# Suture Anchors Display Higher Resistance than Interference Screws for Biceps Tenodesis

## *Las anclas de sutura muestran mayor resistencia que los tornillos de interferencia para la tenodesis del bíceps*

Rodrigo de Marinis[1] Julio J. Contreras[1] Daniel Paccot[2] Felipe Palma[3] Pablo Besa[1] Felipe Toro[2] Rodrigo Guzmán[3] René Pozo[2]

[1] Shoulder and Elbow Unit, Department of Orthopedics and Traumatology, Faculty of Medicine, School of Medicine, Pontificia Universidad Católica de Chile, Santiago, Chile
[2] Shoulder and Elbow Unit, Clínica Alemana de Santiago, Universidad del Desarrollo, Santiago, Chile
[3] LIBFE Laboratory, School of Kinesiology, Universidad de los Andes, Santiago, Chile

**Address for correspondence** Julio J. Contreras, MD, Shoulder and Elbow Unit, Department of Orthopedics and Traumatology, Faculty of Medicine, School of Medicine, Pontificia Universidad Católica de Chile, Santiago 12455, RM, Chile (e-mail: juliocontrerasmd@gmail.com).

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## Abstract

**Objective** To assess four different fixation techniques for biceps tenodesis.

**Materials and Methods** A total of 32 fresh frozen sheep shoulders were randomly divided into 4equal groups according to each tenodesis technique: Biotenodesis screw (BTS), SwiveLock tenodesis screw (SLS) (Arthrex, Inc., Naples, FL, United States), triple lasso-loop (TLL), and double lasso-loop (DLL). All tenodesis were performed suprapectorally at the bicipital groove. For interference screws (ISs), no additional knots were added after fixation. All specimens were tested for ultimate load to failure (ULF), and the yield point (YP) was calculated. The mode of failure was recorded for each specimen. The statistical analysis was performed using a Kruskal-Wallis test and the Dunn post-hoc test. Significance was set at $p < 0.05$.

**Results** The ULF recorded for each experimental group was as follows: BTS group = 126.2 (range: 94.8–161.1) N; SLS group = 95.8 (range: 75.9–130) N; DLL group = 208.4 (range: 195.3–219.5) N; and TLL group = 261.4 (range: 194.9–306.5) N. The mode of failure for all specimens in the IS groups was tendon pullout from fixation, while specimens in the suture anchor (SA) groups mostly failed by tendon rupture. Both SA techniques showed a significantly higher ULF and YP when compared with each IS technique ($p < 0.01$). There were no significant differences in terms of the ULF or YP achieved between the use of DLL and of TLL.

**Conclusion** In the present animal cadaveric testing model, SA techniques demonstrated a higher ULF when compared with knotless IS techniques. Specifically, within

**Keywords**
- biceps
- tenodesis
- suture anchor
- interference screw

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the SA techniques, the mechanical resistance to axial load of the DLL was found to be comparable that of the TLL.

**Level of Evidence** Basic science study.

## Resumen

**Objetivo** Evaluar cuatro técnicas de fijación diferentes para la tenodesis del bíceps.

**Materiales y Métodos** En total, 32 hombros de ovejas frescos congelados fueron divididos aleatoriamente en 4 grupos iguales según cada técnica de tenodesis: tornillo biotenodesis (TBT), tornillo de tenodesis SwiveLock (TSL) (Arthrex, Inc., Naples, FL, Estados Unidos), triple *lasso-loop* (TLL), y doble *lasso-loop* (DLL). Todas las tenodesis se realizaron suprapectoralmente en la corredera bicipital. Para los tornillos de interferencia (TI), no se añadieron nudos adicionales después de la fijación. Todas las muestras fueron sometidas a carga de falla final (CFF), y se calculó el punto de cedencia (PC). Se registró el modo de fallo para cada muestra, y se realizó un análisis estadístico utilizando una prueba de Kruskal-Wallis y la prueba *post hoc* de Dunn. Se consideró significativo un valor de $p < 0{,}05$.

**Resultados** La CFF registrada para cada grupo experimental fue la siguiente: grupo TBT = 126,2 (rango: 94,8–161,1) N; grupo TSL = 95,8 (rango: 75,9–130) N; grupo DLL = 208,4 (rango: 195,3–219,5) N; y grupo TLL = 261,4 (rango: 194,9–306,5) N. El modo de fallo para todas las muestras en los grupos TI fue la extracción del tendón de la fijación, mientras que las muestras en los grupos de anclaje de sutura (AS) en su mayoría fallaron por ruptura del tendón. Ambas técnicas de AS mostraron una CFF y un PC significativamente más altos cuando se compararon con cada técnica de TI ($p < 0{,}01$). No hubo diferencias significativas en términos de la CFF o del PC logrados entre el uso de DLL y de TLL.

**Conclusión** En este modelo de prueba cadavérica animal, las técnicas de AS demostraron una CFF más alta en comparación con las técnicas de TI sin nudos. Específicamente, dentro de las técnicas de AS, se encontró que la resistencia mecánica a la carga axial de DLL es comparable a la de TLL.

**Nivel de Evidencia** Estudio de ciencia básica.

**Palabras Clave**
- bíceps
- tenodesis
- anclaje de sutura
- tornillo de interferencia

## Introduction

Long head of the biceps tendon (LHBT) pathology is a largely recognized source of shoulder pain.[1–4] Available evidence shows that biceps tenodesis is an effective and safe procedure to treat LHBT pathology when surgery is indicated.[5–9]

Different fixation methods have been described for tenodesis of the LHBT,[10,11] and suture anchors (SAs) and interference screws (ISs) are the most commonly performed. Previous studies[12–15] have compared these fixation methods, with mixed results. When using SAs, the knot technique may have an impact on the mechanical resistance of the tenodesis to axial loads.[16] Lafosse et al.[17] describe the use of a triple lasso-loop (TLL) for tendon tenodesis and repairs, while Bois et al.[18] recommend a double lasso-loop (DLL) for SA tenodesis of the LHBT. For IS, many authors[19–21] describe a knotless technique that spares the use of a security knot. To our knowledge, SA tenodesis techniques using TLL or DLL have not been biomechanically tested, nor directly compared with knotless ISs in the available literature.

Given its similarity to human anatomy, LHBT tenodesis models in sheep have been validated.[22–25] The purpose of the present study is to biomechanically assess (mechanical resistance and yield point) four different tenodesis techniques in a cadaveric sheep model.

We hypothesize that the use of TLL and DLL fixation techniques will demonstrate superior mechanical resistance and a higher yield point when subjected to axial loads, in comparison to the tested knotless IS techniques.

## Materials and Methods

After obtaining approval from the institutional ethics committee, 35 fresh frozen sheep shoulders were acquired from an authorized local distributor. All specimens were between 8 and 10 months old to ensure adequate bone quality. Every specimen was thawed at room temperature for one day before dissection. In three specimens, the shoulder joint was not intact upon arrival to our laboratory, and they were excluded from the study. The long head of the biceps muscle was dissected carefully and detached from its proximal and distal end. Then, the humerus was freed from all surrounding soft tissue and osteotomized with an oscillating saw at the distal end of the diaphysis.

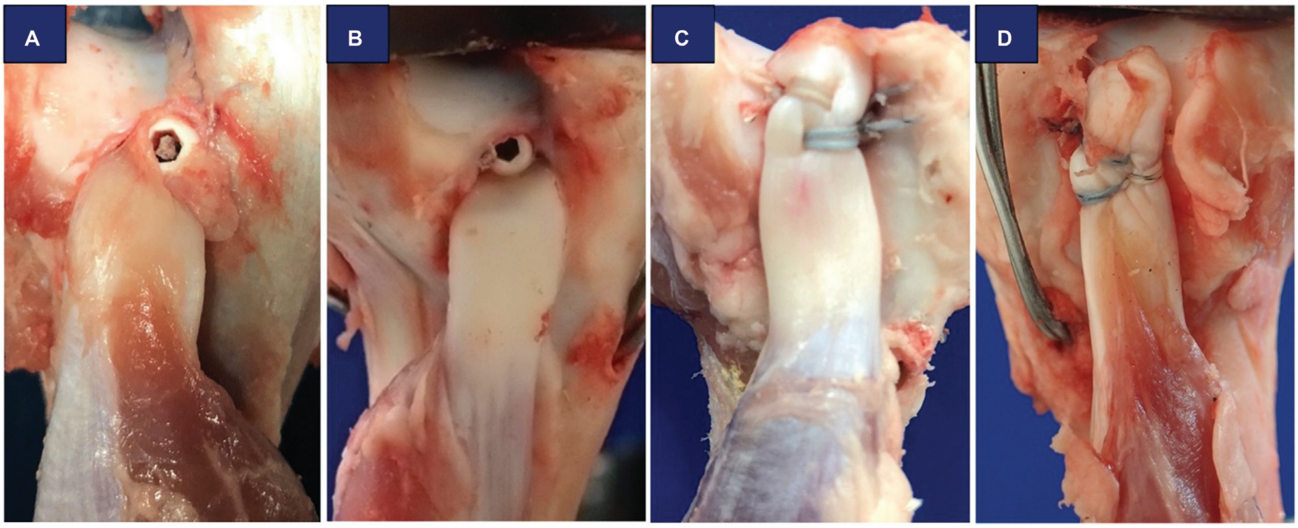

**Fig. 1** Long head of the biceps tenodesis techniques performed at the bicipital groove. (**A**) Knotless tenodesis with biotenodesis screw. (**B**) SwiveLock screw knotless tenodesis. (**C**) Double lasso-loop tenodesis. (**D**) Triple lasso-loop tenodesis.

### Surgical Technique

After the dissection was completed, all specimens underwent tenodesis of the LHBT performed 2 cm distal to the articular margin of the humerus, in the bicipital groove.

The technique for each group was as follows:

1. Biotenodesis screw (BTS): Fiberwire no. 2 (Arthrex, Inc., Naples, FL, United States) suture was used to whipstitch the last 2 cm of the proximal end of the LHBT. Then, an 8.5 × 30 mm tunnel was drilled in the bicipital groove. The free ends of the Fiberwire suture were passed through the distal loop of the cannulated biotenodesis screwdriver and retrieved at its handle. The proximal end of the LHBT was then pushed into the tunnel, and fixation was achieved by an 8 × 23mm BTS. The suture ends were then cut, and no additional knots were performed (►**Fig. 1A**).
2. SwiveLock (Arthrex) tenodesis screw (SLS): The proximal biceps tendon was whipstitched in the same fashion as that of the previous group, and a 6.5 × 25 mm tunnel was drilled in the bicipital groove. Fixation was achieved with a 6.25 × 19.1 mm SLS, and the suture ends were cut after fixation (►**Fig. 1B**).
3. Double lasso-loop (DLL): Using the same SA fixation than that of the TLL group, a DLL was performed as described by Bois et al.[18] (►**Fig. 1C**). Fixation was then secured with a five-throw knot.
4. Triple lasso-loop (TLL): A double-loaded BioComposite Corkscrew FT (Arthrex) 5,5 × 14,7mm anchor was fixed in the bicipital groove. A TLL was performed as described by Lafosse et al.[17] at the proximal end of the biceps tendon. This technique consists in passing three consecutive loops through the tendon and securing them with a five-throw knot (►**Fig. 1D**).

### Biomechanical Testing

After LHBT tenodesis was performed in each group, the distal end of the biceps muscle and tendon was reinforced with a Krakow stitch to prevent failure at this site and enable secure anchoring to the testing clamp (►**Fig. 2A**). The humeral head was flattened using an oscillating saw and then fixed using 1.5-mm wire through a 3-mm tunnel drilled at the humeral head (avoiding the tenodesis area). Each specimen was then mounted in a custom-made structure, attaching the humeral head proximally and the previously reinforced distal biceps end distally (►**Fig. 2C**). The testing clamp was designed as previously reported by Shi et al.,[26] and it was linked to a force transductor connected to a computerized system (Stress-Strain, Kinetecnics, Santiago, Chile ).

A preloading force of 5 N was applied to all specimens. Then, an axial load parallel to the humeral shaft's axis was applied at a constant speed of 1 mm/s until failure. Ultimate load to failure (ULF) was recorded, as described by Golish et al.,[27] and the yield point (YP) was stablished for each measurement. The macroscopic mode of failure was recorded for each specimen.

### Statistical Analysis

The study power was set at 80%, and $\alpha$ was set at 0.05. Using the ULF reported by Patzer et al.,[12] a sample size of six tendons was had to be included in each group to reach significance. Nonetheless, we decided to measure eight for each group to increase the statistical power.

Statistical analysis was performed using a Kruskal-Wallis test to assess median differences among groups. The Dunn post-hoc test (with Bonferroni adjustment) was used to determine the significance of pairwise comparisons. The Cohen effect size and a post-hoc power analysis were performed for each comparison. Significance was set at $p < 0.05$. All statistical analyses were performed with the STATA 14/IC (StataCorp LLC, College Station, TX, United States) software..

## Results

A total of 32 sheep specimens were divided into 4 equal groups ($n = 8$). The ULF recorded for each experimental

**Fig. 2** Set up of the specimens. (**A**) Isolated biceps tendon with a Krakow stitch to reinforce the distal muscle and tendon. (**B**) Tenodesis performed at the bicipital groove and head flattened with an oscillating saw cut. (**C**) Specimen mounted in a custom-made testing structure to test axial load. Note that fixation wires avoid the tenodesis area.

group was as follows: BTS group = 126.2 (range: 94.8–161.1) N; SLS group = 95.8 (range: 75.9–130) N; DLL group = 208.4 (range: 195.3–219.5) N; and TLL group = 261.4 (range: 194.9–306.5) N (►**Table 1**).

The TLL group presented a significantly higher ULF than the SLS ($p < 0.01$) and BTS ($p < 0.01$) groups. We found no statistically significant difference between the median ULF of the TLL group compared with the DLL group ($p > 0.99$) (►**Table 1**). Overall, the SA techniques (TLL and DLL) rendered a higher ULF when compared with the IS techniques (SLS and BTS) ($p < 0.01$), as shown in ►**Fig. 3**.

Concordantly, the YP analysis showed a significant difference between the SA and IS techniques (►**Fig. 4**). Though the TLL group presented a higher YP than the DLL group, this difference did not reach statistical significance.

For all SLS and BTS group specimens, the mode of failure was tendon pullout from fixation (►**Fig. 5**). In the TLL group, six failed at the myotendinous junction, one, at the knot fixation site, and one, at the anchor eyelet. Finally, in the DLL group, five failed at the knot fixation site (►**Fig. 5**), and three had a proximal tendon tear below the fixation site.

## Discussion

The main finding obtained in the present work was that the use of SAs (TLL and DLL) provided higher mechanical resistance and a higher YP than tested knotless IS techniques to axial loads. This result confirms our hypothesis. The second most important finding was that there were no significant differences between the TTL and DLL fixation techniques in terms of mechanical resistance and YP.

There are several biomechanical reasons that could explain these results. Although the available literature[12,22,23,28] slightly favors IS over SA techniques in terms of ULF, these studies vary widely in the type of knot used with SA, and all include a security knot when testing the IS. Gigi et al.[16] demonstrated that the number of loops around the tendon significantly increased the ULF in a human cadaveric testing model for SA tenodesis. The authors[16] compared a simple-loop technique against a triple-loop technique (without a lasso) and found that the ULF values were of 46.12 ± 14.37 N and 122.2 ± 26.73 N respectively. In another similar study by Papp et al.,[10] SA biceps tenodesis augmented with a transverse ligament suture showed higher mechanical resistance compared with ISs alone. In that study,[10] SA including a knot through the transverse ligament yielded an ULF of 263.2 N (95% confidence interval [95%CI]: 221.7–304.6 N) compared with an ULF of 159.4 N (95%CI: 118.4–200.5 N) for ISs. In the present study, the sutures were not only passed around, but also through the tendon, presumably adding strength to the construct. These data suggest that, when using the SA technique, the type of knot is critical to the ULF achieved. This may explain our relatively higher ULF results in SA tenodesis techniques (209–239 N), when comparing them

**Table 1** Comparison of Ultimate Load to Failure and Yield Point among different tenodesis techniques

| Comparison | Kruskal Wallis test with Dunn posthoc test | | Power analysis | |
|---|---|---|---|---|
| | Mean rank difference (N) | Significance (adjusted *p*- value) | Effect size | Power |
| *Ultimate load to failure* | | | | |
| BTS versus SLS | 3.63 | > 0.999 | 0.643 | 0.224 |
| BTS versus DLL | -11.75 | 0.074 | 2.257 | 0.987 |
| BTS versus TLL | -15.38 | 0.006* | 2.233 | 0.985 |
| SLS versus DLL | -15.38 | 0.006* | 3.847 | 0.999 |
| SLS versus TLL | -19.00 | < 0.001* | 2.928 | 0.999 |
| DLL versus TLL | -3.63 | > 0.999 | 0.966 | 0.436 |
| *Yield point* | | | | |
| BTS versus SLS | -1.13 | > 0.999 | 0.165 | 0.061 |
| BTS versus DLL | -14.38 | 0.013* | 3.022 | 0.999 |
| BTS versus TLL | -17.00 | 0.002* | 2.645 | 0.998 |
| SLS versus DLL | -13.25 | 0.029* | 2.902 | 0.999 |
| SLS versus TLL | -15.88 | 0.004* | 2.538 | 0.997 |
| DLL versus TLL | -2.63 | > 0.999 | 0.536 | 0.170 |

**Abbreviations:** BTS, biotenodesis screw; DLL, double lasso-loop; N, Newtons; SLS, SwiveLock screw; TLL, triple lasso-loop.
**Note:** *Statistically significant difference among techniques ($p < 0.05$).

to previously reported ones (46–187 N).[12,15,16,23,27,28] Consistently, the modes of failure for SA (mostly tears) also differed from those previously reported (slippage).[16]

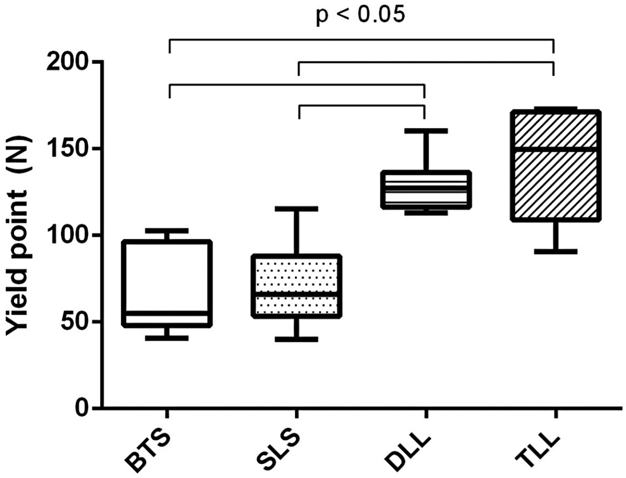

**Fig. 4** Boxplot showing the yield point for each technique. **Abbreviations:** BTS, biotenodesis screw; SLS, SwiveLock screw; TLL, triple lasso-loop; DLL, double lasso-loop; N, Newtons.

A 112-N load at the LHBT is estimated when bearing 1 kg of weight in the hand with the elbow at 90°.[29] This load has been proposed to be sufficient for daily life activities and might indicate a minimum desirable tenodesis resistance. In the present study, only the SLS group demonstrated a performance lower than 112 N in terms of ULF. Moreover, the ULF for both IS groups (BTS and SLS) was lower than previously reported.[12,15,23,28] The inferior performance of our IS groups may be explained by the technique we chose, which spares the use of a security knot. Many articles[19–21] regarding the biceps tenodesis technique do not mention the need to tie the sutures after an IS tenodesis. In our experience, sparing the use of a security knot is common in the clinical practice, despite the lack of evidence that may support this variation in the technique. One human cadaveric study performed by Mazzoca et al.,[28] comparing different tenodesis fixation methods, highlighted the importance of adding a security knot when using ISs, but did not directly test knotless the mechanical strength of IS tenodesis. The security knot is performed by passing only one end of the suture through the tenodesis screwdriver and then tying both ends when performing IS fixation, as shown in ►**Fig. 6**. The resistance of this construct uses both the fit of the IS and SA stability (tendon-screw construct). Performing a knotless biceps tenodesis with ISs may not render enough mechanical

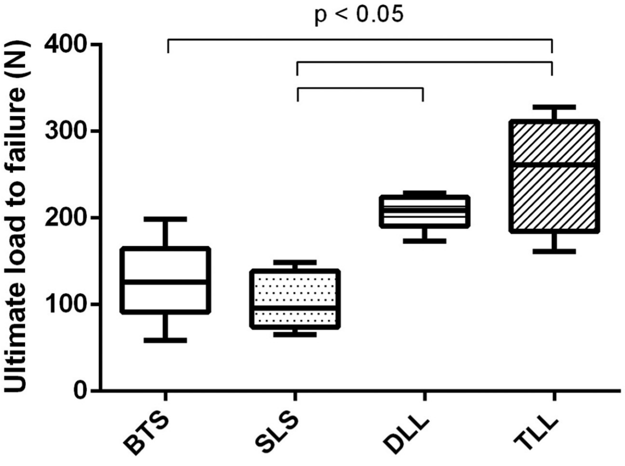

**Fig. 3** Boxplot showing the ultimate load to failure for each technique. **Abbreviations:** BTS, biotenodesis screw; SLS, SwiveLock screw; TLL, triple lasso-loop; DLL, double lasso-loop; N, Newtons.

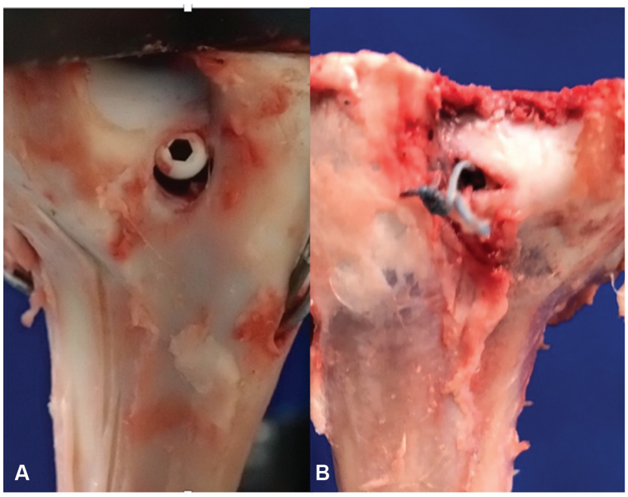

**Fig. 5** Modes of failure. (**A**) Failed SwiveLock screw tenodesis showing pull out from fixation. (**B**) Double lasso-loop tenodesis showing failure at the knot fixation site by tendon tear.

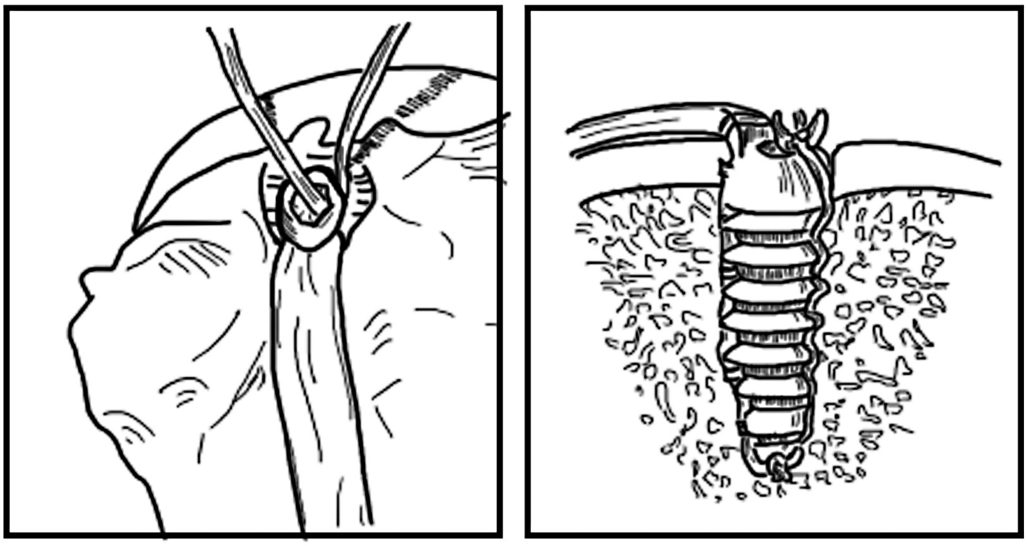

**Fig. 6** The tendon-screw construct. Adding a security knot in this fashion provides both the fit of the interference screw and suture anchor stability.

resistance to perform daily life activities at time zero, though the clinical relevance of this data cannot be established by the present study.

There are several limitations to our study. First, we did not cycle our constructs before measuring the ULF. Though previous data shows that precyclic and postcyclic ULF do not differ significantly for IS tenodesis,[28] it is believed that postcyclic data better simulates in-vivo strength of the tenodesis techniques. Moreover, it was assumed that all biceps were of uniform diameter due to their comparable sizes and ages. However, we did not measure the bicipital diameter before executing the surgical technique. Another limitation to this study is that we did not test for ULF using a security knot for IS tenodesis. Though a direct comparison with knotless techniques would have been desirable, our purpose was to test SA and IS tenodesis techniques as performed in our institution. Finally, the use of animal cadaveric specimens, although validated, has its own inherent limitations, as animal tissue may differ biomechanically from human cadaveric tissue or in-vivo LHBT.

## Conclusions

In the present animal cadaveric testing model, SA techniques demonstrated a higher ultimate load failure when compared with knotless IS techniques. Specifically, in the SA techniques, the mechanical resistance to axial load of the DLL was found to be comparable to that of the TLL.

Conflict of Interests
The authors have no conflict of interests to declare.

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