

TA Rupture Assessment Analysis – are Our "GOLD-Standards" of Tendon Repair Valid?

Simone Frunz

Luzerner Kantonsspital

Markus Knupp

Universitat Basel

Beat Goepfert

Universitat Basel

Lukas Iselin (✉ lukas.iselin@luks.ch)

Luzerner Kantonsspital <https://orcid.org/0000-0002-3300-6519>

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Abstract

Background: Current studies showed that operative treatment has advantages in comparison to conservative treatment for acute Achilles tendon ruptures. The gold standard therapy in our clinic is the operative treatment with the four strand Adelaide suture. The goal of this study is to evaluate which suture material (a) B Braun; MonoMax, b) Ethicon; PDS CTX) is more appropriate for Achilles tendon suture.

Methods: Ten pairs of fresh frozen Achilles tendons were obtained from human donors aged 41 – 85. The tendons were fixed on a testing machine and loaded until failure. The goal of this setup was to create a natural rupture pattern. The ruptured tendons were sutured either with BB or PDS and again loaded until failure.

The failure mode in all sutured tendons was a pullout of the suture material through the tendon fibres.

Results: The ruptures occurred on different locations. The maximal forces in the sutured tendons occurring at the rupture were for the BB-suture between 144 N and 232 N (Mean 197 (SD 67) N) and for the PDS-suture between 158 N and 226 N (Mean 194(SD 70) N). The failure mode in all sutured tendons was a pullout of the suture material through the tendon fibres.

Conclusion: Due to the failure mode we are not able to evaluate which suture material is better to use for the Achilles tendon repair with the Adelaide suture. Either the Adelaide suture is not an appropriate suture technique for Achilles tendon repair or the natural rupture pattern has in comparison to the *in vitro* rupture patterns constructed by sharp dissection a bigger influence on the pullout strength of suture techniques than we thought. This would mean that probably the data from most *in vitro* studies are not applicable for daily life.

Background

The rupture of the Achilles tendon is one of the most common tendon ruptures. ⁹

The injury occurs most frequently in middle aged man (30–45 years). ¹

In the actual development with increased expectancy of life in combination with an increased athletic demand upon the aging body, the incidence of Achilles tendon ruptures is also expected to increase. ^{8, 14}

There is no consensus on the treatment of acute Achilles tendon ruptures. While some surgeons prefer conservative treatment to avoid complications from surgery most physicians consider operative treatment to be more reliable in young and mid-aged patients. The latter has been shown to reduce the risk for rerupture by the factor 3. Additional, surgical treatment may allow earlier return to work and shows a better range of motion in the ankle. ^{1, 4, 6}

Early functional postoperative treatment with mobilisation and weight bearing also leads to better functional outcomes compared to immobilisation and partial weight bearing after operation. ⁷

Early mobilisation after surgery relies on a strong repair. The rate of failure is influenced by the surgical technique and the suture material.⁸ While several studies have assessed different suture techniques only limited data is published on different suture material.

The gold standard in our clinic for the operative treatment of Achilles tendon rupture is the Adelaide suture (Fig. 1). Due to its properties as a four strand suture we assume that the Adelaide suture is an appropriate suture for the treatment of Achilles tendon rupture.^{17,12}

In the present *in vitro* study we used an established suture technique, the Adelaide suture, and compared two different suture materials with regard to failure under load.

Methods

The tests were performed at the Center of Biomechanics according to the rules of the permission of the local ethical commission (EK 341/13). Ten pairs of fresh frozen Achilles tendons were obtained from human donors aged 41–85 within 12 hours after death. Inclusion and exclusion criteria are listed in Table 1 below.

Table 1
Inclusion and Exclusion criteria

Inclusion	Exclusion
Consent to the autopsy by a legal proxy	<ul style="list-style-type: none"> - Known Achilles tendon rupture - Tumour affecting the Achilles Tendon - Rheumatoid/vasculitic disorder spectrum (Rheumatoid Arthritis, Lupus, Psoriasis), Endocrine Diseases (e.g. gout) - Other manifestations indicating a change in tissue quality of the Achilles tendon (e.g. local infection or inflammation, skin lesion) - Acute joint infection or previous joint infection of the upper ankle joint.

The specimens contained part of the posterior half of the calcaneus and extended proximally to the musculo-tendinous transition point.

The Achilles tendons were frozen at -20 °C after dissection to preserve the biomechanical properties of the tissue. Dissection, storage and thawing was done according to the protocol published by Woo et al. ¹⁰ (Fig. 2)

The tendons were fixated to the clamps of the testing machine. As final step we used liquid CO₂ to achieve a strong fixation.

Before testing, two reflecting markers (d:6.5 mm, Prophysics AG, Kloten CH) were fixed to the tendon about 2 cm below resp. above the clamps, using cyanoacrylate glue (LOCTITE 401, Henkel & Cie. AG,

Pratteln CH). These four markers were tracked during different loading conditions with six high-speed digital cameras (MX-13+, Sampling rate 30 Hz, Vicon Motion Systems Ltd., Oxford, UK). The placement of the markers and the force measured by the load cell were recorded synchronously with the motion analysis system (Nexus, Vicon Motion Systems Ltd., Oxford, UK).

The following loading cycles were performed:

Preloading the native tendon with 1 Hz between 100 and 800N over 20 cycles.

Loading until failure with 10kN/sec. Due to the variance of the location where the ruptures occurred we decided to weaken the last four specimens at the favored point in the mid tendon part. Therefore we performed an artificial incision with a scalpel (5 mm) in the mid tendon part.

Suturing of the ruptured tendon with the Adelaide suture (four strand cross locked suture-technique) From every pair we sutured each one tendon with

B Braun; MonoMax HRT 40 s; Size: 1 (BB) and one tendon with Ethicon; PDS CTX; Size: 1 (PDS)

Preloading the sutured tendon with 1 Hz between 50 and 100 N over 20 Cycles

Loading until failure with 10kN/sec.

The maximal force until failure of the native tendon was recorded and for the sutured tendon the force-displacement-diagram of the loading cycles until failure were analysed.

Results

Creation of the rupture:

Ten pairs of fresh frozen Achilles tendons were tested under tension until a rupture

occurred. The measured force at the time of rupture ranges between 2408N and 5972N. The area of failure varies within the different tendons. Two tendons ruptured at the distal part of the tendon-bone interface (3786N, 2408N), Two tendons ruptured in the mid tendon part (5821N, 4997N). Four tendons ruptured in the proximal part (5972N, 5500N, 4299N, 4743N). Two tendons ruptured at the tendon muscle interface (3884N, 5287N). Four tendons ruptured close to frozen area (3786N, 2408N, 4543N, 3942N). Two ruptures occurred as pull out ruptures at the proximal clamp (4066N, 5103N). Due to the variance of the location where the ruptures occurred we decided to weaken the last four specimens at the favoured point in the mid tendon part. Therefore we performed an artificial incision with a scalpel (5 mm) in the mid tendon part. These four tendons ruptured at the side of the artificial incision in the mid tendon (3263N, 2463N, 2614N, 2785N). Table 2

Table 2
failure load of native Achilles tendon

Specimen No.	Sample Side 1 [N]	Failure location	Sample Side 2 [N]	Failure location
1	3263	At an artificial made incision mid tendon	2614	At an artificial made incision mid tendon
2	2463	At an artificial made incision mid tendon	2785	At an artificial made incision mid tendon
3	5972	proximal part	5500	proximal part
4	4743	proximal part	4299	proximal part
5	3884	Tendon-muscle interface	5287	Tendon-muscle interface
6	4066	Pull-Out-Rupture at the proximal clamp	5103	Pull-Out-Rupture at the proximal clamp
7	3786	Close to frozen area	4543	Close to frozen area
8	2408	Close to frozen area	5821	mid tendon
9	3710	Distal part tendon –bone interface	4997	mid tendon
10	3079	Distal part tendon –bone interface	3942	Close to frozen area
Average force until failure		4113 [N] SD: 1091 [N]		

Testing of the reconstruction:

The maximal forces in the sutured tendons occurring at the rupture were for the BB-suture between 144 N and 232 N (Mean 197 (SD 67) N) and for the PDS-suture between 158 N and 226 N (Mean 194(SD 70) N). The tendon lengthening until failure load was for the BB-sutures between 5.2 and 12.6 mm (Mean 8.6 (SD 3.5) mm) and for the PDS-suture between 3.4 and 13.7 mm (Mean 5.5 (SD 2.3)mm). The failure mode showed no suture breakage. The main failure mode of the sutured tendons showed a tightening of the suture stitches and knots with a cutting into the tissue of the tendon along the tendons fibres and resulted in a suture pullout.

The Force-Displacement-Diagrams (Fig. 3, 4) show in the most test a clear point when the tensile force reached the failure load of the sutured tendon.

Discussion

A novelty regarding the existing literature and the main strength of this study is the way how we created the rupture. The big amount of the existing literature which examine the tensile strength of suture techniques in an in-vitro setup use a sharp dissection 4-6cm proximal the calcaneal insertion to simulate the tendon rupture.^{2, 3, 5, 7, 8, 10, 13, 16} Cretnik et al published a biomechanical study in 2000, where he was comparing the strength between the percutaneous Ma Griffith and a modified percutaneous MaGriffith technique. They first performed the surgical procedure on the intact tendon and then made a sharp dissection 4.5 cm proximal to the calcaneal insertion, taking care not to injure the already applied suture.² Most authors described in their discussions the sharp preparation of the rupture as a possible limitation or weakness of their study. For scientific reason it is a good way to prepare the tendons always in the same way, so there are standardized conditions for a very specific question like the in vitro tensile strength of a particular technique. But this *in vitro* produced sharp dissection of the Achilles tendon has probably not much in common with a in vivo Achilles tendon rupture. Intraoperative the Achilles tendon rupture appears in most cases not as a straight cut, it is more split up in many single fibers and threads.

In our setup, we wanted a more natural pattern of the rupture. Therefore we created the rupture by maximal load until the rupture occurred. Although the setup was strictly standardized and the loading conditions were all the same, the ruptures appeared on different parts of the tendons. In most specimens the ruptures occurred in each side on the same location. Due to the difficulty we experienced during the preparation of the ruptures we decided to weaken the last four specimens at the mid tendon portion with an artificial incision, to create a predetermined breaking point. That is why there less force until failure was needed to create these ruptures.

It is obviously important to achieve a strong fixation in the clamps, so the testing mechanism can build up the needed forces. The cooling with CO₂ seems to be appropriate, the two clamp pullout ruptures occurred in highest range of forces. The cooling needs to be done very careful. There were four tendons which had the ruptures close to the cooling area and the needed forces to produce this ruptures were below the forces which are needed to produce a mid tendon rupture. So cooling might weaken the tendons in this setup.

As oppose to our hypothesis, we did not find one suture material superior to the other when reconstructing an Achilles tendon rupture with the Adelaide technique in a cadaver setting.

The reason for that is the failure mode. We suspected a rupture of the suture material or a breakdown at the knot. But all sutures showed a pullout through the tendon as failure mode. With this result it is actually not possible to make a statement about the tensile strength of a suture material, because it seems that the mechanism of failure occurs in the combination of the ruptured tendon with the suture technique.

We see two possibilities which can lead to this result:

- 1 The Adelaide suture is despite the four strand suture technique not as appropriate as we thought.
- 2 The natural rupture pattern has in comparison to the *in vitro* rupture patterns constructed by sharp

dissection a bigger influence on the pull out strength of suture techniques than we thought.

A limitation of this study is the utilization of the Adelaide suture. The most comparative studies examined standard sutures like Krackow, Bunnell, Kessler and some percutaneous procedures. But we wanted a specific statement for our clinic where the Adelaide suture was the standard procedure. Another limitation is the creation of the Achilles tendon rupture of the last four specimens, where we used a 5 mm long artificial incision to predetermine the location of the rupture.

Conclusion

As conclusion we need to consider the natural pattern of the Achilles tendon rupture which is totally different from the sharp dissection in most *in vitro* studies which tested the tensile strength of the common suture techniques. It is to consider that in most studies the authors used macroscopic healthy tendons with no history of trauma or systemic disorders which could influence the tendon's stability. Therefore all stitches of the suture technique were done in tendon tissue with good quality. The thready structure of the natural Achilles tendon rupture might have a big influence on the stability of the suture technique. Because due to the macroscopically and probably also microscopically damages around the rupture side, the stitches might not be done in stable tissue. This could have a negative influence on the strength of the Achilles tendon repair. We need further studies which investigate the tensile strength of the common suture techniques in natural Achilles tendon rupture patterns.

Declarations

Ethics approval and consent to participate:

The tests were performed at the Center of Biomechanics at the University of Basel. Ethical committee approval Northwest- und Zentralschweiz - EKNZ (EK 341/13). According to the authorities no written consent for participating in the cadaver study was required additionally to the approval for the autopsy.

Consent for publication:

Not applicable

Availability of data and materials:

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests:

The authors declare that they have no competing interests.

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Authors contribution:

SF, LI have designed the study, SF, BG, MK and LI have conducted the analysis and measurements. SF, LI and MK have drafted the article.

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References

1. Braunstein M, Baumbach SF, Herterich V. Die akute Achillessehnenruptur -Wo stehen wir heute? Unfallchirurg 2017 – 120:1007–1014.
2. Cretnik A, Zlajpah L, Smrkolj V, Kosanovic M. The strength of percutaneous methods of repair of the Achilles tendon: a biomechanical study. Med Sci Sports Exerc. 2000 Jan;32(1):16–20.
3. Demetracopoulos CA, Gilbert SL, Young E, Baxter JR, Deland JT. Limited-Open Achilles Tendon Repair Using Locking Sutures Versus Nonlocking Sutures: An In Vitro Model. Foot Ankle Int. 2014 Jun;35(6):612–8.
4. Erickson BJ, Mascarenahs R, Saltzman BM. Is Operative Treatment of Achilles Tendon Ruptures Superior to Nonoperative Treatment?: A Systematic Review of Overlapping Meta-analyses. Orthop J Sports Med. 2015 Apr 17;3(4).
5. Heitman DE, Ng K, Crivello KM, Gallina J. Biomechanical comparison of the Achillon tendon repair system and the Krackow locking loop technique. Foot Ankle Int. 2011 Sep;32(9):879–87.
6. Hess GW. Achilles tendon rupture: a review of etiology, population, anatomy, risk factors, and injury prevention. Foot Ankle Spec. 2010 Feb;3(1):29–32.
7. Herbort M, Haber A, Zantop T, Gosheger G, Rosslénbroich S, Raschke MJ. Petersen w. Biomechanical comparison of the primary stability of suturing Achilles tendon rupture: a cadaver study of Bunnell and Kessler techniques under cyclic loading conditions. Arch Orthop Trauma Surg. 2008 Nov; 128 (11):1273–7.
8. Huffard B, O' Loughlin PF, Wright T. Achilles tendon repair: Achillon system vs. Krackow suture: An anatomic in vitro biomechanic study. Clin Biomech. 2008;23:1158–64.

9. Kannus P, Józsa L. Histopathological changes preceding spontaneous rupture of a tendon. A controlled study of 891 patients. *J Bone Joint Surg Am.* 1991;73(10):1507–25.
10. Labib SA, Rolf R, Dacus R, Hutton WC. The "Giftbox" repair of the Achilles tendon: a modification of the Krackow technique. *Foot Ankle Int.* 2009 May;30(5):410–4.
11. Maquirriain J. Achilles tendon rupture: avoiding tendon lengthening during surgical repair and rehabilitation. *Yale J Biol Med.* 2011;84(3):289–300.
12. McCoy BW, Haddad SL. The strength of achilles tendon repair: a comparison of three suture techniques in human cadaver tendons. *Foot Ankle Int.* 2010 Aug;31(8):701–5.
13. Sadoghi P, Rosso C, Valderrabano V, Leithner A, Vavken P. Initial Achilles tendon repair strength—synthesized biomechanical data from 196 cadaver repairs. *Int Orthop.* Sep;36(9):1947–51.
14. Schepsis AA, Jnes H, Haas AL. Achilles tendon disorders in athletes. *Am J Sports Med* 2002 Mar-Apr; 30(2): 287–305.
15. Woo SL, Orlando CA, Camp JF, Akeson WH. Effects of postmortem storage by freezing on ligament tensile behavior. *J Biomech.* 1986;19(5):399–404.
16. Yammine K, Assi C. Efficacy of repair techniques of the Achilles tendon: A meta-analysis of human cadaveric biomechanical studies. *Foot (Edinb).* 2017 Mar;30:13.
17. Yildirim Y, Esemeli T. Initial pull-out strength of tendon sutures: an in vitro study in sheep Achilles tendon. *Foot Ankle Int.* 2002 Dec;23(12):1126–30.

Figures

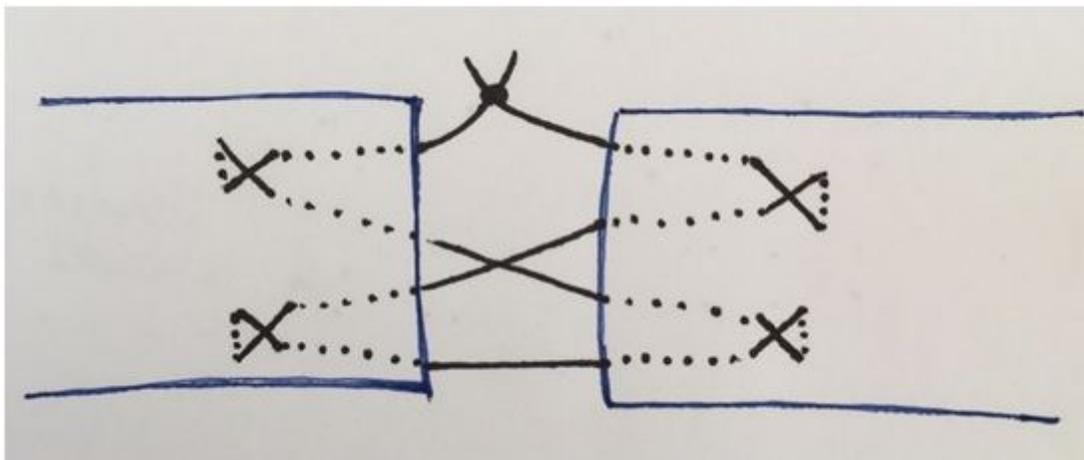


Figure 1

Adelaide suture technique.



Figure 2

Mounted native Achilles tendon during cooling process using liquid CO2.

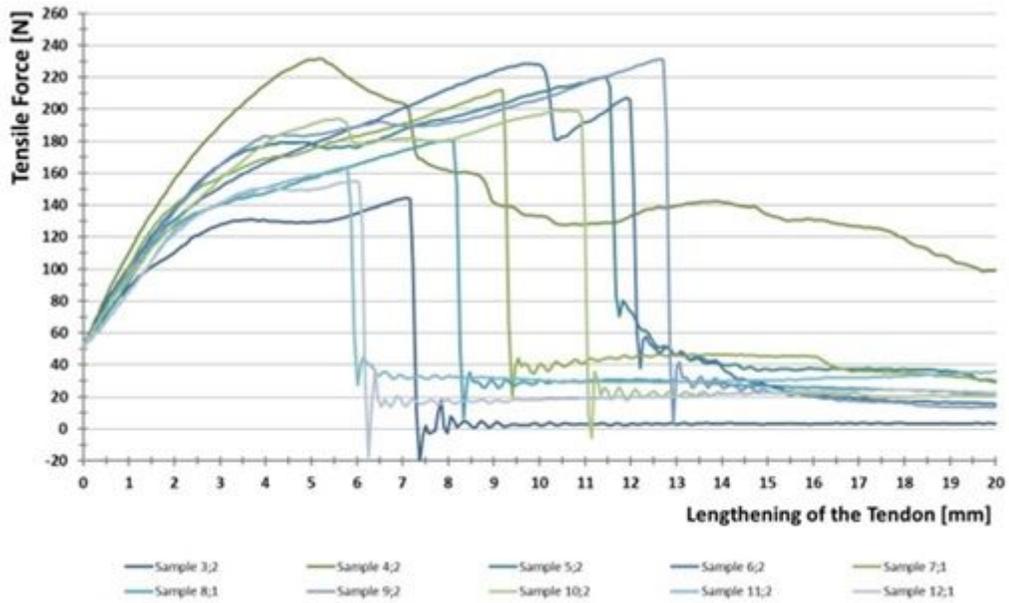


Figure 3

Force-Displacement-Diagram of all sutured tendons with BB MonoMax Suture.

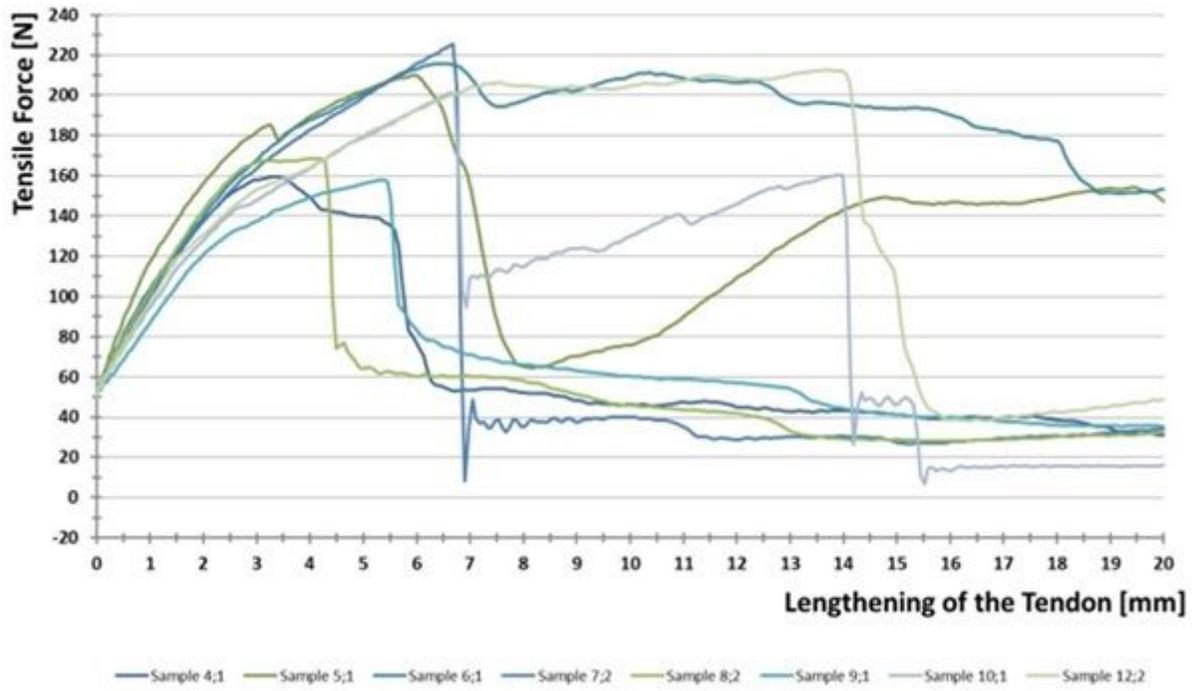


Figure 4

Force-Displacement-Diagram of all sutured tendons with PDS Suture.