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What is This?
Biomechanical Properties of Suture Anchor Repair Compared With Transosseous Sutures in Patellar Tendon Ruptures

A Cadaveric Study

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Background: Ruptures of the patellar tendon are debilitating injuries requiring surgical repair. Reliable data about the most appropriate suture technique and suture material are missing. The standard procedure consists of refixing the tendon with sutures in transpatellar tunnels, sometimes combined with augmentation.

Hypothesis: Suture anchors provide at least equal results concerning gap formation during cyclic loading and ultimate failure load compared with transosseous suture repair.

Study Design: Controlled laboratory study.

Methods: A total of 30 human cadaveric patellar tendons underwent tenotomy followed by repair with 5.5-mm titanium suture anchors, 5.5-mm resorbable hydroxyapatite suture anchors, or transpatellar suture tunnels with No. 2 Ultrabraid and the Krackow whipstitch technique. Biomechanical analysis included pretensioning the constructs at 20 N for 30 seconds and then cyclic loading of 250 cycles between 20 and 100 N at 1 Hz in a servohydraulic testing machine with measurement of elongation. After this, ultimate failure load and failure mode analysis was performed.

Results: Compared with transosseous sutures, tendon repairs with suture anchors yielded significantly less gap formation during cyclic loading (P < .05) and resisted significantly higher ultimate failure loads (P < .05). Common failure mode was pullout of the eyelet within the suture anchor in the hydroxyapatite anchor group and rupture of the suture in the titanium anchor group and—at lower load to failure—in the transosseous group.

Conclusion: Patellar tendon repair with suture anchors yields significantly better biomechanical results than repair with the commonly applied transosseous sutures.

Clinical Relevance: These findings may be of relevance for future clinical treatment of patellar tendon ruptures. Randomized controlled clinical trials comparing suture anchors to transosseous suture repair are desirable.

Keywords: knee; patellar tendon; suture anchors; transpatellar tunnels; transosseous sutures; biomechanics

Ruptures of tendons and ligaments are common injuries in orthopaedic and trauma surgery. Incidences have been estimated at 166.6 out of 100,000 per year for male patients and 52.1 out of 100,000 per year for females. Successful repair of tendons is a challenging task because tendons need to withstand high mechanical loads and they have a poor blood supply. The surgeon has to find a balance between the strength of the repair and potential wound complications, which both increase with increased number of strands and caliber of the suture. Reliable data on the ideal suture technique and material are rare. Ruptures of the patellar tendon usually occur because of degenerative changes caused by factors such as reduced blood supply, diabetes mellitus, renal failure, long-term

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therapy with steroids or abuse of anabolic steroids, repetitive microtrauma, and previous knee surgery. Direct trauma by severe force is more unusual and mainly occurs in combination with complex injuries of the knee joint. Men are more often affected than women (6:1). Bilateral patellar tendon ruptures can occur rather frequently.

MATERIALS AND METHODS

All procedures were approved by the local ethics committee. The knees of 15 human cadavers (30 knees) were used for acquisition of the patella and the patellar tendon. The knee extensor structures were harvested in toto from the quadriceps femoris muscle to the tibial tuberosity to ensure the integrity of the patellar tendon and patella. The mean age of the cadavers from which the tissue was obtained (± standard deviation) was 61 ± 6 years in the titanium anchor group, 59 ± 12 years in the hydroxyapatite anchor group, and 59 ± 14 years in the transosseous suture group (P > .05). The tendons were harvested an average of 1.2 ± 0.4 days postmortem. We used tendons from 13 men and 2 women with a mean weight of 71 ± 21 kg in the titanium anchor group, 73 ± 19 kg in the hydroxyapatite anchor group, and 84 ± 20 kg in the transosseous suture group. There were no visual signs of tendon degeneration.

Tendons were cleaned from remaining muscle tissue by sharp dissection, and they were deep-frozen after harvesting. The constructs were then thawed at 4°C for 24 hours before tenotomy, suturing, and mechanical testing and were kept moist with saline spray during the entire procedure.

The simulation of tendon rupture was created by tenotomy with a scalpel blade approximately 3 mm from the edge of the inferior pole of the patella, the most common clinical rupture site. The distal patellar tendon end and the patella were then rigidly fixed in 2 clamps at their ends. All ruptures were sutured by a single experienced orthopaedic surgeon.

Repairs were performed with 3 different techniques. For the standard transosseous suture repair, 3 transpatellar tunnels were drilled vertically through the patella. An additional incision in line with the fibers of the quadriceps tendon allowed the passage of sutures by a thin shuttlet wire. The patellar tendon was then repaired by 4 separate sutures with No. 2 Ulbrabraids (Smith & Nephew Orthopaedics, Tuttlingen, Germany) with the Krackow whipstitch technique; knots were tied at the patellar tendon end (Figure 1).6,12

For the suture anchor repair, two 5.5-mm anchors fitted with two No. 2 Ulbrabraids each were inserted a few millimeters from the center of the inferior pole of the patella, dividing the patella into almost equal thirds.6 The anchors consisted of either titanium or hydroxyapatite. Repair of the tendon was again performed with the same Krackow whipstitch technique12 as in the tunnel group (Figure 2).

In assigning tendons to the 3 groups, we assigned equal numbers of right and left knees and comparable age, body mass index, and tendon diameter to each group.

For biomechanical evaluation of the constructs, each specimen was placed into a tensile loading fixation of a servohydraulic testing machine (Mini Bionix 858; MTS Systems Co, Minneapolis, Minnesota) (Figure 3). The sutured tendons were pretensioned with 20 N for 30 seconds before testing. Then, 250 cycles of mechanical loading between 20 and 100 N were applied at a repetition rate of 1 Hz. The increase in construct length was recorded. Length changes are reported as the difference in length from the first to the 250th cycle. The preload was decreased from 20 N to 10 N, and after pausing for 30 seconds, a failure test with a ramp speed of 20 mm/s was performed. The maximum failure load and failure mode of the constructs were analyzed.
All statistical analyses were performed using Statistical Package for Social Sciences (SPSS 15.0, SPSS Inc, Chicago, Illinois). Normal distribution was analyzed by the Shapiro-Wilk test. All values are presented in the form of mean ± standard deviation.
standard deviation (SD). Analysis of variance was used for parametric data and Kruskal-Wallis test for nonparametric data. A P value less than .05 (2-tailed) was considered to be statistically significant.

RESULTS

Cyclic Elongation

Compared with transosseous sutures, tendon repairs with suture anchors yielded significantly less gap formation during initial cyclic loading. Between the first and the 20th cycle, the titanium anchor group showed an elongation of 2.9 ± 0.8 mm, the hydroxyapatite anchor group showed an elongation of 3.7 ± 0.4 mm, and the transosseous suture group showed an elongation of 17.2 ± 3.7 mm. Between the 20th and the 250th cycle, the titanium anchor group showed an elongation of 1.4 ± 0.4 mm, the hydroxyapatite anchor group showed an elongation of 1.2 ± 0.5 mm, and the transosseous suture group showed an elongation of 10.3 ± 2.4 mm. The elongation was significantly smaller for the suture anchors compared with the transosseous suture technique between the first and the 20th cycle and between the 20th and 250th loading cycle (P < .05) (Figure 4).

Maximum Failure Load

The maximum load to failure was 597 ± 118 N in the titanium anchor group, 689 ± 100 N for the hydroxyapatite anchor group, and 301 ± 114 N for the transosseous suture group. The suture anchors showed significantly higher failure loads compared with the transosseous suture technique (P < .05) (Figure 5).

Failure Mode

The failure mode in the titanium anchor group (n = 10) was a bony anchor pullout (Figure 6) in 5 cases and a tendon pullout in 5 cases. The hydroxyapatite anchor group (n = 10) failed because of a suture failure at the anchor eyelet in 7 cases and a tendon pullout in 3 cases. The transosseous suture group (n = 10) failed in 4 cases because of a knot failure and in 6 cases because of a tendon pullout.

DISCUSSION

The most important findings of our study were that patellar tendon repairs with suture anchors yielded significantly less gap formation during cyclic loading and resisted significantly higher ultimate failure loads compared with transosseous sutures. Incomplete patellar tendon ruptures can be treated nonoperatively in patients with preserved extensor mechanism integrity. In patients with complete ruptures and insufficient extensor mechanism, surgical repair is necessary. For biomechanical evaluation of the various methods of tendon repair, cyclic loading and ultimate failure loading are usually performed. Cyclic loading more adequately represents the in vivo conditions during regular functional rehabilitation after tendon repairs. However, ultimate failure testing represents the occurrence of a high load event that may happen unintentionally and lead to construct failure. The standard procedure of patellar tendon repair consists of reattaching the tendon with sutures in transpatellar tunnels, sometimes combined with augmentation. Benthen et al compared sutures in 4-strand Krackow technique using No. 2 polyester suture (Ethibond, Ethicon, Somerville, New Jersey) with No. 2 polyblend suture (FiberWire, Arthrex, Naples, Florida) during simulated ruptures in bovine Achilles tendons. The results of the study showed a 260% higher ultimate failure load and 33% less gap formation on cyclic loading for the polyblend suture.

Norris et al compared the various cutout parameters of different transosseous sutures in sawbones and found that No. 5 polyester suture (Ethibond) and No. 5 polyblend suture (FiberWire) sustained higher cutout loads than the same sutures in No. 2. The results also revealed lower cut-out loads for Ethibond compared with FiberWire.

For a long time, patellar tendon repairs were augmented by a cerclage and treated with immobilization of the knee in an extended position and protected physical therapy during follow-up. In 1999, Marder et al first reported good results of primary tendon repair without augmentation and with early rehabilitation, initiating a change toward augmentation-free repairs.

However, in a cadaver study in 2002, Ravalin et al demonstrated less gap formation for cable or cerclage augmentation of the patellar tendon repair compared with primary suture without augmentation.

In 2001, Kasten et al compared the methods of augmentation after patellar tendon ruptures using either a wire cerclage or a polydioxanone (PDS; Ethicon) cord in a group of 27 patients. The investigators found a higher rate of infection in the PDS cord group but also emphasized the advantage of avoiding implant removal, as may be necessary with wire cerclage.

In 2010, Krushinski et al investigated the influence of pretensioning the patellar tendon sutured with the Krackow technique by cycling the knee 10 times from 90° to 5° of flexion, revealing no relevant decrease in gap formation by pretensioning the construct. We therefore applied the pretensioning model established in a biomechanical study from 2012 investigating tendon suture materials and techniques. The findings of Krushinski et al correspond well to our results, showing rather high and early gap formation during cyclic loading of the transosseous sutures. This may be explained by a longer distance that has to be bridged by pure suture material compared with the suture anchor technique.

Even though there is now a large and continuously increasing number of studies dealing with suture anchors in shoulder surgery, data about suture anchor repair in knee surgery are limited.

In 2006, Bushnell et al compared transosseous sutures with suture anchors in patellar tendon ruptures in...
a human cadaveric study, revealing significantly less gap formation and comparable ultimate failure loads for repairs with suture anchors. The authors discussed further advantages of suture anchors, such as a reduced need for tissue dissection and damage and a potentially reduced risk of patellar fractures and intra-articular damage compared with transpatellar tunnels.  

The reported advantages of the suture anchor technique include reduced operation time, easily accessible implantation site, higher strength, and more consistent ultimate failure loads compared with transosseous sutures. These aspects enable the surgeon to allow earlier functional rehabilitation, leading to faster remodeling and strengthening of the collagen fibers in the repaired tendon. 

Gaines et al described the repair of patellar tendon ruptures with suture anchors and a combination of Krackow and Bunnell sutures but did not report biomechanical data in relation to transosseous sutures. 

Kamath et al recently described their technique of suture anchor repair for rupture of the patellar ligament after total knee arthroplasty in a case report. Benner et al reported a case series of 13 patellar tendon ruptures after repair of the anterior cruciate ligament by a bone–patellar tendon–bone autograft. They demonstrated good results for a repair with suture anchors but with additional Dall-Miles cerclage augmentation. Anand et al described a 2-year follow-up of 5 patients who underwent patellar tendon reinsertion by suture anchors for fractures of the inferior pole of the patella, reporting promising clinical results.

The results of our study may also be of interest regarding other tendons and ligaments. Randomized controlled clinical trials comparing suture anchors to transosseous suture repair are desirable for the future.

CONCLUSION

Patellar tendon repair with suture anchors yields significantly better biomechanical results than the commonly applied transosseous sutures. These findings may be of relevance for the clinical treatment of patellar tendon ruptures.

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