JSES International 7 (2023) 2393–2399

Contents lists available at ScienceDirect

JSES International

journal homepage: www.jsesinternational.org

# Biomechanical properties of suprapectoral biceps tenodesis with double-anchor knotless luggage tag sutures vs. subpectoral biceps tenodesis with single-anchor whipstitch suture using all-suture anchors

Richard W. Nicolay, MD[a], Amirhossein Jahandar, MS[a], Julia S. Retzky, MD[a], Andreas Kontaxis, PHD[a], Nikhil N. Verma, MD[b], Michael C. Fu, MD, MHS[a,*]

[a]Department of Orthopaedic Surgery, Hospital for Special Surgery, New York City, NY, USA
[b]Section of Shoulder and Elbow Surgery, Division of Sports Medicine, Department of Orthopaedic Surgery, Rush University Medical Center, Chicago, IL, USA

A R T I C L E I N F O

*Keywords:*
Biceps tenodesis
Proximal biceps brachii tendon
Biomechanics
Suprapectoral
Subpectoral
All-suture anchor

*Level of evidence:* Basic Science Study; Biomechanics

**Background:** As the use of all-suture anchors continues to increase, limited biomechanical data on the use of these anchors in various configurations for tenodesis of the long head biceps tendon (LHBT) exists. The aim of this study was to compare the biomechanical properties of a 2-anchor luggage tag suprapectoral biceps tenodesis (Sup-BT) vs. a single-anchor whipstitch subpectoral biceps tenodesis (Sub-BT) using all-suture anchors. The hypothesis was that the Sub-BT will have a higher ultimate load to failure and less creep relative to the Sup-BT construct.

**Methods:** Eighteen fresh frozen cadaveric humeri were used. The specimens were randomly divided into 2 groups of 9; i) The Sup-BT were performed with 2 1.8 mm knotless all-suture anchors using a luggage-tag fixation configuration, ii) The Sub-BT were performed using a single 1.9 mm all-suture anchor and a whipstitch suture configuration with a tied knot. The humeri were tested on a hydraulic MTS machine where the specimens were preloaded at 5 N for 2 minutes and then cyclically loaded from 5 to 50 N for 1000 cycles at 1 Hz while maximum displacement was recorded with a motion system and markers attached to the bone and bicep tendon. The tendon was then tensioned at a rate of 1 mm/s to obtain the ultimate load to failure. CT scans of the specimens were used to calculate the bone mineral density at the site of the anchor/bone interface and video recordings were captured during load to failure to document all modes of failure.

**Results:** There was no significant difference in the average load to failure of the Sup-BT and Sub-BT groups (197 N ± 45 N (SD), 164 N ± 68 N (SD) respectively; $P = .122$) or creep under fatigue between the Sup-BT vs. Sub-BT specimens (3.1 mm, SD = 1.5 vs. 2.2 mm, SD = 0.9; $P = .162$). The bone mineral density was statistically different between the 2 groups ($P < .001$); however, there were no observed failures at the anchor/bone interface and no correlation between failure load and bone mineral density.

**Conclusion:** The ultimate load to failure and creep between a Sup-BT with 2 knotless all-suture anchors using a luggage tag suture configuration was equivalent to a Sub-BT with 1 all-suture anchor using a whipstitched suture configuration and a tied knot. Surgeons can perform either technique confidently knowing that they are biomechanically equivalent in a cadaver model at time zero, and they offer similar strength to other fixation methods cited in the literature.



Tenodesis is a popular procedure to address pathology of the long head of the biceps tendon (LHBT). Many different fixation methods have been described, including soft tissue attachment,[31] interference screws,[1] cortical buttons,[30] and suture anchors.[19] The position of the tenodesis has also been studied extensively and both the suprapectoral and subpectoral location have been popularized.[6,9,34] Suprapectoral tenodeses are often performed arthroscopically, while subpectoral biceps tenodeses are more commonly performed via a mini-open approach. Each approach has its respective benefits and drawbacks. An arthroscopic suprapectoral tenodesis avoids the morbidity associated with the subpectoral

Institutional review board approval was not required for this cadaveric study.

*Corresponding author: Michael C. Fu, MD, MHS, Department of Orthopaedic Surgery, Hospital for Special Surgery, 535 E 70th Street, New York, NY 10021, USA.
*E-mail address:* fum@hss.edu (M.C. Fu).

https://doi.org/10.1016/j.jseint.2023.07.013

incision and dissection, while a mini-open subpectoral approach addresses LHBT pathology in the lower part of the bicipital tunnel and allows for more robust suturing of the tendon such as a Krakow or a whipstitch configuration. A large, well-performed systematic review and meta-analysis from 2020 concluded that the fixation strength of suprapectoral and subpectoral tenodeses were biomechanically equivalent and interference screws were equivalent to the fixation strength of cortical buttons, suture anchors, and soft tissue attachment.[5] This study and several others evaluating the biomechanical properties of the aforementioned fixation techniques for either suprapectoral biceps tenodesis or subpectoral biceps tenodesis[25,26] made it clear that despite the wealth of biomechanical data of biceps tenodesis, no single technique has consistently demonstrated biomechanical superiority over the others.

Recently, all-suture anchors and knotless anchors have been gaining popularity, especially given the potential complications of fixation with interference screws, including fractures of the humerus[28] and reaction to biodegradable screws.[21] Modern small-diameter knotless all-suture anchors have enabled arthroscopic suprapectoral biceps tenodesis techniques using multiple anchors to create an area of tendon compression against the humerus in an onlay fashion.[24] In addition, the use of these anchors simplifies the surgical technique and eliminates any need to exteriorize the tendon. Although several recent studies have investigated the biomechanical properties of all-suture anchors for subpectoral[3,10,20,23,29] and suprapectoral[16] biceps tenodeses, no prior study has directly compared the biomechanical properties of knotless all-suture anchors for subpectoral vs. suprapectoral biceps tenodeses. Moreover, while the surgical technique for suprapectoral biceps tenodesis with 2 luggage tag sutures has been described using a SwiveLock anchor (Arthrex, Naples FL, USA)[14] or a single all-suture anchor,[14,18] no previous study has evaluated the biomechanical properties, including load to failure and displacement, of a suprapectoral biceps tenodesis performed with 2 luggage tag sutures and 2 all-suture anchors.

The aim of this study was to compare the strength (load to failure) and creep under fatigue between 2 different LHBT fixations; i) suprapectoral tenodesis (Sup-BT) with 2 knotless all-suture anchors in luggage tag fashion and ii) subpectoral tenodesis (Sub-BT) with 1 all-suture anchor with a whipstitch configuration. The hypothesis was that the Sub-BT would have a higher ultimate load to failure and less displacement with cyclic loading relative to Sup-BT.

## Materials and methods

### *Cadaveric preparation*

Eighteen fresh frozen cadaver specimens were utilized. To gain access to the biceps tendon, the transverse humeral ligament was released completely, and the vincula was removed. The Sup-BT was performed in nine cadavers (chosen randomly) using 2 1.8-mm knotless all-suture FiberTak anchor (Arthrex, Naples FL, USA) placed 5 mm adjacent to the articular margin and 15 mm distal in the bicipital groove using a luggage-tag fixation configuration, with approximately 1 cm between anchors. The luggage tag was created by passing a bird-beak suture passer through the center of the tendon at the level of the anchor. The working suture was retrieved and partly pulled through the center of the tendon, to form a loop. The suture was then released, and the bird-beak was passed through the loop to retrieve the end of the working suture on the other side of the tendon (Fig. 1, *1A*). The working suture was then shuttled through the knotless mechanism in the all-suture anchor in standard fashion (Fig. 1, *1B*).

The Sub-BT was performed in the other nine cadavers using 1 1.9-mm all-suture FiberTak anchor placed in a subpectoral position,

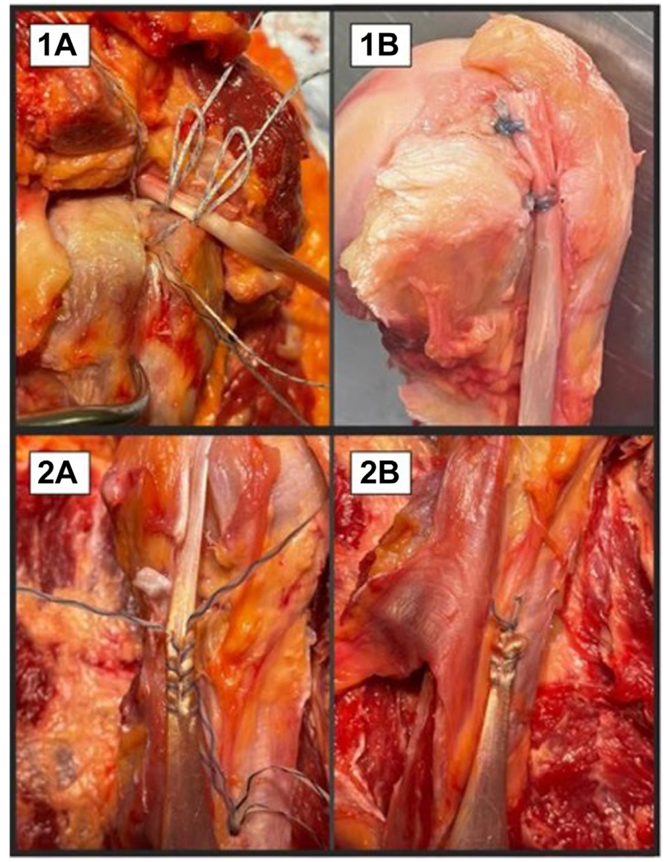


**Figure 1** Photographs of anchor and knot constructs. **1A**—demonstrates the configuration of the working suture from each knotless suture anchor in the Sup-BT. **1B**—demonstrates the suture configuration and tendon fixation after tensioning. **2A**—demonstrates the whipstitch pattern of the Sub-BT. **2B**—demonstrates the Sub-BT after shuttling, tensioning, and tying the tendon to bone. *Sub-BT*, subpectoral tenodesis.

in the bicipital groove, 15 mm proximal to the inferior border of the pectoralis major tendon. The LHBT was sutured using a whipstitch configuration (Fig. 1, *2A*). The sutures were tensioned to shuttle the tendon down firmly to bone, the sutures were then tied with a surgeon's knot dressed with 2 alternating half-hitches from the opposite post, 2 alternating half-hitches on the original post, and finally 1 half-hitch on the opposite post for a total of 5 alternating half-hitches (Fig. 1, *2B*). One whipstitch limb was used following recommendations by Hong et al who demonstrated that a single Krakow row is as strong as a double Krakow row.[15]

### *Biomechanical testing*

The humeri were loaded into the testing jig on a hydraulic uniaxial MTS machine. The jig's frame was fixed on the lower part of the MTS and helped aligned the humeral axis along the pulling axis of the MTS machine. The LHBT was held with a non-frozen jaw clamp with asymmetrical teeth that was attached to the upper part of the MTS and was pulling the tendon in the direction of the humeral axis. Infrared optical markers were placed on the tendon (adjacent to the proximal suture repair), the humeral bone to record motion during testing and to the clamp to record any tendon/clamp slippage (Fig. 2). The specimens were preloaded at 5 N for 2 minutes and then cyclically loaded from 5 to 50 N for 1000 cycles at 1 Hz while maximum displacement was recorded. After the cyclic loaded test was finished, the LHBT was tensioned at a slow rate of 1 mm/s until failure of the LHBT fixation was visually observed. The

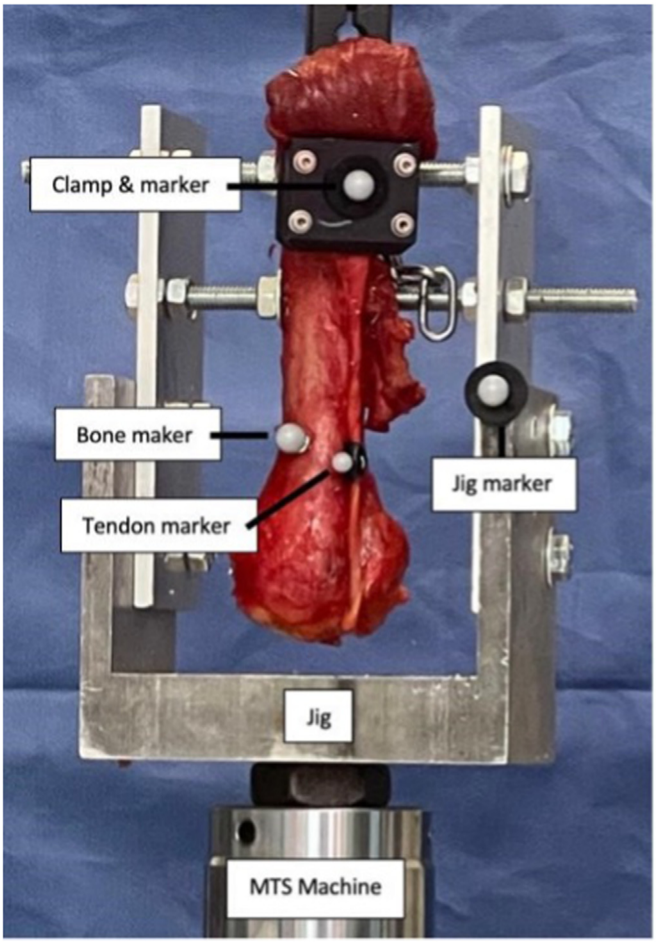


**Figure 2** Photograph of the testing set-up with a Sup-BT specimen mounted onto the testing jig on the MTS machine. Infrared markers were placed on the clamp, bone, tendon, and jig and the relative position of each was tracked throughout testing with 4 infrared cameras. *Sup-BT*, suprapectoral tenodesis.

ultimate load to failure was defined as the maximum load of the load/displacement curve during the test. Video recordings were captured during load to failure and all modes of failure were documented.

### *Bone density*

After testing, each cadaveric humeri underwent CT scan to determine the bone mineral density adjacent to the anchor site. A reference phantom of known density was used to calibrate the Hounsfield unit of the images from each CT scan. The bone mineral density for each specimen was measured in grams per cubic millimeter (g/mm$^3$).

### *Statistical analysis*

The normality of the continuous load to failure data was tested with the Kolmogorov–Smirnov test ($P = .200$) and a nonparametric Mann–Whitney U-test (2-tailed) was utilized to analyze the means of the Sup-BT and the Sub-BT specimens. The bone density and the measures of creep under fatigue for the Sup-BT and Sub-BT were compared with heteroscedastic Student's t-tests. The creep under fatigue was defined as the displacement after 1000 cycles subtracted by the displacement after the first 100 cycles. All analyses were performed using SPSS statistical software (IBM Corp., Armonk, NY, USA). Statistical significance was determined at the $P < .05$ level.

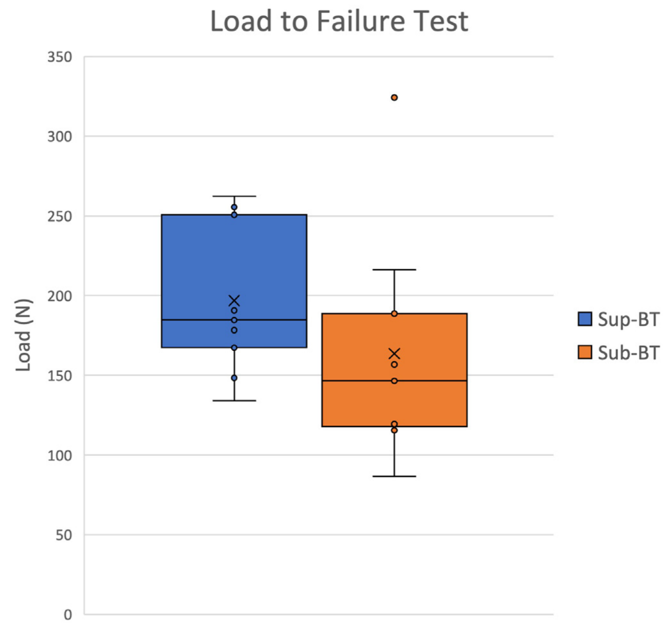


**Figure 3** Boxplot of the ultimate load to failure of the suprapectoral biceps tenodesis (Sup-BT) and the subpectoral biceps tenodesis (Sub-BT) specimens in Newtons (N).

## Results

There was no significant difference in the average load to failure of the Sup-BT vs. Sub-BT (197 N ± 45 N (SD), 164 N ± 68 N (SD) respectively; $P = .122$) (Fig. 3). The creep under fatigue was also not significantly different between the Sup-BT vs. Sub-BT specimens (3.1 mm, SD = 1.5 vs. 2.2 mm, SD = 0.9; $P = .162$) (Fig. 4). Although the average bone density adjacent to the anchor site was higher in the Sub-BT group (518 ± 21 g/mm$^3$) compared to the suprapectoral group (324 ± 34 g/mm$^3$, $P < .001$), there were no observed failures at the anchor/bone interface in either group (Fig. 5) (Table I).

The Sup-BT cohort demonstrated 3 distinct failure mechanisms, failure at the anchor-suture interface (n = 5, 56%), failure at the tendon-suture interface (n = 3, 33%), and failure of the knot (n = 1, 11%) (Fig. 6). The Sub-BT cohort similarly demonstrated 3 distinct failure mechanisms: failure of the knot (n = 6, 67%), failure at the tendon-suture interface (n = 2, 22%), and failure at the anchor-suture interface (n = 1, 11%) (Fig. 7). In the Sub-BT group, the knot failures were low outliers with mean average failure of 117 ± 40.6 N while the suture breakage specimen (failure at the anchor-suture interface) was the lone high outlier which demonstrated failure at 324 N.

## Discussion

The results indicate that the biomechanical strength of the Sup-BT and Sub-BT in a cadaveric model using all-suture anchors was equivalent at time zero. Our load to failure results were consistent with previously published values for Sub-BT (range 68-239 N, mean 158 N)[3,5,12] and Sup-BT (range 47-290 N, mean 205 N)[2,5,17] performed with both solid and all-suture anchors. This study, and nearly all others, demonstrates that the strength of most proposed fixation methods for the LHBT are supraphysiologic, as the maximum physiologic load the LHB has been estimated as 11-55 N.[7] For readers that prefer either of these fixation techniques for biceps

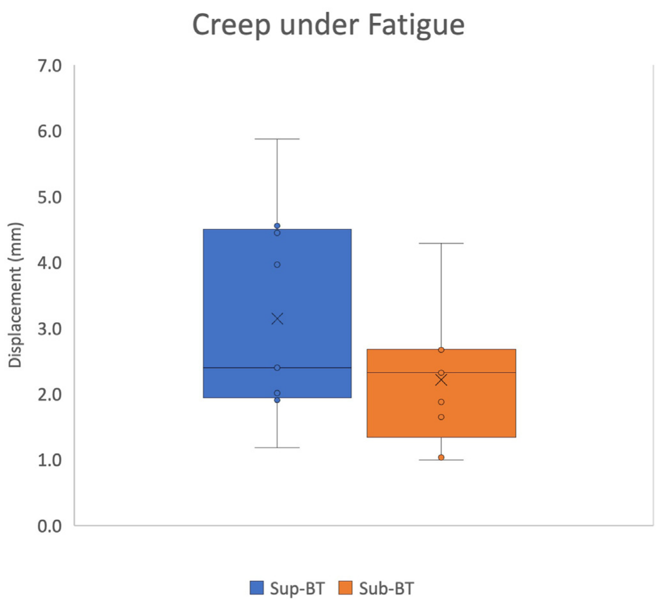


**Figure 4** Boxplot of the creep under fatigue of the suprapectoral biceps tenodesis (Sup-BT) and the subpectoral biceps tenodesis (Sub-BT) specimens in millimeters (mm).

tenodesis, they can perform them confidently knowing that they are biomechanically equivalent in a cadaver model at time zero and they offer similar strength to other fixation methods cited in the literature.

The present study builds on the existing literature by evaluating the biomechanical properties of sup-BT performed with 2 luggage tag sutures and 2 all-suture anchors and comparing the load to failure and displacement of sup-BT vs. sub-BT performed with all-suture anchors. Although this study demonstrates biomechanical equivalence between these 2 techniques, the 2 techniques have significant clinical differences. First, the Sup-BT offers the ability to complete the procedure arthroscopically at the time of concomitant arthroscopic procedures while avoiding the potential complications of an open Sub-BT approach. The Sub-BT approach, however, removes the portion of the LHBT in the groove and subpectoral region. The work of Taylor et al demonstrated the importance of the subpectoral region and its fibro-osseous anatomy.[33] When there is indefinable pathology in the bicipital groove, many authors advocate that the subpectoral tenodesis is superior. However, the subpectoral tenodesis poses increased risk of wound complications, iatrogenic nerve injury, and postoperative humeral fracture.[4,8,11,22,27,28] Surgeons must consider all of these factors when choosing a particular technique. In the authors opinion, the fact that the arthroscopic technique allows removal of the tendon from the groove and placement between the inferior border of the groove and superior border of the pec tendon should eliminate groove pain as a potential issue.

Frank et al performed a study using the same Sub-BT technique as this study. Their results demonstrated a higher ultimate load to failure (230.61 N ± 55.08 N (SD)) and concluded that subpectoral fixation with all-suture anchors, conventional suture anchors and interference screws were biomechanically equivalent. They did however demonstrate that when torsional forces were applied to each humerus to induce a spiral fracture, the fractures always passed through the interference screw drill hole and not the holes from the anchors. This implicated that the large interference screw drill size (8 mm) serves as a stress riser for fracture.[10]

Biceps tenodesis is commonly performed using either onlay fixation in which the tendon is compressed to the cortical surface

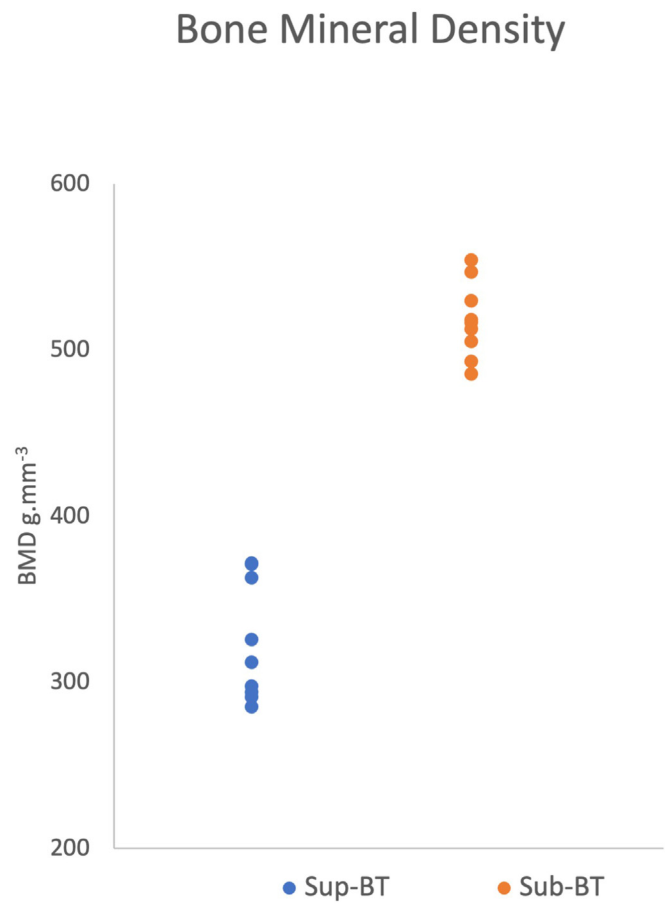


**Figure 5** Plot of the bone mineral density (BMD) of the bone surrounding the anchor in the suprapectoral biceps tenodesis (Sup-BT) and the subpectoral biceps tenodesis (Sub-BT) specimens in grams per cubic millimeter (g/mm$^3$).

**Table I**
Biomechanical and bone density results.

| | Load to failure (N) | | | Creep under fatigue (mm) | | | Bone density (g/mm$^3$) | | |
|---|---|---|---|---|---|---|---|---|---|
| Tenodesis | Mean | SD | *P* value | Mean | SD | *P* value | Mean | SD | *P* value |
| Suprapectoral | 197 | 45 | .122 | 3.1 | 1.5 | .162 | 324 | 34 | <.001 |
| Subpectoral | 164 | 68 | | 2.2 | 0.9 | | 518 | 21 | |

*SD*, standard deviation; *N*, Newtons; *mm*, millimeters; *g/mm$^3$*, grams/cubic millimeter.

via suture anchors or unicortical buttons, or inlay fixation, which involves passing the biceps tendon through drill holes in the proximal humerus and fixation with either an interference screw or bicortical buttons. The inlay technique has the theoretical advantage of improved healing at the tendon-cancellous bone interface; however, animal studies have shown that there is no difference with regard to healing at the cortical surface between the 2 methods.[32] Therefore, the authors speculate that there would be no difference in the degree of tendon-bone healing between the 2 onlay techniques analyzed in the present study; however, additional animal-based studies are required to further substantiate this claim.

When analyzing the failure modes for each specimen, the knot failures in the Sub-BT group were not anticipated. The knot failures were outliers in the load to failure group with the average failure for the 3 specimens observed at 117 N. Hanypsiak et al measured

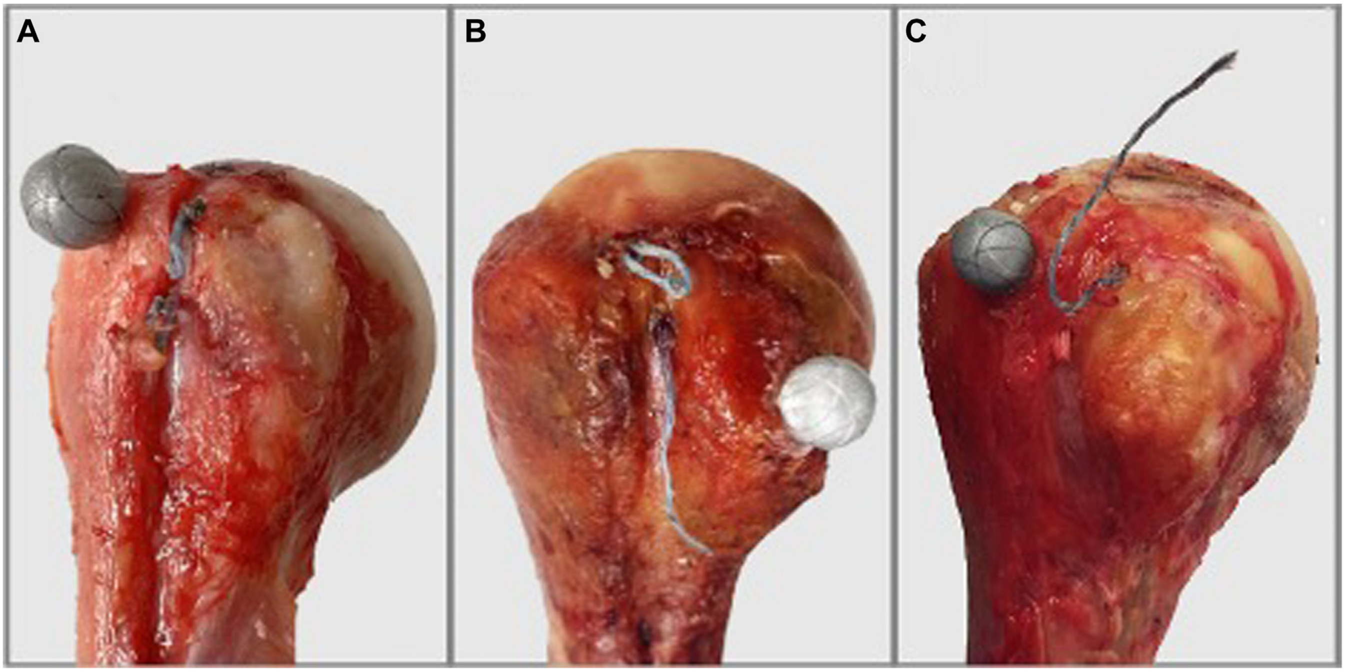


**Figure 6** Photographs of the suprapectoral failure categories. **A**—Pullout at the suture/tendon interface of both anchors. **B**—Pullout at the suture/tendon interface of the proximal anchor and breakage of the suture of the distal anchor (knot failure). **C**—Suture breakage of both anchors (knot failure).

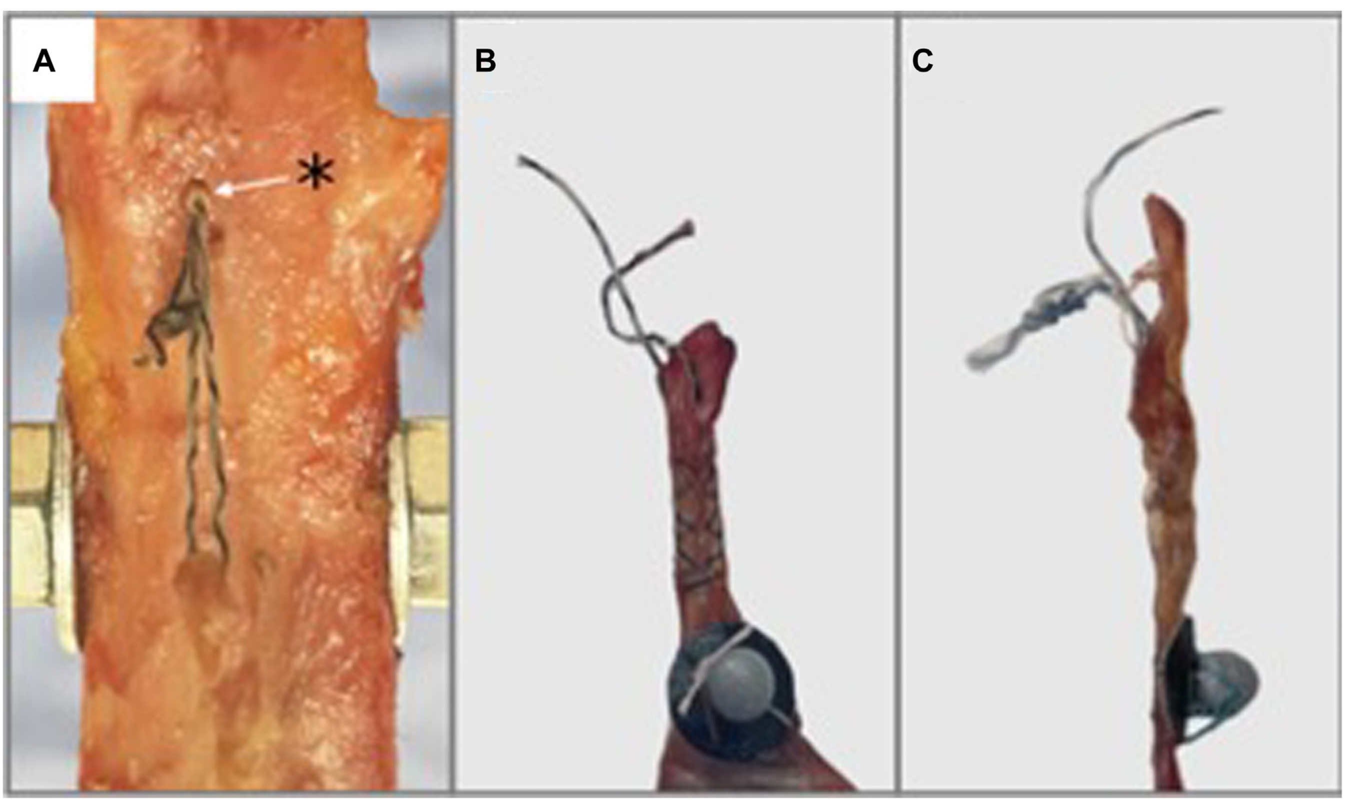


**Figure 7** Photographs of the subpectoral failure categories. **A**—Pullout with failure at the suture/tendon interface. **B**—Failure of the knot. **C**—Suture breakage at the anchor interface.

the knot strength of 73 expert arthroscopists and demonstrated a wide ultimate failure range from 29-360 N and the mean failure for half-hitches was 193.74 ± 84.07 N.[13] Given these findings, surgeons performing a tied Sub-BT technique should be reminded to scrutinize their knot tying to ensure the strength of their knots and reduce the risk of knot failure. In the Sup-BT knotless group, this mode of failure was eliminated, which in large part, lead to the higher average load to failure. This is an advantage in that it

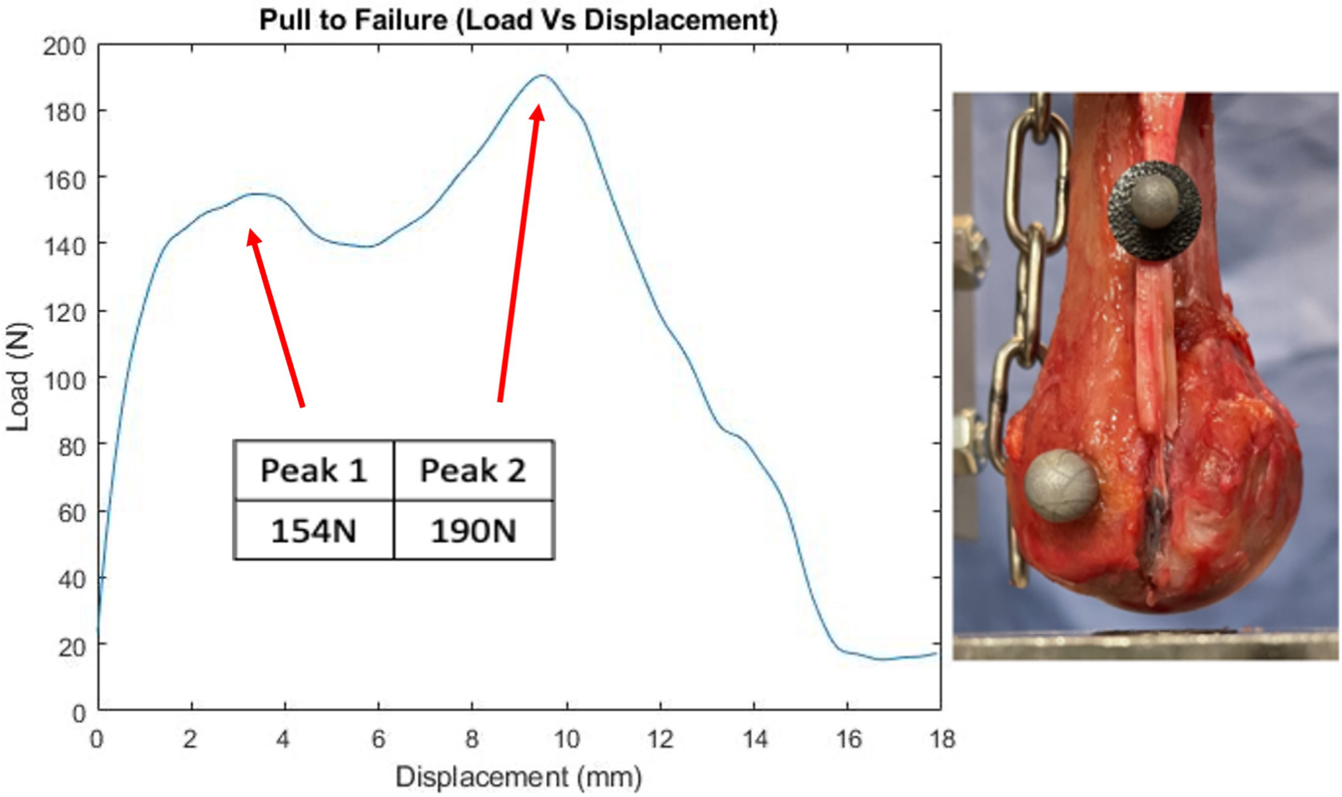


**Figure 8** Subpectoral double peak indicates that the second anchor provides a backup mechanism which acts to resist load synergistically once load is applied.

removes the human risk and variability associated with knot tying. In addition, a double peak load to failure curve was identified in many of the Sup-BT specimens (Fig. 8). This finding indicated that the dual anchors acted synergistically once load was applied to each, and the second anchor provided a backup mechanism to the anchor that was disproportionately loaded first. Although the knot failure and double peak findings were interesting findings and may have explained the differences between the Sup-BT and Sub-BT groups, statistical analysis demonstrated that there was no significant difference in ultimate load to failure or creep between the 2 groups.

This study has several notable limitations. First, this is a biomechanical cadaveric time-zero study and the results must be interpreted as such. One theoretical advantage of the 2-anchor Sup-BT technique is that it creates an area of tendon compression against the humerus, which may improve healing, which would not be evident in a time-zero cadaveric study. Second, the 2 techniques analyzed in this article were chosen because they are the senior author's preferred fixation methods for Sup-BT and Sub-BT. The results from these techniques may not extrapolate to other techniques using different anchors or different suture configurations. Also, the Sup-BT and Sub-BT have inherent differences both mechanically and clinically. One obvious mechanical difference is the difference between the metaphyseal suprapectoral and diaphyseal subpectoral bone. CT was used to measure the differences, however there were no anchor pull-outs or failures observed at the bone/anchor interface. So, the difference in bone density did not impact the results of this biomechanical study. As previously discussed, the clinical differences between the Sup-BT and Sub-BT techniques are numerus and not entirely understood. Additionally, this study did not perfectly replicate the Sup-BT technique as it would be performed in vivo. The Sup-BT is performed arthroscopically, while in this study it was performed open. Although the fixation technique was equivalent, there may be unknown factors about arthroscopic fixation that affected the results of this study.

## Conclusion

The ultimate load to failure and creep between a Sup-BT with 2 knotless all-suture anchors using a luggage tag suture configuration was equivalent to a Sub-BT with 1 all-suture anchor using a whipstitched suture configuration and a tied knot. For readers that prefer either of these fixation techniques for biceps tenodesis, they can perform them confidently knowing that they are biomechanically equivalent in a cadaver model at time zero and they offer similar strength to other fixation methods cited in the literature.

## Disclaimers:

Funding: No funding was disclosed by the authors.
Conflicts of interest: Dr. Verma has the following disclosures: American Orthopaedic Society for Sports Medicine: Board or committee member, American Shoulder and Elbow Surgeons: Board or committee member, Arthrex Inc.: Paid consultant, Arthroscopy Association of North America: Board or committee member, Breg: Research support, Omeros: Stock or stock Options, Ossur: Research support, SLACK Incorporated: Editorial or governing board, Smith & Nephew: IP royalties/Research support, Stryker: Paid consultant, Vindico Medical-Orthopedics Hyperguide: Publishing royalties/Financial or material support and Wright Medical Technology Inc.: Research support.
Dr. Fu is a consultant for Stryker.
The other authors, their immediate families, and any research foundation with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

## References

1. Amouyel T, Le Moulec YP, Tarissi N, Saffarini M, Courage O. Arthroscopic biceps tenodesis using interference screw fixation in the bicipital groove. Arthrosc Tech 2017;6:e1953-7. https://doi.org/10.1016/j.eats.2017.07.025.
2. Baleani M, Francesconi D, Zani L, Giannini S, Snyder SJ. Suprapectoral biceps tenodesis: a biomechanical comparison of a new "soft anchor" tenodesis technique versus interference screw biceps tendon fixation. Clin Biomech 2015;30:188-94. https://doi.org/10.1016/j.clinbiomech.2014.12.001.
3. 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;32:1247-52. https://doi.org/10.1016/j.arthro.2016.01.016.
4. Dein EJ, Huri G, Gordon JC, McFarland EG. A humerus fracture in a baseball pitcher after biceps tenodesis. Am J Sports Med 2014;42:877-9. https://doi.org/10.1177/0363546513519218.
5. Dekker TJ, Peebles LA, Preuss FR, Goldenberg BT, Dornan GJ, Provencher MT. A systematic review and meta-analysis of biceps tenodesis fixation strengths: fixation type and location are biomechanically equivalent. Arthroscopy 2020;36:3081-91. https://doi.org/10.1016/j.arthro.2020.05.055.
6. van Deurzen DFP, Gurnani N, Alta TDW, Willems JH, Onstenk R, van den Bekerom MPJ. Suprapectoral versus subpectoral tenodesis for long head biceps brachii tendinopathy: a systematic review and meta-analysis. Orthop Traumatol Surg Res 2020;106:693-700. https://doi.org/10.1016/j.otsr.2020.01.004.
7. Elser F, Braun S, Dewing CB, Giphart JE, Millett PJ. Anatomy, function, injuries, and treatment of the long head of the biceps brachii tendon. Arthroscopy 2011;27:581-92. https://doi.org/10.1016/j.arthro.2010.10.014.
8. Erdle NJ, Osier CJ, Hammond JE. Humerus fractures after open subpectoral biceps tenodesis: three cases with 2-year functional outcome data and review of the literature. JBJS Case Connect 2020;10:e0033. https://doi.org/10.2106/JBJS.CC.19.00033.
9. Forsythe B, Zuke WA, Agarwalla A, Puzzitiello RN, Garcia GH, Cvetanovich GL, et al. Arthroscopic suprapectoral and open subpectoral biceps tenodeses produce similar outcomes: a randomized prospective analysis. Arthroscopy 2020;36:23-32. https://doi.org/10.1016/j.arthro.2019.07.009.
10. Frank RM, Bernardoni ED, Veera SS, Waterman BR, Griffin JW, Shewman EF, et al. Biomechanical analysis of all-suture suture anchor fixation compared with conventional suture anchors and interference screws for biceps tenodesis. Arthroscopy 2019;35:1760-8. https://doi.org/10.1016/j.arthro.2019.01.026.
11. Friedel R, Markgraf E, Schmidt I, Donicke T. [Proximal humerus shaft fracture as a complication after keyhole-plasty. A case report]. Unfallchirurgie 1995;21:198-201.
12. Golish SR, Caldwell PE 3rd, Miller MD, Singanamala N, Ranawat AS, Treme G, et al. Interference screw versus suture anchor fixation for subpectoral tenodesis of the proximal biceps tendon: a cadaveric study. Arthroscopy 2008;24:1103-8. https://doi.org/10.1016/j.arthro.2008.05.005.
13. Hanypsiak BT, DeLong JM, Simmons L, Lowe W, Burkhart S. Knot strength varies widely among expert arthroscopists. Am J Sports Med 2014;42:1978-84. https://doi.org/10.1177/0363546514535554.
14. Haupt ET, O'Keefe K, Farmer K. Arthroscopic all-Inside biceps tenodesis: technique and outcomes. Arthrosc Tech 2019;8:e1485-9. https://doi.org/10.1016/j.eats.2019.07.034.
15. Hong CK, Hsu KL, Kuan FC, Chen Y, Hsu CC, Yeh ML, et al. The double Krackow suture technique does not offer a significant benefit compared to the Krackow suture technique in subpectoral biceps tenodesis using a double-loaded suture anchor. Arthroscopy 2020;36:701-7. https://doi.org/10.1016/j.arthro.2019.11.097.
16. Hong CK, Hsu KL, Kuan FC, Lin CL, Yeh ML, Su WR. Biomechanical evaluation of a transtendinous all-suture anchor technique versus interference screw technique for suprapectoral biceps tenodesis in a cadaveric model. Arthroscopy 2018;34:1755-61. https://doi.org/10.1016/j.arthro.2018.01.007.
17. 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;31:831-5. https://doi.org/10.1016/j.arthro.2014.11.043.
18. Kannan A, Cogan CJ, Zhang AL. Arthroscopic single-portal suprapectoral biceps tenodesis with all-suture anchor. Arthrosc Tech 2022;11:e279-84. https://doi.org/10.1016/j.eats.2021.10.020.
19. Lacheta L, Imhoff AB, Siebenlist S, Scheiderer B. Subpectoral biceps tenodesis: all-suture anchor onlay technique. Arthrosc Tech 2020;9:e651-5. https://doi.org/10.1016/j.eats.2020.01.019.
20. Lacheta L, Rosenberg SI, Brady AW, Dornan GJ, Millett PJ. Biomechanical comparison of subpectoral biceps tenodesis onlay techniques. Orthop J Sports Med 2019;7:2325967119876276. https://doi.org/10.1177/2325967119876276.
21. Mazzocca AD, Rios CG, Romeo AA, Arciero RA. Subpectoral biceps tenodesis with interference screw fixation. Arthroscopy 2005;21:896. https://doi.org/10.1016/j.arthro.2005.04.002.
22. McCrum CL, Alluri RK, Batech M, Mirzayan R. Complications of biceps tenodesis based on location, fixation, and indication: a review of 1526 shoulders. J Shoulder Elbow Surg 2019;28:461-9. https://doi.org/10.1016/j.jse.2018.09.005.
23. Otto A, Siebenlist S, Baldino JB, Murphy M, Muench LN, Mehl J, et al. All-suture anchor and unicortical button show comparable biomechanical properties for onlay subpectoral biceps tenodesis. JSES Int 2020;4:833-7. https://doi.org/10.1016/j.jseint.2020.08.004.
24. Parvaresh K, Vadhera AS, Cregar W, Maheshwar B, Azua E, Chahla J, et al. Arthroscopic biceps tenodesis using the knotless lasso technique. J ISAKOS 2022;7:84-5. https://doi.org/10.1016/j.jisako.2022.03.004.
25. Patzer T, Rundic JM, Bobrowitsch E, Olender GD, Hurschler C, Schofer MD. Biomechanical comparison of arthroscopically performable techniques for suprapectoral biceps tenodesis. Arthroscopy 2011;27:1036-47. https://doi.org/10.1016/j.arthro.2011.03.082.
26. Patzer T, Santo G, Olender GD, Wellmann M, Hurschler C, Schofer MD. Suprapectoral or subpectoral position for biceps tenodesis: biomechanical comparison of four different techniques in both positions. J Shoulder Elbow Surg 2012;21:116-25. https://doi.org/10.1016/j.jse.2011.01.022.
27. Reiff SN, Nho SJ, Romeo AA. Proximal humerus fracture after keyhole biceps tenodesis. Am J Orthop 2010;39:E61-3.
28. Sears BW, Spencer EE, Getz CL. Humeral fracture following subpectoral biceps tenodesis in 2 active, healthy patients. J Shoulder Elbow Surg 2011;20:e7-11. https://doi.org/10.1016/j.jse.2011.02.020.
29. Smuin DM, Vannatta E, Ammerman B, Stauch CM, Lewis GS, Dhawan A. Increased load to failure in biceps tenodesis with all-suture suture anchor compared with interference screw: a cadaveric biomechanical study. Arthroscopy 2021;37:3016-21. https://doi.org/10.1016/j.arthro.2021.03.085.
30. Snir N, Hamula M, Wolfson T, Laible C, Sherman O. Long head of the biceps tenodesis with cortical button technique. Arthrosc Tech 2013;2:e95-7. https://doi.org/10.1016/j.eats.2012.12.001.
31. Stapleton EJ, Ghobrial I, Curtis AS. Simple soft tissue biceps tenodesis. Arthrosc Tech 2022;11:e1951-6. https://doi.org/10.1016/j.eats.2022.07.011.
32. Tan H, Wang D, Lebaschi AH, Hutchinson ID, Ying L, Deng XH, et al. Comparison of bone tunnel and cortical surface tendon-to-bone healing in a Rabbit model of biceps tenodesis. J Bone Joint Surg Am 2018;100:479-86. https://doi.org/10.2106/JBJS.17.00797.
33. Taylor SA, O'Brien SJ. Clinically relevant anatomy and biomechanics of the proximal biceps. Clin Sports Med 2016;35:1-18. https://doi.org/10.1016/j.csm.2015.08.005.
34. Werner BC, Evans CL, Holzgrefe RE, Tuman JM, Hart JM, Carson EW, et al. Arthroscopic suprapectoral and open subpectoral biceps tenodesis: a comparison of minimum 2-year clinical outcomes. Am J Sports Med 2014;42:2583-90. https://doi.org/10.1177/0363546514547226.