Title

Predictors of Hand Function Following Digit Replantation: Quantitative Review and Meta-Analysis.

Journal

Hand, 16(1)

Authors

Shaterian, Ashkaun
Sayadi, Lohrasb
Tiourin, Ekaterina
et al.

Publication Date

2021

DOI

10.1177/1558944719834658

Peer reviewed

Surgery Article

HAND
2021, Vol. 16(1) 11–17

DOI: 10.1177/1558944719834658
journals.sagepub.com/home/HAN

Predictors of Hand Function Following Digit Replantation: Quantitative Review and Meta-Analysis

Ashkaun Shaterian[1], Lohrasb Ross Sayadi[1], Ekaterina Tiourin[2], Daniel J. Gardner[1], Gregory R. D. Evans[1], and Amber Leis[1]

Abstract

Background: Digit replantation affords the opportunity to restore hand function following amputation. To date, however, few studies have evaluated functional outcomes following replantation. Therefore, it was the objective of this study to perform a meta-analysis to better characterize the predictors of hand function. **Methods:** A literature search was performed using the PubMed database to identify studies that focused on digit amputation/replantation and functional outcomes. Studies were evaluated for patient- and injury-related factors and their respective effects on clinical outcomes of sensation, grip strength, and Disabilities of the Arm, Shoulder, and Hand (DASH) scores. Statistical analysis was conducted across the pooled data set to identify significant trends. **Results:** Twenty-eight studies representing 618 replanted digits were included in this study. We found the average grip strength was 78.7% (relative to contralateral), the average 2-point discrimination (2PD) was 7.8 mm, and the average DASH score was 12.81. After conducting statistical analysis, we found patients with more proximal injuries had lower grip strength scores ($P < .05$). We found 2PD scores were influenced by age, mechanism of injury, and amputation level ($P < .05$). Finally, we found DASH scores after replantation were predicted by mechanism of injury and level of amputation ($P < .05$). The following variables did not influence outcomes: gender, tobacco use, ischemia time, and digit number. **Conclusions:** Digit replant does not restore premorbid hand function but does result in adequate hand function. Expected functional outcomes following replant should be considered in the decision-making process. These data can help risk-stratify patients, guide postreplant expectations, and influence the decision for replantation.

Keywords: digits, anatomy, hand, amputation, trauma, diagnosis, replant, surgery, specialty, outcomes, research and health outcomes, meta-analysis, hand function, DASH

Introduction

Digit amputation represents a devastating injury wherein replantation affords the ability to restore hand function. Epidemiologic studies have shown an average incidence of more than 45 000 traumatic finger amputations per year, with most of these injuries affecting young, healthy patients.[1,2] Furthermore, the average replant time approaches 4.5 hours per digit, with an average hospitalization cost of US $42 561.[3,4] As such, digit amputation/replantation can result in psychological, physical, and financial burden.[5,6] With improvements in technology and research, replant survival has increased to 86% to 93% wherein the preoperative predictors of survival have been well established.[7-10] To date, however, studies evaluating postreplant hand function have been more limited.

The decision to replant is, in part, contingent on the expected long-term function.[11,12] Several authors have argued against attempted replantation in select cases where poor predicted function, stiff digits, or delayed return to work is expected.[13-15] Furthermore, some studies have found patients opt for revision amputation (vs replantation) once informed of postreplant expectations. Ozer et al,[12] for example, found that 15% of patients declined replantation due to expected recovery time and poor replant function. To this end, expected postreplant hand function remains a vital

[1]University of California, Irvine, Orange, USA
[2]University of California, Irvine, USA

Supplemental material is available in the online version of the article.

Corresponding Author:
Daniel J. Gardner, Department of Plastic Surgery, University of California, Irvine, 200 South Manchester Avenue, Suite 650, Orange, CA 92868, USA.
Email: gardned1@uci.edu

factor in a surgeon's decision to offer, and patient's decision to undergo, hand replantation. While the factors influencing survivability of replanted digits are important, a better understanding of the factors that improve hand function can serve to improve outcomes in replant medicine.

Reliable measures of hand function include sensation, range of motion, and grip strength.[16] The Disabilities of the Arm, Shoulder, and Hand (DASH) questionnaire was similarly developed to understand and quantify the disability experienced by patients with upper extremity disease.[17] Despite the significance of expected hand function, few studies have evaluated the predictors of hand function after replantation. In addition, many of the retrospective studies include small patient numbers and often present contrary data findings.[18-22] Therefore, it was the objective of this study to perform a review of literature and meta-analysis to identify predictors of hand function following replantation in the context of 2-point discrimination (2PD), grip strength, and DASH score. We hope the presented data can help improve surgeon decision-making and educate patients regarding expected postreplant hand function.

Materials and Methods

Search Strategy

A systematic review was conducted in accordance with Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines using the PubMed database.[23] The following words were used in our search: "replantation," "amputation," "digit," "finger," "phalanx," "hand," and "function." We reviewed database publications prior to 2018. The database was last accessed on May 31, 2018. Figure 1 shows the study selection process for studies ultimately included in our final analysis.

Selection Criteria

Inclusion and exclusion criteria were set to identify a specific study population. Papers were considered for inclusion based on the following criteria: (1) studies evaluating functional outcomes following replantation; (2) studies that focused on digital amputation; (3) studies with sample size with at least 4 patients; and (4) studies that presented individual patient data (vs summary statistics). Exclusion criteria included the following: (1) studies that represented review, meta-analysis, or case reports; (2) studies that evaluated amputations proximal to the digit (ie, hand, wrist, forearm); and (3) studies that included heterotopic replantations. If studies met inclusion criteria and also presented data on proximal amputations, revascularization, or heterotopic replantation, the data were stratified to only include data that met our inclusion criteria. For the list of studies included in our analysis, refer to Supplemental Table S1.

Data Extraction and Statistical Analysis

Articles were evaluated for patient- and injury-related variables, as well as clinical outcomes pertaining to hand function following replantation. Patient demographics included age, sex, and tobacco use. Injury characteristics included level of amputation, mechanism of injury, digit number, and ischemia time. Objective functional outcomes included grip strength, 2PD, and DASH score. To ensure comparability between studies, units were standardized when necessary (eg, unit conversions of pounds to kilograms in strength measurements).

Data were pooled across studies into a combined data set, and univariate statistical analyses were conducted. Per current literature review, the variables used in our statistical model do not represent confounding variables, and thus, a multivariate analysis was not indicated. Summary statistics using Student t test, χ^2, regression analysis, and analysis of variance tests were used where appropriate to evaluate outcomes across variables. Statistical significance was set with $P < .05$, with all tests 2-sided.

Results

Twenty-eight articles representing 619 digit replants were included in this study. Study characteristics are summarized in Supplemental Table S1. Studies were published between 1982 and 2018 and represented the following countries: Japan, Italy, Korea, China, United States, Turkey, Taiwan, Finland, and Singapore. Patient demographics and injury characteristics are summarized in Table 1. Following replant, we found the average grip strength was 78.7% (relative to contralateral), the average 2PD was 7.8 mm, and the average DASH score was 12.81. After conducting statistical analysis, we found various patient- and injury-related variables to predict postreplant hand function in the context of grip strength, 2PD, and DASH scores (Tables 2, 3, and 4).

A widely used clinical measure of motor hand function is grip strength.[16] Low hand grip strength is associated with limited physical hand function and consequently increased disability in performing activities of daily living.[24] In our study, we found grip strength was influenced by the level of digital amputation prior to replantation (Table 2). Statistical analysis revealed a trend where more distal amputations resulted in increased grip strength after replant ($P < .05$). For example, patients with distal phalanx replants had 1.6-fold increased grip strength relative to patients who had proximal phalanx replants. The remaining summary statistics are presented in Table 2. Age, sex, tobacco use, mechanism of amputation, Tamai zone, digit number, and ischemia time did not predict grip strength following digit replantation.

Maintaining sensation of the hand is important for fine motor control, prevention of injury, and quality of life.[25] The 2PD test serves as a reliable measure of sensory tactile function and is associated with nerve integrity following injury

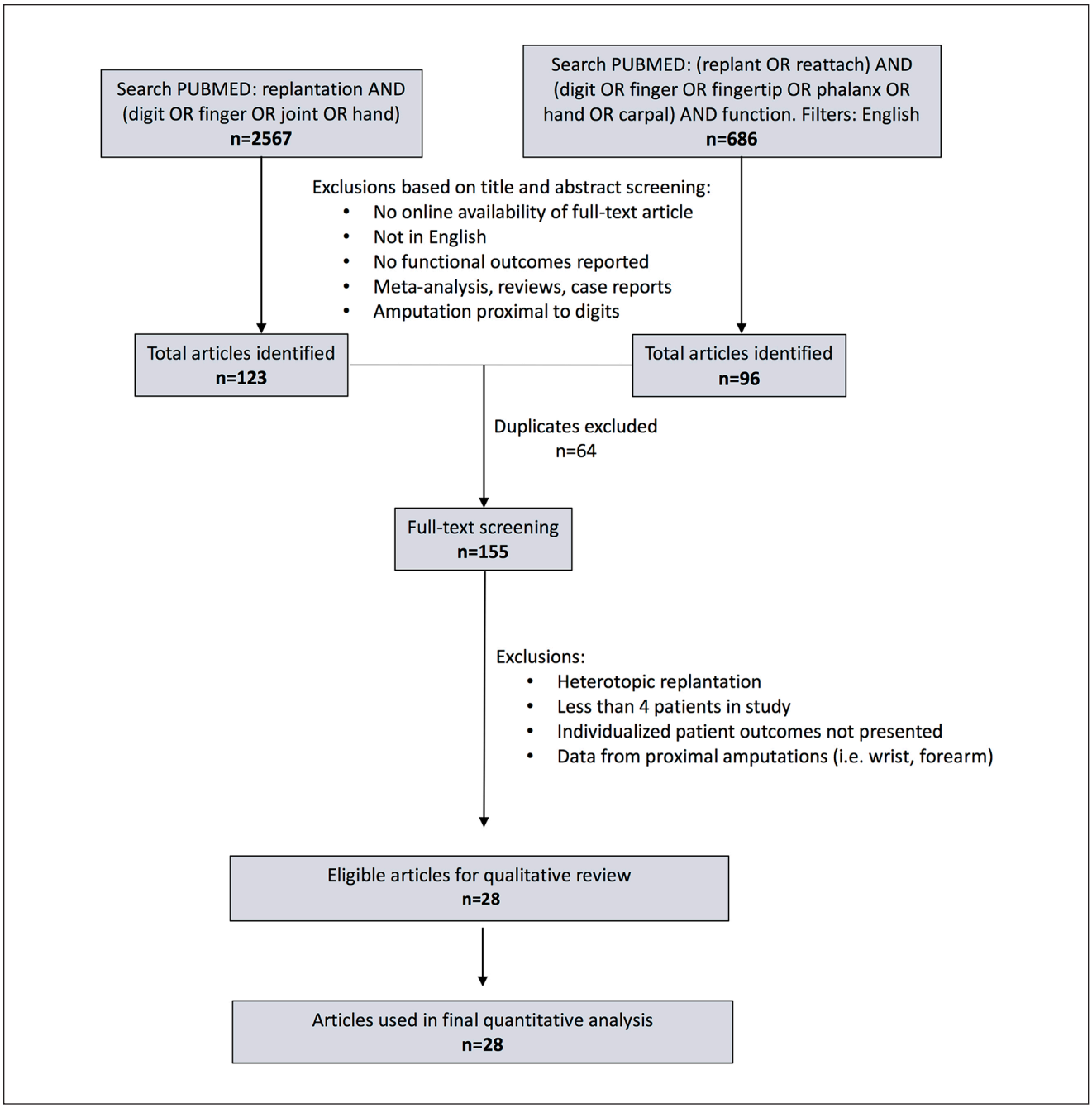

Figure 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses flow diagram illustrating the study selection process for inclusion in this meta-analysis.

and/or surgery.[26] In the current study, we found static 2PD was influenced by age, mechanism of amputation, and level of amputation (Table 3, $P < .05$). Linear regression analysis revealed a 5% increase in patients' 2PD for each year of older age ($P < .05$, odds ratio [OR] = 0.05). Furthermore, we found a trend with improved recovery of sensation following sharp or blunt cut injuries compared with crush or avulsion injuries. For example, we found patients who had avulsion injuries had a 1.3-fold increase in 2PD relative to their counterparts who had sharp cut injuries ($P < .05$, OR = 1.3). Remaining summary statistics are presented in Table 3. In addition to age and mechanism of injury, we found the level of amputation to predict 2PD ($P < .05$). Here, we found patients with amputations at the level of the nail bed were also associated with more preserved sensation as measured by the 2PD test compared with patients who had amputations

Table 1. Patient Demographics.

Variable	Percentage (%)
Age (n=489)	31.8 ± 16.57[†]
Sex (n=433)	
Male	78.3%
Female	21.7%
Tobacco Use (n=95)	13.7%
Amputated Digit (n=562)	
Thumb	15.3%
Index	24.7%
Middle	26.5%
Ring	24.4%
Little	9.1%
Mechanism of Amputation (n=503)	
Sharp Cut	44.5%
Blunt Cut	9.7%
Crush	26.6%
Avulsion	19.1%
Tamai Zone (n=266)	
I	81.6%
II	18.4%
Amputation Level (n=124)	
Proximal Phalanx	38.7%
PIP Joint	21.0%
Middle Phalanx	12..1%
DIP Joint	11.3%
Distal Phalanx	8.1%
Fingertip	8.9%
Ischemia Time (n=117)	
<12 hours	68.4%
>12 hours	31.6%

[†]Standard deviation of sample

Table 2. Variables Influencing Grip Strength Following Replant.

Variable	Comparison	Odds ratio	*P* value
Amputation level	Proximal phalanx	Ref.	<.05
	Proximal interphalangeal joint	1.1	
	Middle phalanx	1.4	
	Distal interphalangeal joint	1.4	
	Distal phalanx	1.6	

Note. The following variables were considered but did not achieve statistical significance: age, sex, tobacco use, mechanism of amputation, digit number, and ischemia time.

at other levels of the digit ($P < .05$). Patient sex, tobacco use, Tamai zone, ischemia time, and digit number did not show a significant association with static 2PD.

The DASH questionnaire (score range = 0-100) captures patient-reported perspectives of hand function.[27] We found patient-reported DASH scores to correlate with the mechanism of injury and level of amputation (Table 4, $P < .05$). Patients who experienced digit replantation following avulsion amputations had a 16.9-fold increase and 9.4-fold increase in DASH scores compared with patients who experienced sharp ($P < .05$, OR = 16.9) or blunt cut injuries ($P < .05$, OR = 9.4), respectively. Regarding the level of amputation, we found a trend where patients who had amputations through the distal and proximal interphalangeal joints had increased DASH scores relative to patients who had amputations through the proximal, middle, and distal phalanx. Patients who had amputations through the proximal interphalangeal joints had a 4.3-fold increase in DASH scores relative to patients who had a distal phalanx amputation ($P < .05$, OR = 4.3). Remaining summary statistics are presented in Table 4. Patient age, sex, tobacco use, Tamai zone, ischemia time, and digit number did not show a significant correlation with DASH scores that report patient-reported functional assessments.

Table 3. Variables Influencing 2-Point Discrimination Following Replant.

Variable	Comparison	Odds ratio	*P* value
Age	Per year of age	0.05	<.05
Mechanism of amputation	Sharp cut	Ref.	<.05
	Blunt cut	0.9	
	Crush	1.0	
	Avulsion	1.3	
Amputation level	Nail bed	Ref.	<.05
	Distal phalanx	2.3	
	Distal interphalangeal joint	2.8	
	Middle phalanx	1.9	
	Proximal interphalangeal joint	3.0	
	Proximal phalanx	1.8	

Note. The following variables were considered but did not achieve statistical significance: sex, tobacco use, ischemia time, and digit number.

Table 4. Variables Influencing Disabilities of the Arm, Shoulder, and Hand Scores Following Replant.

Variable	Comparison	Odds ratio	*P* value
Mechanism of amputation	Sharp cut	Ref.	<.05
	Blunt cut	1.8	
	Crush	15.2	
	Avulsion	16.9	
Amputation level	Distal Phalanx	Ref.	<.05
	Distal interphalangeal joint	3.1	
	Middle Phalanx	0.7	
	Proximal interphalangeal joint	4.3	
	Proximal phalanx	1.2	

Note. The following variables were considered but did not achieve statistical significance: age, sex, tobacco use, ischemia time, and digit number.

Discussion

In the current study, we performed a review of literature and meta-analysis to identify predictors of hand function following digit replantation. Here, we found the average grip strength was 78.7% (relative to contralateral), the average 2PD was 7.8 mm, and the average DASH score was 12.81. After conducting statistical analysis, we found various patient- and injury-related variables to predict postreplant hand function in the context of grip strength, 2PD, and DASH scores. We failed to find an association between sensation, grip strength, and DASH scores with the following variables: sex, tobacco use, ischemia time, digit number, and Tamai zone.

Grip strength is an important indicator of hand function. It is necessary for work and completion of activities of daily living and has been shown to predict disability.[28,29] A previous study showed grip strength to be 70% (SD = 31.4%) after replant; however, it did not stratify by various patient- and injury-related variables.[4] In our study, we found grip strength was predicted by the level of injury with more distal amputations, resulting in increased grip strength after replant. This likely represents the increased tendon involvement with more proximal injuries. Furthermore, more proximal injuries may also involve the flexor tendon sheath wherein adhesions may restrict tendon excursion, increase the force of work, and decrease grip strength.[30] Ultimately, grip strength is an important indicator of hand function and may represent a strict prerequisite for some patients based on sociodemographic factors (ie, occupation). Identifying limitations to premorbid grip strength preoperatively can be used to educate patients to better meet their goals and expectations.

Sensation is a necessary component for functional hand wherein decreased hand sensation can result in loss of protective abilities and fine motor control.[25] Similar to previous studies, we found sensation decreased with older age,[31,32] more proximal levels of injury,[33] and crush/avulsion mechanisms of injury.[34,35] The correlation between age and 2PD likely represents the decreased potential for axonal regeneration in nerves of older patients, as has been previously shown.[32] Similarly, the correlation between mechanism of injury and 2PD may reflect the severity of damage sustained by sensory nerves, severity of soft tissue damage and inflammation preventing nerve regeneration, or need for interposition nerve conduits/grafts. Given the importance of protective sensation and critical sensation in select regions of the hand, these data can help better counsel patients and determine whether revision amputation would better serve their goals.

Patient-reported outcome measures are increasingly used to determine function and satisfaction with replantation. Currently, various tools are available, including the Upper Extremity Function Scale, DASH, and the Michigan Hand Outcomes Questionnaire.[8,36] In this meta-analysis, the most commonly used tool was the DASH questionnaire. This questionnaire evaluates degree of disability and primarily focuses on activities of daily living, pain, and subjective changes in range of motion.[4,37] Our data found that the level and mechanism of injury predict DASH scores. Higher DASH scores correlated with joint level amputations (vs phalanx amputations) and likely represent the stiffness and decreased range of motion that result from joint injuries. We similarly found higher DASH scores correlated with mechanisms of injury, with higher scores for avulsion/crush injuries and blunt/sharp cut injuries. This likely represents the severity of injury and subsequent inflammation of the soft tissue structures (ie, tendon, flexor sheath, ligaments) that may hinder normal digit range of motion and function. As such, other authors have recommended against replantation in crush/avulsion injuries due to poor postoperative function.[38]

The data examining postoperative strength, sensation, and DASH score are necessary to stratify patients who would benefit most from replantation. Revision amputation does have benefits over replantation in select patients and must be individualized based on expected function after replant. Patients most concerned with ability to return to work or those necessitating precise dexterity/sensation may be better served with a revision amputation if faced with a high probability of stiff, insensate digit.[39] While the decision to offer replant is often guided by survivability, the expected postoperative hand function must be taken into account. Ultimately, this study provides data to better understand the functional status of the replanted digit, wherein improved patient education and physician decision-making can lead to outcomes more aligned with patient goals.

There are several imitations to this meta-analysis. First, this study represents a retrospective analysis and risks unmeasured biases and confounding variables. A comprehensive review of literature was attempted, but there may be studies meeting inclusion/exclusion criteria that were not included in the current analysis. Other limitations included variability in the timing, quantity, and quality of reported outcome measures. Postoperative regimens including rehabilitation protocols were not routinely documented and likely not standardized across studies. Despite these limitations, this meta-analysis represents a reliable analysis that identifies significant trends and predictors that can be used to improve replant medicine.

In conclusion, digit replant following amputation is associated with variable levels of recovery in hand function. Few studies have identified predictors of hand function following replant. In this study, we found that the mechanism of injury, level of amputation, and patient age influence hand function after replant. These variables can be used to educate patients, risk-stratify, and guide physician

decision-making to improve clinical outcomes following amputation.

Ethical Approval

This study was approved by our institutional review board.

Statement of Human and Animal Rights

This article is a meta-analysis of existing data and does not contain any additional studies with human or animal subjects.

Statement of Informed Consent

No identifying information about patients was included in this article.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

References

1. Conn JM, Annest JL, Ryan GW, et al. Non-work-related finger amputations in the United States, 2001-2002. *Ann Emerg Med*. 2005;45(6):630-635. doi:10.1016/j.annemergmed.2004.10.012.
2. US Bureau of Labor Statistics. *Databases, Tables & Calculators by Subject*. http://data.bls.gov/data. Published 2011. Accessed February 25, 2019.
3. Friedrich JB, Poppler LH, Mack CD, et al. Epidemiology of upper extremity replantation surgery in the United States. *J Hand Surg Am*. 2011;36(11):1835-1840. doi:10.1016/j.jhsa.2011.08.002.
4. Unglaub F, Demir E, VonReim R, et al. Long-term functional and subjective results of thumb replantation. *Microsurgery*. 2006;26(8):552-556. doi:10.1002/micr.20287.
5. Tessler O, Bartow MJ, Tremblay-Champagne MP, et al. Long-term health-related quality of life outcomes in digital replantation versus revision amputation. *J Reconstr Microsurg*. 2017;33(6):446-451. doi:10.1055/s-0037-1601052.
6. Bhuvaneswar CG, Epstein LA, Stern TA. Reactions to amputation: recognition and treatment. *Prim Care Companion J Clin Psychiatry*. 2007;9(4):303-308.
7. Tatebe M, Urata S, Tanaka K, et al. Survival rate of limb replantation in different age groups. *J Hand Microsurg*. 2017;9(2):92-94. doi:10.1055/s-0037-1605353.
8. Sebastin SJ, Chung KC. A systematic review of the outcomes of replantation of distal digital amputation. *Plast Reconstr Surg*. 2011;128(3):723-737. doi:10.1097/PRS.0b013e318221dc83.
9. Dec W. A meta-analysis of success rates for digit replantation. *Tech Hand Up Extrem Surg*. 2006;10(3):124-129. doi:10.1097/01.bth.0000225005.64605.17.
10. Shaterian A, Rajaii R, Kanack M, et al. Predictors of digit survival following replantation: quantitative review and meta-analysis. *J Hand Microsurg*. 2018;10(2):66-73. doi:10.1055/s-0038-1626689.
11. Bueno RA Jr, Battiston B, Ciclamini D, et al. Replantation: current concepts and outcomes. *Clin Plast Surg*. 2014;41(3):385-395.
12. Ozer K, Kramer W, Gillani S, et al. Replantation versus revision of amputated fingers in patients air-transported to a level 1 trauma center. *J Hand Surg Am*. 2010;35(6):936-940. doi:10.1016/j.jhsa.2010.02.031.
13. Jazayeri L, Klausner JQ, Chang J. Distal digital replantation. *Plast Reconstr Surg*. 2013;132(5):1207-1217.
14. Sebastin SJ, Chung KC. Challenges in measuring outcomes following digital replantation. *Semin Plast Surg*. 2013;27(4):174-181. doi:10.1055/s-0033-1360584.
15. Urbaniak JR, Roth JH, Nunley JA, et al. The results of replantation after amputation of a single finger. *J Bone Joint Surg Am*. 1985;67(4):611-619.
16. Walaszek I, Zyluk A. Long term follow-up after finger replantation. *J Hand Surg Eur Vol*. 2008;33(1):59-64.
17. Hoang-Kim A, Pegreffi F, Moroni A, et al. Measuring wrist and hand function: common scales and checklists. *Injury*. 2011;42(3):253-258. doi:10.1016/j.injury.2010.11.050.
18. Daoutis N, Gerostathopoulos N, Bouchlis G, et al. Clinical analysis and evaluation of the function of replanted and revascularized parts of the upper limb. *Microsurgery*. 1992;13(4):178-181.
19. Daoutis N, Efstathopoulos D, Gerostathopoulos N, et al. Replantation of the thumb: survival rate and functional recovery in correlation with type of injury. *Microsurgery*. 1993;14(7):454-456.
20. Ekerot L, Holmberg J, Niechajev I. Thumb replantation or not? *Scand J Plast Reconstr Surg*. 1986;20(3):293-295.
21. Patel AA, Blount AL, Owens PW, et al. Functional outcomes of replantation following radiocarpal amputation. *J Hand Surg Am*. 2015;40(2):266-270. doi:10.1016/j.jhsa.2014.10.017.
22. Ciclamini D, Tos P, Magistroni E, et al. Functional and subjective results of 20 thumb replantations. *Injury*. 2013;44(4):504-507. doi:10.1016/j.injury.2012.11.009.
23. Moher D, Liberati A, Tetzlaff J, et al. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *PLoS Med*. 2009;6(7):e1000097.
24. Gunther CM, Burger A, Rickert M, et al. Grip strength in healthy Caucasian adults: reference values. *J Hand Surg Am*. 2008;33(4):558-565. doi:10.1016/j.jhsa.2008.01.008.
25. Bowden JL, Lin GG, McNulty PA. The prevalence and magnitude of impaired cutaneous sensation across the hand in the chronic period post-stroke. *PLoS One*. 2014;9(8):e104153. doi:10.1371/journal.pone.0104153.
26. Dellon AL, Mackinnon SE, Crosby PM. Reliability of two-point discrimination measurements. *J Hand Surg Am*. 1987;12(5, pt 1):693-696
27. Hudak PL, Amadio PC, Bombardier C. Development of an upper extremity outcome measure: the DASH (disabilities of the arm, shoulder and hand) [corrected]. *Am J Ind Med*. 1996;29(6):602-608.
28. Lin DC, Chang JH, Shieh SJ, et al. Prediction of hand strength by hand injury severity scoring system in hand injured patients. *Disabil Rehabil*. 2012;34(5):423-428. doi:10.3109/09638288.2011.607550.

29. Duncan SF, Saracevic CE, Kakinoki R. Biomechanics of the hand. *Hand Clinics*. 2013;29(4):483-492.
30. Jaibaji M. Advances in the biology of zone II flexor tendon healing and adhesion formation. *Ann Plast Surg*. 2000;45(1):83-92.
31. Bowden JL, McNulty PA. Age-related changes in cutaneous sensation in the healthy human hand. *Age (Dordr)*. 2013;35(4):1077-1089. doi:10.1007/s11357-012-9429-3.
32. Schmauss D, Finck T, Megerle K, et al. The normal sensibility of the hand declines with age—A proclamation for the use of delta two-point discrimination values for sensibility assessment after nerve reconstruction. *J Peripher Nerv Syst*. 2014;19(3):197-204. doi:10.1111/jns.12085.
33. Gelberman RH, Urbaniak JR, Bright DS, et al. Digital sensibility following replantation. *J Hand Surg Am*. 1978;3(4):313-319.
34. Glickman LT, Mackinnon SE. Sensory recovery following digital replantation. *Microsurgery*. 1990;11(3):236-242.
35. He JY, Chen SH, Tsai TM. The risk factors for failure of an upper extremity replantation: is the use of cigarettes/tobacco a significant factor. *PLoS One*. 2015;10(10):e0141451. doi:10.1371/journal.pone.0141451.
36. Alderman AK, Chung KC. Measuring outcomes in hand surgery. *Clinics in Plastic Surgery*. 2008;35(2):239-250.
37. Gummesson C, Atroshi I, Ekdahl C. The disabilities of the arm, shoulder and hand (DASH) outcome questionnaire: longitudinal construct validity and measuring self-rated health change after surgery. *BMC Musculoskelet Disord*. 2003;4:11. doi:10.1186/1471-2474-4-11.
38. Prucz RB, Friedrich JB. Upper extremity replantation: current concepts. *Plast Reconstr Surg*. 2014;133(2):333-342.
39. Casal D, Gomez MM, Antunes PC, et al. Defying standard criteria for digital replantation: a case series. *Int J Surg Case Rep*. 2013;4(7):597-602. doi:10.1016/j.ijscr.2013.03.033.