Limited Scar Resection for Chronic Achilles Repair: Use of a Rat Model

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Introduction

Acute rupture of the Achilles tendon is misdiagnosed in up to 24% of patients.[1] Without acute intervention, the tendon ends retract, the injury gap fills with scar tissue, and treatment becomes more difficult.[2] Current treatment of chronic Achilles tendon ruptures involves debridement of scar tissue back to normal tendon ends, followed by interposition of healthy graft tissue to fill the gap, such as in the gastrocnemius fascia turndown (GFT) technique.[3] Direct repair with the limited scar resection (LSR) technique offers a less invasive alternative, allowing for primary repair of the tendon without a graft, avoiding donor site morbidity.[4] However, LSR has not been adopted as a common surgical alternative due to concern that scar tissue does not heal as well as healthy donor graft tissue. Therefore, the objective of this study was to define and compare the healing properties of the Achilles tendon after chronic injury reconstruction with GFT or LSR, utilizing an animal model to control the injury and treatment strategies. We hypothesized that LSR would have superior healing properties to the GFT and non-repair control groups in a chronic Achilles injury model.

Methods

After facility acclimation, 90 male Sprague Dawley rats (400-450g) were used (IACUC approved). Animals were randomized equally into three groups: non-repair (NR), gastrocnemius fascia turndown (GFT), and limited scar resection (LSR). Chronic Achilles injury was generated via unilateral blunt transection of the right Achilles tendon in each rat, followed by 1 week of immobilization of the injured limb in a maximally dorsiflexed position and 5 weeks of cage-activity without immobilization. 6 weeks after the index surgery, GFT and LSR groups underwent chronic Achilles reconstruction. In the GFT technique, all interposed scar tissue was debrided, then the gastrocnemius fascia was flipped on a distal hinge to bridge the gap, reconstructing the tendon. In the LSR technique, a small midsection of the scar tissue was removed to restore the tendon to pre-injury length, followed by end-to-end primary repair of the remaining scar tissue ends. A modified Kessler repair was used in both techniques. The hind limb was immobilized in plantarflexion after the index surgery. Animals were sacrificed at 3 and 6 weeks after repair. The NR group was sacrificed at 9 and 12 weeks from the index procedure to match sacrifice points for all three groups. All rats underwent biweekly in vivo assessments including ambulatory kinetics and kinematics, passive ankle joint mechanics, and ultrasound. Ex vivo assessments included mechanical testing and histology. Cycles to failure comparisons were made using a nonparametric Kruskal-Wallis ANOVA. Other ex-vivo comparisons were made using 1-way ANOVAs. In-vivo assessment comparisons were made using a 2-way ANOVA with repeated measures on time with follow-up t-tests between groups at each time point. Significance was set at $p < 0.05$ for all tests.

Results

Ultrasound

Ultrasound assessment showed successful post-injury elongation of the Achilles tendon in all groups which is critical to the chronic Achilles injury model. The cross-sectional area of each of the repaired tendons was significantly increased compared to the NR tendons at both time points. The LSR repair had increased vascularity compared to NR in the post-repair period, with increased contrast wash-in rate and decreased contrast time to peak at the 9 week time point.

Mechanical Testing

Stiffness of LSR and GFT repairs was significantly lower compared to NR at 3 weeks. At 6 weeks, LSR and GFT tendon stiffness improved, such that there was no longer a difference between the three groups. Modulus was significantly lower in both LSR and GFT groups at both 3 and 6 weeks. Cycles to failure (CTF) was significantly higher in NR at 3 weeks as compared to both LSR and GFT. CTF improved in both repair groups at 6 weeks such that there was no longer a difference between the three groups.

Passive Joint Mechanics

Passive joint mechanics revealed significantly increased dorsiflexion stiffness in the GFT repair group at the first post-repair time point

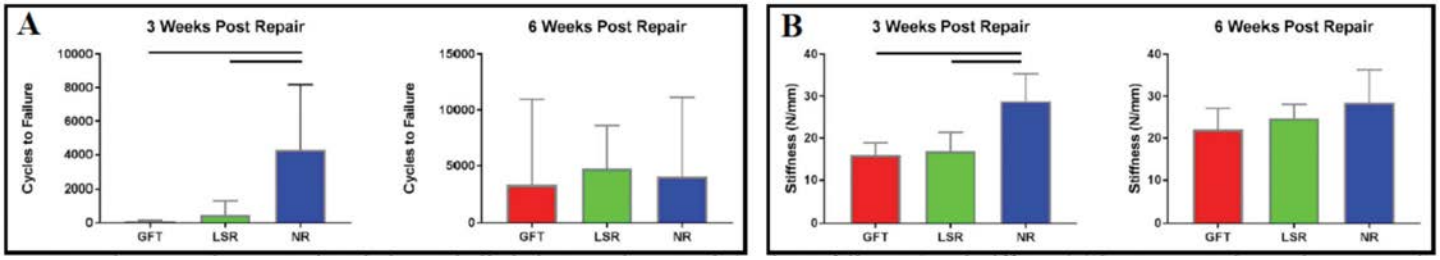

Figure 1. Both GFT and LSR repair techniques similarly improve in strength (cycles to failure, **A**) and stiffness **(B)** between 3 and 6 weeks post repair.

at 8 weeks when compared to NR. LSR repair had increased dorsiflexion stiffness that trended toward significance at the 8 week time point compared to NR. Both LSR and GFT groups had significantly decreased range of motion at the 8 week post-repair time point as compared to NR.

Ambulatory Assessment

Gait analysis of the GFT and LSR repair groups had significantly decreased ground reaction forces (peak vertical force, peak propulsion forces) as compared to the NR group at the first post-repair assessment 8 week time point. Ground reaction forces were recovered quickly in the LSR group, with no significant difference from the NR group at 10 and 12 weeks. Ground reactive forces for the GFT group remained significantly decreased from the NR group at both 10 and 12 weeks without recovery.

Discussion

The present study supports that both LSR and GFT reconstruction techniques are viable options for treatment of the chronic Achilles tendon injury in a rat model. We established that the injury surgery successfully recreated the elongated Achilles tendon typical of the chronic Achilles injury. Both reconstruction techniques established increased dorsiflexion stiffness and decreased range of motion across the ankle joint. This is representative of the re-establishment of normal length and tension of the Achilles complex in both of the repair groups, which is critical to the success of operative management of a chronic Achilles injury. Ground reaction forces were expectedly decreased after surgery, but quickly recovered in the LSR group, while the GFT group remained significantly decreased through the study. This is reflective of the decreased morbidity incurred by the LSR technique, allowing for a significantly shorter recovery time. Vascular analysis provided evidence of adequate microcirculation and vascularization of this tissue, contesting the notion that a lack of circulation in scar tissue would be a barrier to healing in this technique. Mechanical testing results raise the question of whether these tendons fared better with non-operative management compared to either reconstruction technique. However, it must be noted that at the 3 week and 6 week post-repair sacrifice points, the NR tendons are actually matured to 9 and 12 weeks, respectively. The difference in the relative maturity of the tendon in NR vs GFT/LSR groups inherently introduces a difference in stiffness and strength between the groups. Importantly, the repair groups were able to match the stiffness and strength of the NR group at the 6 week time point, when they have had relatively half the time for healing and scar maturation as the NR group. A limitation of the rat model is that the gastrocnemius muscle of the rat is relatively thinner with a larger soleus as compared to humans, and as such the GFT procedure may cause relatively larger morbidity to the gastrocnemius muscle in the rat.

Significance

This study supports that the limited scar resection technique is a viable surgical alternative, particularly when minimizing postoperative morbidity and surgical time are paramount. The study also suggests the non-operative management of chronic Achilles injuries may yield similar results as compared to operative management, which necessitates further research into conservative treatment modalities for this condition.

References

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