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Characteristics of Secondary Procedures following Digit and Hand Replantation

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Abstract

Introduction Secondary procedures following digit and hand replants are often necessary to optimize functional outcomes. To date, the incidence and characteristics of secondary procedures have yet to be fully defined.

Materials and Methods A literature search was performed using the NCBI (National Center for Biotechnology Information) database for studies evaluating secondary procedures following digit and hand replantation/revascularization. Studies were evaluated for frequency and type of secondary procedure following replantation. Descriptive statistical analysis was conducted across the pooled dataset.

Results Nineteen studies representing 1,485 replants were included in our analysis. A total of 1,124 secondary procedures were performed on the 1,485 replants. Secondary procedures most commonly addressed tendons (27.1%), bone/joints (16.1%), soft tissue coverage (15.4%), nerve (5.4%), and scar contractures (4.5%). A total of 12.7% of replants resulted in re-amputation (16.7% of secondary procedures). The details of secondary procedures are further described in the article.

Conclusion Secondary procedures are often necessary following hand and digit replants. Patients should be informed of the possible need for subsequent surgery, including delayed amputation, to improve hand function. These data improve our understanding of replant outcomes and can help patients better comprehend the decision to undergo replantation.

Keywords
- digit and hand replantation
- secondary procedure
- traumatic amputation

Introduction

Traumatic amputations to the upper extremity can alter a patient's quality of life due to both the physical and psychological impact.[1,2] Injuries to the hands or digits often necessitate complex reconstruction in an effort to preserve functional capabilities.[3,4] With advancing microsurgical techniques and evidence-based guidelines, digit replantation has become an available option with survival rates of 86 to 93% following amputation.[5–8] Despite reported success rates in replant literature,[5] secondary procedures are often necessary to improve functional outcomes. To date, however, few studies have characterized the necessity of secondary procedures after replant.

Replants often have restricted function that differs from the premorbid hand.[9,10] Traumatic amputation and operative replantation result in an inflammatory injury response resulting in scar formation, joint contractures, and tendon adhesions.[11,12] Direct trauma may also result in bone loss, joint destruction, and segmental tendon/nerve injury that impairs normal hand function.[13] Ultimately, functional outcomes after replantation are limited by various etiologies[14] wherein revision procedures are often necessary to improve

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function. Procedures such as tenolysis, joint capsulotomy, and soft tissue reconstructions, amongst others, are commonly used after replantation. To date, however, our understanding of these secondary procedures is limited. The rate of secondary procedures varies in the literature between 15 and 93.2%,[14–22] with increased heterogeneity across studies.

The need for secondary procedures following replantation warrants additional investigation. Therefore, it was the aim of the current study to perform a review of literature and meta-analysis to systematically evaluate the need for secondary procedures following replantation. By characterizing the frequency and type of secondary procedures needed, we hope to gain a better understanding of replant outcomes, guide surgeon decision making, and improve patient education.

Materials and Methods

Search Methodology

The objective of this study was to characterize the incidence of secondary procedures following hand and digit replants. A systematic review was conducted in accordance with PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines to assess the NCBI (National Center for Biotechnology Information) database for studies published prior to 2018. The database was last accessed on May 30, 2018. The following keywords were used in our search: "hand," "finger," "digit," "replantation," "replant," "secondary procedure," "reprocedure," "reoperation," and "revision." The study selection process is outlined in ►**Fig. 1**.

Inclusion/Exclusion Criteria

Inclusion/exclusion criteria were established to define a specific study population. Papers were considered for inclusion based on the following criteria: (1) the study cohort included patients of all ages and sexes, (2) the study evaluated hand or digit replant or revascularization following amputation, and (3) the study detailed secondary procedures following replant. Our study focused on delayed secondary procedures following replant and excluded early secondary procedures that occurred within 1 week of replant for reasons such as bleeding, vascular compromise, etc. Excluded studies included those that (1) represented meta-analyses, reviews, or case reports, (2) involved heterotopic replantation, and (3) evaluated amputations proximal to the hand (i.e., forearm, elbow). If studies also included data on heterotopic replantation or proximal amputations, data were stratified to only include data meeting our inclusion/exclusion criteria.

Data Extraction and Statistical Analysis

Data were independently extracted by two study team members (LRS and AA) and reviewed to confirm accuracy. The following data variables were obtained: total number of patients, total number of surviving replants, frequency of secondary procedures, and type of secondary procedures performed. Data from studies were then combined into a pooled dataset. Descriptive summary statistics were used to evaluate the frequency of secondary procedures following replant.

Results

The current analysis evaluated 19 studies representing 1,485 hand and digit replants.[4,14,15,17–19,23–35] Studies were most frequently published between 1984 and 2018 but included publications from 1978 to 2018. Studies represented a range of geographic locations. Studies were most frequently conducted in the United States but represented the following countries: the United Kingdom, Austria, Australia, Finland, Vietnam, Japan, Thailand, South Korea, and Taiwan.

In this study, we analyzed the frequency of delayed secondary procedures of nonvascular etiology occurring at least 1 week after initial replantation (►**Fig. 2**). We found that a total of 1,124 secondary procedures were performed on the 1,485 replants. Subgroup analysis was subsequently performed to characterize the necessity of secondary procedures performed after replantation. As shown in ►**Fig. 2**, we found that the most common secondary procedures included tendon operations (27.1%), followed by bone/joint procedures (16.1%), soft tissue coverage (15.4%), nerve-related procedures (5.4%), scar contractures releases (4.5%), and "other" procedures (14.7%). A total of 12.7% of replants resulted in re-amputation (16.7% of secondary procedures) due to tendon adhesions, infection, necrosis/gangrene, nonunion/malunion, or pain/hypersensitivity. Owing to limitations in data reporting, we found that 3% of secondary procedures were not detailed.

Next, further analysis was performed to better characterize the types of tendon-based procedures. As shown in ►**Fig. 3**, we found that the 70.2% of delayed tendon procedures involved tenolysis procedures (14.4% of all replants) to release tendon adhesions and improve tendon excursion. Tendon repair and tendon reconstruction was required in 5.3% of replants (25.9% of delayed tendon procedures) and were most commonly performed for tendon rupture or repair of tendon gaps. We found 0.8% of replants (3.9% of delayed tendon procedures) required a tendon transfer procedure. Studies did not routinely describe the type of tendon transfer or reason for performing the tendon transfer.

Subgroup analysis was then performed to better evaluate the types of joint-related procedures (►**Fig. 4**). Among joint-related operations, we found that joint contracture release accounted for 55.5% of joint-related procedures (5.1% of all replants). Cited reasons for capsulotomies included restricted range of motion and digit stiffness. We found that joint arthrodesis was performed in 2.9% of replants (31.4% of secondary joint-related procedures) and joint arthroplasty was performed in 1.2% of replants (13.1% of secondary joint-related procedures). Cited reasons of joint arthrodesis included digit stiffness, malunion/nonunion, and tendon adhesions. The authors did not cite specific indications for arthroplasty procedures.

Next, we stratified nerve-based procedures to better understand their etiology. As shown in ►**Fig. 5**, we found that nerve repair/reconstruction represented 88.5% of secondary nerve procedures (3.6% of all replants). Cited reasons included repair of unrepaired nerves at time of primary surgery and

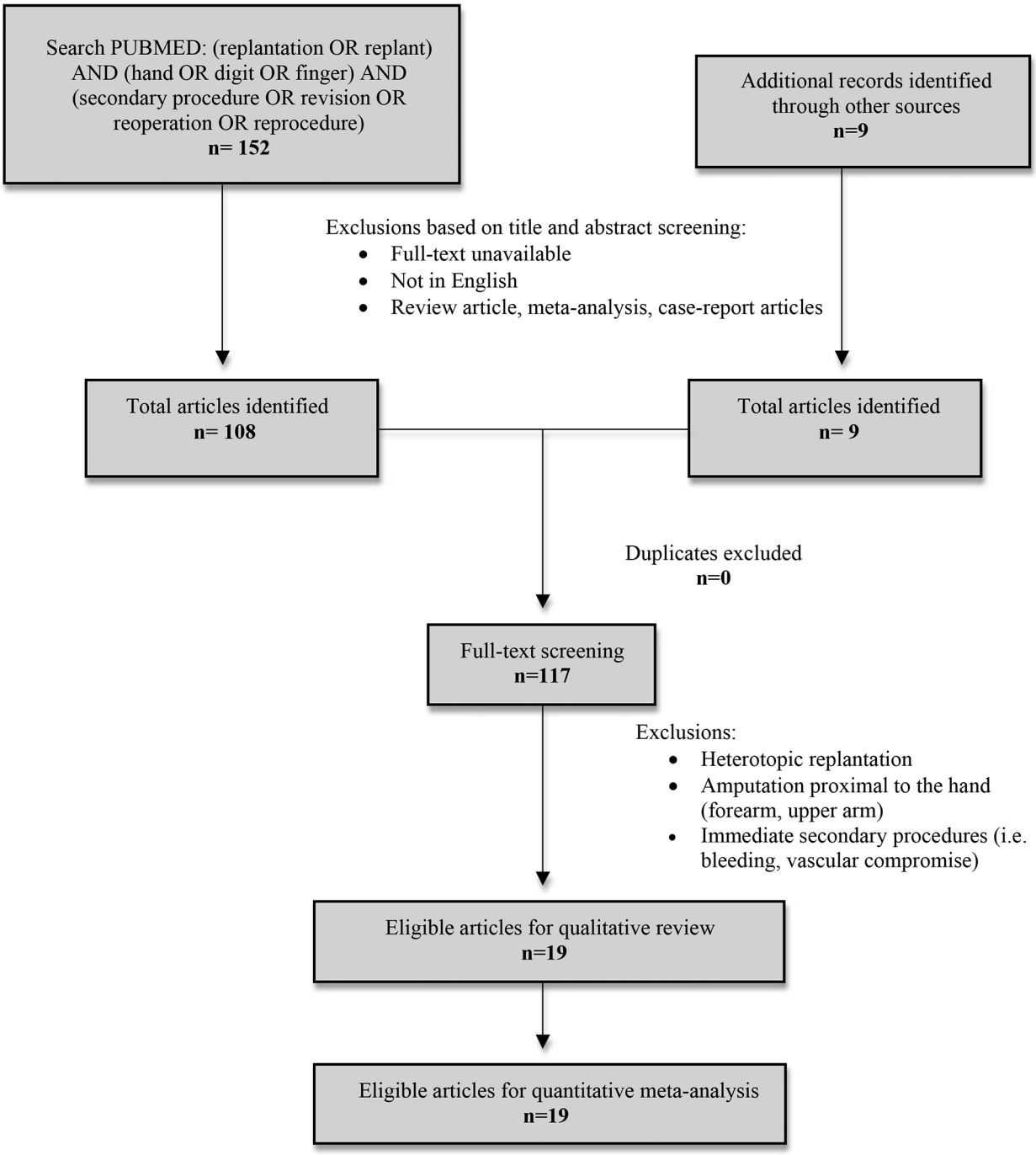

Fig. 1 Study selection process.

inadequate restoration of sensation post-replant. Neurolysis and neurectomy were necessary in 11.5% of all nerve-related procedures (0.5% of all replants) for reasons commonly related to symptomatic neuromas or pain/hypersensitivity.

Soft tissue coverage procedures comprised 15.4% of secondary procedures and were commonly performed via skin graft, local flap, or regional flap. Procedures related to scar contracture release comprised 4.5% of secondary procedures and commonly consisted of Z-plasty procedures, local flaps, and unspecified techniques. Finally, we classified the remaining 14.6% of secondary procedures as "other" procedures (due to variability in data presentation) that included the following: removal of foreign body, hardware removal, excision of finger mass/lesion, toe-to-hand transfer, intrinsic release, collateral ligament repair, pulley repair/reconstruction, nailbed removal, drainage of abscess, digit-shortening procedures, digit-lengthening procedures, flap revision procedures for bulk or aesthetics, and unspecific procedures.

Discussion

Secondary operations after hand and digit replant are often necessary to improve hand function. To date, the data characterizing the need for secondary procedures are limited.

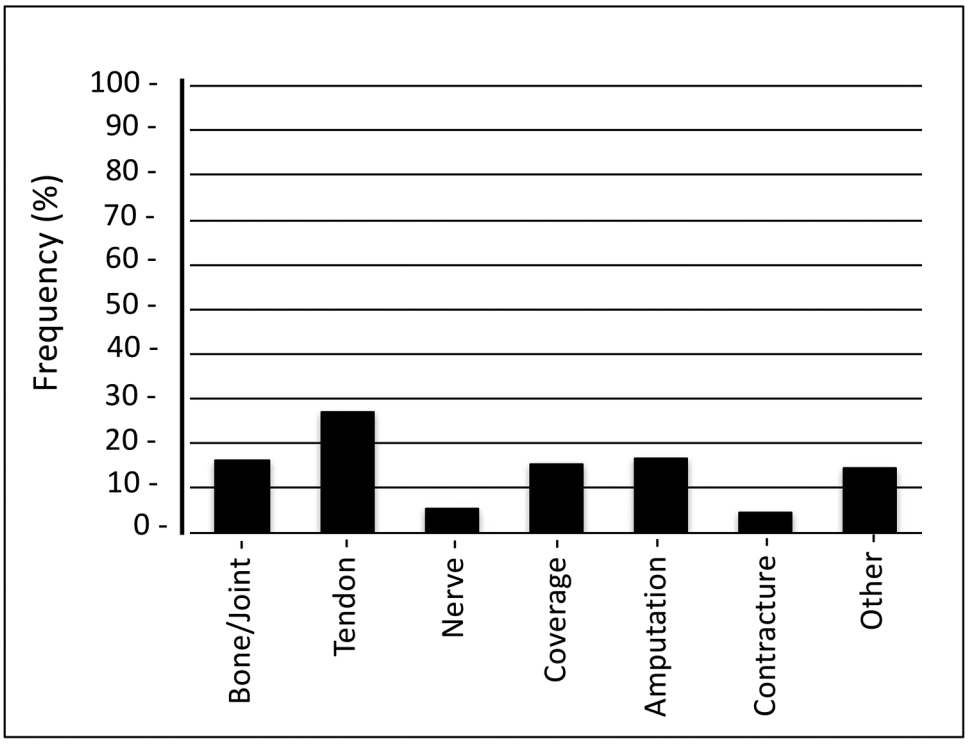

Fig. 2 Frequency of secondary procedures following replant.

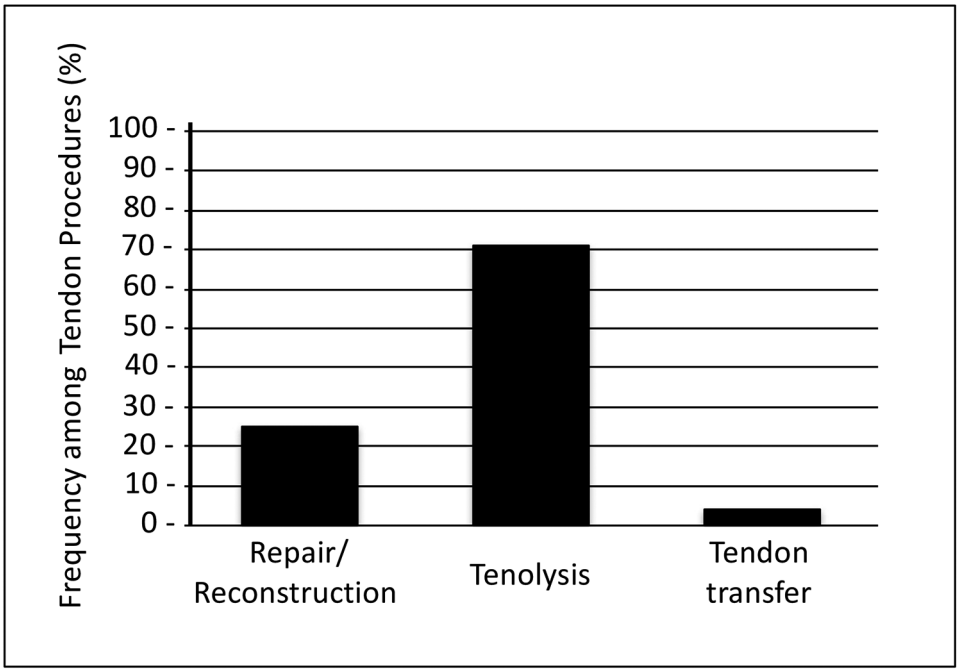

Fig. 3 Frequency of tendon-related procedures following replant.

In this study, we conducted a literature review and performed a meta-analysis of 19 studies to characterize the incidence of secondary procedures after replantation. We found that a total of 1,124 secondary procedures were performed on 1,485 hand and digit replants. The most common procedures included tenolysis, revision amputation, tendon repair/reconstruction, and capsulotomy.

The secondary procedure rate found in this study is comparable to other studies.[18–20,22,35–39] Various studies, however, often identify different frequencies of commonly performed secondary procedures.[17,22,39] Previous reports have cited tendon-related secondary procedures to be most common, whereas other studies have indicated bone/joint or soft tissue procedures to be most common.[17,22,39] After

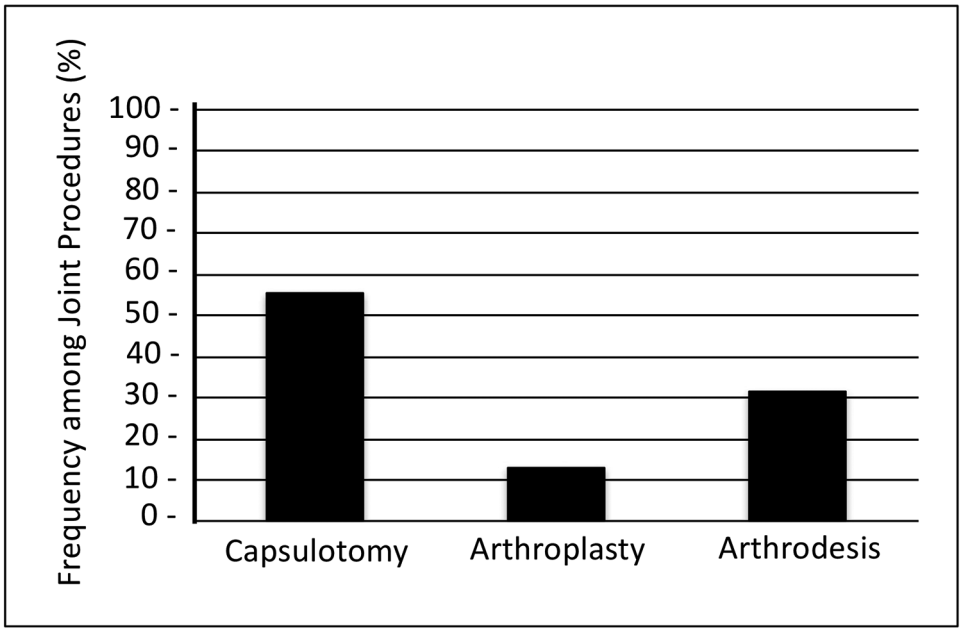

Fig. 4 Frequency of joint-related procedures following replant.

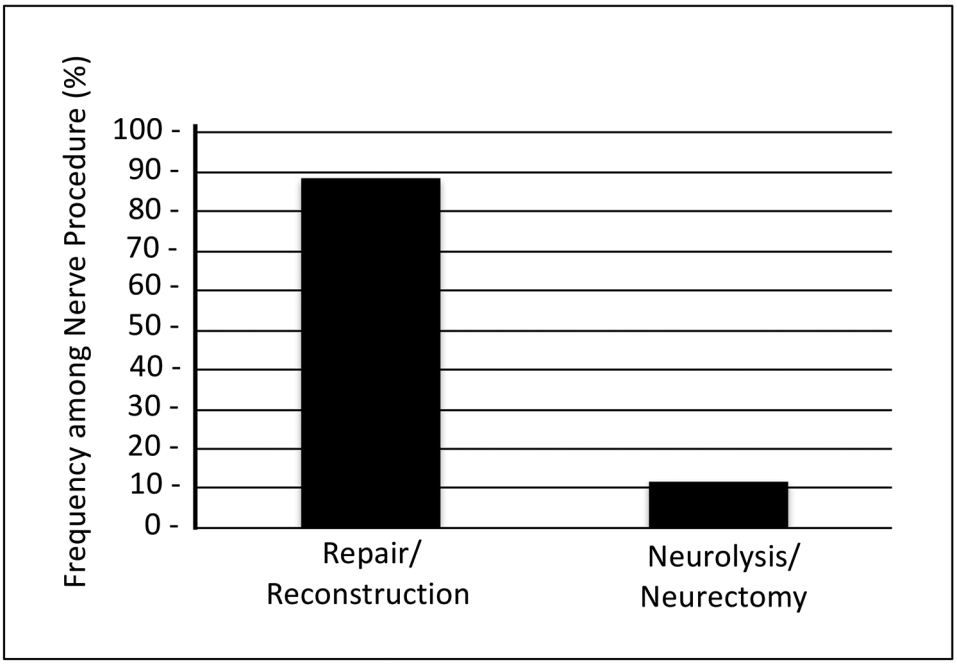

Fig. 5 Frequency of nerve-related procedures following replant.

conducting our meta-analysis, we found tenolysis, revision amputation, tendon repair/reconstruction, and capsulotomy were the most commonly performed secondary procedures. As such, patients should be counseled on limited expected hand function post-replant and the possible need for future surgery to improve function. Similarly, patients should be counseled that 12.7% of patients undergo a delayed reamputation procedure. Ultimately, this information can be used to help educate patients, guide surgeon decision making, and prognosticate the need for subsequent surgery.

Secondary procedures following replantation are common, wherein the order of reconstruction must be prioritized to optimize outcomes.[36] Supple skin coverage is often a prerequisite prior to any skeletal, joint, or tendon-based procedures. Once stable soft tissue coverage is obtained, skeletal stabilization/reconstruction can be prioritized, followed by joint-based procedures and reconstructions. Similarly, tendon-based procedures and reconstructions can be attempted once skeletal stability and passive range of joint have been established.[36] As such, previous studies have divided

secondary procedures into "early" reoperations, mainly for skin coverage and "late" reoperations aimed at functional improvement.[14] Given the inherent difficulty of secondary reconstructions with risks to the anastomosed vessels, several authors have recommended primary repair/reconstruction of all injured structures in hand injury management.[40] At times, limitations due to the nature of injury and the constraints dictated by the ischemia time, full formal repair of all structures may not be possible wherein secondary reconstruction is inevitable. To this end, the sequence of reconstruction following replant must be considered to optimize clinical outcomes.

Secondary procedures can be influenced by perioperative variables, intraoperative decision making, and postoperative management protocols. Preoperative factors including (1) level of amputation, (2) mechanism of injury, (3) number of digits involved, and (4) patient age have been shown to influence the incidence of secondary procedures after replantation.[14,36] These variables, in part, reflect the severity of injury. Avulsion and crush injuries, for example, have been found to have an increased incidence of secondary procedures that may be related to the larger zone of injury and severity of soft tissue damage.[41] Patient age likely influences need for secondary procedures through age-dependent inflammatory responses,[14,42,43] compliance issues, and ability to remodel joints and regenerate nerves.[13,44,45] To this end, identifying preoperative risk factors for secondary procedures can be used to help educate patients and guide perioperative management.

Proper intraoperative management can impact the success rate of the replantation and decrease the incidence of secondary procedures. Tendon suture size/configurations[46,47] and method of skeletal fixation[13,46,48–50] can dictate early active range of motion postoperatively and can therefore influence the potential for tendon adhesions. The decision on type of skeletal fixation following joint injury can similarly influence mobilization postoperatively.[46,51] Repair of periosteum has been reported to prevent tendon adhesions,[51] whereas tension-free neurorrhaphy via possible bone shortening or interposition grafts can optimize nerve regeneration.[13,46] Ultimately, intraoperative technique can influence the need for secondary procedures, wherein this data can help identify common secondary procedures that can be reduced through intraoperative decision making.

Postoperative management will also influence clinical outcomes following replant. Early motion rehabilitation protocols allow for tendon excursion and can prevent tendon adhesions and joint contractures.[52] Concurrent injuries precluding active range of motion can alternatively be treated with early passive rehabilitation programs. Routine patient follow-up allows for early identification of potential issues (i.e., stiffness, joint contractures, tendon adhesions) and the initiation of early treatment. Further, patient compliance with routine follow-up and rehabilitation protocols can influence post-replant hand function. Ultimately, the need for secondary procedures is dependent on the surgeon and patient and is influenced by various pre-, intra-, and postoperative factors. To this end, further research is necessary to better understand the causal relationship behind secondary procedures.

This study has several limitations. This study represents a retrospective study and risks potential unmeasured bias. While our study attempted to include all studies meeting inclusion/exclusion criteria, we cannot ensure that all studies were identified and included in the current analysis. Differences in surgical practices and postoperative treatment protocols were not routinely recorded and were not stratified in this study. This study may also overestimate the frequency of secondary procedures as this study only included studies that reported on secondary procedures. Despite these limitations, this study represents a reliable study that characterizes the need for secondary procedures following replant and can ultimately be used to improve replant medicine.

Conclusion

Secondary procedures are often necessary to improve hand function after replant. In this study, we conducted a meta-analysis and characterized the frequency of secondary procedures to obtain a better understanding of replant outcomes. These data can be used to gain a better understanding of replant outcomes, guide surgeon decision making, and improve patient education. Ultimately, further research is necessary to better understand the causal relationship behind secondary procedures.

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Conflict of Interest
None declared.

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