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Reconstructive

Long Term Follow-up of Composite Flaps for Single-stage Reconstruction of Concomitant Tendon and Soft Tissue Defects

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Background: Tendon rupture in the setting of significant soft tissue loss poses a challenging reconstructive situation, which requires (1) recreating a stable gait cycle, (2) reducing shear forces and re-rupture risk, and (3) providing adequate soft tissue coverage. In this study, we outline our experience with composite flaps in single-step reconstruction of various lower extremity tendinous injuries with soft tissue loss.

Methods: A retrospective review of all patients requiring free tissue transfer at our tertiary wound care center between 2011 and 2020 was performed. Patients undergoing single-stage free tissue transfer for both soft tissue coverage and tendon reconstruction were selected. Variables of interest included demographics, comorbid conditions, baseline functionality, reconstructive details, and wound characteristics. Outcomes of interest were flap success, return to ambulation, time to ambulation, and postoperative complications.

Results: Nineteen patients were included in this study. Patients were on average 48.0 years old (SD 16.5), with a median Charlson Comorbidity Index of 1.00 (IQR: 0.0–2.5). Defects were most often on the ankle (n = 1 3, 68.4%), with extension to the foot or leg in six of these cases. Median wound size was 68.0 cm^2 (IQR: 48.0–120.0). The most common tendon requiring reconstruction was the Achilles (n = 13, 68.4%). An anterolateral thigh flap with attached fascia lata extension rolled into a neotendon was used in all 19 cases. At baseline, all patients were ambulatory. Only one patient (5.3%) required return to the operating room for suspected vascular compromise. At a median of 14.4 months (IQR: 8.5–40.5), all 19 patients were ambulatory.

Conclusions: Simultaneous reconstruction of tendinous injuries and soft tissue defects can be readily achieved via composite free flaps. Although other methods of reconstruction can be considered for smaller soft tissue and tendon loss, this approach has significant utility for patients with large defects and yields robust return to preinjury functionality. *(Plast Reconstr Surg Glob Open 2022;10:e4023; doi: 10.1097/GOX.0000000000004023; Published online 13 January 2022.)*

INTRODUCTION

Lower extremity tendon rupture is a debilitating event, impacting a patient's ability to bear weight and ambulate. For isolated tendon injury, suitable intervention is based on the distance between viable tendon components. The Kuwada classification system guides treatment for Achilles tendon rupture based on the size of the tendon gap.[1] Incomplete ruptures can be treated nonoperatively with casting. Small defects (<3 cm) can often be repaired with specialized suturing techniques, such as the Kessler or Krackow.[2,3] Larger defects require tendon lengthening procedures (3–6 cm), and the largest disruptions within a tendon require tendon transfers or grafting for reconstruction (>6 cm). However, even cases of isolated tendon injury are not without difficulty. Repair of acute Achilles tendon rupture is associated with postoperative complications in

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approximately one in every nine patients,[4,5] and reported re-rupture rates are as high as 3.5%–8.8%.[5,6] Treatment becomes even more challenging in the comorbid patient, with peripheral vascular disease, diabetes mellitus, and tobacco use contributing to microangiopathy, which often promotes tendon rupture and worsens postoperative outcomes.[7]

When tendon injury is associated with soft tissue loss, reconstructive complexity increases. Goals for simultaneous tendinous and soft tissue reconstruction include (1) recreation of a stable gait cycle and preinjury functionality, (2) sustained reduction of shear forces on the neotendon, and (3) adequate soft tissue coverage for return to normal footwear and function. Although this can be accomplished through multistage procedures, such as tendon transfer with subsequent free tissue transfer (FTT), a single-stage process using a single donor site is preferable. A handful of case reports demonstrate successful tendon reconstruction and soft tissue coverage through a single procedure involving composite flaps.[8–12] A composite flap includes both a standard donor site, such as the anterior lateral thigh (ALT) flap, for soft tissue coverage, and an additional contiguous tissue extension, such as the fascia lata (FL), for neotendon reconstruction. Our group has previously published on the successful reconstruction of a large tibialis anterior tendon defect in the setting of significant soft tissue loss in the anterior compartment of the leg.[13] However, current literature could benefit from more substantial reviews of composite flap use in simultaneous tendon repair and soft tissue coverage (Fig. 1). The aim of this study was to describe the surgical technique and postoperative outcomes for reconstruction of lower extremity tendinous defects with concomitant soft tissue loss via composite flaps in a single procedure.

Takeaways

Question: Are composite flaps a reliable way to achieve single-stage reconstruction of concomitant tendon and soft tissue defects?

Findings: Nineteen patients underwent single-stage reconstruction of concomitant tendon and soft tissue defects using an anterolateral thigh flap with attached fascia lata extension rolled into a neotendon. All patients were ambulatory at an average follow up of 14.4 months.

Meaning: Simultaneous reconstruction of tendinous injuries and soft tissue defects can be successfully achieved using composite free flaps.

METHODS

Retrospective Review

A retrospective review was performed for all patients requiring soft tissue coverage at a single tertiary wound care center between the years 2011 and 2020. Patients were included for this study if they (1) had a tendinous defect with soft tissue loss, (2) underwent a single FTT procedure for simultaneous reconstruction of the tendon defect and soft tissue loss, and (3) had a minimum of 3 months of follow-up. This study was approved by the institutional review board (MHRI 2018-173).

Fig. 1. This is a representative image of a patient with concurrent tendon injury and soft tissue loss. This patient sustained an injury to the Achilles tendon after a dog bite. After multiple attempts at repair with subsequent dehiscence at outside hospitals, the patient presented to our tertiary wound care center for treatment.

Data Collection

Variables of interest included patient demographics (age, sex, etc.), comorbid conditions (diabetes, hypertension, etc.), defect descriptions (wound location, tendon involved, soft tissue defect size, tendon gap size, etc.), and preinjury functionality. Comorbid conditions were collected to calculate Charlson Comorbidity Index for each patient.[14] Operative details (donor site, vascular anastomotic technique, and tendon suturing technique) were reviewed. Primary outcomes included assessment of flap success, return to ambulation, time to ambulation, and postoperative complications.

Surgical Methods

All patients received a preoperative angiogram of the affected extremity to assess for suitable microvascular anastomotic recipient sites and preexisting vascular disease requiring intervention. When the patient was deemed ready for definitive reconstruction and closure, a free ALT flap with contiguous FL extending laterally up to or including the tensor fasciae latae was harvested. The ALT flap was harvested in the standard fashion, with initial

Fig. 2. The composite free ALT flap with rolled and secured fascia lata for neotendon creation.

incision and dissection to the perforators occurring on the medial aspect of the flap. The FL was rolled and serially secured with PDS during ischemia time. This process created a neotendon, which was then secured to the proximal and distal attachment points with either a modified Krackow or Kessler stitch. A Cook-Schwartz Doppler was routinely placed to ensure that there was no compression of vascular outflow during flap inset and dressing placement. Flaps were inset with PDS, and the recipient and donor sites were closed in layers after appropriate hemostasis was achieved (Fig. 2). (**See Video [online],** which displays the appropriate inset of the composite flap.)

As standard, all patients were transferred to the intensive care unit for flap monitoring every hour. Occasionally, patients required external fixation to restrict mobility and promote healing. The decision to place patients in external fixation was made based upon the size of the soft tissue defect and suspicion for significant soft tissue swelling; external fixation was in place for an average of 1.5 months. Patients were assessed in clinic every 1-2 weeks, and return to function was routinely assessed by limb salvage center providers.

Statistical Methods

Continuous variables were described by means and SDs or median and interquartile range, as appropriate. Categorical variables were described by frequencies and percentages and differences. Kaplan–Meier plots were produced to evaluate time to achieve weight-bearing status within the cohort. Statistical analysis was performed with STATA (StataCorp, College Station, Tex.).

RESULTS

Patient Demographics and Comorbid Conditions

A total of 19 patients were identified for inclusion during the study period. Average patient age at the time of reconstruction was 48.0 years (SD 16.5), and average BMI was 31.0 kg/m^2 (SD 5.8). Thirteen (68.4%) patients were men, and six (31.6%) were women. Four patients (21.1%) were active smokers, and three (15.8%) were former smokers. Median Charlson Comorbidity Index was 1.0 (IQR 0.0–2.5). Three patients (15.8%) were diabetic, and two (10.5%) had vascular disease (Table 1).

Defect Descriptions and Preoperative Evaluation

The tendinous injury involved the Achilles tendon in 13 patients (68.4%), the anterior tibialis tendon in four (21.1%), and other tendons in two (10.5%). The soft tissue injury involved the ankle only in seven patients (36.8%), both the ankle and leg in four patients (21.1%), and the ankle and hindfoot in two (10.5%). Other sites of soft tissue injury included the leg only in four patients (21.1%), knee in one patient (5.3%), and the forefoot in one (5.3%). The average size of the tendon gap was 10.0 cm (SD 4.3), and the median size of the soft tissue defect was 68.0 cm^2 (IQR: 48.0–120.0). Preoperative angiogram demonstrated three vessel runoff to the distal extremity in 15 patients (78.9%), and two vessel runoff in the other four (21.1%). Three vessel runoff can be defined as patent vascular flow identified on preoperative angiogram from the anterior tibial artery, posterior tibial artery, and peroneal artery. Two-vessel runoff involves two of these three arteries. No patients required vascular intervention to restore distal blood flow. Preinjury, all patients (n = 19) were able to independently ambulate without assistive devices (Table 2).

Table 1. Patient Demographics and Comorbid Conditions

Characteristic	N (%), Mean (SD), Median (IQR)
Age (y)	48.0 (SD 16.5)
Gender	
Men	13 (68.4%)
Women	6 (31.6%)
Body mass index (kg/m^2)	31.0 (SD 5.8)
Smoking status	
Active	4 (21.1%)
Former	3 (15.8%)
Charlson Comorbidity Index	1.0 (IQR: 0.0–2.5)
Diabetes	3 (15.8%)
Vascular disease	2 (10.5%)

Operative Details

All patients were reconstructed with a composite ALT and FL flap. In 12 cases (63.2%), the composite flap was fasciocutaneous, in five (26.3%) the flap was adipofacial, and in two cases (10.5%) a myocutaneous flap was harvested. The recipient vessel was the posterior tibial artery in 16 cases (84.2%), the anterior tibial artery in two (10.5%), and the geniculate artery for the one case of patellar tendon reconstruction (5.2%). An estimated 17 (89.5%) of the vascular anastomoses were performed in an end-to-side fashion, whereas two (10.5%) were end-to-end. When possible, two venous anastomoses were used (n = 13, 68.4%), and one anastomosis was used for the other six patients (31.8%). Twelve patients (63.2%) were placed into external fixation to ensure immobility during the healing period. Average operating time was 563.9 minutes (SD 126.2) (Table 2).

Procedural Outcomes

Nineteen patients (100%) returned to full weight-bearing and ambulation after receiving a composite flap for tendon and soft tissue reconstruction. Median time to ambulation

Table 2. Defect Description

Characteristic	N (%), Mean (SD), Median (IQR)
Tendon injured	
Achilles	13 (68.4%)
Anterior tibial	4 (21.1%)
Extensor hallucis longus	1 (5.3%)
Patellar	1 (5.3%)
Location of soft tissue defect	
Ankle only	7 (36.8%)
Ankle and leg	4 (21.1%)
Ankle and hindfoot	2 (10.5%)
Leg only	4 (21.1%)
Forefoot	1 (5.3%)
Knee	1 (5.3%)
Size of tendon gap (cm)	10.0 (SD 4.3)
Size of soft tissue defect (cm^2)	68.0 (IQR: 48.0–120.0)
Angiogram results	
Three-vessel run-off	15 (78.9%)
Two-vessel run-off	4 (21.1%)
Preinjury ambulation	
Yes	19 (100.0%)

Fig. 3. This photograph was taken immediately after reconstruction. The patient demonstrated rapid return to plantarflexion and had robust return to ambulation.

was 4.4 months (IQR: 3.4–7.8). Median length of follow-up was 14.4 months (IQR: 8.5–40.5). Flap failure occurred in one patient (5.3%), who required a return to the operating room for suspected vascular compromise on postoperative day one. During operative takeback, the patient was found to have a clot in the venous outflow track. Despite revision, the flap was unable to be salvaged (Figs. 3, 4).

Other postoperative complications included partial dehiscence in five patients (26.3%), partial flap necrosis in three patients (15.8%), and infection in four (21.1%). Three patients (15.8%) underwent flap debulking at a later time point. Donor site complications included hematoma formation (n = 2, 10.5%) and dehiscence (n = 1, 5.3%), neither of which required a return to the operating room (Table 3).

DISCUSSION

This retrospective review of patients receiving composite FTT for simultaneous reconstruction of tendon and soft tissue defects demonstrates the high success rate of this procedure. In a single-stage operation, composite flaps are able to meet the goals of tendon and soft tissue reconstruction—recreating tendon integrity, returning patients to weight-bearing and ambulation, and reproducing appropriate soft tissue coverage.

Flap Selection and Success

Tendon repair to the lower extremity is notoriously challenging, even in the absence of soft tissue deficits. Complex suturing aimed at recreating the tensile mechanics of tendon motion requires aggressive techniques that may lead to tendon ischemia and wound breakdown.[7] In cases of isolated tendon injury, complication rates remain high.[4] When coupled with extensive soft tissue loss, this complexity is compounded. Local flap options, such as the gastrocnemius and reverse sural artery, are appropriate in select situations, but limited arc of rotation and significant donor site morbidity limit generalized use.[7]

The composite ALT and FL flap offers a robust option for reconstructing lower extremity tendon and soft tissue defects. The ALT has a relatively long pedicle, allowing for more distant vascular anastomosis from the area of injury, which becomes especially important in traumatic lower extremity tendinous repair.[15] ALT flaps yield minimal donor site morbidity and have the option for neurotization and protective sensation with inclusion of the lateral femoral cutaneous nerve.[16] For these reasons, the composite ALT and FL flap has overtaken other FTT sites, such as the lateral arm flap with vascularized triceps aponeurosis, for simultaneous tendon and soft tissue reconstruction in

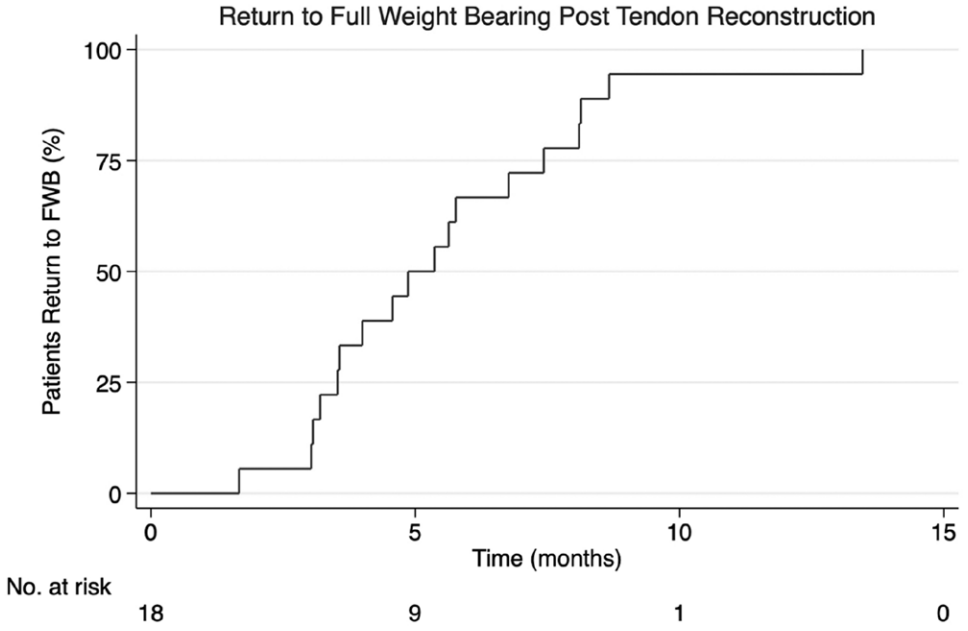

Fig. 4. Kaplan–Meier plot illustrating the robust return to weight-bearing after reconstruction of lower extremity tendon defects with composite anterior lateral thigh and fascia lata flaps. Eighteen of the 19 patients attained full weight-bearing status and also returned to ambulation.

Table 3. Operative Details and Outcomes

Characteristic	N (%), Mean (SD), Median (IQR)
Flap type	
Fasciocutaneous	12 (63.2%)
Adipofacial	5 (26.3%)
Myocutaneous	2 (10.5%)
Recipient vessel	
Posterior tibial	16 (84.2%)
Anterior tibial	2 (10.5%)
Geniculate	1 (5.2%)
Arterial anastomosis technique	
End-to-side	17 (89.5%)
End-to-end	2 (10.5%)
Venous anastomosis number	
Two vessels	13 (68.4%)
One vessel	6 (31.8%)
External fixation	
Yes	12 (63.2%)
No	7 (36.8%)
Return to weight bearing	
Yes	19 (100%)
Time to ambulation (mo)	4.4 (IQR: 3.4–7.8)
Complications	
Partial dehiscence	5 (26.3%)
Partial flap necrosis	3 (15.8%)
Infection	4 (21.1%)
Donor site complication	3 (15.8%)
Return to operating room	1 (5.2%)

our practice.[17] Although the lateral arm flap has demonstrated success in complex Achilles tendon reconstruction, inclusion of a portion of the triceps tendon for repair is not sufficient to restore long-term, maximal tendon function.[17] This deficiency leads to re-rupture and additional surgeries for definitive correction.

Reconstructive Locations

The composite ALT and FL flap has been successfully used for reconstructing defects of the Achilles tendon coupled with significant soft tissue loss.[18,19] However, few studies demonstrate utility of this reconstructive technique at other tendinous sites. In this review, composite ALT and FL flaps were successfully used for defects in the anterior compartment of the leg and the knee. All of the patients undergoing non-Achilles tendon reconstruction returned to full weight-bearing and ambulation. Although our sample size was relatively small for this cohort, this review demonstrates the versatility of the ALT and FL composite flap, and future studies should include a more robust analysis of other tendinous reconstructions. Sparse case reports on non-Achilles tendon reconstruction with composite flaps exist. Few groups have published case reports on reconstruction of patellar and quadriceps tendon defects.[20,21] However, the patients sustained remarkable range of motion deficiencies, with loss of 20 degree extension and 120 degree of flexion.[20] Future studies must evaluate range of motion after reconstruction in larger patient cohorts to ensure that a stable gait cycle can be reconstituted.

Postoperative Ambulation

The major goal of lower extremity tendon repair is to restore the normal gait cycle so that patients can meet preinjury levels of functionality. To do so, the neotendon must sustain repeated force while gliding—without gaps and without over-tightening. For example, the Achilles tendon needs to sustain a minimum of 190 N over repeated load cycles and glide 4 cm during the normal gait cycle.[8,17,22] Unfortunately, combined tendon and soft tissue injuries ultimately yield some degree of impairment, even with current methods of composite flap single-stage reconstruction. There can be wide variations in torque loss, ranging from 6.0% to 80.0% differences between injured and uninjured limbs, in patients undergoing composite flap reconstruction.[17] Patients with composite flap reconstruction for Achilles tendon defects had differences between injured and uninjured extremities in domains of range of motion (83% preinjury functionality) and plantarflexion (78.0% preinjury functionality), but no difference in dorsiflexion.[19] This compares favorably to other methods of tendon reconstruction. The systematic review by Iorio found that on average, patients with reconstructed vascularized tendons achieved 80.0% of the range of motion demonstrated on the unaffected side.[7] One hundred percent of our patients were able to achieve preinjury functionality and returned to both weight-bearing and ambulating. Median time to ambulation was 4.4 months (IQR: 3.4–7.8).

Patient Satisfaction

Even though patient reported outcomes were not collected in this retrospective review, several other studies demonstrate the beneficial impact that composite flaps have on quality of life. Jandali et al performed one of the larger studies (n = 20) on composite flap use for Achilles tendon reconstruction.[18] Their group demonstrated significant improvement on both the Achilles tendon Total Rupture Score and the American Orthopaedic Foot and Ankle Society score when comparing preoperative scores and 12-month postoperative scores.[18] Similarly positive results were found in the study by Ehrl et al, where 34 patients undergoing composite flap reconstruction for Achilles defects reported good to very good results for all nine categories assessed on the SF-36 questionnaire.[19] Of note, patient satisfaction was high, even though combined Achilles tendon and soft tissue reconstruction is notorious for high rates of postoperative complications. In their study, 12 of 25 flaps had some degree of postoperative complications, such as partial necrosis, hematoma formation, or issues with donor site healing.[19]

Complications

As mentioned, tendon reconstruction is notoriously challenging, even under optimal conditions. When coupled with extensive soft tissue loss, difficulties are compounded. An estimated 11 of 19 reconstructions had some degree of postoperative complications. Our complication rate is comparable to other series evaluating composite flap use in tendon and soft tissue reconstruction, which report complication rates from 30%–50%.[18,19] Of note, our reported complication rate includes primarily minor complications, such as partial necrosis, which require no more than local wound care for resolution.

However, this series demonstrates a highly favorable FTT success rate, with 94.7% successfully healing. The one

case of FTT loss was secondary to venous outflow thrombosis, which was unable to be salvaged even after operative takeback. This case highlights the need to rapidly identify vascular disruptions in FTT and improve our methods of treating postoperative FTT thrombosis.[23] Venous thrombosis is more common than arterial thrombosis, and most cases of vascular obstruction occur within the first 24–72 hours postoperatively.[23,24]

Limitations and Future Directions

This study is limited by its retrospective nature. In addition, formal functional analyses of reconstructions are relatively limited in general plastic surgery, and future studies evaluating the utility of composite flaps in tendon reconstruction should include preoperative and postoperative evaluations of functionality and patient satisfaction. Through these measures, providers will more aptly be able to meet physical and psychosocial needs of patients with tendon and soft tissue defects. A more robust analysis of patients undergoing tendon reconstruction at sites other than the Achilles will provide clearer evidence for composite flap use in those regions of the body.

CONCLUSIONS

Composite flaps, such as the ALT and FL, can be successfully employed in reconstructing various lower extremity tendon and soft tissue defects in a single-step procedure. Although the Achilles tendon is the most common setting for composite flap use, future studies should examine the utility of composite flaps throughout the body. The ALT is an optimal donor site, and its combination with the FL for tendon repair leads to rapid return to preinjury function, while yielding a sustained ability to bear weight and ambulate.

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