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]
- 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].
- Recently, direct repair with the limited scar resection (LSR) technique has been proposed as a less invasive alternative, allowing for primary repair of the tendon without a graft, thus avoiding donor site morbidity [4].
- However, it is unclear if LSR provides similar or improved healing outcomes when compared to the traditional GFT technique or a chronically untreated Achilles tendon.
- **Our objective was to compare the healing response of the LSR and GFT techniques in a novel rat model of chronic Achilles tendon injury.**
- We hypothesized that the LSR technique would result in superior tendon mechanical properties when compared with the GFT or non-repaired chronic Achilles tendon injury models.

Materials and Methods

Study Design:

- After facility acclimation, 90 male Sprague Dawley rats (400-450g) were used (IACUC approved) and randomized equally into three groups: Non-repair (NR), gastrocnemius fascia turndown (GFT), and limited scar resection (LSR) (Fig. 1).
- 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.
  - **GFT:** all interposed scar tissue was debrided, then the gastrocnemius fascia was flipped on a distal hinge to bridge the gap, reconstructing the tendon.
  - **LSR:** 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.

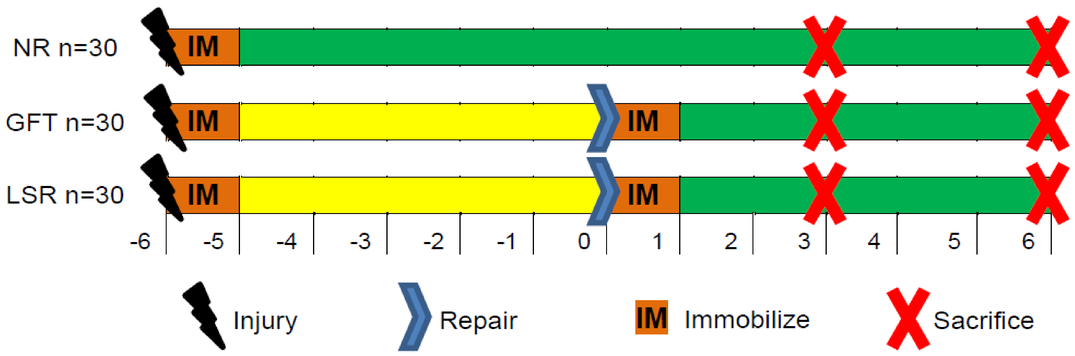


Figure 1: Study design indicating timepoints (weeks) for Achilles tendon injury, immobilization, LST or GFT repair along with sacrifice time points.

Data Collection:

- In vivo assessments
  - Ambulatory gait kinematics and kinetics (2, 4, 6 weeks post repair)
  - Passive ankle joint mechanics (2, 4, 6 weeks post repair)
  - Ultrasound (3 and 6 weeks post repair)
- Ex vivo assessments (Fig. 2)
  - Fatigue mechanics (3 and 6 weeks post repair)
  - Quasi-static mechanics (3 and 6 weeks post repair)

Statistical Analyses:

- 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 $p<0.05$ and trending differences at $p<0.1$.

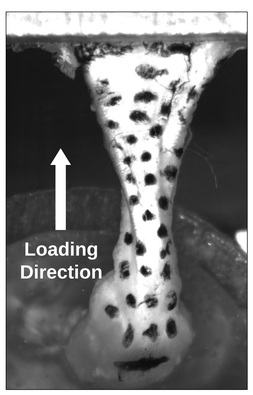


Figure 2. Achilles mechanical testing. Calcaneus-foot complex in PMMA with stain dots for optical strain tracking.

Results

Mechanical Testing:

- Ultrasound assessment showed successful post-injury elongation of the Achilles tendon in all groups at 6 weeks post rupture (data not shown).
- Stiffness of the LSR and GFT repairs was lower compared to NR at 3 weeks (Fig. 3A).
- Stiffness of the LSR group was not different between the NR or GFT groups, while the GFT group had a lower stiffness than the NR group at 6 weeks (Fig. 3A).
- Modulus was lower in both LSR and GFT groups at both 3 and 6 weeks (Fig. 3B)
- Cycles to failure (CTF) was higher in NR when compared to both LSR and GFT at 3 weeks with no differences among groups at 6 weeks (data not shown).

Passive Joint Mechanics:

- Joint range-of-motion decreased for the GFT and LSR groups 2 weeks post-repair, and this difference was sustained at 4 and 6 weeks (Fig. 4A).
- Dorsiflexion stiffness was elevated for the GFT and LSR groups 2 weeks post repair. There were no differences at 4 and 6 weeks (Fig. 4B).

Ambulatory Gait Assessment:

- Kinetic analysis of the GFT and LSR repair groups revealed decreased peak vertical force and peak propulsion force when compared to the NR group at 2 weeks post-repair (Fig. 5). These differences were sustained for the GFT group but not the LSR groups at 4 and 6 weeks post-repair.

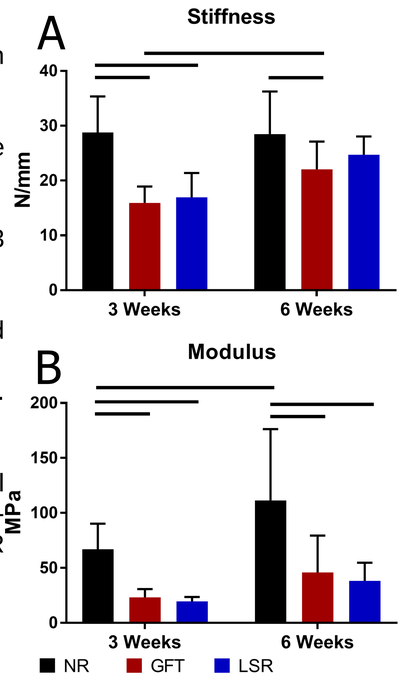


Figure 3. Mechanical Properties. (A) GFT and LSR groups had decreased stiffness at 3 weeks post-repair. GFT group stiffness was still lower at 6 weeks, while LSR group stiffness was no different than NR. **(B)** GFT and LSR groups had lower modulus when compared to NR at 3 and 6 weeks post-repair. Data presented as mean +/- standard deviation. Bars indicate significance $p<0.05$.

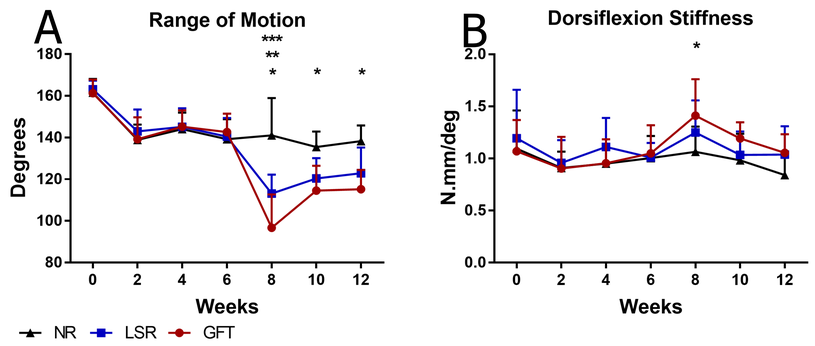
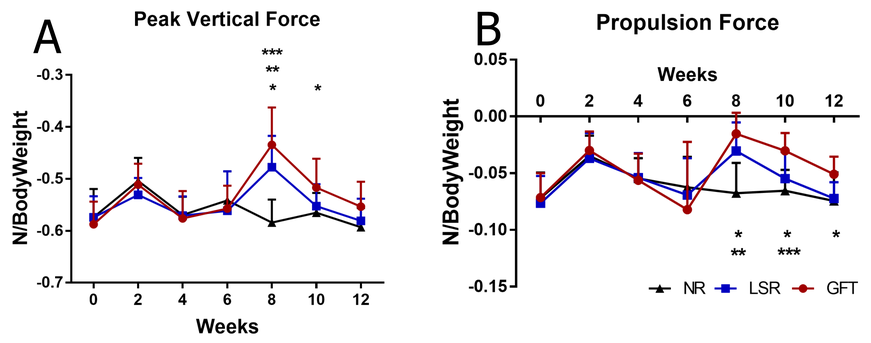


Figure 4. Joint Kinematics (A) GFT and LSR groups had decreased range-of-motion at 2 weeks post repair. GFT range-of-motion sustained these differences at 4- and 6-weeks post-repair. **(B)** GFT and LSR dorsiflexion stiffness was higher 2-weeks post-repair but these differences were not present at later time points. Data presented as mean +/- standard deviation. * indicates significance between GFT vs NR $p<0.05$, ** indicates significant between LSR vs NR $p<0.05$, and *** indicates significance between GFT vs LSR $p<0.05$.

Figure 5. Gait Kinetics. (A) GFT and LSR groups had reduced peak vertical force at 2-weeks post-repair but these differences disappeared at 6 weeks. **(B)** GFT and LSR groups had lower propulsion force at 2 weeks post-repair. These differences were not present in the LSR group but were sustained for the GFT group at 6 weeks post-repair. Data presented as mean +/- standard deviation. * indicates significance between GFT vs NR $p<0.05$, ** indicates significant between LSR vs NR $p<0.05$, and *** indicates significance between GFT vs LSR $p<0.05$.



Conclusions

- The present study supports both LSR and GFT repair techniques as viable options for treatment of chronic Achilles tendon injury.
- This study also presents a novel model for the creation of a chronic Achilles tendon rupture in a rat. This model was reliably able to reproduce a chronically lengthened tendon as is seen typically in a clinical presentation.
- The LSR technique consistently showed faster return to baseline measures in joint kinetics and kinematics when compared to the GFT approach. This could be reflective of the decreased morbidity incurred in the LSR technique, thus allowing for shorter recovery time.
- Interestingly, the non-repaired group consistently showed better healing metrics in most parameters measured, which is consistent with multiple studies supporting conservative treatment for Achilles tendon ruptures.
- **Overall, 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 that 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 & Acknowledgments

[1] Raikin et al., 2013. Foot Ankle Int. 34:475-80. [2] Bevilacqua et al., 2012. Clin Podiatr Med Surg. 29:291-9. [3] Maffulli et al., 2007. Foot Ankle Clin. 12:583-96. [4] Yasuda et al., 2016. J Bone Joint Surg Am. 98:1168-75.

Funding was provided by the Orthopaedic Research and Education Foundation and the NIH/NIAMS supported Penn Center for Musculoskeletal Disorders (P30AR069619).