



Can a Two Simple Stitches Method Provide Secure Fixation Strength in Biceps Tenodesis?: Biomechanical Evaluation of Various Suture Techniques

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Background: The purpose of this study was to compare the initial fixation strength between four different suture methods for the long head of the biceps.

Methods: Forty-eight fresh frozen porcine flexor hallucis longus tendons (mean width at suture site, 8.5 ± 0.9 mm) and phalanx bones were randomly assigned to one of the four arthroscopic biceps tenodesis techniques: simple stitch (SS), mattress suture (MS), lasso-loop (LL), and two simple stitches (2SS). A biceps tenodesis was performed according to the four techniques using all-suture type suture anchors (1.9-mm SUTUREFIX anchor with No. 1 ULTRABRAID sutures). Biomechanical evaluations were performed to test load to failure (N), stiffness (N/mm), stress (N/m²), and mode of failure.

Results: As for the SS, MS, LL, and 2SS, the mean load to failure was 50.9 ± 14.61 N, 82.3 ± 24.8 N, 116.2 ± 26.7 N, and 130.8 ± 22.5 N ($p < 0.001$), respectively; mean stiffness was 6.1 ± 1.3 N/mm, 6.7 ± 2.6 N/mm, 7.8 ± 1.4 N/mm, and 8.1 ± 4.2 N/mm, respectively ($p = 0.258$); and mean stress was 0.7 ± 0.3 N/m², 1.4 ± 0.8 N/m², 2.9 ± 0.7 N/m², and 2.7 ± 0.8 N/m², respectively ($p < 0.001$). All the failures happened by the suture cutting through the tendon along its longitudinal fibers.

Conclusions: Neither the SS nor the MS method was enough to securely fix the biceps tendon with a significantly lower mechanical strength; however, the 2SS method showed similar initial fixation strength as the LL technique.

Keywords: Biceps tenodesis, Biomechanical test, Fixation strength, Simple stitch, Lasso-loop, Suture technique

Tendinopathy of the long head of the biceps tendon (LHBT) encompasses a spectrum of pathologies ranging from in-

flammatory tendinitis to degenerative tendinosis. Disorders of the LHBT often occur in conjunction with other shoulder pathologies,¹⁾ which are a significant source of shoulder pain and are generally due to tendinopathy, rupture, anterior and posterior lesions on the superior labrum, pulley tears, and tendon instability.²⁾

Biceps tenotomy and biceps tenodesis are effective treatment options for the pathologic conditions of the LHBT.^{1,3,4)} Recently, several studies have shown that biceps tenodesis has better outcomes than biceps tenotomy in terms of mechanical strength, maintenance of elbow supination/flexion, cramping, and prevention of muscle atrophy and cosmetic deformities.⁵⁻⁸⁾ As the superior outcomes

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of biceps tenodesis emerge, several techniques for proximal biceps tenodesis are being described.⁶⁻⁸⁾ Regardless of the fixation location (supra- or subpectoral), technique (mini-open or arthroscopic), or fixation device (interference screw, suture anchor, or button), biceps tenodesis has shown favorable clinical outcomes.⁹⁻¹¹⁾

Recently, all-suture anchor constructs have been introduced and widely used in shoulder surgery.^{12,13)} In theory, all-suture anchors provide the biomechanical benefits of traditional interference screws while offering a low-profile construct, which is less traumatic to the humeral cortex, thus potentially reducing risk of fracture.¹⁴⁾ In addition, the all-suture anchor allows for easy intra-articular fixation with sufficient fixation strength.¹⁵⁾

The lasso-loop (LL) stitch was first introduced by Lafosse et al.¹⁶⁾ and was shown to have secure fixation strength by improving the tissue grip and reduction force.^{17,18)} Patzer et al.¹⁷⁾ showed that the LL technique achieved strong and secure fixation equivalent to interference screws, and Vestermark et al.¹⁸⁾ also demonstrated that this technique had a greater load to failure compared with the compressive rivet. Despite its promising outcome, LL alone may cause a risk of tendon displacement through suture cutting.¹⁷⁾ And the clinical use of the LL technique is sometimes difficult for less experienced surgeons, especially when using the antegrade suture passer, which automatically retrieves suture threads. For these surgeons, the simple stitch (SS) suture technique is an alternative option that needs less time when compared to the LL technique, especially for the elderly whose demand for the strength of biceps tenodesis may be less than the younger patients. However, the SS alone does not provide sufficient force compared to the LL.¹⁹⁾ So, techniques that utilize the SS twice such as the mattress suture (MS) (one suture thread) or two simple stitches (2SS; two suture threads) are also viable alternatives. It is important to identify whether technically less challenging surgical techniques such as the SS, MS, and 2SS are comparable in biomechanical strength and safety to the LL suture.

Therefore, the purpose of this controlled laboratory study was to compare the biomechanical characteristics of the four biceps tendon tenodesis suture techniques (SS, MS, LL, and 2SS). We hypothesized that compared to the LL, the SS would have inferior biomechanical outcomes, but the 2SS or MS would have equivalent biomechanical outcomes regarding tendon-suture-bone fixation strength.

METHODS

This study was approved by Institute Animal Care and Use

Committee (IACUC KU20153). In this study, 48 fresh frozen porcine flexor digitorum superficialis (FDS) tendons were used. These tendons resemble the human biceps long head in terms of anatomical appearance and biomechanical behavior.²⁰⁾ The porcine FDS tendons (mean width, 8.5 ± 0.9 mm) were harvested 3 hours after being slaughtered and directly frozen under -20°C until the time of testing. Porcine proximal phalanges were also harvested to provide bone beds for biceps tenodesis, and each porcine proximal phalanx was trimmed using an electrical saw to fit in the clamp for the following biomechanical test (Fig. 1).

All biceps tenodesis techniques were performed using all-suture type anchors (1.9-mm SUTUREFIX anchor with No. 1 ULTRABRAID sutures; Smith and Nephew, London, UK). A 1.8-mm drill was used to make unicortical holes perpendicular to the bone surface and a 1.9-mm SUTUREFIX anchor was inserted through the hole. Using the suture thread from the anchor, tenodesis sutures were passed 1 cm from the tendon end. To reduce variability, all tenodesis procedures were performed by one senior investigator (SWC). Fresh frozen FDS tendons were randomly assigned to one of the four arthroscopic biceps tenodesis techniques: SS ($n = 12$), MS ($n = 12$), LL ($n = 12$), and 2SS ($n = 12$) (Fig. 2). For all techniques, a fine needle was used to pass the tendon and all the knot tie was proceeded with a knot-pusher as similar as arthroscopic tie. For the SS, a simple turn was made through the tendon fiber while for the MS, a horizontal mattress stitch was made on the tendon. As for the LL, a loop was created on the upper side of the tendon, and the end of the same suture thread was passed through the loop, as described by Lafosse et al.¹⁶⁾ As for the 2SS, an SS was performed twice using two suture threads. Schematic depiction of stitch methods are shown in Fig. 3.

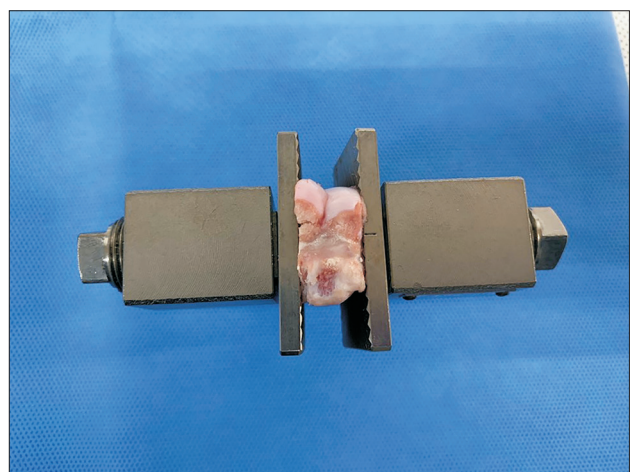


Fig. 1. Porcine proximal phalanx bones fit in the clamp.

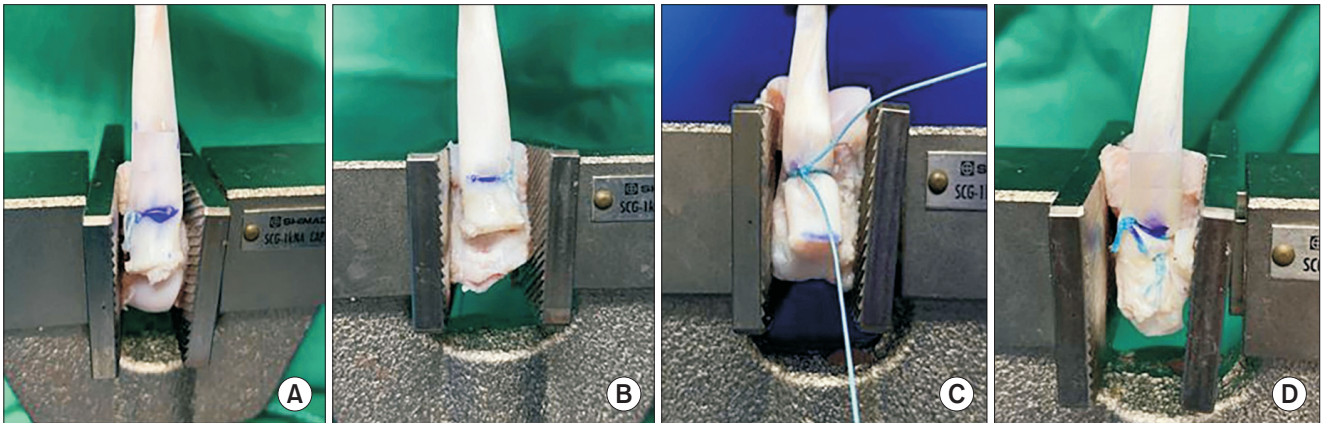


Fig. 2. (A) Simple stitch. (B) Mattress suture. (C) Lasso loop stitch. (D) Two simple stitches.

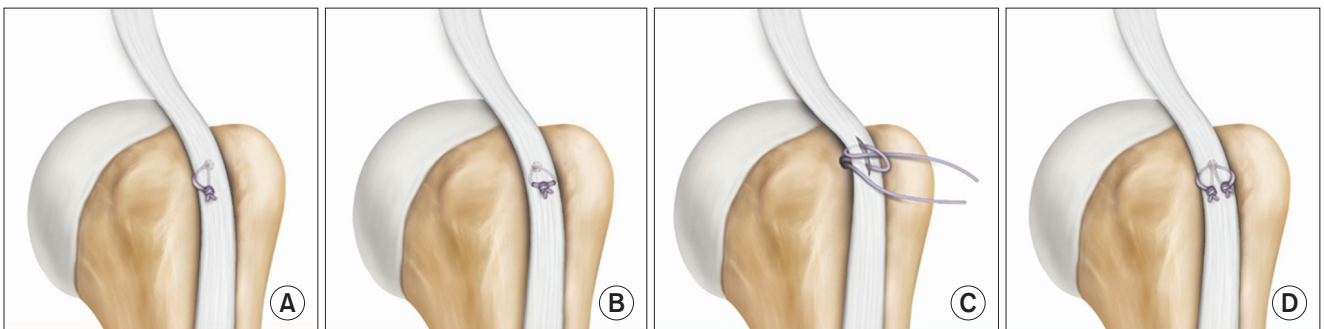


Fig. 3. (A) Simple stitch. (B) Mattress suture. (C) Lasso loop stitch. (D) Two simple stitches.

Biomechanical Testing

A servohydraulic universal testing machine was used for the biomechanical tests (AGS-X trapezium system, Shimadzu, Seoul, Korea). All the biomechanical testing was done immediately after tie was done. During the biomechanical test, the tendons were continuously moisturized with 0.9% normal saline to avoid dry-up. Bone-suture-tendon constructs were fixed perpendicular to the test device with custom-built steel clamps. The bone and tendon parts were rigidly fixed to the lower and upper part of the clamp, respectively (Fig. 4).

Outcome Evaluation

Outcome measures included the mode of failure, ultimate failure load (N), construct stiffness (N/mm), and stress (N/m²). All tendons were preconditioned with a force of 5 N. The tensile test was performed for all constructs at a rate of 1 mm/sec with a preload of 5 N²¹⁾ by using an AGS-X trapezium system (Shimadzu). The tendon was loaded until the suture was pulled out, the suture cut through the tendon, or until knot slippage occurred. The suture cutting through the tendon was defined as the suture cutting

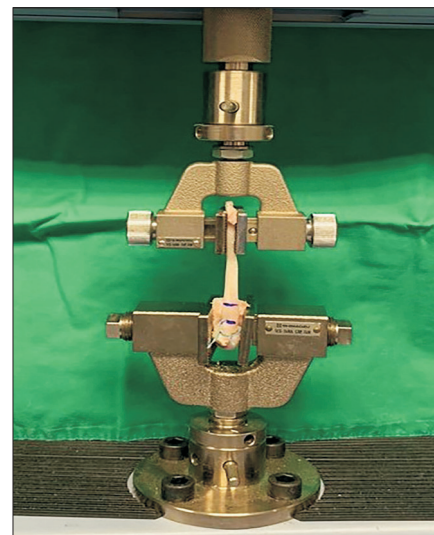


Fig. 4. Biomechanical test setting for the biceps tenodesis.

through from its original position within a longitudinal fiber of the tendon, while knot slippage was defined as slippage without cutting through the tendon. Both the

bone and tendon were fixed to this system along their anatomical direction to allow tensile loading. Ultimate failure load was defined as the highest load attained during testing. Stiffness was defined as the degree to which an object resists its deformation under an applied load, while stress was defined as the resistance of an object to a force, tending to break it apart. Data from the tensile load to failure testing were automatically collected with a data acquisition system on a personal computer. After the failure of the construct, the mode of failure was qualitatively reported.

Statistical Analysis

Data were analyzed using SPSS ver. 21.0 (IBM Corp., Armonk, NY, USA). For load to failure testing and stiffness and stress values, one-way analysis of variance with a Bonferroni post-hoc correction was used. The means and standard deviations were reported and *p*-values of less than 0.013 in a Bonferroni analysis were considered significant. Power analysis (G*Power Software ver. 3.1.9.4; Franz Faul, University of Kiel, Kiel, Germany) indicated that a sample size of 12 per group was required to detect a clinically significant difference in an ultimate failure load (a 25% difference in ultimate failure load; alpha error, 0.05; beta error, 0.2; and drop-out, 20%) based on previous studies.^{19,22)}

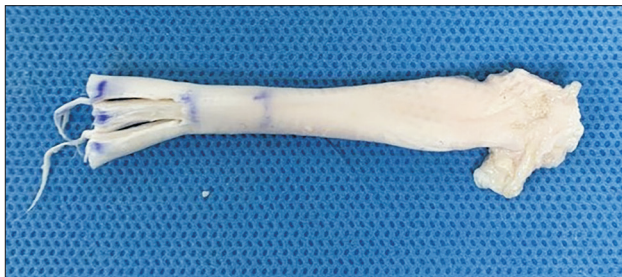


Fig. 5. All failures occurred by the suture cutting through the tendon.

RESULTS

All failures occurred by the suture cutting through the tendon along the longitudinal tendon fibers (Fig. 5). The results of biomechanical testing are shown in Table 1. The ultimate failure load for each of the groups was 50.9 ± 14.61 N, 82.3 ± 24.8 N, 116.2 ± 26.7 N, and 130.8 ± 22.5 N, for the SS, MS, LL, and 2SS methods, respectively ($p < 0.001$). On the other hand, the stress was 0.7 ± 0.3 N/m², 1.4 ± 0.8 N/m², 2.9 ± 0.7 N/m², and 2.7 ± 0.8 N/m², for the SS, MS, LL, and 2SS methods, respectively ($p < 0.001$). The LL and 2SS methods showed a significantly higher ultimate failure load and stress, compared to the SS method (all $p < 0.001$), and the LL method showed a significantly higher stress compared to the MS method ($p < 0.001$). The mean construct stiffness for each of the groups was 6.1 ± 1.3 N/mm, 6.7 ± 2.6 N/mm, 7.8 ± 1.4 N/mm, and 8.1 ± 4.2 N/mm, for the SS, MS, LL, and 2SS methods, respectively. However, there was no statistically significant difference in construct stiffness ($p = 0.258$) (Table 1, Fig. 6). The results of the Bonferroni post-hoc analysis of ultimate failure load, stiffness, and stress are shown in Tables 2-4. The SS method showed significantly lower ultimate failure load and stress test than every other method (all $p < 0.013$), and the LL method did not show significant difference compared with the 2SS method (all $p > 0.013$). There was no statistically significant difference in the construct stiffness in the Bonferroni post-hoc analysis as well (all $p > 0.05$).

DISCUSSION

In this study, the biomechanical properties of the SS and MS methods using one suture thread were significantly lower than those of the LL method, but the 2SS method using two suture threads showed similar initial mechanical strength as the LL method.

As previously demonstrated, a secure tendon fixation is defined as when the suture-tendon construct sustains a load to failure force of about 112 N in a biceps

Table 1. Biomechanical Data of Each Biceps Tenodesis Method

Variable	SS	MS	LL	2SS	<i>p</i> -value
Ultimate load to failure (N)	50.9 ± 14.61	82.3 ± 24.8	116.2 ± 26.7	130.8 ± 22.5	< 0.001
Stiffness (N/mm)	6.1 ± 1.3	6.7 ± 2.6	7.8 ± 1.4	8.1 ± 4.2	0.258
Stress (N/m ²)	0.7 ± 0.3	1.4 ± 0.8	2.9 ± 0.7	2.7 ± 0.8	< 0.001

Values are presented as mean \pm standard deviation.

SS: simple stitch, MS: mattress suture, LL: lasso-loop, 2SS: two simple stitches.

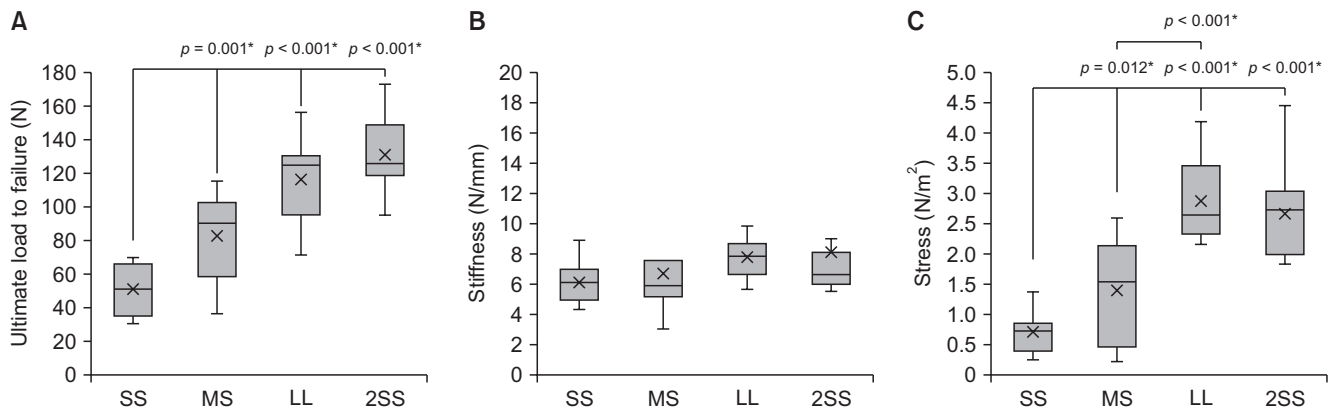


Fig. 6. (A-C) Biomechanical data of each biceps tenodesis method. SS: simple stitch, MS: mattress suture, LL: lasso-loop, 2SS: two simple stitches. *Statistically significant.

Table 2. Results of Bonferroni Post-Hoc Analysis for the Ultimate Load to Failure of Each Suture Method

Variable	SS	MS	LL	2SS
SS		0.001*	< 0.001*	< 0.001*
MS	0.001*		0.027	0.096
LL	< 0.001*	0.027		0.900
2SS	< 0.001*	0.096	0.900	

The mechanical test was performed using an AGS-X materials testing machine. SS: simple stitch, MS: mattress suture, LL: lasso-loop, 2SS: two simple stitches. *Statistically significant, $p < 0.013$.

Table 3. Results of Bonferroni Post-Hoc Analysis for the Stiffness of Each Suture Method

Variable	SS	MS	LL	2SS
SS		0.521	0.015	0.127
MS	0.521		0.295	0.344
LL	0.015	0.295		0.787
2SS	0.127	0.344	0.787	

The mechanical test was performed using an AGS-X materials testing machine. SS: simple stitch, MS: mattress suture, LL: lasso-loop, 2SS: two simple stitches.

Table 4. Results of Bonferroni Post-Hoc Analysis for the Stress of Each Suture Method

Variable	SS	MS	LL	2SS
SS		0.012*	< 0.001*	< 0.001*
MS	0.012*		< 0.001*	0.050
LL	< 0.001*	< 0.001*		0.166
2SS	< 0.001*	0.050	0.166	

The mechanical test was performed using an AGS-X materials testing machine. SS: simple stitch, MS: mattress suture, LL: lasso-loop, 2SS: two simple stitches. *Statistically significant, $p < 0.013$.

tenodesis, which can maintain activities of daily living.⁷⁾ On the basis of this definition, the ultimate failure load of the 2SS method, as well as the LL method, was shown to provide adequate strength in this study to maintain activities of daily living, whereas the SS and MS were not. Gigi et al.¹⁹⁾ reported very similar results with a 46.1 N load to failure using the SS method and a 122.2 N load to failure in a triple LL method. SS is not enough for the secure fixation of the biceps tendon, but 2SS using two suture threads would provide sufficient fixation strength for the biceps tenodesis using suture anchors. We believe that if a surgeon was reluctant to perform the LL method as it needs more time with more steps, the 2SS method would be a good alternative option with sufficient initial fixation strength.

The MS and 2SS methods use an SS twice; however, contrary to the hypothesis of this study, the MS method showed an inferior biomechanical strength compared to the LL and 2SS methods. This may be due to the difference of the number of suture threads used. Previous reports support this result in their claims that increasing the number of sutures would increase load to failure and provide a better repair construct strength.²³⁾

Previously, the ultimate failure loads after a biceps tenodesis using suture anchors were reported to range from 46.1 N to 187 N with failures at the suture-tendon interface in cadaveric specimens.^{6,17,19,21,22)} In this study, we also showed a similar range of ultimate failure loads after a biceps tenodesis using all-suture anchors, ranging from 50.89 ± 14.61 N to 130.84 ± 22.54 N. Most notably, although we used fresh frozen porcine FDS tendons and bones, all failures occurred at the suture-tendon interface, not the anchor pullout. We believe that it can lead to the similar mechanical results in spite of the differences between the human cadaver and porcine bones.

It has been reported that the weakest link of a biceps long head tenodesis with suture anchors is the suture-tendon interface.^{24,25)} Spiegel et al.²⁵⁾ showed that the improved strength of the suture-tendon interface can bring a secure time-zero strength of the repair construct in a biceps tenodesis using suture anchors. Millett et al.²⁴⁾ reported that all the complications occurred within 2 months after a biceps tenodesis, and most of these were tendon ruptures at the suture-tendon fixation site. The strength with which a knot can grasp and hold the tendon is reported to be the most important factor to decrease early structural failure.²⁶⁾ In this study, no anchor pullout occurred, and the failures in all specimens occurred as the suture cutting through the tendon along the longitudinal tendon fibers. This shows that the most vulnerable interface in biceps tenodesis is the suture-tendon interface, not the anchor-

bone interface.

Moreover, many authors have shown that these recently developed all-suture anchors yield promising biomechanical results for a biceps tenodesis, with a similar fixation strength as the interference screw or conventional suture anchors.²⁷⁾ Considering the potential risk of humeral fractures, especially when using an interference screw for the subpectoral biceps tenodesis,¹³⁾ and considering that the surgical technique of an all-suture anchor insertion is relatively easier than the interference screw, the use of all-suture anchors may have a benefit in a biceps tenodesis.

This study is the first to compare the biomechanical characteristics of various SS methods with the LL method using all-suture anchors in a biceps tenodesis. From the results of this study, we found that the SS method did not provide sufficient biomechanical strength, but the 2SS method using two suture threads would be a good alternative to the LL method, showing higher biomechanical properties although it did not reach a statistically significant level. It can provide sufficient fixation strength in a biceps tenodesis using suture anchors. Nevertheless, this study has several limitations. First, this study was not performed using fresh frozen human cadaver specimens, which are the preferred specimens. Instead, young porcine FDS tendons were used; these are reported to have similar anatomical and biomechanical properties as a human biceps tendon.²⁸⁾ Recently, Domnick et al.²⁸⁾ reported that porcine and bovine flexor tendons are suitable substitutes with similar stiffness and failure loads compared with human cadaveric tendon samples. Human tendon donors are mostly elderly, with degenerative biceps tendons and a biceps tenodesis is usually not performed for these patients.²⁹⁾ Moreover, porcine tendons may be superior in terms of tissue quality and minimal variability compared to the human cadaveric specimens. Second, we did not use cyclic loading and assessed the failure load in a single-pull load to failure fashion. Third, we only compared the biomechanical strength among stitch knot techniques. The biceps tenodesis using an interference screw can give a stronger fixation than stitch knot techniques. Further research comparing an interference screw and stitch knot techniques may be needed. Fourth, this is a time-zero study, which provides information only about initial fixation strength and does not account for the biological restoration processes or dynamic biomechanical forces experienced by the biceps muscle. Additional clinical studies may be needed to determine whether the improved time-zero strength would result in reduced failure rates and improved clinical outcomes.

Neither the SS nor the MS method was enough to securely fix the biceps tendon with a significantly lower mechanical strength; however, the 2SS method showed similar initial fixation strength as the LL technique.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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REFERENCES

- Nho SJ, Strauss EJ, Lenart BA, et al. Long head of the biceps tendinopathy: diagnosis and management. *J Am Acad Orthop Surg.* 2010;18(11):645-56.
- Longo UG, Loppini M, Marineo G, Khan WS, Maffulli N, Denaro V. Tendinopathy of the tendon of the long head of the biceps. *Sports Med Arthrosc Rev.* 2011;19(4):321-32.
- Mellano CR, Shin JJ, Yanke AB, Verma NN. Disorders of the long head of the biceps tendon. *Instr Course Lect.* 2015;64:567-76.
- Werner BC, Brockmeier SF, Gwathmey FW. Trends in long head biceps tenodesis. *Am J Sports Med.* 2015;43(3):570-8.
- Leroux T, Chahal J, Wasserstein D, Verma NN, Romeo AA. A systematic review and meta-analysis comparing clinical outcomes after concurrent rotator cuff repair and long head biceps tenodesis or tenotomy. *Sports Health.* 2015;7(4):303-7.
- Mazzocca AD, Bicos J, Santangelo S, Romeo AA, Arciero RA. The biomechanical evaluation of four fixation techniques for proximal biceps tenodesis. *Arthroscopy.* 2005;21(11):1296-306.
- Romeo AA, Mazzocca AD, Tauro JC. Arthroscopic biceps tenodesis. *Arthroscopy.* 2004;20(2):206-13.
- Wolf RS, Zheng N, Weichel D. Long head biceps tenotomy versus tenodesis: a cadaveric biomechanical analysis. *Arthroscopy.* 2005;21(2):182-5.
- Abraham VT, Tan BH, Kumar VP. Systematic review of biceps tenodesis: arthroscopic versus open. *Arthroscopy.* 2016;32(2):365-71.
- Erickson BJ, Basques BA, Griffin JW, et al. The effect of concomitant biceps tenodesis on reoperation rates after rotator cuff repair: a review of a large private-payer database from 2007 to 2014. *Arthroscopy.* 2017;33(7):1301-7.
- Gombera MM, Kahlenberg CA, Nair R, Saltzman MD, Terry MA. All-arthroscopic suprapectoral versus open subpectoral tenodesis of the long head of the biceps brachii. *Am J Sports Med.* 2015;43(5):1077-83.
- Goschka AM, Hafer JS, Reynolds KA, et al. Biomechanical comparison of traditional anchors to all-suture anchors in a double-row rotator cuff repair cadaver model. *Clin Biomech (Bristol, Avon).* 2015;30(8):808-13.
- Su WR, Ling FY, Hong CK, Chang CH, Lin CL, Jou IM. Subpectoral biceps tenodesis: a new technique using an all-suture anchor fixation. *Knee Surg Sports Traumatol Arthrosc.* 2015;23(2):596-9.
- Frank RM, Bernardoni ED, Veera SS, et al. Biomechanical analysis of all-suture suture anchor fixation compared with conventional suture anchors and interference screws for biceps tenodesis. *Arthroscopy.* 2019;35(6):1760-8.
- Hsu AR, Ghodadra NS, Provencher MT, Lewis PB, Bach BR. Biceps tenotomy versus tenodesis: a review of clinical outcomes and biomechanical results. *J Shoulder Elbow Surg.* 2011;20(2):326-32.
- Lafosse L, Van Raebroeckx A, Brzoska R. A new technique to improve tissue grip: "the lasso-loop stitch". *Arthroscopy.* 2006;22(11):1246.e1-3.
- Patzer T, Rundic JM, Bobrowitsch E, Olender GD, Hurschler C, Schofer MD. Biomechanical comparison of arthroscopically performable techniques for suprapectoral biceps tenodesis. *Arthroscopy.* 2011;27(8):1036-47.
- Vestermark G, Hartigan D, Piasecki D, et al. Biceps tenodesis: biomechanical assessment of 3 arthroscopic suprapectoral techniques. *Orthopedics.* 2017;40(6):e1009-16.
- Gigi R, Dolkart O, Sharfman ZT, et al. Biomechanical evaluation of two arthroscopic techniques for biceps tenodesis: triple loop suture versus simple suture. *J Shoulder Elbow Surg.* 2017;26(1):165-9.
- Denard PJ, Dai X, Hanypsiak BT, Burkhart SS. Anatomy of the biceps tendon: implications for restoring physiological length-tension relation during biceps tenodesis with interference screw fixation. *Arthroscopy.* 2012;28(10):1352-8.

21. Golish SR, Caldwell PE 3rd, Miller MD, et al. Interference screw versus suture anchor fixation for subpectoral tenodesis of the proximal biceps tendon: a cadaveric study. *Arthroscopy*. 2008;24(10):1103-8.
22. Kaback LA, Gowda AL, Paller D, Green A, Blaine T. Long head biceps tenodesis with a knotless cinch suture anchor: a biomechanical analysis. *Arthroscopy*. 2015;31(5):831-5.
23. Liu RW, Lam PH, Shepherd HM, Murrell G. Tape versus suture in arthroscopic rotator cuff repair: biomechanical analysis and assessment of failure rates at 6 months. *Orthop J Sports Med*. 2017;5(4):2325967117701212.
24. Millett PJ, Rios D, Martetschlager F, Horan MP. Complications following subpectoral biceps tenodesis with interference screw fixation. *Obere Extrem*. 2014;9(4):276-9.
25. Spiegl UJ, Smith SD, Euler SA, Millett PJ, Wijdicks CA. Biomechanical consequences of proximal biceps tenodesis stitch location: musculotendinous junction versus tendon only. *Knee Surg Sports Traumatol Arthrosc*. 2015;23(9):2661-6.
26. Cummins CA, Murrell GA. Mode of failure for rotator cuff repair with suture anchors identified at revision surgery. *J Shoulder Elbow Surg*. 2003;12(2):128-33.
27. Chiang FL, Hong CK, Chang CH, Lin CL, Jou IM, Su WR. Biomechanical comparison of all-suture anchor fixation and interference screw technique for subpectoral biceps tenodesis. *Arthroscopy*. 2016;32(7):1247-52.
28. Domnick C, Wieskotter B, Raschke MJ, et al. Evaluation of biomechanical properties: are porcine flexor tendons and bovine extensor tendons eligible surrogates for human tendons in in vitro studies? *Arch Orthop Trauma Surg*. 2016;136(10):1465-71.
29. Muller S, Flury R, Zimmermann S, et al. The new LasoLoop360° technique for biomechanically superior tissue grip. *Knee Surg Sports Traumatol Arthrosc*. 2019;27(12):3962-9.