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Review

Efficacy of repair techniques of the Achilles tendon: A meta-analysis of human cadaveric biomechanical studies

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HIGHLIGHTS

- A systematic review of human biomechanical studies for Achilles repair.
- The maximal load to failure was significantly higher when using double row technique for Achilles reinsertion.
- Bunnell and Krakow sutures were significantly stronger than the Kessler sutures for mid-tendon repair.
- Recommendations for future research to address the gaps related to Achilles repair.

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ABSTRACT

Purpose: Achilles injuries are very common, mainly among young athletes. When indicated, the surgical treatment aims for strong repairs that can resist distraction and consequently ruptures. The majority of the published clinical meta-analyses reported comparisons between broad treatment modalities such as conservative treatment, open, and minimally invasive surgery.
Methods: A meta-analysis has been conducted to assess further clinical and biomechanical variables on human cadavers related to the efficacy of Achilles repair. A total of 26 studies with 596 legs met the inclusion criteria. The maximal load to failure was set as the primary outcome. Eleven studies were amenable to meta-analysis.
Results: In the reinsertion group, the analysis of the *single row vs. double row* subgroup showed a significantly higher strength for the latter (1.27, 95% CI = 0.748–1.806, I^2 = 81%, P < 0.0001). In the mid-tendon repair group, the *Achillon vs. Krackow sutures* and the *Bunnell vs. Krackow sutures* subgroups showed no difference while the Bunnell and Krakow sutures were significantly stronger than the Kessler sutures (0.96, 95% CI = 0.510–1.405, I^2 = 63.3%, P < 0.0001 and 1.37, 95% CI = 2.286–0.468, I^2 = 83.4%, P = 0.003; respectively).
Conclusions: The assessment of heterogeneity located variables such as age, suture/material type, number of strands, type of testing machine and software, preloading, ankle position and loading type as potential confounders. The results of this meta-analysis are likely to have a significant impact in clinical practice.

1. Introduction

The Achilles tendon is the most frequently ruptured tendon; almost a third of sport-related injuries affect the Achilles tendon [1,2] occurring mostly during activities such as racket games, football and handball [3–5]. Despite the fact that both conservative and surgical treatment are considered as good options for the treatment of Achilles' ruptures, some initial controversy appeared in relation to the rate of re-rupture [6–10]. Recently, Erickson et al. [11] conducted a systematic review of overlapping meta-analyses and concluded that operative treatment of Achilles tendon ruptures decreases significantly re-rupture rates.

In both situations, that of acute ruptures and insertional tendinopathies, there is a lack of evidence in relation to the efficacy of surgical treatment of Achilles injuries, should it be mid-tendon suturing or reinsertion. Though different configurations of sutures in open surgery and material assisting suturing in minimally

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invasive techniques are reported, still the ideal form of surgical treatment of a rupture of the Achilles tendon remains controversial [12–16]. Early weight-bearing mobilization and strengthening exercises are increasingly being used to promote tendon healing [17–21]. Additionally, there is no consensus on which method of Achilles reattachment is optimal and the decision, in practice, is left to the discretion of the surgeon [22,23]. Due to all above, strong repairs that can resist distraction and consequently ruptures are of high clinical importance. However, reports evaluating the biomechanical strength of different sutures/materials, though there are many, were thought to be too varied for a quantitative synthesis of related evidence. One published systematic review [24] and one comprehensive review [25] only attempted to appraise biomechanical data from cadaveric studies, but no weighted pooled results were generated.

This meta-analysis aims to bring quantitative data to two clinically relevant issues. Its objective is to conduct an evidence synthesis on the efficacy of repair techniques for Achilles mid-tendon rupture *and* detachment from biomechanical studies on human cadavers.

2. Methods

The PRISMA guidelines was followed to conduct this meta-analysis [26].

2.1. Search strategy

A systematic electronic search was conducted through a number of databases such as Medline, Embase, Scielo, CINAHL, Google Scholar and the Cochrane Library from inception to Dec 1st, 2015. The Boolean combination of keywords such as [Achilles AND (suture* OR load* OR biomechanic*) AND (cadaver* NOT animal)] were used. The websites of the following journals were searched too: *Acta Orthopedica*; *American Journal of Sports Medicine*; *Anatomical Sciences International*; *Bone & Joint Journal*; *Clinical Anatomy*; *European Journal of Anatomy*; *Foot and Ankle International*; *Journal of American Podiatric Medical Association*; *Journal of Anatomy*; *Journal Bone and Joint Surgery*; *Journal of Foot and Ankle Research*; *Journal of Foot and Ankle Surgery*; *Medecine et Chirurgie du Pied*; *Surgical and Radiological Anatomy*; and *The Foot*. Then the references of the relevant papers were checked. All included articles were citation-tracked using Google Scholar to ensure that all relevant articles were identified. Duplicates were deleted.

2.2. Criteria for study selection

Studies which employed open, mini-open, or percutaneous Achilles tendon repair in human cadavers were included. Repair at any level of the Achilles tendon using any type of suture techniques and materials were also included. The primary outcome was defined as the tensile strength expressed as the maximal load to failure of the repair. The mode of failure was set as the secondary outcome.

2.3. Data extraction and analysis

Data extraction included sample size, cadaver demographics, type of intervention, material for repair, number of strands, type of testing machine and software, preconditioning (preloading), loading type, ankle position, and the results. Titles and abstracts were initially screened then full-text articles of potentially relevant studies were obtained when the primary outcome was thought to be reported. Those which met the inclusion criteria were included along with other relevant studies located by reference checking.

Analysis was performed using StatsDirect v2.7.8 (Altrincham, United Kingdom). Meta-analysis of the standardized mean effect was used to generate the pooled effect size for the primary outcome. Odds ratio meta-analysis was conducted for the secondary outcome. Heterogeneity amongst studies using I^2 statistics was examined; as the number of studies in each subgroup was expected to be very small, the fixed-effect model for analysis was selected in order to generalize the results of the meta-analysis to a population of studies with similar characteristics, even if the I^2 was superior to 50%. Descriptive analysis was conducted when the data were not amenable to meta-analysis.

3. Results

3.1. Search results

The search strategy yielded 163 citations. Of these, 32 studies were potentially relevant after abstract screening. Full text screening downsized the number to 24 relevant studies. Reference checking yielded another 2 relevant studies. In total, 26 studies including 569 legs met the inclusion criteria (Fig. 1). Seven studies reported results of Achilles reinsertion repair and 19 studies reported those of mid-tendon repair. In the reinsertion repair group, only the *single row vs. double row* subgroup was amenable to meta-analysis. Four subgroups were subject for meta-analysis in the mid-tendon repair group. Results of single comparative studies were reported in both groups. The characteristics of all included studies are shown in Table 1.

3.2. Reinsertion repair

3.2.1. Single row vs. double row techniques

Four studies [10,23,27,28] with a total of 70 ankles compared load to failure between single row and double row reinsertion techniques *via* an open approach. The pooled effect size was in favor of the double row technique (1.27, 95% CI = 0.748–1.806, I^2 = 81%, P < 0.0001).

Three studies [23,27,28] with a total of 58 ankles showed that the DR technique, though not statistically significant, yielded anchor pull-outs 3.5 times more than the SR technique while SR yielded the same OR value in relation to suture failure (OR = 3.5, 95% CI = 0.842 14.594, I^2 = 0%, P = 0.08).

Results from single comparative studies [23,29–31] are shown in Table 2.

3.3. Mid-tendon repair

3.3.1. Achillon vs. Krackow sutures

Three studies [32–34] with a total of 40 ankles compared load to failure between 3-strand Achillon *via* minimally invasive surgery approach and 4-strand Krackow sutures *via* open approach. No technique was found to be superior (0.05, 95% CI = −0.614 to 0.720, I^2 = 81.9%, P = 0.8). Only one study [32] reported quantitative data on the mode of failure outcome, therefore analysis was not possible. However, all three studies stated that the predominant mode of failure was suture/knot failure for the Krackow stiches and tearing of the suture loops through the tendon tissue for the Achillon device.

3.3.2. Bunnell vs. Kessler sutures

Four studies [35–38] including five arms with a total of 92 ankles compared the same between Bunnell and Kessler sutures *via* open technique. The Bunnel sutures showed a significantly better outcome (0.96, 95% CI = 0.510–1.405, I^2 = 63.3%, P < 0.0001). The Kessler suture ruptured 1.5 times more than the Bunnell while the Bunnell teared the tendon 1.5 times more than the Kessler stich, however,