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# Review of the optimal timing and technique for extensor tendon reconstruction in composite dorsal hand wounds

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## Abstract

**Aim:** The management of complex dorsal hand wounds with extensor tendon loss is controversial. Treatment has focused on soft tissue coverage, but there is limited evidence comparing immediate *vs.* staged tendon reconstruction. This review evaluates existing literature to determine the optimal management of composite hand defects.

**Methods:** A MEDLINE database review was performed including objective measurements such as number of operations, total active motion, grip strength, days to maximum range of motion (ROM), and return to work. Data extraction included demographics, surgical techniques, complications, and relative outcome. We compared primary and secondary staged reconstruction to correlate any significant differences in outcome and determine optimal timing and technique for extensor tendon reconstruction. We extracted information on flap types including regional and free tissue transfer with tendinous components *vs.* staged tendon grafts.

**Results:** Comparison of outcomes showed that patients with immediate reconstruction had fewer operations, faster return to maximum ROM, and greater chance of returning to work. The most successful single stage flaps include the radial forearm, suitable for reconstructing one to three tendons and the dorsalis pedis for three or four tendons; however, there were significantly more complications in immediate reconstruction particularly regarding donor site morbidity. Pedicled flaps had better total active motion. The two-stage approach resulted in acceptable functional outcomes without significant complications.



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**Conclusion:** Immediate cutaneous tendinous flaps have clear advantages over staged approaches for reconstruction of composite dorsal hand wounds. Benefits include less operations, faster time to maximum ROM, and higher percent of patients returning to work; however, significantly more flap related complications were seen. Immediate pedicled radial forearm provided the best total active motion with least complications. When patient circumstances dictate, a fascial perforator free flap offers a suitable environment for staged tendon grafts with good functional outcomes reported albeit longer time to achieve them.

**Keywords:** Composite dorsal hand wound flap extensor tendon reconstruction

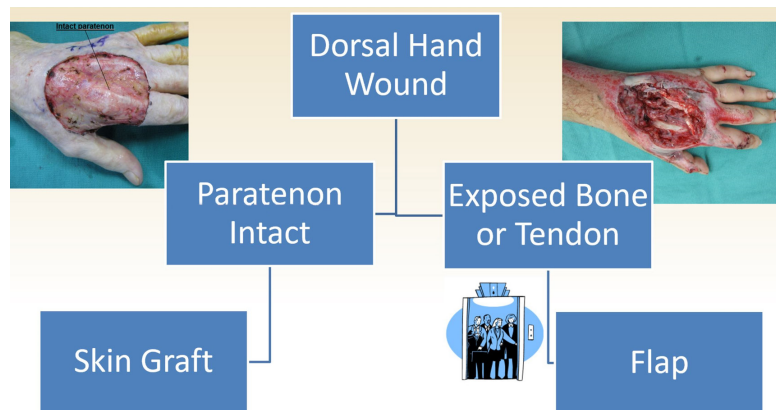
## INTRODUCTION

Complex dorsal hand wounds present a challenging problem for hand and reconstructive surgeons. The proximity to the surface makes open injury to extensor tendons relatively common<sup>[1]</sup>. The surgical timing and flap choice for composite dorsal hand wounds are debated. Traditional management focuses on debridement, skeletal fixation, and soft tissue coverage. There is limited evidence on optimal extensor tendon reconstruction in a wound with tendinous defect. These injuries have been approached with a multitude of techniques with varying degrees of success.

The goal of extensor tendon treatment is to restore function while minimizing disability<sup>[2]</sup>. Restoration of thin, pliable tissue with reliable vascularity and a gliding surface facilitates motion<sup>[3]</sup>. Analysis of treatment options begins with assessment of the wound. The paratenon provides a well-vascularized compartment that minimizes adhesion to surrounding tissue. If paratenon is intact, skin graft or substitute matrix are viable options. When there is denuded tendon or exposed bone, reconstruction typically elevates to flap selection [Figure 1]. Numerous coverage options are available for these types of defects and are determined based on the extent of zone of injury and tissue match. An Allen's test is vital to ascertain competence of the palmar arch for deciding upon a reverse radial forearm flap with retrograde flow or an appropriate recipient for anastomosis. A decision must be made whether immediate or staged tendon reconstruction is preferable and which flaps best with the least complications.

Single-staged procedures include either composite pedicle forearm flaps or free tissue transfers with accompanying vascularized tendon graft. Alternatively, primary reconstruction with nonvascularized tendon grafts may be performed in conjunction with conventional flap coverage<sup>[4]</sup>. Staged approaches include initial flap coverage and subsequent delayed tendon reconstruction with grafts or transfer [Figure 2]. Reid<sup>[5]</sup> reported success using a multiple-staged approach with a primary abdominal flap and delayed tendon grafts to restore function in the hand. Taylor and Townsend<sup>[6]</sup> described the single-stage dorsalis pedis cutaneotendinous free flap with positive results withstanding donor site morbidity. The dorsalis pedis flap can provide up to four vascularized tendons<sup>[7-11]</sup>. Reid and Moss<sup>[12]</sup> performed a one-stage flap repair using radial forearm flap containing palmaris longus and brachioradialis tendon. Modifications can provide palmaris longus, flexor carpi radialis, and/or brachioradialis with paddle location dependent on desired orientation when transposed<sup>[13,14]</sup>. Pedicle flaps obviate the need for microsurgery when it is relatively contraindicated due to patient factors and status. Other flap choices including ulnar island<sup>[15]</sup>, posterior interosseous<sup>[16,17]</sup>, lateral arm<sup>[18,19]</sup>, and free anterolateral thigh<sup>[20-22]</sup> have been described to incorporate strips of tendon or fascia for reconstitution. Latissimus, serratus, and gracilis are common muscle flaps. Consideration of positioning and availability of a two-team approach to expedite harvest and inset is warranted.

The goals of reconstruction are to provide adequate soft tissue coverage, enable tendons to glide with excursion, and provide adequate power for pull through<sup>[23]</sup>. To determine whether a specific technique for management of cutaneous-tendinous hand defects provides superior outcomes, we performed a systematic



**Figure 1.** Analysis of defect and indicated reconstruction options

review of existing literature. We compared immediate *vs.* staged tendon reconstruction with evaluation of functional outcomes for evidence-based decision making.

## METHODS

**Identification of Relevant Literature - Database search:** The authors performed a systematic search of the literature using the MEDLINE database (1969 through 2017) to identify articles that included the following keywords: “extensor tendon reconstruction”. To ensure adequate coverage, the authors utilized a Boolean search for keywords: [(hand OR extensor tendon) AND (“ROM” OR ROM OR grip strength OR patient outcome OR return to work OR disability)]. The abbreviation of ROM was used to assess and locate abstracts that included that term.

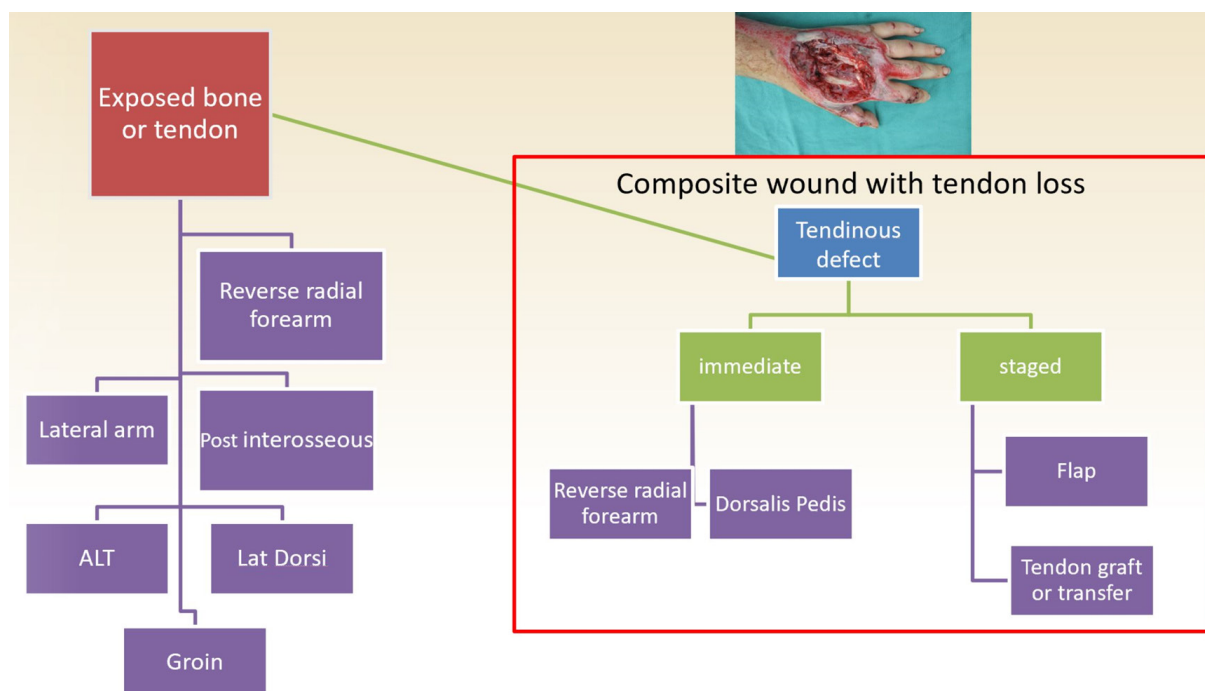
**Search Limits:** The pool of citations was then limited to those relevant to humans and published in English. The authors limited the results to exclude case reports. Inclusion criteria required objective measurements of data analysis including: ROM, grip strength, and patient outcomes related to return to work or disability. Amputation and arthrodesis were accounted for as a confounding factor and excluded when elucidated. The review of MEDLINE using these limits and search terms identified seven reliable studies, which represented 61 patients. Data points extracted were patient demographics, surgical technique, timing of tendon reconstruction, outcomes, and complications.

Flap types recorded included primary pedicle and free flaps with/without tendinous components *vs.* staged tendon grafts. Results of metacarpophalangeal total active motion, days to max ROM, grip strength, complication rate, number of operations, and percent returning to work were compared between immediate *vs.* staged techniques and pedicled *vs.* free flap repairs using a two-sample *t*-test assuming unequal variances. The authors adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines.

## RESULTS

Sixty one patients analyzed in this review included males and females ranging in age from 13 to 70 who had undergone either an immediate 50 or staged 11 tendon reconstruction surgery. Of the fifty immediate (single) surgery group, 39 were free flaps and 11 were pedicled. In the eleven staged group, 6 were free and 5 were pedicled flaps [Table 1].

The most reported single-stage cutaneous tendinous flaps include radial forearm and the dorsalis pedis flap. Comparisons of outcomes [Table 2] showed immediate reconstruction had significantly fewer operations, 1.5 *vs.* 5.2 ( $P < 0.001$ ) and led to faster return to maximum ROM 214 *vs.* 551 days ( $P < 0.001$ ). Concurrently,



**Figure 2.** Flap choice for reconstruction of composite dorsal hand wound with tendinous defect, immediate vs. staged. ALT: anterolateral thigh flap

the patients tended to have a greater percentage of returning to work 88% vs. 43% ( $P < 0.04$ ). Unplanned return to operating room for immediate reconstruction occurred in 20% whereas reoperation in addition to planned second stage occurred in ten of eleven staged reconstructions. Flap debulking was not reported as a complication in this review. Immediate reconstruction had significantly higher complication rate 36% ( $P < 0.001$ ). Complications included: partial donor site graft loss, flap venous occlusion, tendon adhesions and joint contracture requiring tenolysis and capsulectomy.

Staged reconstruction resulted in significantly more operations 5.2 vs. 1.5 ( $P < 0.001$ ), longer days to maximum ROM 551 vs. 214 ( $P < 0.001$ ), and less percentage returning to work 43% vs. 88% ( $P < 0.04$ ). The staged approach nonetheless resulted in acceptable functional outcomes with no significant difference in total active motion 61 vs. 57 degrees ( $P < 0.3$ ) or grip strength 50% vs. 57% ( $P < 0.3$ ), and no significant complications reported.

Of the immediate single surgery group, 39 were free flaps and 11 were pedicled. In the staged group, 6 were free and 5 were pedicled. When comparing the pedicled vs. free flap surgeries, the pedicled group had a significantly higher metacarpophalangeal total active motion 75 vs. 55 ( $P < 0.007$ ). Differences in the days to maximum ROM, complication rate, and number of operations were not significant however, and there was not enough data to compare grip strength or percent of patients who returned to work in these groups.

## DISCUSSION

Our results are concordant with Sundine and Scheker<sup>[24]</sup> who found that immediate reconstruction allowed for faster return to maximum ROM, fewer operations, and a greater chance of adequate recovery for vocation. Taylor and Townsend<sup>[6]</sup> used a vascularized single-stage reconstruction utilizing a dorsalis pedis free flap, which allows for a one-stage reconstruction for most dorsal hand extensor injuries. The proposed benefit of this technique is transferring tendons with an intact vascular supply and within their tendon sheath which may facilitate faster tendon repair healing, thus allowing for rehabilitation

**Table 1. Overview of articles**

Author	Adani et al. <sup>[26,27]</sup>	Koul et al. <sup>[33]</sup>	Ulusal et al. <sup>[19]</sup>	Sundine et al. <sup>[24]</sup>	Scheker et al. <sup>[25]</sup>	Al-Qattan <sup>[29]</sup>	Lu et al. <sup>[17]</sup>
# of Patients	12	8	8	14	9	4	6
Type of Surgery	single composite, 7 dorsalis pedis free flap, 5 radial forearm island flap	single, 7 free flap with palmaris longus graft, 1 posterior interosseous artery with palmaris longus graft	single lateral arm composite free flap triceps	7 staged vs. 7 single	single tendon graftstaged, groin flaps	single, posterior interosseous artery	
Average Patient Age	33	29	32	25 vs. 33	38	21	No Data
Average Time to Surgery Post-Injury	14 days	2.3 days	11 days	No Data	Within 24 hours	7 months	No Data
ROM	full MP ROM IPJ case 2	stiff 192 at 8 weeks, 237 at 12 weeks, combined 268 at 12 weeks, 274 at 6 months	No Data	51 vs. 56	48	Average 82	No Data
Complications	tenolysis 1/12, hypertrophic scar, donor partial skin graft loss 6/12	no extension lag	two rays, three tenolysis	None	2 complications recorded	None	no tenolysis
Grip Strength	No Data	average 54 at 12 weeks	No Data	Average 50% vs. 53%	Average 60%	No Data	No Data
Follow-up Timing	No Data	No Data	15 months	No Data	No Data	8 months	No Data
Time to Max ROM	No Data	No Data	No Data	630 vs. 214 days	3 months	430 days	No Data
% Returned to Work	No Data	No Data	No Data	43 vs. 86	89	No Data	No Data
Average # of Operations	1.33	1	1.75	6 vs. 2	1.22	4	No Data

ROM: range of motion

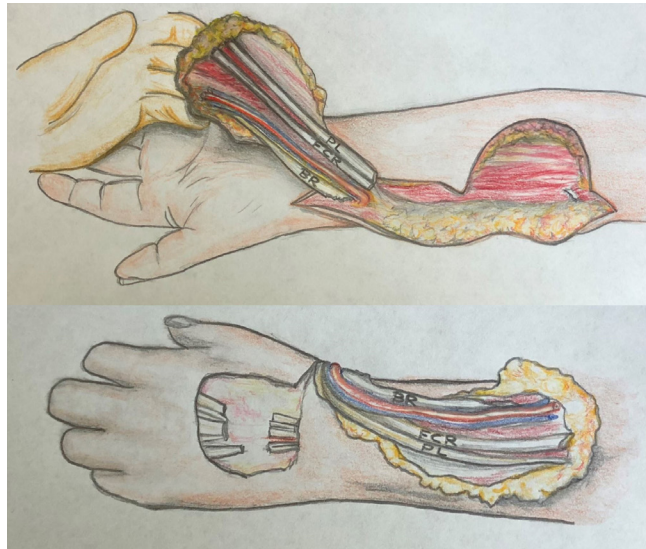
**Table 2. Comparison of surgical outcomes**

Flap Type °	MP TAM (°) (P = 0.3123)	Days to Max ROM *(P < 0.001)	Grip Strength (P = 0.2713)	Complication rate *(P < 0.001)	#Operations *(P < 0.001)	Return to work *(P = 0.0381)
Immediate n 50	56.99	213.86	57%	36%	1.45	88%
Staged n 11	61.39	551.18	50%	0%	5.18	43%
°	*(P = 0.0067)	(P = 0.1610)	°	(P = 0.4740)	(P = 0.0604)	°
Pedicled n 16	75.25	522.4	NR	30%	3.4	NR
Free n 45	55.4	380.62	NR	29%	1.93	NR

ROM: range of motion; #: number of operations; \*: P &lt; 0.05 considered significant; TAM: total active motion; NR: not recorded

to be initiated earlier. Scheker et al.<sup>[25]</sup> reported better function with primary reconstruction, with fewer operations, a shorter hospital stay, minimal complications, and a shorter period of disability. Adani et al.<sup>[26,27]</sup> reviewed completely vascularized single stage reconstruction using dorsalis pedis and radial forearm cutaneoutendinous flaps. Our study confirmed that there is significantly less operations required, an earlier return to maximum ROM, and greater chance of returning to work; in contrast to some reports, there was no significant difference in total active motion and significantly more complications reported in immediate reconstruction. Obvious advantages to a single stage technique include avoidings need to re-elevate the flap for tendon graft and the ability to start earlier active ROM rehabilitation. With potential expedition however comes more risk. Considering the significantly higher rate of complications mostly relating to donor site graft loss and delayed healing of foot wounds, the radial forearm flap lends to less donor site morbidity for immediate composite reconstruction.

Multiple staged reconstruction is commonly utilized for large composite defects<sup>[28]</sup>. The procedure allows for wound closure and fracture union while tendon reconstruction is commonly delayed to subsequent procedures. The staged approach resulted in acceptable functional outcomes with no significant difference in total active motion or grip strength and no significant complications. Good to excellent total active motion has previously been reported in two stage technique with rod placement for extensor zone six<sup>[29]</sup>.



**Figure 3.** Pedicled composite radial forearm flap with tendon orientation upon transposition

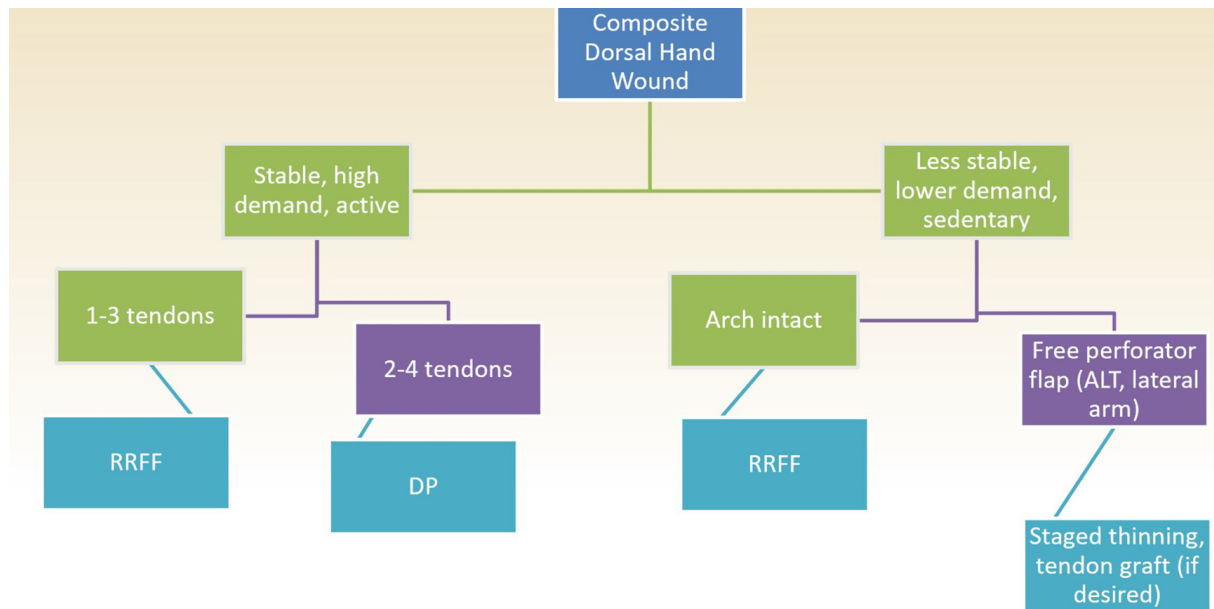
Anterior lateral thigh and lateral arm perforator flaps are considered ideal for coverage of dorsal hand soft tissue defects with minimal donor site morbidity<sup>[30,31]</sup>. Due to the varying presentation and degree of severity of these complex injuries, there is vast heterogeneity in the surgical management depicted. Lack of structured data collection and inconsistency in reporting outcomes limits the conclusiveness of retrospective literature review.

Tendon graft is the most common reported staged reconstruction technique; if significantly delayed, myostatic contracture may necessitate a tendon transfer for adequate power. We do acknowledge the variable postoperative protocols and compliance with therapy regimens with retrospective reviews. Early active motion is favored with the lowest rate of extensor lag, averting the need for tenolysis after static splinting. Fortunately, tendon rupture is rare<sup>[32,33]</sup>. Available evidence suggests better outcomes with dynamic over static splinting after repair of extensor tendons in Zone V-VIII of the hand<sup>[34,35]</sup>. Early mobilization after tendon transfers is also safe and beneficial in the initial rehabilitation phase<sup>[36]</sup>.

Review of the literature for reconstruction of extensor hand defects provides us with a myriad of different procedural modalities to choose from. The present review was limited by lack of consistent objective measurements. Scrutiny in criteria of data collection refined the specificity and increased the reliability of evidence to draw from. Decreased sensitivity lowered the power of the study; particularly lacking data on staged reconstruction and elicitation of complications. The significantly less operations and earlier time to maximum ROM provide a basis to support and favor the use of single-stage reconstruction. By effect, immediate cutaneous tendinous reconstruction allows for expedited recovery and quicker return to work. These factors correlate with significant decreases in cost and saved productivity for quality of life. Pedicled composite radial forearm flap showed the best potential for total active motions, earlier recovery, and least complications and can include modifications of slips for tendon repair coaptation [Figure 3].

The staged approach nonetheless resulted in acceptable functional outcomes. Choice of staging tendon reconstruction can be justified in certain cases dependent on patient condition and preference.

The algorithm in Figure 4 provides some guidance in choosing the best individualized plan for this challenging problem.



**Figure 4.** Algorithm for composite dorsal hand wound reconstruction. RRF: reverse radial forearm flap; DP: dorsalis pedis; ALT: anterolateral thigh

In conclusion, while this study does provide a foundation, further multi-center studies are needed to improve power. Limitations of review include retrospective recall bias, inability to stratify cohorts, variable compliance postoperative rehab regimens, and the lack of objective functional data measurements for comparison between tendon graft and transfers and the need for hunter rod pseudosheath creation. When no extensor tendon reconstruction is performed, compensatory tenodesis effect from scar contracture may be functionally tolerable to the patient. The results of total active motion in these cases are likely not followed. Future studies will look at prospective comparison risk/benefit Hunter rod placement, critical lengths of nonvascularized tendon grafts, as well as a cost analysis to compute the comparative efficacy of immediate reconstruction, particularly factoring in gain of productivity and quality of life factors.

## DECLARATIONS

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### Authors' contributions

Primary author interpretation of results and summarization: Lies S  
 Manuscript submission: Horowitz A  
 Reviewed manuscript: Lee G  
 Edited manuscript: Zhang AY

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Not applicable.

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None.

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All authors declared that there are no conflicts of interest.

### Ethical approval and consent to participate

Not applicable.

### Consent for publication

Not applicable.

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