A Biomechanical Comparison of an Open and Three Minimally Invasive Percutaneous Achilles Repair Techniques During a Simulated Rehabilitation Protocol

The Steadman Clinic
Steadman Philippon Research Institute
Vail, CO

Thomas O. Clanton, MD
C. Thomas Haytmanek, MD
Brady T. Williams, BS
David M. Civitarese, BA
Travis L. Turnbull, PhD
Coen A. Wijdicks, PhD
Robert F. LaPrade, MD, PhD
A Biomechanical Comparison of an Open and Three Minimally Invasive Percutaneous Achilles Repair Techniques During a Simulated Rehabilitation Protocol

Dr. Thomas O. Clanton

My disclosure is in the Final AOFAS Mobile App.

I have potential conflicts with this presentation due to:

Arthrex, Inc: Consultant, IP royalties, Paid presenter or speaker, Research support; Saunders/Mosby-Elsevier: Publishing royalties, financial or material support; Small Bone Innovations: Consultant, Paid presenter or speaker; Stryker: Consultant, IP royalties, Paid presenter or speaker; Wright Medical Technology, Inc.: Consultant, Paid presenter or speaker.

Additional Co-Authors and institutional disclosures are listed below:

LaPrade RF - Arthrex, Inc: Consultant, IP royalties, Research support; Linvatec: Research support; Ossur: Consultant, Research support; Smith & Nephew: Consultant, IP royalties, Research support.

Wijdicks CA - Research Support: AlloSource, Arthrex, Biomet, Ceterix Orthopaedics, ConMed Linvatec, Depuy Synthes, Ossur, Smith & Nephew; Arthrex: Current employee; however, from the inception to completion of this study Wijdicks CA was an employee of the Steadman Philippon Research Institute

The Steadman Philippon Research Institute is a 501(c)(3) non-profit institution supported financially by private donations and corporate support from the following entities: Smith & Nephew, Arthrex, Inc., Siemens Medical Solutions USA, Inc., ConMed Linvatec, Össur Americas, Synthes, Ceterix Orthopaedics, Inc., AANA, University of Oslo, The Steadman Clinic, Vail Valley Medical Center
Background

- For the treatment of Achilles tendon rupture, several options exist from non-operative management to open surgical repair; however, surgical repair is often preferred in healthy and active populations.
- The original description of a mini-open method combined with the percutaneous technique came from Kakiuchi in 1995.5
- Recently, minimally invasive percutaneous repair methods have progressed significantly with more complex assistive devices and suture passing techniques.
- Percutaneous techniques reportedly combine low rates of complication, reduced operating time, and improved cosmesis.2,7
- However, current biomechanical comparisons of minimally invasive percutaneous repairs and open repair methods are somewhat limited.3,4,6
The purpose of the present study was to biomechanically analyze three commercially available minimally invasive percutaneous techniques compared to an open Achilles repair during a simulated progressive rehabilitation program. It was hypothesized that no significant biomechanical differences would exist between repair techniques.
Materials & Methods

• Specimens
  – Thirty-three fresh frozen, foot and ankle (mid-tibia to toe tip) human cadaveric specimens (mean age 53 years, range 25-65, 19 male, 14 female) with no history of previous Achilles injury, surgery, or other definitive foot and ankle pathology were included in the final analysis.

• Specimen Preparation and Surgical Technique
  – A standardized simulated mid-substance rupture was created 6 cm proximal to the tendon insertion. Specimens were then randomly assigned to one of four different Achilles repair techniques:
    1. Open repair consisting of three modified kessler sutures and a running epitendinous 2-0 monofilament absorbable suture
    2. Achillon® Achilles Tendon Suture System (Integra LifeSciences Corporation, Plainsboro NJ)
    3. PARS Achilles Jig System (PARS, Arthrex Inc., Naples FL)
    4. Achilles Midsubstance SpeedBridge™ Repair variation (PARS, Arthrex Inc., Naples FL)
Surgical Techniques

Photographs and simplified schematic diagrams illustrating the four different repair constructs and suture configurations:

1. Open Repair (modified Kessler x 3 + epitendinous 2-0 absorbable monofilament)
2. Achillon® Achilles Tendon Suture System
3. PARS Achilles Jig Repair System
4. Achilles Midsubstance SpeedBridge™ Repair variation

*Crossed sutures for the PARS and SpeedBridge repairs indicate those that were performed in a locking fashion.
Biomechanical Testing

- Repairs were isolated and secured in an adjustable clamping fixture attached to the base of a dynamic tensile testing machine (Instron E10000).
- Repairs were subjected to a protocol representative of a progressive postoperative rehabilitation: 250 cycles at 1 Hz: (1) 20-100 N, (2) 20-200 N, (3) 20-300 N, (4) 20-400 N.
- Loads were based on load ranges observed during passive ankle flexion (20-100 N) and walking in a Cam Walker with (190 N) and without (369 N) a one inch heel lift.¹ ⁸
Results

- During biomechanical testing, all repairs survived the first 250 cycles of cyclic loading from 20-100 N, while no repairs survived all four loading stages (1000 cycles).
- However, within the first loading stage, significant differences were observed in the elongation (displacement) of repairs.

Stacked bar graph demonstrating progressive elongation of each repair construct over the first cyclic loading stage (20-100 N). OPEN, Open Repair (n = 9); ACH, Achillon® Achilles Tendon Suture System (n = 6); PARS, PARS Achilles Jig Repair System (n = 9); SB, Achilles Midsubstance SpeedBridge™ Repair variation (n = 9). *Open repairs exhibited significantly less (p < 0.05) elongation than the minimally invasive percutaneous repairs.
Results

• No significant differences were observed in the total number of cycles to failure during progressive cyclic loading.

• Failure was defined either as a precipitous drop in load, resulting from complete failure at the suture-tendon interface, or repair elongation that exceeded the maximum actuator travel of the tensile testing machine (> 5 cm).
Results

• Mechanisms of repair failure
  – The primary mechanism of failure was suture cut-out at the suture-tendon interface resulting in complete failure (9/9 Open, 5/6 Achillon, 5/9 PARS, 2/9 SpeedBridge).
  – Percutaneous repairs (1/6 Achillon, 3/9 PARS, 5/9 SpeedBridge) often failed by repair elongation to the point where the maximum actuator travel was reached (> 5 cm), leaving one or more intact suture strands spanning the repair site.
  – Two SpeedBridge repairs failed when suture limbs pulled out of one of the distal suture anchors, and one PARS repair failed due to fracture of the calcaneus at the potting.

• Unsuccessful repairs excluded from analysis
  – Additionally, 6 Achillon-repaired tendons and 1 PARS-repairs insufficiently captured the tendon (missed anteriorly) while 1 SpeedBridge repair did not achieve sufficient suture anchor purchase in the calcaneus. These repairs were deemed unsuccessful and were excluded from analysis.
Conclusions/Clinical Significance

• Minimally invasive percutaneous repair techniques demonstrated an increased susceptibility to significant early repair elongation compared to the open technique.

• Percutaneous repairs may have an increased risk of insufficient tendon capture due to the minimally invasive approach in which direct visualization of the tendon during passage of sutures is limited compared to open repairs.

• Ultimate failure strengths of minimally invasive percutaneous repairs versus open repairs, as indicated by the number of cycles to failure, were comparable across all techniques.

• The preferential treatment for a midsubstance Achilles rupture is ultimately dictated by surgeon preference and judgment based on patient-specific factors including a patient’s physical demands, healing capacity, cosmetic concerns, and rehabilitation requirements in addition to surgeon experience and comfort level with individual repair techniques.
References


