

Tibialis Anterior Reconstruction With Hamstring Autograft Using a Minimally Invasive Approach

Foot & Ankle International®
2018, Vol. 39(5) 535–541
© The Author(s) 2018
Reprints and permissions:
sagepub.com/journalsPermissions.nav
DOI: 10.1177/1071100717750883
journals.sagepub.com/home/fai

Sydney C. Karnovsky, BA^{1,2}, Bridget DeSandis, BA¹, Andrea K. Papson, DPT, SCS, CMPT, ATC, CSCS¹, Quinn O'Malley¹ , Robert DiGiacomo, DPT, ATC¹, Martin J. O'Malley, MD¹, Taylor N. Cabe, BA¹, and Mark C. Drakos, MD¹

Abstract

Background: Tibialis anterior tendon ruptures are rare and can cause significant dysfunction. Often, conservative measures are prescribed because of the morbidity of a tendon transfer as an operative solution. We present a novel reconstruction technique using hamstring autograft, which may obviate the need for local tendon transfer and long-term bracing.

Methods: Patients who underwent tibialis anterior reconstruction with hamstring autograft between 2011 and 2015 were screened for inclusion. Eight were included. Functional outcomes were assessed pre-and-postoperatively using the Foot and Ankle Outcome Score (FAOS), Visual Analog Pain Scale (VAS), and Short-Form-12 (SF-12) general health questionnaire. Isokinetic testing using a dynamometer (Biodex System 4 Pro) was performed at 60 and 120 degrees/s, respectively, for inversion/eversion and plantarflexion/dorsiflexion on both ankles at a minimum of 6 months postoperatively to determine peak torque, average power, and total work. Range of motion (ROM) testing was also performed, using a goniometer, at a minimum of 6 months postoperatively. Average follow-up was 17.3 (6.0-40.0) months for strength testing and ROM testing, and 18.5 (12.0-26.0) months for functional outcome scores.

Results: Average postoperative functional scores improved for all tests. ROM was similar between the uninvolved and involved ankles for inversion/eversion and plantarflexion/dorsiflexion. Patients showed deficits in dorsiflexion strength in all measures tested and improvements in inversion strength. All patients were able to ambulate without a brace.

Conclusion: Use of a hamstring autograft for tibialis anterior reconstruction resulted in good clinical outcomes. This procedure successfully restored ankle ROM postoperatively and tendon strength in inversion and dorsiflexion, with most patients showing little deficit when comparing their involved and uninvolved sides.

Level of Evidence: Level IV, Case series.

Keywords: tibialis anterior reconstruction, hamstring autograft, semitendinosus, gracilis, isokinetic testing

Introduction

Tibialis anterior tendon (TAT) ruptures are rare orthopedic injuries with few published reports documenting treatment methods and results.¹ When the TAT does tear, it is usually the result of either trauma to the ankle or chronic degeneration of the tendon. Traumatic rupture commonly occurs following laceration or blunt force trauma to the muscle.⁴ Degeneration is commonly seen in the elderly, as well as in people with diabetes, gout, psoriasis, or a history of corticosteroid injections. Signs of injury to the TAT include pain in the ankle and weakness affecting both dorsiflexion and inversion.⁷ Identifying this weakness can be difficult, as intact extensor hallucis and digitorum longus muscles often preserve some dorsiflexion strength at the level of the ankle. In addition to pain and weakness, another diagnostic sign is

a palpable mass at the anterior ankle where the tendon has retracted and is usually bulbous as a result of chronic tendinopathy.⁸

TAT ruptures can be treated either conservatively or operatively. Conservative treatment typically includes use of an ankle-foot orthosis on a permanent basis to avoid foot slapping.^{2,9,12} Operative treatment has historically been either a direct end-to-end repair or a tendon reconstruction using a tendon transfer.^{1,2,5,11,12} A surgeon's choice between

¹Hospital for Special Surgery, New York, NY, USA

²Georgetown University School of Medicine, Washington, DC, USA

Corresponding Author:

Sydney C. Karnovsky, BA, Hospital for Special Surgery, 535 East 70th Street, New York, NY 10021, USA.
Email: s.karnovsky@gmail.com

these treatment options depends on the functional deficit the patient has, the activity level of the patient, comorbidities, chronicity of injury, and the length of the tendon gap. With regard to a tendon transfer, an extensor hallucis longus (EHL) transfer is typically the tendon of choice. Because most cases are degenerative in nature, primary repair is usually reserved for acute traumatic lacerations while chronic cases require augmentation with a tendon graft due to degeneration of the tendon.^{2-4,12}

EHL transfer has been shown to produce good results but it often leads to weakness in the great toe. EDL and Achilles transfers have also been reported, but there is little information showing success rates of these procedures.⁹ Allograft reconstruction is an option that helps preserve toe strength, but increases risks of wound issues and theoretical late rejection complications. More recently, autograft and allograft tendon(s) from the hamstrings with an open technique have been reported to provide good results for reconstruction of the anterior tibialis tendon.^{1-4,12} Hamstring tendons have historically been used for anterior cruciate ligament (ACL) grafts and have been shown to be safe and have little donor site morbidity.¹³ We present a series of patients who underwent TAT reconstruction with a minimally invasive technique using a hamstring autograft that preserved the soft tissue envelope of the tendon as well as provided a thorough reconstruction of the degenerative TAT.

Methods

Patients who underwent TAT reconstruction with hamstring autograft between 2011 and 2015 by a fellowship-trained orthopedic surgeon were screened for inclusion. Fifteen patients were identified. Of these 15, 10 patients were willing to return for isokinetic strength testing. These 10 were enrolled in the study, and 2 were later excluded because of a concomitant talonavicular fusion in one and a tarsometatarsal fusion in the other. Retrospective chart review was also performed and functional outcomes were assessed pre- and postoperatively using the Foot and Ankle Outcome Score (FAOS), Visual Analog Pain Scale (VAS), and Short Form-12 (SF-12) general health questionnaire. Postoperative questionnaires were given out at least 1 year postoperatively at an average of 18.6 months postoperatively (range 12-26 months).

Postoperative range of motion (ROM) testing as well as isokinetic testing using a dynamometer (Biodex System 4 Pro) was performed for inversion/eversion and plantarflexion/dorsiflexion on the involved and uninvolved ankles at a minimum of 6 months postoperatively. Isokinetic testing was performed at 2 different speeds, 60 and 120 degrees/s, to determine postoperative strength and endurance of the repaired tendon, respectively. Peak torque produced in the testing cycle, maximum work patients could do in any rep,

average power, and total work were measured for each patient. This testing was done on average 17.3 (range 6.0-40.0) months after surgery.

Active range of motion was assessed by a physical therapist. Patients sat with their legs hanging off the end of a table and a goniometer was used to measure dorsiflexion, plantarflexion, inversion, and eversion (in degrees). For dorsiflexion and plantarflexion measurements, the center axis of the goniometer was placed under the lateral malleolus with the stationary arm centered on the tibia and the mobile arm in line with the fifth metatarsal (MT). For inversion and eversion measurements, the center axis of the goniometer was placed in between the malleoli anteriorly. The stationary arm was lined up to the tibial tuberosity along the tibia with the mobile arm along the second MT. For all measurements, 3 trials were performed in which the patient started at neutral and was asked to either dorsiflex, plantarflex, invert, or evert their ankle. After each trial, the patient was instructed to return to neutral and the arms of the goniometer were realigned. The average of the 3 trials is reported for each patient.

Variables of interest in this study were summarized using means and ranges. Differences between the affected and contralateral side were assessed with *t* tests. Statistical significance was set at $P < .05$. All analyses were performed using SAS software, version 9.3 (SAS Institute, Inc, Cary, NC).

Operative Technique

For all patients, the TAT was identified. Upon confirmation of a rupture and/or a significant degree of tendon degeneration, the damaged area (midsubstance for all 8 patients) was removed. Usually this meant removing 2 to 3 cm of the distal part of the tendon, which left a gap. Determination of which hamstring tendon to harvest and use for the autograft was made on a case by case basis. Either gracilis or semitendinosus was used, depending on size of the tendons. In the 8 patients in this report, 5 received semitendinosus autografts and 3 received gracilis autografts. After determining which tendon to use for the graft, the semitendinosus or gracilis was harvested. The sartorial fascia was transected in line with its fibers exposing the hamstring tendons. Whichever tendon was being used was released from its adhesions and harvested with a Linvatec tendon stripper (ConMed Corporation, Edison, NJ) and then tubularized and prepared (Figure 1). In our experience, the TAT diameter is typically 5 to 6.5 mm, whereas the gracilis and semitendinosus diameters are approximately 3.5 to 4.5 mm. Thus, we suggest using a double-bundle technique to approximate the normal TAT girth by weaving the hamstring tendon selected (either semitendinosus or gracilis) back down over itself in order to reestablish the size of the native TAT.

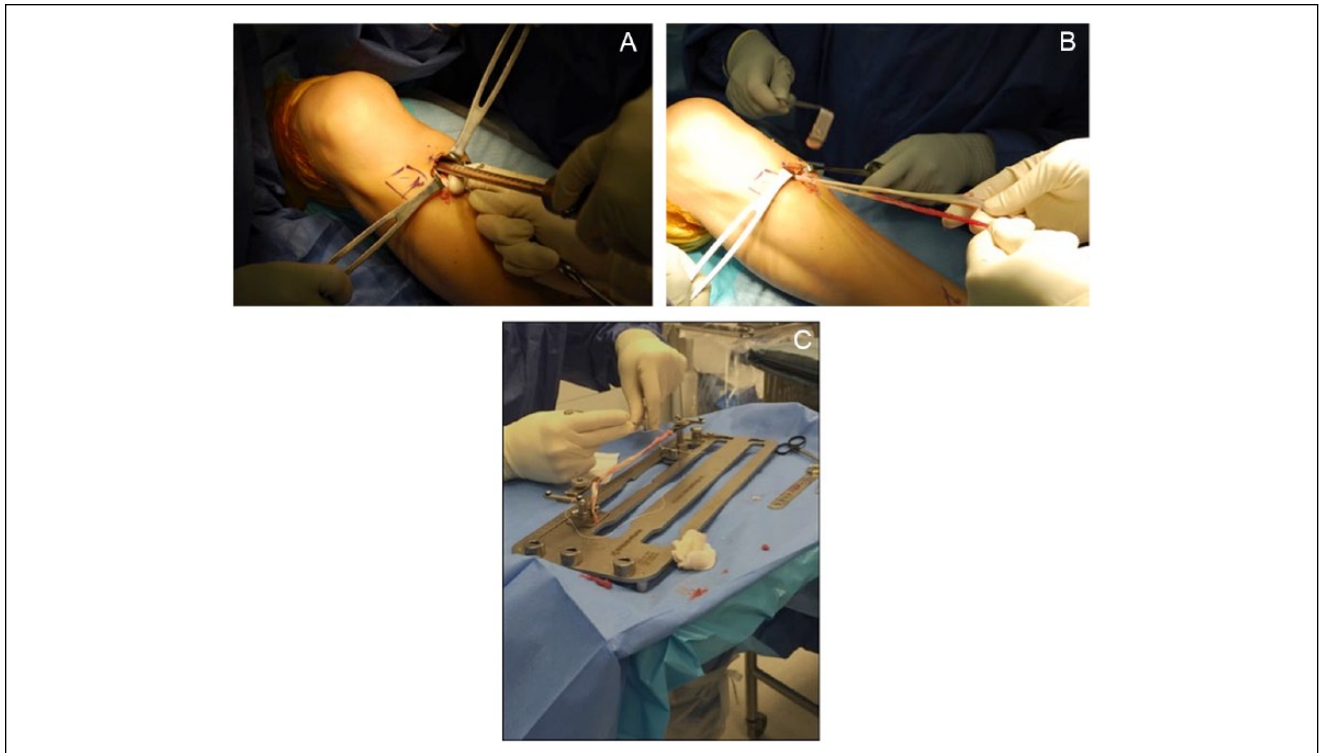


Figure 1. (A) The gracilis and/or semitendinosus tendons are harvested using the Linvatec tendon stripper. (B) The gracilis and semitendinosus are shown during harvest. (C) The tendons are prepared and tubularized using the Graft Master III (Smith & Nephew, Andover, MA) for assistance.



Figure 2. The tendon stump is mobilized.

The ruptured TAT could usually be palpated most commonly at the level of the ankle joint. An incision was made slightly proximal to the tendon tear to access the more normal tendon during this portion of the operation (Figure 2). This incision was approximately 2 to 3 cm in length and centered over the tendon. The TAT was then mobilized and brought into the incision. The tibialis anterior stump was resected back to normal-looking tendon based on texture and appearance. A second 2- to 3-cm oblique incision was then made over the medial aspect of the medial cuneiform in



Figure 3. The hamstring graft is secured in the bone tunnel using a Bio-Tenodesis screw.

order to locate the TAT attachment. Once this was found, there was typically some residual TAT remnant present as well. A bone tunnel was then drilled obliquely in the medial cuneiform at the TAT insertion site in the same vector as the native TAT. The diameter of the tunnel was made within 0.5 mm of the hamstring graft. Next, the hamstring graft was inserted into the base of the bone tunnel and a Bio-Tenodesis screw (Arthrex, Naples, FL), typically sized 4.75 x 15 mm, was used to secure the distal end of the graft to the medial

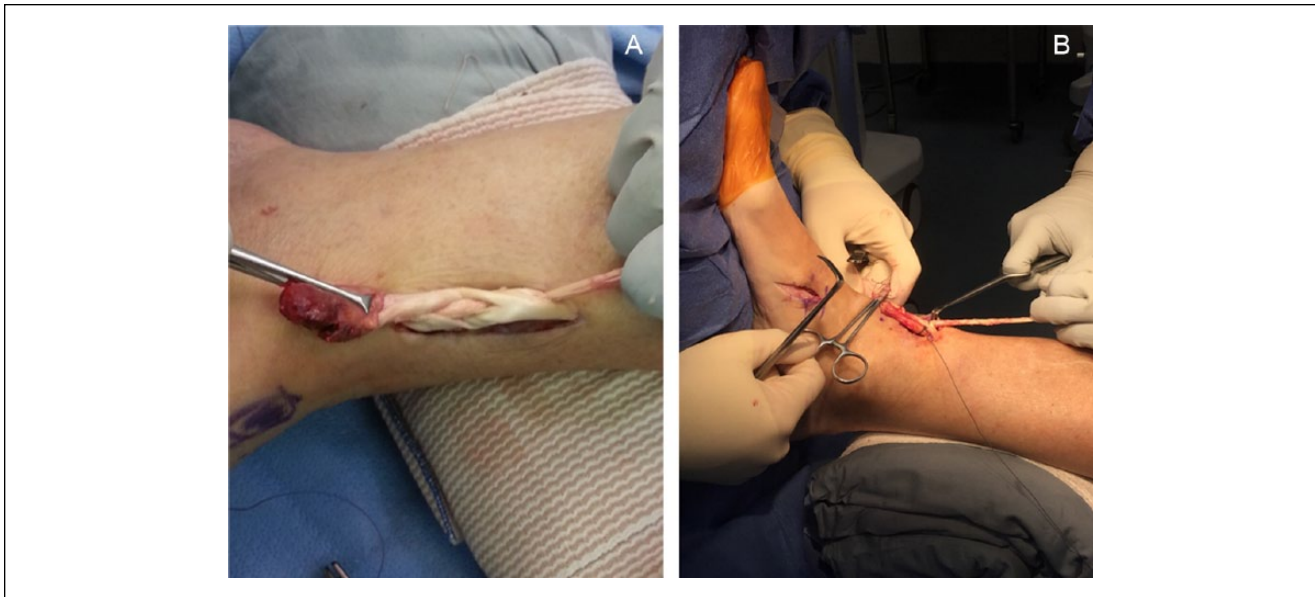


Figure 4. (A) The hamstring autograft is woven into the remaining native TAT using a Pulvertaft maneuver. (B) Following the Pulvertaft maneuver, the new tendon is secured at the Pulvertaft weave site using sutures.

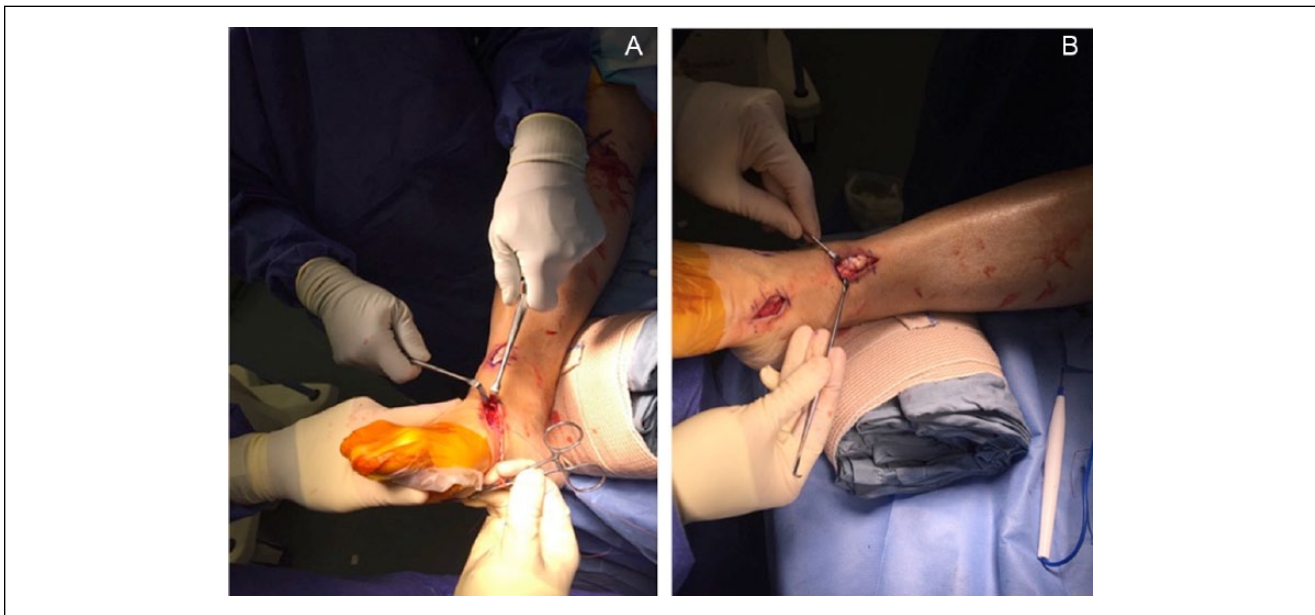


Figure 5. (A) The hamstring autograft is distally passed back down to create a double-bundle effect. (B) The hamstring graft is tied to the sutures in the Bio-Tenodesis screw and native tendon stump.

cuneiform (Figure 3). The hamstring tendon was then passed subcutaneously and proximally to the TAT stump. An extensor retinaculum release was performed in order to relieve tension and prevent stenosis of the graft. The tendon was then tensioned to confirm adequate fixation and remove crimp from the graft. A Pulvertaft maneuver was then executed with the foot in approximately 5 degrees of dorsiflexion, and the tendon was secured proximally with several No.

2 Orthocord sutures (Figure 4). Usually 2 passes were made through the proximal tendon. The remaining graft was then subcutaneously tunneled distally back down to the insertion site and secured with the other limb of suture from the Bio-Tenodesis screw (Figure 5). This further improved the tension as the native TAT was pulled distally while securing the second limb of the graft in the medial cuneiform. The whole graft was then tubularized with a 3-0 Vicryl suture and with

a whip stitch with 2-0 Vicryl between the skin incisions. The wounds were closed and all patients were placed in a splint in a neutral non-weightbearing position for 2 weeks. At 2 weeks postoperatively, the incisions were inspected and sutures were removed. Following suture removal, patients were placed in a controlled ankle movement (CAM) walker boot and instructed to bear weight as tolerated for 4 weeks with passive dorsiflexion ROM exercises. Active ROM was allowed at 6 to 12 weeks postoperatively and strengthening exercises were started at 8 to 10 weeks postoperatively. Patients were allowed to progress out of the CAM boot at around 10 weeks postoperatively and could expect to return to normal activities by 4 to 5 months postoperatively.

Results

Average postoperative scores improved for the VAS pain, SF-12, and all subscales of the FAOS (Table 1). The VAS pain scale, SF-12, and FAOS pain, symptoms, daily activities, sports, and quality subscales all improved postoperatively with average pre- to postoperative changes of 2.7 (range 0 to 8), 11.4 (range 0 to 24.7), 23.3 (range 0 to 41.7), 13.6 (range -3.6 to 28.6), 13.5 (range -4.4 to 38.2), 25 (range -15 to 65), and 36.7 (range 0 to 75), respectively. None of these changes reached statistical significance.

Range of motion results were similar between the non-operative and operative ankles for inversion, eversion, plantarflexion, and dorsiflexion, with average differences (in degrees) between the nonoperative and operative side of 1.1, -1.3, 3.6, and -0.2, respectively (Table 2).

Strength and endurance testing was categorized by comparing the operative side to the nonoperative side. Patients showed, on average, improvements in inversion strength and endurance in all measures tested. Patients showed more deficits in dorsiflexion strength and endurance, with mean measures of peak torque, average power, and total work in dorsiflexion of 69%, 60%, and 48%, respectively, that of the nonoperative side at 60 degrees/s; and 68.4%, 62.8%, and 56%, respectively, that of the nonoperative side at 120 degrees/s (Table 3). All patients were able to ambulate without a brace or noticeable limp. There were no infections or nerve complications. One patient had some knee soreness related to the hamstring harvest site that resolved within 4 weeks.

Discussion

Traumatic rupture of the TAT is not common and the diagnosis is frequently delayed. Because of the rarity of the condition, there is no clear treatment algorithm for this condition. In the few published reports of TAT ruptures, EHL, EDL, and peroneus brevis transfers are the most frequently described options for TAT reconstruction.² Despite their relative popularity in the literature, none of these

Table 1. Functional Outcome Scores.

Outcome	Pre- to Postoperative Change	P Value (P < .05)
VAS pain scale	2.67 (0 to 8)	.278
SF-12	11.4 (0 to 24.7)	.419
FAOS pain	23.3 (0 to 41.7)	.215
FAOS symptoms	13.6 (-3.6 to 28.6)	.567
FAOS activities	13.53 (-4.4 to 38.2)	.289
FAOS sports	25 (-15 to 65)	.223
FAOS quality of life	36.7 (0 to 75)	.063

options are ideal because they all involve the potential for associated foot morbidity.² The largest series of patients receiving operative treatment in the literature reports 19 TAT ruptures in 18 patients.⁹ Seven of these patients received a direct repair of the tendon and 12 had interpositional tendon grafts, with 5 receiving a plantaris graft, 5 an EDL graft, 1 an Achilles graft, and 1 where both an Achilles and an EHL graft was used.⁹ This article did not explain the choice of donor tendon or any sort of treatment algorithm, highlighting the need for further investigation into the various treatment options for TAT ruptures.⁹

Recently, in order to decrease the associated foot morbidity involved with local tendon transfers, several authors have described operative techniques that use hamstring grafts to reconstruct ruptured TATs. One study described using a semitendinosus autograft with a minimally invasive technique in 12 patients.⁶ This study reported functional outcome scores but lacked objective ROM or strength-testing data for their patients.⁶ Another study reported a series of 2 patients receiving a double-bundle gracilis autograft. Strength testing was performed on both patients, 2 years postoperatively, using a Cybex system. This study did not report the speed of testing, but found that the 2 patients had dorsiflexion strength that was 83% and 78% that of the operative side.¹⁰ These early results demonstrated the potential successful use of hamstring autografts to reconstruct ruptured TATs but had limited numbers and follow-up measures.

In the current study, we report on 8 patients who underwent hamstring reconstruction for TAT ruptures who were all assessed using isokinetic strength testing, ROM testing, in addition to clinical outcome surveys. Our results build on the small amount of existing literature that supports the use of hamstring autografts for TAT ruptures. We found improved clinical outcome scores as well as only small strength deficits between the involved and uninvolved sides in ROM and isokinetic strength testing. Based on our results, the use of a hamstring autograft led to a positive change in symptoms in our patient population, specifically allowing patients to ambulate without a brace. The postoperative strength and ROM results demonstrate that although

Table 2. Range of Motion Testing Results.

	Nonoperative Side	Operative Side	Nonoperative – Operative Side Difference	P Value ($P < .05$)
Plantarflexion	43.2 (30 to 50)	39.6 (0 to 47.3)	3.6 (-2.3 to 50)	.56
Eversion	14.8 (7.3 to 34.3)	16.0 (10 to 25)	-1.3 (-7.7 to 23)	.70
Dorsiflexion	9.8 (0 to 15)	10 (0 to 55)	-0.2 (-3 to 45)	.97
Inversion	27.2 (12 to 40)	26.1 (15 to 40)	1.1 (-12 to 16.7)	.76

Table 3. Isokinetic Strength Testing Results at 60 degrees/s (Strength) and 120 degrees/s (Endurance).

	Operative Side (Shown as % of Nonoperative Side) at 60 degrees/s	P Value ($P < .05$)	Operative Side (Shown as % of Nonoperative Side) at 120 degrees/s	P Value ($P < .05$)
Peak torque (inversion)	120 (67-152)	.142	111 (82-169)	.335
Peak torque (dorsiflexion)	69 (34-124)	.026	68.4 (21-109)	.026
Average power (inversion)	125 (68-161)	.112	126 (75-229)	.493
Average power (dorsiflexion)	60 (46-87)	.005	62.8 (64-102)	.045
Total work (inversion)	131 (64-194)	.128	135 (77-269)	.419
Total work (dorsiflexion)	48 (15-77)	.001	56 (5-86)	.016

a functional deficit following TAT reconstruction with a hamstring autograft does exist, it does allow for patients to walk comfortably without a brace or noticeable limp. Although TAT injury and subsequent reconstruction is perhaps a factor for more high-demand activities such as running, for routine activities of daily living, our patients did not report a clinical deficit. Our patient population showed only small differences in ROM between the uninvolved and involved sides, showing that the operation did not significantly inhibit them from making a return to nearly full ROM in their ankles. Our finding that postoperative deficits in dorsiflexion strength exist at both 60 and 120 degrees/s is consistent with previous reports that also found a decrease in dorsiflexion following operative repair and reconstruction of the TAT using a variety of operative techniques.^{2,5,10}

Based on these results, and prior literature, restoring full dorsiflexion strength to the operative side may not be typical.⁵ Additionally, our minimally invasive technique has the advantage of utilizing smaller incisions and thus may lead to a quicker recovery. Making 3 smaller incisions rather than 1 large 10-cm incision has a theoretical benefit of reducing the risk of wound complications in the foot and ankle. The smaller incisions had minimal wound healing issues and allowed for early weightbearing. It is also unlikely that the graft stretched out as passive range of motion was not significantly different from the operative side. The hamstring harvest was also through a small incision and has been well established in the orthopedic literature, with only modest strength deficits at high knee flexion angles, which may not be clinically significant for this

patient group. Furthermore, by obviating the need to use the EHL tendon, or any other foot tendon, our technique reduced the risk of associated foot morbidity.¹

Our study has several limitations. Given the incidence of the pathology, the numbers from which we had to draw are small. Inversion strength as compared to the nonoperative side increased, on average, in our patient population. This result is unusual, as after an injury to the TAT, the expected result is measurable weakness in inversion strength.⁵ Inversion differences between the operative and nonoperative side were not statistically significant, which is likely due to the existence of 1 or 2 outliers in each test that showed a 150% to 230% increase in strength. This large increase can be partially attributed to an increase in physical therapy on the affected side as well as asymmetric strengthening of the posterior tibial tendon, which is the main inverter of the foot. Some patients may have overcompensated when they lost dorsiflexion strength, leading them to build additional inversion strength in the posterior tibial tendon as well as the TAT. Additionally, the FAOS was used to assess patient outcomes, but it is not validated for this specific condition because of the small number of patients presenting with TAT injuries.

In conclusion, despite these limitations, both the strength-testing measurements and clinical scores that were obtained demonstrate that in this series of patients, using a hamstring autograft to reconstruct a ruptured TAT was a successful operative technique that led to good patient outcomes and low clinical morbidity. Further study is needed to investigate the results of more patients as well as the long-term outcomes of this procedure.

Approval Statement

The study took place at the Hospital for Special Surgery and was approved by the institution's Foot and Ankle Registry, which is approved by our Institutional Review Board.


Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article. ICMJE forms for all authors are available online.

Funding

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

ORCID iD

Quinn O'Malley  <https://orcid.org/0000-0002-7864-5963>

References

- Burton A, Aydogan U. Repair of chronic tibialis anterior tendon rupture with a major defect using gracilis allograft. *Foot Ankle Spec.* 2016;9(4):345-350.
- Goehring M, Liakos P. Long-term outcomes following anterior tibialis tendon reconstruction with hamstring autograft in a series of 3 cases. *J Foot Ankle Surg.* 2009;48(2):196-202.
- Huh J, Boyette DM, Parekh SG, Nunley JA. Allograft reconstruction of chronic tibialis anterior tendon ruptures. *Foot Ankle Int.* 2015;36(10):1180-1189.
- Kontogeorgakos V, Koutalos A, Hantes M, Manoudis G, Badras L, Malizos K. Traumatic tibialis anterior tendon rupture: treatment with a two-stage silicone tube and an interposition hamstring tendons graft protocol. *Knee Surg Sports Traumatol Arthrosc.* 2015;23(3):875-878.
- Kopp FJ, Backus S, Deland JT, O'Malley MJ. Anterior tibial tendon rupture: results of operative treatment. *Foot Ankle Int.* 2007;28(10):1045-1047.
- Michels F, Van Der Bauwhede J, Oosterlinck D, Thomas S, Guillo S. Minimally invasive repair of the tibialis anterior tendon using a semitendinosus autograft. *Foot Ankle Int.* 2014;35(3):264-271.
- Ouzounian TJ, Anderson R. Anterior tibial tendon rupture. *Foot Ankle Int.* 1995;16(7):406-410.
- Reb CW, Stenson JF, Daniel JN. Tibial anterior tendon reconstruction using augmented half-thickness tendon segment transposition. *Foot Ankle Spec.* 2017;10(2):144-148.
- Sammarco VJ, Sammarco GJ, Henning C, Chaim S. Surgical repair of acute and chronic tibialis anterior tendon ruptures. *J Bone Joint Surg.* 2009;91(2):325-332.
- Stavrou P, Symeonidis PD. Gracilis tendon graft for tibialis anterior tendon reconstruction: a report of two cases. *Foot Ankle Int.* 2008;29(7):742-745.
- Van Acker G, Pingen F, Luitse J, Goslings C. Rupture of the tibialis anterior tendon. *Acta Orthop Belg.* 2006;72(1):105-107.
- Van Den Bekerom MPJ, Kerkhoffs GMMJ, McCollum GA, Calder JD, van Dijk CN. Management of acute lateral ankle ligament injury in the athlete. *Knee Surg Sports Traumatol Arthrosc.* 2013;21(6):1390-1395.
- Yasuda K, Tsujino J, Ohkoshi Y, Tanabe Y, Kaneda K. Graft site morbidity with autogenous semitendinosus and gracilis tendons. *Am J Sports Med.* 1995;23(6):706-714.