25%
Metacarpal	0	1	<1%

DIP – distal interpharyngeal joint, *PIP* – proximal interpharyngeal joint, *MCP* – metacarpopharyngeal joint.

Table 5. Level of injury in replantation of complete and incomplete traumatic amputations (*n* = 74)

	Complete	Incomplete	Percent
Distal to nailbed (Tamai 1)	0	0	0%
Nailbed to DIP (Tamai 2)	10	4	19%
Middle phalanx and PIP	29	8	50%
Proximal phalanx and MCP	15	6	28%
Metacarpal	0	2	3%

DIP – distal interpharyngeal joint, *PIP* – proximal interpharyngeal joint, *MCP* – metacarpopharyngeal joint.

Table 6. Traumatic amputation of digits

Complete	125
Incomplete[1]	52
Total number of amputations	177
Number of replanted digits	74

[1]Incomplete amputation is described as an intact skin bridge only with digit devascularised and suffering loss of sensation.

Table 7. Causes for primary and secondary terminalisation

Loss of digit	32
Unreplantable digit[1]	58
Patient factors[2]	13
Total	103

[1]Definition of unreplantable digit included multilevel injury, lack of distal target vessels, tissue or bony loss, contamination, and crushed or severely avulsed digit.

[2]Patient factors included patient decision, comorbidities, and other life-threatening injuries that took priority.

Table 8. Mechanism of injury in terminalised and replanted digits (*n* = 177)

Mechanism	Terminalised (*n* = 103)	Replanted (*n* = 74)
Sharp (*n* = 84)	40%	60%
Avulsion (*n* = 40)	67%	33%
Crush (*n* = 44)	75%	25%
Blast (*n* = 9)	100%	0%

Table 9. Survival rate with comparison to preoperative factors

	Overall		Age		Gender		Mechanism		
	Complete (*n*=54)	Incomplete (*n*=20)	<60 years (*n*=62)	≥60 years (*n*=12)	Male (*n*=68)	Female (*n*=6)	Avulsion (*n*=13)	Crush (*n*=11)	Sharp (*n*=50)
Survival	85%	90%	87%	83%	85%	100%	69%	91%	90%
Failure	15%	10%	13%	17%	15%	0%	31%	9%	10%

Table 10. Survival rate versus protocols

	Minimal (*n* = 20)		Incomplete (*n* = 38)		Complete Buncke (*n* = 11)	
	Number	Percent	Number	Percent	Number	Percent
Survival	19	95%	33	87%	10	91%
Failure	1	5%	5	13%	1	9%
Time until surgery	6.43 hours (2 – 12 hours)		6.24 hours (2 – 11 hours)		6.18 hours (4 – 7 hours)	

Table 11. Complications in successful digit replants

	Minimal (*n* = 15)	Incomplete (*n* = 32)	Complete (*n* = 10)
Soft tissue[1]	4	13	0[a]
Bone[2]	3	2	2
Tendon[3]	0	4	0
Nerve[4]	2	0	0
Total	9	19	2
Complication rate	60%	50%	20%[b]

[1]Necrosis, delayed healing, contracture requiring Z plasty, venous congestion requiring anticoagulation, and cold intolerance. [2]Non-union. [3]Adhesions, inflammation, and rupture. [4]Hyperalgesia

[a]p = .047241 overall, [b]p = 0.0484 when compared to minimal protocol.

Table 12. Functional Outcomes for Replanted Digits

	Overall (*n* = 46)		Minimal (*n* = 14)		Incomplete (*n* = 23)		Complete (*n* = 9)	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range
MCP motion[a]	70.3°	0° – 105°	68.5°	35° – 105°	72°	25° – 103°	68.9°	0° – 90°
PIP motion[b]	45.0°	0° – 100°	50.5°	0° – 88°	51.4°	0° – 100°	21.4°	0° – 50°
DIP/IP motion[c]	20°	0° – 62°	19.6°	0° – 55°	22.0°	0° – 62°	13°	0° – 42°
Monofilament test[d]	4.41	2.83 – 6.65	4.41	2.83 – 6.65	4.78	2.83 – 6.65	3.09	2.83 - 3.61
Grip strength injured[e]	56.5 lbs	0 – 120lbs	39.3 lbs	0 – 85 lbs	63.7 lbs	15 – 95lbs	73.0 lbs	51 – 120 lbs
% of grip uninjured[f]	61.7%	0 – 93%	47.3%	0 – 91%	72.6%	25 – 100%	62.6%	63 – 86%
Pinch strength of injured[g]	10.4 lbs	3 – 26 lbs	9.4 lbs	2 – 15 lbs	11.3 lbs	3 – 26lbs	11.0 lbs	3 – 20lbs
% of pinch uninjured[h]	60.4	12 – 105	53.5	14 – 71	66.9	17 – 89	55.9	12 – 105

Return to work (months)[i]	10.1	2 – 26	12.3	2 – 25	8.1	3 – 19	11.7	2 – 26
Follow up (months)[j]	12.6	3 – 26	12.4	5 – 25	10.6	3 –21	17.7	3 – 26

DIP – distal interpharyngeal joint, *PIP* – proximal interpharyngeal joint, *MCP* – metacarpopharyngeal joint.

[a]p = 0.8965 [b]p = 0.0669, [c]p = 0.5378, [d]p = 0.0465, [e]p = 0.0430, [f]p = 0.0420, [g]p = 0.7944, [h]p = 0.4923, [i]p = 0.1406, [j]p = 0.0333

Table 13. Incomplete protocol summary[a] (*n* = 38)

	Number of digits
Preoperative anticoagulation (vs none)	8 (30)
No digital block (vs digital block)	31 (7)
Dry gauze (vs wet) (vs none)	20 (15) (3)
Indirect ice (vs direct)	3 (35)

[a]The incomplete protocol required fulfilment of two or three of the above preoperative criteria

Table 14. Survival rate vs Buncke components

	Anticoagulation		Digital block		Gauze		
	Yes	No	Yes	No	None	Dry	Wet
	(*n* = 16)	(*n* = 50)	(*n* = 16)	(*n* = 47)	(*n* = 1)	(*n* = 40)	(*n* = 21)
Survival	94%	90%	100%	89%	100%	98%	81%[a]
Failure	6%	10%	0%	11%	0%	2%	19%

[a]p=0.0252 in survival rate for dry versus wet gauze

Table 15. Complication rate in successful digit replants following traumatic amputation for preoperative management

	Number of complications (%)
Anticoagulation (*n* = 15)	5 (27%)
No anticoagulation (*n* = 45)	23 (49%)
Digital block (*n* = 16)	10 (63%)
No digital block (*n* = 42)	17 (36%)
No gauze (*n* = 1)	0 (0%)
Dry gauze (*n* = 39)	15 (38%)
Wet gauze (*n* = 17)	11 (65%)