

The TightRope implant, which has been used in 2 million procedures globally,¹ simplifies ACL reconstruction and facilitates advanced techniques such as the GraftLink® technique. This update summarizes the published biomechanical and clinical ACL studies for the ACL TightRope implant.

Kulshrestha V,
Sood M,
Kumar S,
Kawale A

In Vivo Citations: Clinical Outcomes

[Original study: early patient-reported functional outcome of all-inside ACL reconstruction as compared to anteromedial portal technique.](#) *Eur J Orthop Surg Traumatol.* 2021;10.1007/s00590-021-02912-6. doi:10.1007/s00590-021-02912-6

- In this randomized study, 80 young active males requiring ACL reconstruction surgery were equally randomized to anteromedial portal technique and all-inside technique.
- The mean improvement in Tegner score was significantly better as compared to the anteromedial portal technique group.
- At 2-year of follow-up, all-inside ACL reconstruction provides a better chance of return to preinjury level of activity with accompanied patient satisfaction as compared to anteromedial portal technique.

Kamitani A,
Hara K,
Arai Y,
et al

[Adjustable-loop devices promote graft revascularization in the femoral tunnel after ACL reconstruction: comparison with fixed-loop devices using magnetic resonance angiography.](#) *Orthop J Sports Med.* 2021. doi:10.1177/2325967121992134

- In this Level 3 cohort study, 42 patients underwent ACL reconstruction using quadrupled semitendinosus autograft and inside-out tunnel preparation.
- This is the first study to compare graft revascularization in vivo between fixed-loop devices (FLDs) (Smith & Nephew EndoButton™) and adjustable-loop devices (ALDs) (Arthrex TightRope® implant) in vivo, focusing on the contact area between the graft and femoral tunnel wall.
- MRA imaging at three-months post-ACL reconstruction showed that blood flow reached the superior end of the tendon graft in the femoral tunnel in more patients who underwent ACL reconstruction with an ALD than with an FLD.
- Findings suggest that the increased graft-to-bone contact area created by ALDs leads to earlier revascularization (0 to 3 months) in the superior end of the socket compared to FLDs, which leave a gap between the graft tip and the superior end of the socket.
- This study's conclusion supports the long-discussed value of TightRope implants to retention and fully seat grafts to achieve the "potted plant" effect.

Uribe-Echevarria B,
Magnuson JA,
Amendola A,
Bollier MJ,
Wolf BR,
Hettrich CM

[Anterior cruciate ligament reconstruction: a comparative clinical study between adjustable and fixed length suspension devices.](#) *Iowa Orthop J.* 2020;40(1):121-127.

- The purpose of this Level IV evidence study is to prospectively measure graft elongation in vivo along with patient-reported outcomes.
- Thirty-seven skeletally mature patients diagnosed with anterior cruciate insufficiency who underwent ACL reconstruction using autogenous hamstring graft were included in this study.
- The adjustable-length cortical suspension device did not demonstrate increased laxity as compared to fixed-length devices. There was no difference in patient-reported outcomes between the groups.

Smith PA,
Cook CS,
Bley JA

[All-inside quadrupled semitendinosus autograft shows stability equivalent to patellar tendon autograft anterior cruciate ligament reconstruction: randomized controlled trial in athletes 24 years or younger.](#) *Arthroscopy*. 2020;36(6):1629-1646. doi:10.1016/j.arthro.2020.01.048

- All-inside quadrupled semitendinosus grafts are suitable in high-risk patients as BTB alternative.
- This randomized controlled trial compared clinical outcomes of knee ACL autograft reconstruction using all-inside quadrupled semitendinosus vs bone-patellar tendon-bone (BPTB) in high-risk young athletes.
- ACL reconstruction with an all-inside quadrupled semitendinosus autograft construct is equivalent to patellar BPTB autograft.

Onggo JR,
Nambiar M,
Pai V

[Fixed- versus adjustable-loop devices for femoral fixation in anterior cruciate ligament reconstruction: a systematic review.](#) *Arthroscopy*. 2019;35(8):2484-2498. doi:10.1016/j.arthro.2019.02.029

- A multidatabase search was performed in July 2018 according to PRISMA guidelines. Articles directly comparing FLDs and ALDs were included.
- Thirteen biomechanical, two prospective, and six retrospective studies were included. Clinical studies showed no statistically significant differences in clinical, functional, radiologic, and complication outcomes between the two groups.
- FLDs and ALDs produced similar clinical outcome scores and graft re-rupture rates. “Biomechanical outcomes were improved with retensioning of ALDs after tibial fixation, as per manufacturer recommendations.”

Ranjan R,
Gaba S,
Goel L,
et al

[In vivo comparison of a fixed loop \(EndoButton CL\) with an adjustable loop \(TightRope RT\) device for femoral fixation of the graft in ACL reconstruction: a prospective randomized study and a literature review.](#) *J Orthop Surg (Hong Kong)*. 2018;26(3):2309499018799787. doi:10.1177/2309499018799787

- IKDC and Lysholm scores, knee stability by AP laxity, and SSD using KT-1000 were used to determine functional outcomes between TightRope® implant and EndoButton during ACL reconstruction.
- Knee stability and SSD were statistically insignificant between the two groups at both six months and two years. At final follow-up (two years), the IKDC and Lysholm results between TightRope implant and EndoButton were similar; however, at six-months post-op, the EndoButton appeared to be better.
- ACL reconstruction with either TightRope implant or EndoButton for femoral fixation “gives substantially equivalent functional results and knee stability at mid-term follow-up.”



Burton DA,
Schaefer EJ,
Shu HT,
Bodendorfer BM,
Argintar EH

[Primary anterior cruciate ligament repair using suture tape augmentation: a case series of 29 patients with minimum 2-year follow-up.](#) *Arthroscopy.* 2021;37(4):1235-1241. doi:10.1016/j.arthro.2020.11.034

- To evaluate clinical outcomes and patient-reported outcomes of patients who underwent primary ACL repair using suture tape augmentation.
- In this Level IV prospective case series, patients with a proximal tear of the ACL who underwent primary ACL repair with a minimum two-year follow-up were included.
- Primary surgical repair of proximal ACL tears using suture tape augmentation results in a low rate of revision surgery, which 2 of 29 patients required.

Parkes CW,
Leland DP,
Levy BA,
et al

[Hamstring autograft anterior cruciate ligament reconstruction using an all-inside technique with and without independent suture tape reinforcement.](#) *Arthroscopy.* 2021;37(2):609-616. doi:10.1016/j.arthro.2020.09.002

- This is a 1:2 matched-cohort comparison of patients who underwent hamstring autograft ACL reconstruction with and without independent suture tape reinforcement.
- This is a Level III, retrospective comparative study.
- ACL reconstruction with hamstring autografts and independent suture tape reinforcement result in low complication, low graft failure, and low reoperation rates.

Yasen SK,
Borton ZM,
Eyre-Brook AI,
et al

[Clinical outcomes of anatomic, all-inside, anterior cruciate ligament \(ACL\) reconstruction.](#) *Knee.* 2017;24(1):55-62. doi:10.1016/j.knee.2016.09.007

- Two-year outcomes of 108 patients treated with ACL reconstruction using the GraftLink® technique (FlipCutter® reamer, ACL TightRope® implant, and quadrupled semitendinosus autograft) are reported.
- The GraftLink technique demonstrates good short- to medium-term subjective and objective outcomes with low complication and failure rates.

Schurz M,
Tiefenboeck TM,
Winnisch M,
et al

[Clinical and functional outcome of all-inside anterior cruciate ligament reconstruction at a minimum of 2 years' follow-up.](#) *Arthroscopy.* 2016;32(2):332-337. doi:10.1016/j.arthro.2015.08.014

- All-inside ACL reconstruction using the GraftLink technique leads to improved functional outcomes in active patients at a minimum follow-up of two years.
- No difference was noted in stability between the ACL-reconstructed and the contralateral normal knee at two years.

Boyle MJ,
Vovos TJ,
Walker CG,
Stabile KJ,
Roth JM,
Garrett WE, Jr

[Does adjustable-loop femoral cortical suspension loosen after anterior cruciate ligament reconstruction? A retrospective comparative study.](#) *Knee.* 2015;22(4): 304-308. doi:10.1016/j.knee.2015.04.016

- Adjustable-loop suspension does not clinically loosen after ACL reconstruction.
- There was no significant difference in postoperative knee stability or graft failure rate between adjustable-loop and fixed-loop femoral cortical suspension in patients undergoing primary ACL reconstruction.



Benea H,
d'Astorg H,
Klouche S,
Bauer T,
Tomoaia G,
Hardy P

[Pain evaluation after all-inside anterior cruciate ligament reconstruction and short term functional results of a prospective randomized study.](#) *Knee.* 2014;21(1):102-106. doi:10.1016/j.knee.2013.09.006

- The results show that postoperative pain, knee stability, ranges of motion, and transplant positioning were slightly better with the all-inside technique.
- The all-inside technique can be considered a valid, reliable procedure with very good results for pain, stability, and knee function. It is a promising option for minimally invasive ACL reconstruction.

Blackman AJ,
Stuart MJ

[All-inside anterior cruciate ligament reconstruction.](#) *J Knee Surg.* 2014;27(5):347-352. doi:10.1055/s-0034-1381960

- Reports suggest similar results in the early postoperative period when compared with traditional techniques.
- All-inside techniques offer the advantages of improved cosmesis, less postoperative pain, decreased bone removal, and gracilis preservation.

In Vitro Citations: Biomechanical Validation

Uchida R,
Nakamura N,
Suzuki T,
et al

[Excellent bone plug-socket integration at 8 weeks after anterior cruciate ligament reconstruction using an adjustable-length loop cortical fixation device.](#) *J ISAKOS.* 2019;4(1):9-14. doi:10.1136/jisakow-2018-000244

- This clinical study evaluated bone plug-socket integration in ACL reconstructions using the BTB TightRope® implant.
- Twenty patients with BTB TightRope implants underwent CT at four and eight weeks postoperatively for assessment of the union between the graft and socket wall. Patients were also evaluated at two years using IKDC and KT-2000 knee stability measurement.
- Excellent bone integration was observed at eight weeks. All knees were rated normal or nearly normal according to IKDC with a mean side-to-side difference of 0.2 mm. Adjustable-length loop cortical fixation devices could be safely applied for anatomic rectangular tunnel ACL reconstruction.

Monaco E,
Bachmaier S,
Fabbri M,
Lanzetti RM,
Wijdicks CA,
Ferretti A

[Intraoperative workflow for all-inside anterior cruciate ligament reconstruction: an in vitro biomechanical evaluation of preconditioning and knot tying.](#) *Arthroscopy.* 2018;34(2):538-545. doi:10.1016/j.arthro.2017.08.283

- Four all-inside ACL reconstruction groups were evaluated. Groups included one or both sides knotted and with and without intraoperative preconditioning.
- Initial graft tension is increased with intraoperative preconditioning in single-side knotted and both-side knotted groups versus without preconditioning. Furthermore, dynamic elongation is reduced for single-side knotted and both-side knotted constructs.
- “All-inside ACL reconstruction with preconditioning according to intraoperative workflow leads to a statistically significant improved mechanical behavior and may allow for optimizing initial graft tension and elongation for all-inside ACL reconstruction to reduce knee laxity.”



Noonan BC,
Bachmaier S,
Wijdicks CA,
Bedi A

[Intraoperative preconditioning of fixed and adjustable loop suspensory anterior cruciate ligament reconstruction with tibial screw fixation – an in vitro biomechanical evaluation using a porcine model.](#) *Arthroscopy*. 2018;34(9):2668-2674. doi:10.1016/j.arthro.2018.04.014

- Biomechanical evaluation of three ACL reconstruction techniques using suspensory femoral fixation and interference screw tibial fixation. The groups were: group 1: ALD and screw; group 2: preconditioned ALD and screw; and group 3: closed loop and screw.
- Surgical placement of an interference screw imparted a time-zero laxity of 0.53 mm and loss of tension (62%).
- The operating characteristics of the TightRope® implant allow for restoration of screw-induced graft slackening and optimizing tension. This was not possible with an FLD (EndoButton). Total elongation varied across groups, with group 2 (preconditioned ALD) showing the least elongation (group 1: 2.22 ± 0.52; group 2: 0.65 ± 0.29; and group 3: 1.79 ± 0.28).
- ACL reconstruction with femoral TightRope implant fixation and intraoperative preconditioning allows for the restoration of time-zero screw-imparted slack and leads to significantly reduced cyclic elongation in accordance with native ACL function.

Smith PA,
Piepenbrink M,
Smith SK,
Bachmaier S,
Bedi A,
Wijdicks CA

[Adjustable- versus fixed-loop devices for femoral fixation in ACL reconstruction: an in vitro full-construct biomechanical study of surgical technique-based tibial fixation and graft preparation.](#) *Orthop J Sports Med*. 2018;6(4):2325967118768743. doi:10.1177/2325967118768743

- This was the first study to test biomechanical strength of the entire graft construct with an expanded cycling protocol.
- The largest pull-to-failure force was observed for the TightRope implant/GraftLink® technique construct, which was statistically significantly different than all other devices.
- The ACL TightRope implant is the only device that was effectively retensioned.
- Elongation with the ACL TightRope implant construct was comparable to FLDs.
- The GraftMax™ button (ConMed) exceeded maximum elongation limits for ACL reconstruction.
- The UltraButton™ adjustable fixation device (Smith & Nephew) lost the greatest amount of force during cycling.

Kusano M,
Kazui A,
Uchida R,
Mae T,
Tsuda T,
Toritsuka Y

[Loop length change of an adjustable-length femoral cortical suspension device in anatomic rectangular tunnel anterior cruciate ligament reconstruction with a bone-patellar tendon-bone graft and associated clinical outcomes.](#) *Arthroscopy*. 2018;34(11):3063-3070. doi.org/10.1016/j.arthro.2018.06.034

- This clinical study evaluated ACL reconstruction with a BTB graft fixed using a BTB TightRope implant.
- The loop length of the BTB TightRope implant was measured by CT at 1 and 12 weeks after the surgery. Subjective and objective outcomes scores were also assessed at 2 years postoperatively.
- The loop length change of the BTB TightRope implant was negligible at 12 weeks. At 2-years postoperatively, 98% of patients were graded as normal or nearly normal according to IKDC with side-to-side difference of 0.2 mm.



Chang MJ,
Bae TS,
Moon YW,
Ahn JH,
Wang JH

[A comparative biomechanical study of femoral cortical suspension devices for soft-tissue anterior cruciate ligament reconstruction: adjustable-length loop versus fixed-length loop.](#) *Arthroscopy*. 2018;34(2):566-572. doi:10.1016/j.arthro.2017.08.294

- An ACL TightRope® implant was tested against EndoButton (FLD) in a device-only model as well as in a biomechanical model.
- There were no significant differences in terms of total displacement, temporal pattern of displacement, or ultimate failure load between the devices.

Mickelson DT,
Lefebvre T,
Gall K,
Riboh JC

[Adjustable-loop femoral cortical suspensory fixation for patellar tendon anterior cruciate ligament reconstruction: a time zero biomechanical comparison with interference screw fixation.](#) *Am J Sports Med*. 2018;46(8):1857-1862. doi:10.1177/0363546518771365

- This biomechanical study compared BTB TightRope implants and metallic interference screws in an ACL reconstruction.
- Human BTB grafts were fixated into porcine femurs with a BTB TightRope implant or metallic interference screw and biomechanically tested.
- Authors compared time zero biomechanical properties between metallic interference screws and ALCFD for femoral fixation of bone-tendon-bone grafts in ACL reconstruction.
- The ALCFD and interference screws were divided into two groups (eight samples each) and human bone-tendon-bone allografts were fixated in porcine distal femurs. The constructs were preconditioned and subjected to cyclic loading before being pulled to failure.
- The loads to failure (mean \pm SD, 700 \pm 256 N compared to 688 \pm 215 N, $P = .92$) and linear stiffness (219 \pm 48 N/mm compared to 218 \pm 49 N/mm, $P = .97$) were not significantly different between the ALCFD and interference screw groups, respectively. The authors concluded that ALDs are acceptable alternatives to an interference screw for femoral fixation during ACL reconstruction with BTB grafts.

Nye DD,
Mitchell WR,
Liu W,
Ostrander RV

[Biomechanical comparison of fixed-loop and adjustable-loop cortical suspensory devices for metaphyseal femoral-sided soft tissue graft fixation in anatomic anterior cruciate ligament reconstruction using a porcine model.](#) *Arthroscopy*. 2017;33(6):1225-1232.e1. doi:10.1016/j.arthro.2016.12.014

- Fixed- and adjustable-loop buttons were tested on metaphyseal bone. This type of testing is much more relevant than pure mechanical testing which doesn't take in vivo conditions (bone, tissue, button position, etc) into consideration.
- The ACL TightRope implant was biomechanically equivalent to fixed-loop button fixation, whereas the Ziploop™ (Zimmer Biomet) showed statistically significantly lower stiffness and more displacement during cycling.



Noonan BC,
Dines JS,
Allen AA,
Altchek DW,
Bedi A

[Biomechanical evaluation of an adjustable loop suspensory anterior cruciate ligament reconstruction fixation device: the value of retensioning and knot tying.](#) *Arthroscopy*. 2016;32(10):2050-2059. doi:10.1016/j.arthro.2016.02.010

- ACL TightRope® RT implants were tested against the EndoButton device using an expanded cycling protocol similar to previous studies (Barrow et al, *Am J Sports Med*. 2014;42(2):343-349; Johnson et al, *Am J Sports Med*. 2015;43(1):154-160). ACL TightRope implants were tested without retensioning, with retensioning, with knotted shortening strands, and with retensioning plus knotted shortening strands.
- ACL TightRope implants without retensioning were within 0.4 mm of EndoButton devices. This difference was deemed not clinically significant by the authors ($P = .101$).
- Retensioned and knotted ACL TightRope implants displaced less than all other groups, including EndoButton devices. Ultimate loads were similar.
- Retensioned and knotted ACL TightRope implants showed the lowest cyclic displacement. However, all displacements were within a fraction of a millimeter, so there is likely no clinical importance.

Johnson JS,
Smith SD,
LaPrade CM,
Turnbull TL,
LaPrade RF,
Wijdicks CA

[A biomechanical comparison of femoral cortical suspension devices for soft tissue anterior cruciate ligament reconstruction under high loads.](#) *Am J Sports Med*. 2015;43(1):154-160. doi:10.1177/0363546514553779

- The TightRope implant with retensioning increases the ultimate strength (1020 N), reduces the cyclic displacement to 1.81 ± 0.51 mm, and is placed in the sub-2 mm category with FLDs.

Smith PA,
DeBerardino TM

[Tibial fixation properties of a continuous-loop ACL hamstring graft construct with suspensory fixation in porcine bone.](#) *J Knee Surg*. 2015;28(6):506-512. doi:10.1055/s-0034-1394167

- All-inside GraftLink® continuous-loop soft-tissue graft with TightRope suspensory fixation provided adequate strength for tibial fixation in ACL reconstruction and is superior to interference screw fixation.

Petre BM,
Smith SD,
Jansson KS,
et al

[Femoral cortical suspension devices for soft tissue anterior cruciate ligament reconstruction: a comparative biomechanical study.](#) *Am J Sports Med*. 2013;41(2):416-422. doi:10.1177/0363546512469875

- The TightRope implant has the necessary biomechanical properties with regard to ultimate failure strength, displacement, and stiffness for initial fixation of soft-tissue grafts in the femoral tunnel for ACL reconstruction.
- Ultimate failure strength was greater than the previously reported strength needed for activities of daily living and rehabilitation exercises.
- The TightRope implant construct reapproximated the native stiffness of the ACL.



Mayr R,
Heinrichs CH,
Eichinger M,
Coppola C,
Schmoelz W,
Attal R

Barrow AE,
Pilia M,
Guda T,
Kadrmaz WR,
Burns TC

Ono Y,
Sato Y,
Mukai H,
et al

(Misleading Literature) In Vitro Citations: Biomechanical Validation

Biomechanical comparison of 2 anterior cruciate ligament graft preparation techniques for tibial fixation: adjustable-length loop cortical button or interference screw. *Am J Sports Med.* 2015;43(6):1380-1385. doi:10.1177/0363546515574062

- Grafts only pretensioned to 11 lb (50 N) for 5 minutes. Arthrex GraftLink® technique pretensions grafts to 20 lb (80 N) on the GraftPro® board. Once implanted, grafts can be tensioned and retensioned after cycling, which would eliminate the first 2 stages of displacement and bring the total GraftLink technique displacement to 3 mm.
- Graft was prepared insufficiently. Only three passes of FiberLoop® suture were used and they were not retained for backup.

Femoral suspension devices for anterior cruciate ligament reconstruction: do adjustable loops lengthen? *Am J Sports Med.* 2014;42(2):343-349. doi:10.1177/0363546513507769

- See DeBerardino TM, Smith PA, Cook JL. Femoral suspension devices for anterior cruciate ligament reconstruction: letter to the editor. *Am J Sports Med.* 2014;42(2):NP15-6.
- While the cause of the error is unknown, possible hypotheses are improper loading of the device, improper manipulation of the device, and/or poor calibration of their testing machine.

Randomized comparative study of suspension femoral fixation device in graft position maintenance in anterior cruciate ligament reconstruction: EndoButton CL vs TightRope RT. *Asia Pac J Sports Med Arthrosc Rehabil Technol.* 2021; 25:42-46. doi:10.1016/j.asmart.2021.05.007

- This CT from Japan compared in vivo elongation of TightRope® RT implant against EndoButton CL for femoral suspensory fixation in hamstring autograft double-bundle ACL reconstruction. Both cohorts used a TightRope RT implant for tibial fixation.
- Both constructs were tensioned, ranged, and retensioned using the tibial TightRope to confirm time-zero graft tension.
- MRIs were taken within 7 days after ACL reconstruction, and at 3-, 6-, and 12-months postoperatively.
- There were no significant differences in elongation between the TightRope implant and EndoButton at any timepoint and there were no significant differences in the HOP index, KSM-100, Lachman test, lateral pivot shift test, or the Lysholm score.

Reference

1. Arthrex, Inc. Sales data on file (as of July 10, 2018). Naples, FL; 2018.