Suture Repair with a Novel Adjustable-Loop Device Reduces Fragment Displacement in Tibial Eminence Avulsion Fractures: A Biomechanical Analysis

Brittany M. Glaeser[1], Jonathan C. Riboh[2], Oliver L. Hauck [1], Coen A. Wijdicks[1]
[1]Arthrex, Inc., Naples, FL, [2]OrthoCarolina, Charlotte, NC
Email of Presenting Author: Brittany.Glaeser@Arthrex.com

Disclosures: B.M. Glaeser & O.L. Hauck & C.A. Wijdicks (3A-Arthrex), J.C. Riboh (3B-Smith & Nephew, Stryker, Arthrex; 4-Restor3d)

INTRODUCTION: Tibial eminence avulsion fractures most commonly occur in the pediatric population due to the bone surrounding the anterior cruciate ligament (ACL) footprint being weaker than the ACL, causing the bone to fracture prior to ligament rupture[1]. Surgical intervention, typically indicated in more severe fractures, involves reduction of the bony avulsion commonly using sutures tied over a tibial metal cortical button[2]. The addition of adjustable-loop cortical button devices (ALD) to suture fixation is a novel technique variation that may reduce the avulsed fragment by permitting higher initial compressive forces and alleviating initial creep via re-tensioning as shown in previous biomechanical studies[3]. The study objective was to biomechanically compare standard fixation to ALD suture fixation in a porcine cadaveric model. It was hypothesized that the ALD repair would have less cyclic elongation and higher ultimate load versus the standard repair, and better restore native (uninjured) function.

METHODS: Twenty porcine stifles were dissected of all muscle and ligamentous tissue surrounding the ACL. Femurs and tibias were potted and loaded onto a materials tensile testing machine so that the ACL fibers were parallel to the direction of the load (Figure 1). To evaluate the native biomechanical properties and remove initial creep in the ligament, the native ACL was cyclically loaded between 10-50 N, 10-100 N, and 10-150 N for 100 cycles each at 1 Hz. Following native testing, a Type III tibial eminence avulsion fracture was created and repaired with the specimen immobilized on the machine in its initial positioning. Fracture reduction was achieved via suspensory suture fixation through a single tunnel placed at the anterior third of the fracture using either a standard technique tied over a metal button (n=10) or an ALD (n=10). Repaired specimens underwent 10 pre-conditioning cycles at 0.5 Hz to simulate intraoperative knee cycling[3], followed by manual re-tensioning (ALD repairs only) and final knot tying at the tibial cortical button with 5 alternating half-hitches. Repaired specimens then underwent the same cyclic loading sequence as the native specimens with endpoint pull-to-failure at a rate of 200 mm/min. Cyclic elongation, cyclic stiffness, and ultimate load outcomes were statistically analyzed using a one-way RM ANOVA with a post-hoc Bonferroni multiple comparisons procedure ($p<0.05$) and a Student's t-test ($p<0.05$).

RESULTS: Total displacement after the cyclic loading protocol showed significantly less total elongation ($p<0.001$) for the ALD group (0.76 ± 0.23 mm) compared to the control group (5.50 ± 1.28 mm) (Figure 2). There were no statistical differences in cyclic stiffness between repair groups. All constructs survived cyclic loading and were subsequently pulled to failure. Significantly higher ultimate loads ($P = 0.023$) were achieved by the ALD repairs (532 ± 100 N) compared to the standard repair (410 ± 118 N) (Figure 3). Failure modes for the standard repair included suture tear through the ACL (7/10), suture tear at the button interface (2/10), and button migration through the bone (1/10). Failure modes for the ALD included suture tear through the ACL (4/10), button migration through the bone (3/10), and suture tear at the ALD interface (2/10).

DISCUSSION: The reduced cyclic elongation of the ALD repair compared to the standard repair suggests that ALDs maintain a greater reduction of the avulsion fracture at time-zero. Similar cyclic stiffness between repairs groups indicate that ALD repairs would be a viable alternative to the standard repair with the benefit of maintaining better fracture reduction which is important to ensure proper healing during the early stages of rehabilitation. In addition, the higher ultimate load of the ALD repair better restores native ACL function compared to the standard repair. Limitations of the study include morphological differences between porcine and human ACL and did not allow for a dual tunnel fixation. Additionally, this was a time-zero analysis, which do not permit in vivo healing and, therefore, simulate a "worst-case" scenario.

SIGNIFICANCE/CLINICAL RELEVANCE: Adjustable-loop devices provide the ability to intraoperatively precondition and re-tension the tibial eminence avulsion repair, whereas this cannot be done with standard repairs. This advancement may mitigate gap formation and restore native function during fracture healing and early rehabilitation.

REFERENCES:

[1] D.K. Chouhan, M.S. Dhillon, R. John, and A. Khurana, "Management of neglected ACL avulsion fractures: a case series and systematic review," *Injury,* vol. 48, no. 2, pp. S54-S60, August 2017.
[2] O. Hapa, F.A. Barber, G. Suner, R. Ozden, S. Davul, E. Bozdag, and E. Sunbuloglu, "Biomechanical Comparison of Tibial Eminence Fracture Fixation with High-Strength Suture, EndoButton, and Suture Anchor," *Arthroscopy: The Journal of Arthroscopic & Related Surgery,* vol. 28, no. 5, pp. 681-687, May 2012.
[3] P.A. Smith, M. Piepenbrink, S.K. Smith, S. Bachmaier, A. Bedi, and C.A. Wijdicks, "Adjustable-Versus Fixed-Loop Devices for Femoral Fixation in ACL Reconstruction: An In Vitro Full-Constrcut BiomechanicalStudy of Surgical Technique-Based Tibial Fixation and Graft Preparation," *Orthopaedic Journal of Sports Medicine,* vol. 6, no. 4, April 2018.

IMAGES AND TABLES:

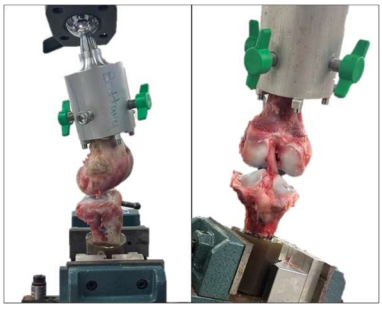

Fig 1. Test setup. ACL fibers were oriented so that they are parallel to the direction of load.

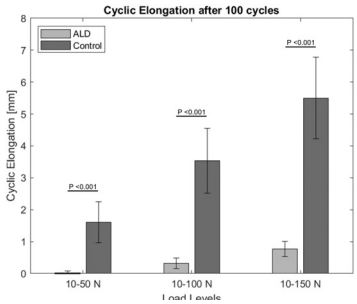

Fig 2. Cyclic elongation results after 100 cycles at each load level.

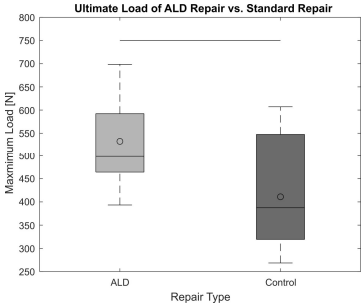

Fig 3. Ultimate load of repair groups