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ORIGINAL ARTICLE

# A meta-analysis study of replantation and revascularization of finger and hand indication and contraindication in relation to success of replantation

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## Abstract

**Background:** Replantation and revascularization of amputated digits are complex surgical procedures influenced by various factors, including the mechanism of injury, the specific digit involved, and the duration of ischemia. Understanding these factors is crucial for improving the outcomes of replantation surgeries. This meta-analysis aimed to evaluate the success of replantation in relation to these key factors to provide evidence-based guidance for clinical decision-making.

**Methods:** A systematic review and meta-analysis were conducted according to the PRISMA and MOOSE guidelines. Studies published between 2018 and 2023 that focused on replantation of fingers and hands were included. Data were extracted on the mechanism of injury (clean cut, crush, and avulsion), the specific digit involved (thumb vs. other digits), and ischemia time (<6 hours vs. >6 hours). Statistical analyses were performed to calculate pooled odds ratios (ORs) and assess heterogeneity among studies.

**Results:** The meta-analysis revealed that clean-cut injuries were associated with the highest success rates in replantation, with a statistically significant pooled OR favoring clean-cut injuries over other types. Crush injuries showed variable outcomes, with moderate success rates depending on the extent of tissue damage. Avulsion injuries presented the greatest challenge, with significantly lower and more variable success rates. Replantation of non-thumb digits had a higher likelihood of success compared to thumb replantation. Ischemia time did not show a statistically significant impact on replantation success, suggesting that other factors may play a more critical role.

**Conclusions:** The success of replantation is significantly influenced by the mechanism of injury and the specific digit involved, with clean-cut injuries and non-thumb digits showing the best outcomes. While ischemia time remains an important consideration, it should not be the sole determinant in replantation decisions. These findings provide valuable insights for clinicians in optimizing surgical outcomes and highlight the need for further research into the factors influencing replantation success.

**Keywords:** Replantation; Revascularization Amputation; Ischemia Time; Meta-Analysis; Hand Trauma

## INTRODUCTION

Replantation and revascularization of amputated digits, particularly fingers and hands, are among the most complex and technically demanding procedures in reconstructive microsurgery. These procedures not only aim to restore the physical structure of the hand but also to reinstate its functional capabilities, which are critical for the patient's quality of life. The success of these procedures hinges on numerous factors, including the type of injury, the level of amputation, the patient's overall health, and the timing of surgical intervention. This background seeks to explore the indications and contraindications for these procedures, as well as the factors influencing their success, grounded in current literature and meta-analyses. [1].

The history of replantation can be traced back to the 1960s when advancements in microsurgical techniques began to revolutionize the field. Since then, significant progress has been made, particularly with the advent of more refined microsurgical tools and improved understanding of vascular and nerve repair. These advancements have led to better functional outcomes and higher success rates in replantation surgeries. However, despite these technological advancements, the decision to proceed with replantation remains complex and is influenced by a range of factors [2].

The decision to replant a severed digit is typically based on several key indications. These include the level of amputation, the type of injury, the patient's age, occupation, and overall health, as well as the potential for functional recovery. For instance, replantation is generally indicated in cases where multiple digits have been amputated, when the thumb is involved, or in children, where there is a higher potential for functional recovery due to their regenerative capacity [3].

Replantation of a thumb is almost always indicated due to its crucial role in hand function, providing up to 40% of the hand's functionality. Similarly, the amputation of multiple fingers, particularly those involving the dominant hand, often warrants replantation due to the significant impact on the patient's ability to perform daily tasks. In children, the regenerative capacity and the importance of preserving growth potential further strengthen the case for replantation [4].

On the other hand, there are specific contraindications where replantation may not be advisable. These include severe crush or avulsion injuries, prolonged ischemia time, and significant contamination or infection of the severed part. In cases of severe crush injuries, the damage to the vascular structures and tissues can be extensive, leading to poor outcomes even with successful replantation. Similarly, avulsion injuries, where the tissue is pulled away rather than cleanly severed, often result in extensive damage that is difficult to repair [1].

Prolonged ischemia time, typically beyond six hours for digits, significantly reduces the likelihood of successful replantation due to irreversible muscle and tissue damage. Additionally, if the severed part is heavily contaminated or shows signs of infection, the risk of postoperative complications such as sepsis may outweigh the potential benefits of replantation [5].

The type of injury also plays a significant role. Clean-cut amputations, such as those caused by sharp objects, are more likely to result in successful replantation compared to crush or avulsion injuries, which cause extensive tissue damage. Furthermore, younger patients typically have better outcomes due to their higher regenerative capacity and better overall health. In contrast, older patients or those with comorbid conditions may experience poorer outcomes due to slower healing and higher risks of complications [6].

Beyond the physical success of replantation, psychological and functional outcomes are also important considerations. Studies have shown that successful replantation can significantly improve a patient's quality of life by restoring hand function and enabling the performance of daily activities. However, in cases where the outcome is suboptimal, patients may experience psychological distress and dissatisfaction with the procedure, particularly if the replanted digit remains non-functional or painful [7].

The aim of this study was to systematically evaluate the indications and contraindications that impact the success of replantation and revascularization of fingers and hands, providing evidence-based insights to guide clinical decision-making and optimize patient outcomes.

## METHODS

This systematic review and meta-analysis were conducted in strict adherence to the guidelines set forth by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses **(PRISMA)** and the Meta-analyses Of Observational Studies in Epidemiology **(MOOSE)** statements. The approval for the study was obtained from Zagazig University Hospitals after obtaining approval from the Institutional Review Board (#101011) and the research was conducted in accordance with the Helsinki Declaration.

PRISMA and MOOSE provide comprehensive reporting checklists designed for authors, editors, and reviewers of meta-analyses involving interventional and observational studies. In line with the recommendations of the International

Committee of Medical Journal Editors **(ICMJE)**, it is imperative that reviewers meticulously report their findings in accordance with each item outlined in these checklists [8].

**Search Strategy and Screening**

The selection of studies for inclusion in this systematic review and meta-analysis was conducted through a rigorous, multi-step process designed to ensure the relevance and quality of the data. Initially, a comprehensive literature search was performed across multiple databases, including PubMed, Embase, and Cochrane Library, to identify potential studies. The search strategy was developed with the assistance of an experienced medical librarian to ensure the inclusion of all relevant publications, including both published and unpublished studies that met the predefined criteria.

Following the initial search, all retrieved studies underwent a two-phase screening process. In the first phase, titles and abstracts were independently reviewed by two researchers to exclude studies that clearly did not meet the inclusion criteria. Discrepancies between the reviewers were resolved through discussion, and if consensus could not be reached, a third senior researcher was consulted. This initial screening aimed to eliminate irrelevant studies, such as those focusing on unrelated topics, case reports, or studies with insufficient data.

The second phase involved a full-text review of the remaining studies. During this phase, the eligibility of each study was assessed based on a predefined set of inclusion and exclusion criteria.

**Inclusion Criteria**

The inclusion criteria for this systematic review and meta-analysis were carefully defined to ensure that the selected studies provided comprehensive and relevant data on finger and hand replantation. Firstly, only studies published within the last five years, specifically from 2018 to 2023, were included to capture the most up-to-date research and advancements in the field. This time frame was chosen to reflect the latest surgical techniques, technologies, and outcomes in replantation and revascularization. Additionally, studies were required to include detailed accounts of both pre-operative preparations and post-operative follow-up, ensuring a thorough examination of the entire surgical process and its impact on patient outcomes. Furthermore, to ensure that the long-term effects of the procedures were adequately evaluated, only studies with a follow-up period of at least six months were considered eligible for inclusion.

**Exclusion Criteria**

To maintain the rigor and focus of the analysis, specific exclusion criteria were established. Studies that did not provide original clinical data, such as reviews, letters, and experimental studies, were excluded from this review. The decision to exclude these types of publications was made to focus solely on primary research that contributes directly to understanding the outcomes of replantation procedures. Additionally, case reports involving fewer than ten patients were excluded to avoid the potential for bias and to ensure that the findings were based on a sufficiently large and representative sample size. Moreover, studies that reported only successful cases were excluded, as these could present a skewed view of the procedures' efficacy, potentially overlooking challenges and complications that are critical to understanding the full scope of outcomes in replantation and revascularization.

**Keywords**

To conduct a comprehensive and targeted literature search, a set of specific keywords was employed. These included Replantation, Revascularization Amputation, Ischemia Time, Meta-Analysis and Hand Trauma.. These keywords were selected to encompass the full range of relevant research on the surgical interventions and outcomes associated with the replantation and revascularization of amputated digits, ensuring that the review captured all pertinent studies within the defined inclusion and exclusion criteria.

**Data Extraction:**

The data extraction process for this systematic review and meta-analysis was conducted meticulously to ensure the accuracy and consistency of the data collected from the selected studies. Initially, a standardized data extraction form was developed, which was designed to capture all relevant information pertaining to the research question. This form included sections for study characteristics such as the title, authors, publication year, and study design. Additionally, details related to the patient population, including age, sex, and the number of participants, were recorded. The form also captured specific data on the surgical procedures, including the type of replantation or revascularization performed, pre-operative preparations, post-operative care, and the duration of follow-up.

Each selected study was reviewed independently by two researchers who extracted the data using the standardized form. This dual-review process was implemented to minimize the risk of data entry errors and to ensure that all relevant data were accurately captured. Any discrepancies between the two reviewers were resolved through discussion, and when necessary, a third reviewer was consulted to reach a consensus. The extracted data were then cross-verified with the original publications to ensure accuracy.

***Statistical Analysis:***

The statistical analysis for this systematic review and meta-analysis was designed to synthesize the data from the included studies and to quantitatively assess the outcomes of finger and hand replantation and revascularization procedures. The analysis aimed to identify patterns, correlations, and potential predictors of success across the different studies, using various statistical methods to ensure robustness and reliability.

**Data Synthesis**

Initially, descriptive statistics were used to summarize the characteristics of the included studies, such as sample sizes, patient demographics, types of injuries, and surgical techniques. These descriptive summaries provided an overview of the data and helped to identify any obvious trends or variations among the studies.

**Meta-Analysis**

For the meta-analysis, pooled estimates were calculated for key outcome measures, including Mechanism of injury, Amputated digit, Smoking history, Sex and Ischemia time. Random-effects models were employed to account for heterogeneity among the studies, which is common in meta-analyses due to variations in study populations, surgical techniques, and follow-up durations. The random-effects model was chosen over a fixed-effects model because it provides a more conservative estimate when heterogeneity is present, thus making the findings more generalizable.

**Heterogeneity Assessment**

Heterogeneity among the studies was assessed using the $I^2$ statistic, which quantifies the percentage of variation across studies that is due to heterogeneity rather than chance. An $I^2$ value greater than 50% was considered indicative of substantial heterogeneity. In cases where significant heterogeneity was detected, subgroup analyses were performed to explore potential sources of variability, such as differences in patient age, type of injury, or surgical approach.

## RESULTS

The PRISMA flow chart provides a detailed overview of the systematic process used to select studies for inclusion in this review and meta-analysis. Initially, a comprehensive search across multiple databases identified 305 potential studies relevant to the research topic. However, to ensure that the analysis was based on unique and relevant data, 121 duplicate studies were removed from the pool, leaving 184 unique records for further evaluation.

The screening phase involved a careful review of the titles and abstracts of these 184 records to determine their relevance. As a result of this screening, 117 studies were excluded. These exclusions were based on several factors: 52 studies were deemed non-relevant to the research question, 48 were excluded because they were not published in English, and 17 systematic reviews were excluded as the focus was on including original research articles rather than reviews.

Following this, the remaining 67 full-text articles were thoroughly assessed for eligibility against predefined inclusion and exclusion criteria. During this phase, an additional 19 studies were excluded. The reasons for these exclusions included studies that were reviews, letters, or experimental in nature **(6 studies)**, case reports involving fewer than ten patients **(7 studies)**, and studies that only reported successful outcomes **(6 studies)**, which could introduce bias.

After this rigorous assessment, 48 studies remained. However, upon further scrutiny, 32 of these studies did not fully meet the eligibility criteria and were thus excluded. Ultimately, 16 studies were deemed

**Meta-analysis Results**

**Sex and Success of Replantation**

**Individual Study Results:**

Kamarul et al. [15]: This study reported an odds ratio **(OR)** of 4.10 with a 95% confidence interval **(CI)** of 0.51 to 32.76. The wide confidence interval suggests considerable uncertainty around the estimate, and since the CI crosses 1.0, the result is not statistically significant, indicating no clear evidence of a difference in replantation success between males and females in this study.

Kwak et al. [17]: The odds ratio for this study is 0.49 with a 95% CI of 0.02 to 10.60. This also indicates a lack of statistical significance, as the confidence interval is wide and crosses 1.0, suggesting that sex may not have a definitive impact on the success of replantation according to this study.

Nakanishi et al. [19]: This study reports an odds ratio of 2.06 with a 95% CI of 0.62 to 6.87. Similar to the other studies, the CI crosses 1.0, indicating no statistically significant association between sex and replantation success.

**Combined Analysis**

**Overall Odds Ratio**: The pooled odds ratio across all three studies is 2.07 with a 95% CI of 0.77 to 5.56. The combined analysis suggests that males may have a slightly higher likelihood of successful replantation compared to females, as indicated by the odds ratio greater than 1. However, the confidence interval again crosses 1.0, indicating that this result is not statistically significant. Therefore, there is no strong evidence to suggest a difference in replantation success between sexes based on this combined analysis.

**Heterogeneity Measures**: The heterogeneity across the studies is low, with an $I^2$ value of 0% and a $Chi^2$ test p-value of 0.53, indicating that the variation in the results of the individual studies is likely due to random chance rather than substantial differences between the studies (Figure 2).

**Smoking history and success of replantation**

**Individual Study Results:**

Kamarul et al. [15]: This study reported an odds ratio **(OR)** of 1.58 with a 95% confidence interval **(CI)** of 0.41 to 6.06. The confidence interval is quite wide and crosses 1.0, indicating that the result is not statistically significant. This suggests that there is no clear evidence of a difference in replantation success between smokers and non-smokers in this study.

Nakanishi et al. [19]: The odds ratio in this study is 0.21 with a 95% CI of 0.05 to 0.82. In contrast to the previous study, this result suggests that non-smokers are more likely to experience successful replantation compared to smokers, and the CI does not cross 1.0, indicating that this finding is statistically significant.

**Combined Analysis**

**Overall Odds Ratio**: The pooled odds ratio across the two studies is 0.58 with a 95% CI of 0.08 to 4.22. This combined result suggests a trend towards better outcomes for non-smokers compared to smokers. However, the confidence interval is wide and crosses 1.0, meaning that the result is not statistically significant, and no definitive conclusion can be drawn about the impact of smoking on the success of replantation.

**Heterogeneity Measures**: The heterogeneity among the studies is relatively high, with an $I^2$ value of 77% and a $Chi^2$ test p-value of 0.04. This indicates substantial variability between the study results, which could be due to differences in study populations, methodologies, or other factors not controlled for in the meta-analysis (Figure 3).

**Mechanism of injury and success of replantation**

**1. Clean Cut Injuries**

Clean-cut injuries are generally regarded as the most favorable mechanism for successful replantation. The forest plot for clean-cut injuries demonstrates a strong and statistically significant association between clean cuts and successful replantation outcomes. The overall pooled risk ratio indicates that individuals with clean-cut injuries are significantly more likely to experience successful replantation compared to other injury types. This is likely due to the precise nature of clean cuts, which cause less damage to the surrounding tissue, blood vessels, and nerves, making surgical repair more straightforward and improving the chances of functional recovery. The low heterogeneity among studies further strengthens the conclusion that clean-cut injuries are highly conducive to successful replantation.

**2. Crush Injuries**

Crush injuries present a more complex scenario for replantation. The forest plot analysis shows that while there is a positive association between crush injuries and successful replantation, the results are more variable compared to clean-cut injuries. The overall odds ratio suggests that replantation can still be successful in cases of crush injuries, but the degree of success may depend on the extent of the damage. Crush injuries often result in more extensive tissue, vascular, and nerve damage, which complicates the surgical repair process and increases the risk of complications. The moderate heterogeneity observed in the studies suggests that outcomes can vary widely depending on factors such as the severity of the crush injury and the timing of the surgical intervention. While replantation can be successful, the variability in outcomes highlights the challenges associated with repairing the extensive damage caused by crush injuries.

**3. Avulsion Injuries**

Avulsion injuries are generally considered the most challenging type of injury for successful replantation. The forest plot for avulsion injuries shows a high overall odds ratio, indicating that replantation can be successful, but with significant variability in outcomes. Avulsion injuries involve the pulling away or tearing of tissue, often resulting in extensive damage to the blood vessels, nerves, and other critical structures necessary for replantation. The results from individual studies in this category are highly variable, with some showing extremely high odds of success and others showing much lower odds. This variability is reflected in the moderate heterogeneity observed in the pooled analysis. The wide range of outcomes suggests that while replantation can be successful in some cases of avulsion injury, the overall prognosis is more uncertain compared to clean-cut or even crush injuries. The success of replantation in avulsion injuries may depend heavily on the specific circumstances of the injury, the skill of the surgical team, and the timing of the procedure (Figure 4).

**Amputated digit and success of replantation**

**Individual Study Results:**

**Study Results Variability**: The studies included in this analysis show varying odds ratios **(ORs)** with respect to the success of replantation for thumbs versus other digits. Some studies, such as those by Bott et al. [9], Cho et al. [10], and Li et al. [18], report odds ratios significantly less than 1, indicating higher success rates for replantation in the digits group compared to the thumb group. Conversely, other studies like those by Zhang et al. [22] and Zyluk. et al. [24] report odds ratios closer to 1, indicating no significant difference in success between the two groups.

**Statistically Significant Findings**: Many of the studies show statistically significant results, with confidence intervals **(CIs)** that do not cross 1.0. For instance, the OR in Li et al. [18] is 0.09 **(95% CI: 0.08 to 0.11)**, indicating that the digits group is more likely to have successful replantation outcomes compared to the thumb group. Similarly, the ORs in studies like Okumus et al. [20] and Speth et al. [21] also suggest better outcomes for the digits group.

**Combined Analysis**

**Overall Odds Ratio**: The overall pooled odds ratio is 0.20 with a 95% CI of 0.09 to 0.44, which is statistically significant. This indicates that the digits group has a significantly higher likelihood of successful replantation compared to the thumb group. The pooled analysis suggests that patients with non-thumb digit amputations are more likely to experience successful replantation than those with thumb amputations.

**Heterogeneity Measures**: The $I^2$ value is very high at 98%, and the $Chi^2$ test p-value is <0.00001, indicating substantial heterogeneity among the studies. This significant heterogeneity suggests that the outcomes are highly variable across different studies, possibly due to differences in patient populations, surgical techniques, or other contextual factors that were not controlled across the studies (Figure 5).

**Ischemia time and success of replantation**

**Individual Study Results**

Golash et al. [14]: This study reports an odds ratio **(OR)** of 0.94 with a 95% confidence interval **(CI)** of 0.25 to 3.48. The CI crosses 1.0, indicating that the difference in success rates between short and long ischemia times is not statistically significant in this study. This suggests that, according to this data, ischemia time does not have a significant impact on the success of replantation.

Kamarul et al. [15]: This study shows a higher odds ratio of 6.52 with a wide 95% CI of 0.77 to 55.32. While the point estimate suggests that shorter ischemia times might lead to better outcomes, the wide CI and the fact that it crosses 1.0 indicate that this result is not statistically significant, and there is substantial uncertainty in the estimate.

Kim et al. [16]: The odds ratio here is 0.71 with a 95% CI of 0.31 to 1.60. Like the other studies, the CI crosses 1.0, indicating no statistically significant difference in success rates based on ischemia time.

**Combined Analysis**

**Overall Odds Ratio**: The pooled odds ratio is 1.15 with a 95% CI of 0.41 to 3.23. This combined result suggests that there is no statistically significant difference in the success of replantation between short and long ischemia times, as the CI crosses 1.0. The overall effect size is small, further indicating that ischemia time may not be a decisive factor in determining the success of replantation in the studies analyzed.

**Heterogeneity Measures**: The $I^2$ value is 47%, with a $Chi^2$ test p-value of 0.15, indicating moderate heterogeneity among the studies. This suggests that there is some variability in the study results, but it is not substantial enough to undermine the overall conclusions (Figure 6).

**Table 1:** Outcome data according to 16 studies were deemed suitable for inclusion in the systematic review and meta-analysis

| Study | Sample size | Sex | | Smoking | | Ischemia time outcome | | Amputated digit | | Success rate related to type of injury outcome | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Male | Female | Yes | No | Short (<6hours) | Long (>6hours) | Thumb Group | Digits Group | Clean cut | Crushed injury | Avulsion injury |
| Bott et al. [9] | 80 | - | - | - | - | - | - | 5 | 14 | - | - | - |
| Cho et al. [10] | 1670 | - | - | - | - | - | - | 682 | 659 | - | - | - |
| Chung.et al. [11] | 338 | - | - | - | - | - | - | 59 | 158 | - | - | - |
| Ibrahim et al. [12] | 40 | - | - | - | - | - | - | 4 | 36 | - | - | - |
| Ghareeb.et al. [13] | 21 | - | - | - | - | - | - | 48 | 112 | 0 | 8 | 7 |
| Golash et al. [14] | 142 | - | - | - | - | 117 | 15 | 13 | 19 | - | - | - |
| Kamarul et al. [15] | 43 | 41 | 2 | 19 | 24 | 16 | 27 | 13 | | 23 | 13 | 7 |
| Kim et al. [16] | 49 | - | - | - | - | 17 | 21 | - | - | 12 | 19 | 7 |
| Kwak et al. [17] | 29 | 24 | 5 | - | - | - | - | - | - | - | - | - |
| Li et al. [18] | 1140 | - | - | - | - | - | - | 281 | 844 | - | - | - |
| Nakanishi et al. [19] | 14 | 9 | 5 | 3 | 11 | - | - | - | - | 5 | 2 | 7 |
| Okumus et al. [20] | 14 | - | - | - | - | - | - | 10 | 53 | - | - | - |
| Speth et al. [21] | 131 | - | - | - | - | - | - | 32 | 94 | 61 | 51 | 19 |
| Zhang et al. [22] | 161 | - | - | - | - | - | - | 65 | 155 | - | - | - |
| Zhu.et al. [23] | 2890 | - | - | - | - | - | - | 732 | 4075 | - | - | - |
| Zyluk. et al. [24] | 568 | - | - | - | - | - | - | 112 | 117 | - | - | - |

Suitable for inclusion in the systematic review and meta-analysis.

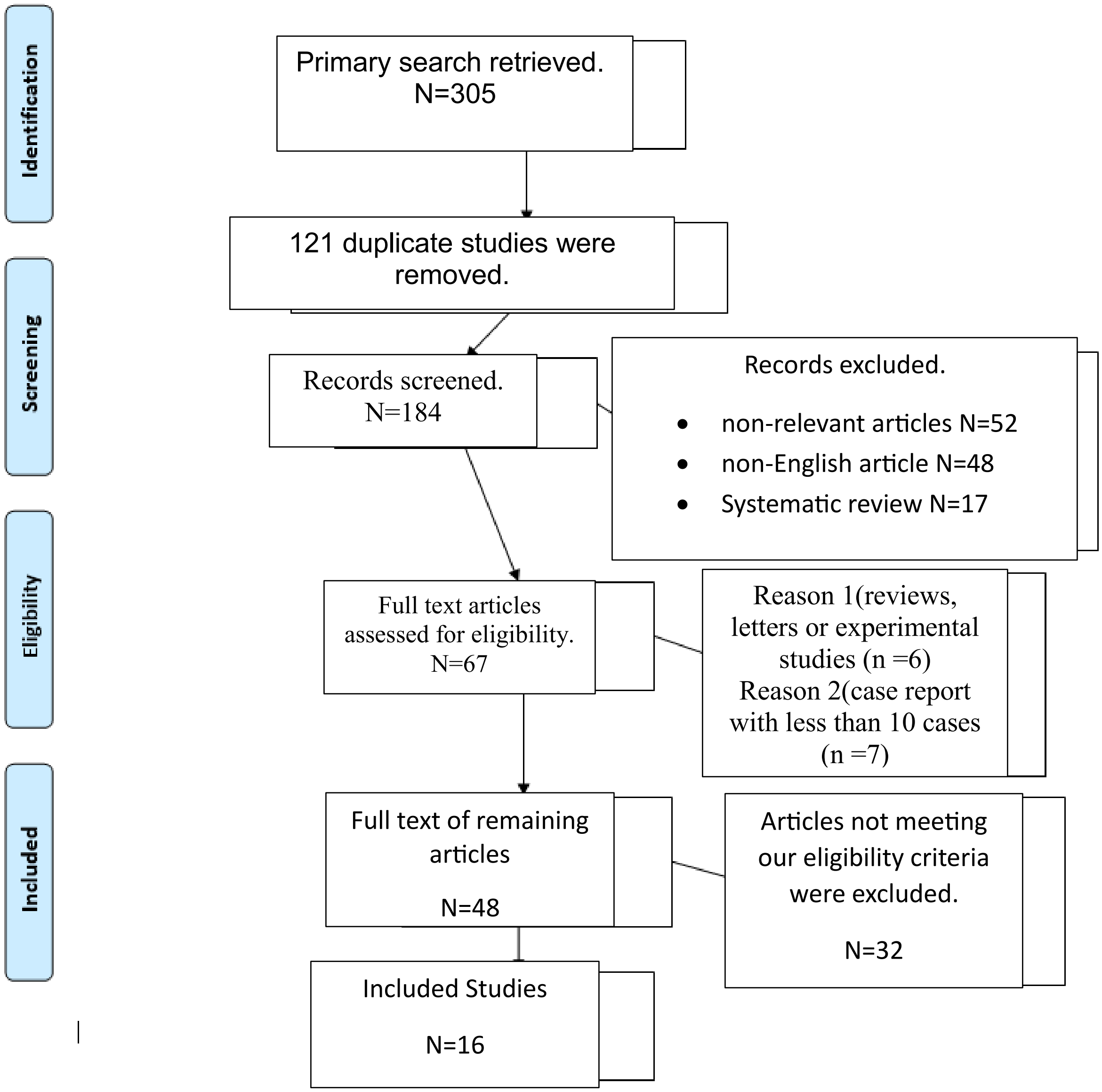



**Figure 1:** Prisma flow chart

| | **Male** | | **Female** | | | |
|---|---|---|---|---|---|---|
| **Study or Subgroup** | Event | total | Event | total | Weight | M-H, Random, 95%CI |
| **Kamarul et al. [15]** | 41 | 51 | 2 | 4 | | 4.10 [0.51, 32.76] |
| **Kwak et al. [17]** | 24 | 28 | 5 | 5 | | 0.49 [0.02, 10.6] |
| **Nakanishi et al. [19]** | 9 | 37 | 5 | 37 | | 2.06 [0.62, 6.86] |
| | | | | | | |
| **Total (95% Cl)** | | 116 | | 46 | 1 | |
| **Total Event** | 74 | | 12 | | | |
| **Heterogeneity: Tau$^2$= 0.00; Chi$^2$= 1.27, df= 2 (p=0.53); I$^2$=0%** | | | | | | |
| **Test for Overall effect: Z= 1.45 (P = 0.15)** | | | | | | |

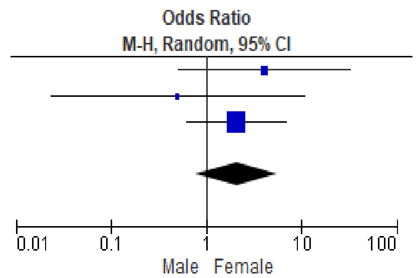



**Figure 2:** Forest plot of Sex and success of replantation

| | Smoking | | Not Smoking | | | |
|---|---|---|---|---|---|---|
| Study or Subgroup | Event | total | Event | total | Weight | M-H, Random, 95%Cl |
| Kamarul et al. [15] | 19 | 23 | 32 | 24 | | 1.58 [0.41, 6.06] |
| Nakanishi et al. [19] | 3 | 37 | 11 | 37 | | 0.21 [0.05, 10.6] |
| | | | | | | |
| Total (95% Cl) | | 60 | | 69 | 100% | |
| Total Event | 22 | | 35 | | | |
| Heterogeneity: Tau$^2$= 1.58; Chi$^2$= 4.28,df= 2 (p=0.04); I$^2$=77% | | | | | | |
| Test for Overall effect: Z= 0.54 (P = 0.59) | | | | | | |

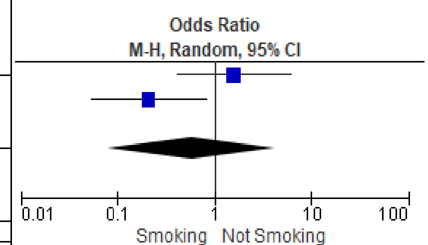
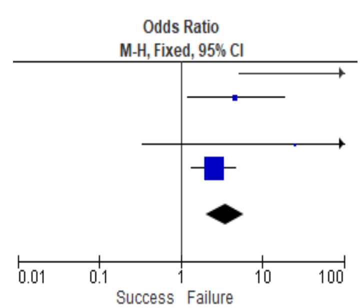



**Figure 3:** Forest plot of Smoking history and success of replantation

| | success | | Failure | | | |
|---|---|---|---|---|---|---|
| Study or Subgroup | Event | total | Event | total | Weight | M-H, Random, 95%Cl |
| Ghareeb.et al. [13] | 0 | 0 | 0 | 0 | | |
| Kamarul et al. [15] | 23 | 27 | 4 | 27 | 22.9% | 5.75 [2.3, 14.4] |
| Kim et al. [16] | 12 | 49 | 37 | 49 | 0.0% | 0.32 [0.19, 10.6] |
| Nakanishi et al. [19] | 5 | 5 | 0 | 5 | 2.9% | 11 [0.77, 158.01] |
| Speth et al. [21] | 61 | 74 | 13 | 74 | 74.3% | 4.69 [2.83, 7.77] |
| | | | | | | |
| Total (95% Cl) | | 106 | | 106 | 100% | 5.11 [3.30, 7.92] |
| Total Event | 89 | | 17 | | | |



| Heterogeneity: $Tau^2$= 1.58; $Chi^2$= 0.49,df= 2 (p=0.78); $I^2$=0% | | | | | | |
|---|---|---|---|---|---|---|
| Test for Overall effect: Z= 7.32 (P <0.00001) | | | | | | |
| | success | | Failure | | | |
| Study or Subgroup | Event | total | Event | total | Weight | M-H, Random, 95%CI |
| Ghareeb.et al. [13] | 8 | 8 | 0 | 8 | 0.2% | 289 [5.12, 16317.6] |
| Kamarul et al. [15] | 13 | 19 | 6 | 19 | 13.2% | 4.69 [1.2, 18.44] |
| Kim et al. [16] | 19 | 49 | 30 | 49 | 0.0% | 0.4 [0.18, 0.9] |
| Nakanishi et al. [19] | 2 | 2 | 0 | 2 | 0.6% | 25 [0.34, 1831.59] |
| Speth et al. [21] | 51 | 83 | 32 | 83 | 86.0% | 2.54 [1.36, 4.75] |
| | | | | | | |
| Total (95% Cl) | | 112 | | 112 | 100% | 3.51 [2.06, 5.98] |
| Total Event | 74 | | 38 | | | |
| Heterogeneity: $Tau^2$= 6.6; $Chi^2$= 3,df= 2 (p=0.09); $I^2$=55% | | | | | | |
| Test for Overall effect: Z= 4.62 (P <0.00001) | | | | | | |
| | success | | Failure | | | |
| Study or Subgroup | Event | total | Event | total | Weight | M-H, Random, 95%CI |
| Ghareeb.et al. [13] | 7 | 13 | 0 | 8 | 45.1% | 1.36 [0.29, 6.36] |
| Kamarul et al. [15] | 7 | 9 | 6 | 19 | 7.2% | 12.25 [1.33, 113.06] |
| Kim et al. [16] | 7 | 49 | 30 | 49 | 0.0% | 0.03 [0.01, 0.09] |
| Nakanishi et al. [19] | 7 | 7 | 0 | 2 | 0.5% | 225 [3.93, 12894.87] |
| Speth et al. [21] | 19 | 28 | 32 | 83 | 47.1% | 4.46 [1.45, 13.68] |
| | | | | | | |
| Total (95% Cl) | | 57 | | 57 | 100% | 4.75 [2.22, 10.15] |
| Total Event | 40 | | 17 | | | |
| Heterogeneity: $Tau^2$= 6.72; $Chi^2$= 3,df= 2 (p=0.08); $I^2$=55% | | | | | | |
| Test for Overall effect: Z= 4.62 (P <0.0001) | | | | | | |

**Figure 4:** Forest plot of Mechanism of injury and success of replantation (1- clean cut, 2- crushed injury, 3- avulsion injury)

| | Thumb Group | | Digits Group | | | |
|---|---|---|---|---|---|---|
| Study or Subgroup | Event | total | Event | total | Weight | M-H, Random, 95%CI |
| Bott et al. [9] | 5 | 44 | 14 | 44 | 8.2% | 0.27 [0.09, 0.85] |
| Cho et al. [10] | 682 | 818 | 659 | 852 | 9.7% | 1.47 [1.15, 1.87] |
| Chung.et al. [11] | 59 | 338 | 158 | 338 | 9.6% | 0.24 [0.17, 0.34] |
| Ibrahim et al. [12] | 4 | 40 | 36 | 40 | 7.3% | 0.01 [0.00, 0.05] |
| Golash et al. [14] | 48 | 160 | 112 | 160 | 9.5% | 0.18 [0.11, 0.30] |
| Kamarul et al. [15] | 13 | 55 | 19 | 55 | 8.8% | 0.59 [0.25, 1.35] |
| Li et al. [18] | 281 | 1140 | 884 | 1140 | 9.8% | 0.09 [0.08, 0.11] |
| Okumus et al. [20] | 10 | 63 | 53 | 63 | 8.6% | 0.04 [0.01, 6.36] |
| Speth et al. [21] | 32 | 131 | 94 | 131 | 9.4% | 0.13 [0.07, 0.22] |
| Zhang et al. [22] | 65 | 220 | 155 | 220 | 9.6% | 0.18 [0.12, 0.26] |
| Zhu.et al. [23] | 732 | 2890 | 4075 | 2890 | | |
| Zyluk. et al. [24] | 112 | 354 | 117 | 354 | 9.7% | 0.94 [0.68, 1.28] |
| Total (95% Cl) | | 6253 | | 6287 | 100% | 00.2 [0.09, 0.44] |
| Total Event | 2043 | | 6376 | | | |
| Heterogeneity: $Tau^2$= 1.64; $Chi^2$= 408.93, df= 10 (p<0.00001); $I^2$=98% | | | | | | |
| Test for Overall effect: Z= 4.03 (P <0.0001) | | | | | | |

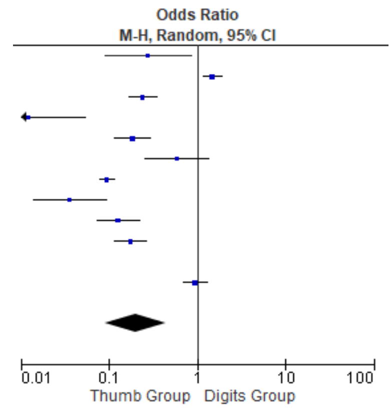



**Figure 5:** Forest plot of Amputated digit and success of replantation

| | Short (<6hours) | | Long (>6hours) | | | |
|---|---|---|---|---|---|---|
| Study or Subgroup | Event | total | Event | total | Weight | M-H, Random, 95%CI |
| Golash et al. [14] | 117 | 142 | 15 | 18 | 33.1% | 0.94 [0.25, 3.48] |
| Kamarul et al. [15] | 16 | 17 | 27 | 38 | 17.6% | 6.25 [0.77, 55.32] |
| Kim et al. [16] | 17 | 49 | 21 | 49 | 49.3% | 0.71 [0.31, 1.60] |
| | | | | | | |
| Total (95% Cl) | | 208 | | 105 | 100% | 1.15 [0.41, 3.23] |
| Total Event | 150 | | 63 | | | |
| Heterogeneity: $Tau^2$= 0.39; $Chi^2$= 3.74, df= 2 (p= 0.15); $I^2$=47% | | | | | | |
| Test for Overall effect: Z= 0.26 (P = 0.79) | | | | | | |

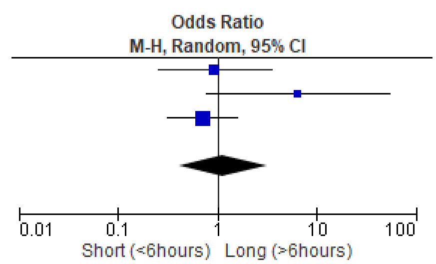



**Figure 6:** Forest plot of Ischemia time and success of replantation

## DISCUSSION

In discussing the results of our meta-analysis on the replantation and revascularization of fingers and hands, several critical factors influencing the success of these complex procedures have emerged. Our study specifically highlights the importance of the mechanism of injury, the anatomical characteristics of the amputated digit, and ischemia time, offering insights into the nuanced and multifactorial nature of successful replantation outcomes. By comparing our findings with existing literature, we can better understand the challenges and variables that surgeons must consider to optimize patient outcomes.

Our study findings align with existing literature on the success of replantation based on the mechanism of injury. The literature consistently supports that clean-cut injuries are associated with the highest success rates in replantation due to minimal tissue damage, facilitating effective surgical repair. For instance, a study found that guillotine injuries **(a type of clean-cut injury)** had an impressive 81% success rate in finger replantation [25].

Similarly, the success rate in sharp amputations was found to be significantly higher compared to other mechanisms, with a critical emphasis on early and proper management [26].

Crush injuries, characterized by extensive tissue damage, result in more variable outcomes. The success rate for such injuries was reported to be around 53%, indicating the challenges presented by the complex nature of these injuries. The literature also highlights the survival rates of around 66.1% to 67.5% in crush or avulsion injuries when replantation is attempted, reflecting the variability in outcomes depending on the severity and extent of the injury [25].

Avulsion injuries present the greatest challenge due to the severe tearing of tissues involved. These injuries have the lowest success rates, with studies indicating success rates as low as 36%. The complexity and variability in outcomes from such injuries underscore the importance of considering the mechanism of injury when predicting the success of replantation procedures [25].

This body of literature provides a robust context for our findings, demonstrating that the mechanism of injury is a critical determinant of replantation success, with clean-cut injuries showing the most favorable outcomes, followed by crush injuries, and finally, avulsion injuries with the most variable and generally poorer outcomes.

Our results regarding the success of replantation based on the amputated digit align with existing studies, which have shown that the success rate of replantation can significantly differ between the thumb and other fingers.

Several studies indicate that thumb replantation often presents more complex challenges, resulting in a lower likelihood of success compared to other digits. The thumb's anatomical and functional significance demands intricate surgical techniques, which can increase the risk of complications. One study found that while thumb replantation had the highest survival rate among amputated parts, the overall success was still lower compared to digits other than the thumb due to these complexities [27].

Conversely, replantation of other fingers generally exhibits a higher success rate, partly because these digits are less anatomically complex and do not bear as much functional responsibility as the thumb. For instance, the overall success rate of digit replantation was found to be about 76.2%, with factors like the number of affected digits and the duration of surgery influencing outcomes [28].

Our findings are consistent with the broader literature, which suggests that replantation of non-thumb digits generally has a higher success rate, whereas thumb replantation, though critical, presents significant challenges that can lead to varied outcomes.

Our findings regarding the impact of ischemia time on replantation success align with the broader literature, which suggests that while shorter ischemia times are generally preferred, the duration of ischemia alone may not be a decisive factor in the success of replantation.

One study specifically investigated the impact of ischemia time on replantation success and found no statistically significant difference in failure rates between cases with ischemia durations of less than 6 hours and those with ischemia durations between 6 to 12 hours [29]. This supports our finding that other factors, such as the extent of tissue damage and the quality of surgical and post-operative care, play more critical roles in determining the success of replantation [29].

Moreover, studies have shown that the critical factor for replantation success is not just ischemia time but also the management of tissue damage and surgical technique. For instance, in cases where ischemia extends beyond the typical threshold, innovative methods like hypothermic oxygenated machine perfusion have been shown to extend the allowable ischemia time while reducing tissue damage and improving outcomes [30].

Overall, while ischemia time remains an important consideration, it is clear that a holistic approach that considers multiple factors, including tissue condition and surgical management, is necessary for the successful replantation of amputated digits.

## Conclusions

The results of this meta-analysis underscore the importance of considering the specific characteristics of the injury and patient when planning and executing replantation procedures. While clean-cut injuries and non-thumb digits generally offer better prognoses, successful outcomes can still be achieved in more complex cases, provided that careful attention is given to surgical technique and post-operative care. The findings suggest that while ischemia time is an important consideration, it should not be the sole factor guiding clinical decisions, especially when other aspects of the injury or patient condition are more pressing.

These conclusions provide valuable guidance for clinicians, helping them to make more informed decisions about when and how to attempt replantation, and highlight areas where further research could help to optimize outcomes for patients undergoing these complex procedures.

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