The Loop ’n’ Tack Knot

Biomechanical Analysis of a Novel Suture Technique for Proximal Biceps Tenodesis

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Background: Secure tendon grasping is critical to the success of any tenodesis procedure. Several techniques currently used for tendon grasping can result in longitudinal splitting of the tendon, causing construct failure and failure of the tenodesis.

Purpose: To compare the Loop ’n’ Tack knot as a tendon-grasping technique with other common suture techniques. We investigated the biomechanical strength and mode of failure.

Study Design: Controlled laboratory study.

Methods: Eleven matched pairs of proximal biceps were harvested from fresh-frozen cadaveric shoulders. One tendon from each pair was stitched using 1 of 4 different techniques. The suture techniques evaluated included the Loop ’n’ Tack with 2 different types of high-strength nonabsorbable suture, a double half-racking stitch, and a Krakow stitch. Samples were cyclically loaded between 5 and 20 N for 100 cycles, followed by a pull to failure at 33 mm/s.

Results: The Loop ’n’ Tack techniques were equivalent to the double half-racking and Krakow techniques for load to ultimate failure ($P = .817$ and $P = .984$, respectively). The double half-racking technique was the stiffest construct, which was significantly greater than the second-stiffest group, the Loop ’n’ Tack method with both FiberLink suture ($P = .012$) and SutureTape ($P = .002$), which had greater stiffness than the Krakow group ($P < .001$). The most common failure mode for the Loop ’n’ Tack stitch was suture breakage compared with the Krakow and double half-racking methods, where the most common mode of failure was suture pullout from the tendon ($P < .001$).

Conclusion: Biomechanical testing found that the Loop ’n’ Tack techniques had similar ultimate load to failure values when compared with the double half-racking and Krakow methods. Mode-of-failure analysis showed that the Loop ’n’ Tack construct typically failed by suture breakage, whereas the other techniques failed by suture pullout.

Clinical Relevance: The Loop ’n’ Tack technique allows for secure grasping of tissue without the need for externalization of the tendon. This technique may be beneficial in compromised or poor-quality tissue without reducing overall pullout strength when compared with a standard half-racking or Krakow stitch.

Keywords: arthroscopic; biceps tenodesis; surgical technique; clinical outcomes; Loop ’n’ Tack

Secure grasping of a tendon is crucial for the success of any tenodesis procedure (such as biceps tenodesis). Currently, many techniques used to grasp a tendon can result in longitudinal splitting of the tendon, causing construct failure and failure of the tenodesis.[6,11,12] Two commonly utilized techniques for tendon grasping are the Krakow[7] and the double half-racking stitch.[8] The Krakow technique (Figure 1A) was originally described in 1986 and involves placing 3 or more locking loops within the tendon.[7] The double half-racking stitch (Figure 1B), otherwise known as the double-cinch stitch, involves 2 overlapping “luggage-tag” stitches in the tendon.[8]

The purpose of the current study was to compare the biomechanical properties of a simple suture technique (the Loop ’n’ Tack knot) with other common suture techniques for tenodesis techniques such as biceps tenodesis. One of the main advantages of the Loop ’n’ Tack knot is that it can be performed arthroscopically and does not require externalization of the tendon, which allows for secure grasping of the tendon in a quick and easy manner. Our hypothesis was that the Loop ’n’ Tack knot would perform equally in terms of biomechanical testing to other suture techniques.

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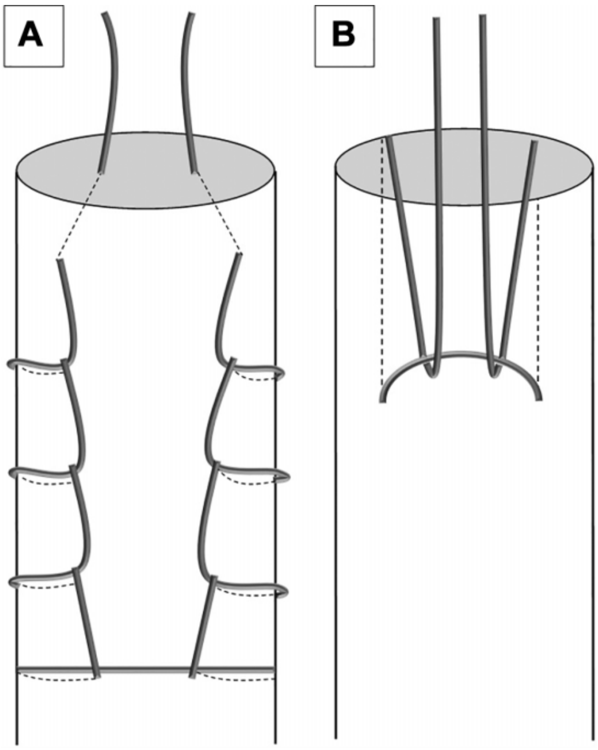

Figure 1. Illustration of (A) Krakow stitch and (B) double half-racking (double-cinch) stitch.

The Loop 'n' Tack Knot

For the purposes of describing this technique, we will describe the Loop 'n' Tack knot for a proximal biceps tenodesis, although it can be performed in a variety of other tenodesis techniques (such as a distal biceps repair). A "luggage-tag" is placed around the entire tendon. Once the luggage-tag has been placed in the desired position, the free end of the suture is placed through an anterior cannula with a grasping suture retriever (KingFisher; Arthrex) inferior to the biceps tendon. A tissue penetrator is then inserted through the cannula to pierce through the midportion of the biceps distal to the luggage-tag knot. Using the tissue penetrator, the free end of the suture is grasped and pulled through the biceps tendon and withdrawn from the cannula. This completes the Loop 'n' Tack knot (Figures 2 and 3).

METHODS

Biomechanical Testing

We harvested 22 matched pairs of proximal biceps from fresh-frozen cadaveric shoulders (mean age, 49 ± 14 years), for a total of 44 specimens. The pairs were randomly split into 2 groups of 11 to provide consistent tissue quality between groups. One tendon from each pair of 11 was

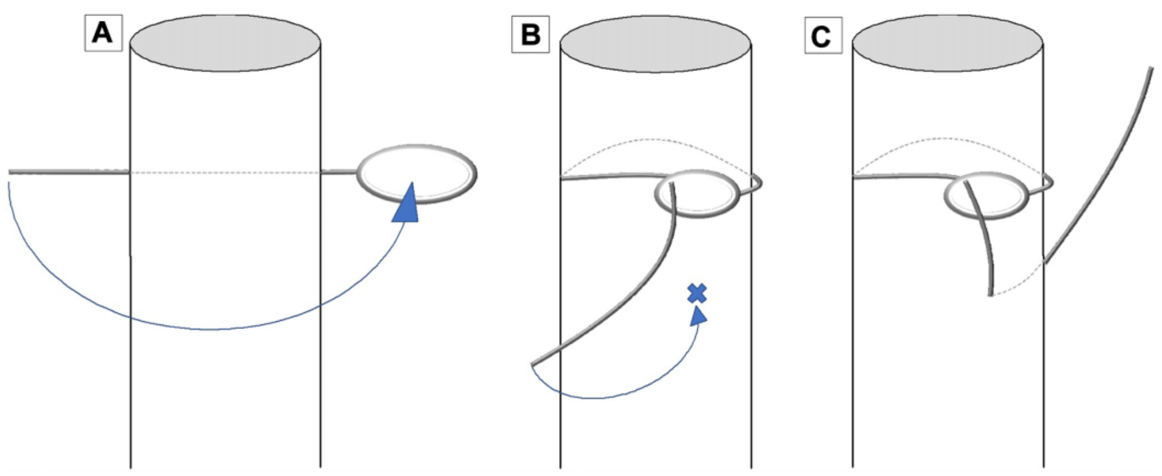

Figure 2. Illustration of the Loop 'n' Tack knot. (A) Looped end of the suture passed around the tendon with subsequent passage of suture-free end through loop to complete the cinch. (B) Tissue penetrator used to pierce the tendon distal to the cinched loop and grasp the free end of suture to pull through the tendon. (C) Loop 'n' Tack knot, complete with the free end of suture available for anchoring.

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Ethical approval was not sought for the present study.

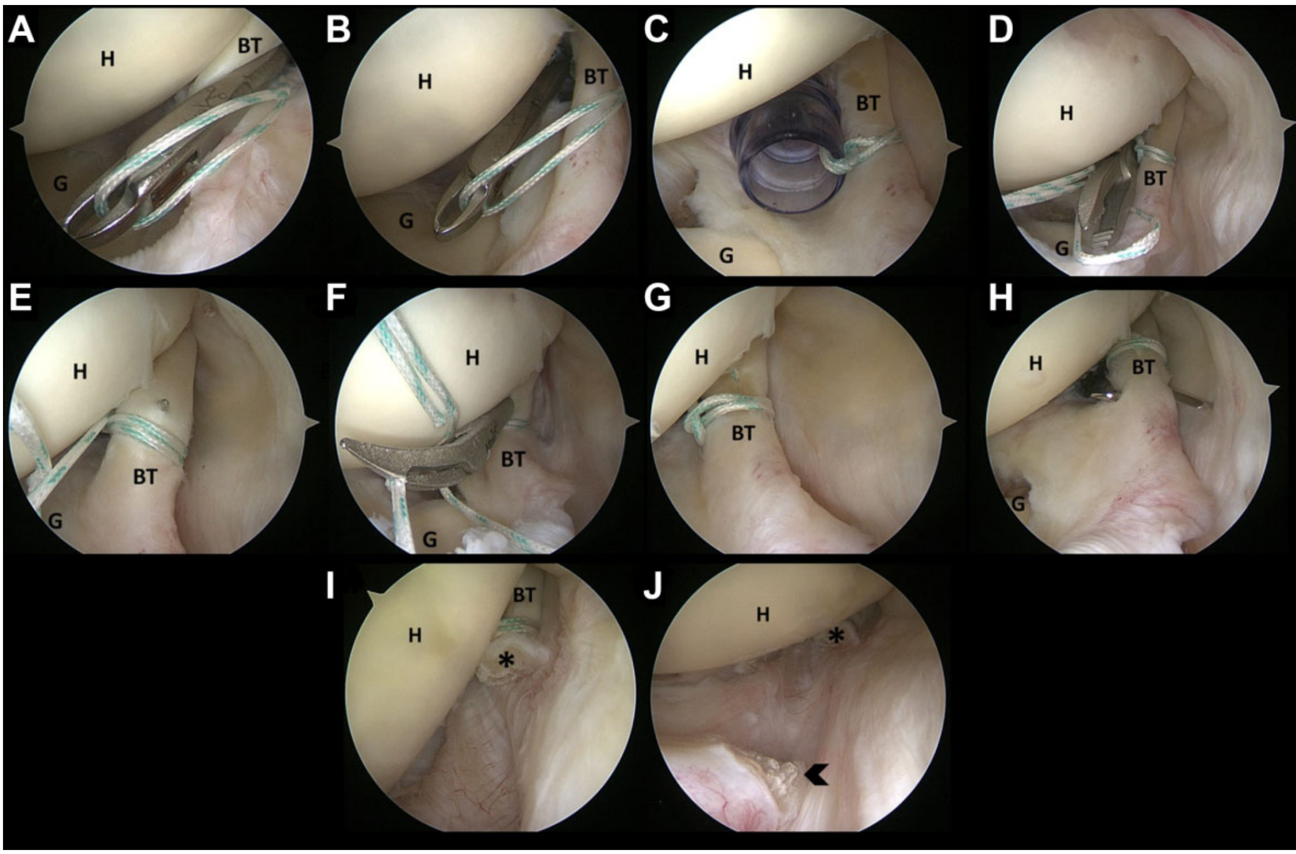

Figure 3. Arthroscopic demonstration of the Loop 'n' Tack knot in a left shoulder in the lateral decubitus position with 30° arthroscope from posterior portal (same orientation for all figures). (A) Looped end of the suture is passed around BT from superior labrum to BT. (B) Suture is pulled inferiorly to BT to complete passage around tendon. (C) Free end of the suture is passed through the looped end and is cinched to BT near insertion at superior labrum. (D) Free end of the suture is passed into the joint with excess slack. (E) Arthroscopic tissue penetrator is passed through BT. (F) The grasping mechanism of the tissue penetrator is used to grab the free end of the suture and pull it through the tendon. (G) Suture has been looped around BT and is now tacked just distal to the loop. (H) BT is cut with a curved arthroscopic scissor at insertion on superior labrum. (I) BT has been secured with a suture anchor at the most distally visualized portion of the intra-articular bicipital groove to tack the BT in place; the asterisk marks the cut end of BT. (J) Cut end of BT seen distally translated from original insertion, marked with arrow. BT, biceps tendon; G, glenoid; H, humerus.

stitched with a 1.3-mm SutureTape (Arthrex) using the Loop 'n' Tack method, approximately 5 mm from the terminal end, as shown in Figures 2 and 3. The contralateral tendon sample was stitched using No. 2 FiberWire (Arthrex) in a standard Krakow pattern. Each Krakow sample was prepared with 3 stitches, ending about 5 mm from the terminal end of the tendon, as shown in Figure 1A. For the next 11 matched pairs, 1 tendon from each pair was stitched with a No. 2 FiberWire in a double half-racking pattern (Figure 1B). The contralateral specimen was stitched with a No. 2 FiberLink (Arthrex) using the Loop 'n' Tack method. This created 4 groups with 11 specimens in each.

Mechanical testing was performed using an E10000 Instron Machine with a 1-kN load cell secured to the cross-head. A pneumatic clamp held the suture tails to the testing surface, and a vise grip fixture secured the proximal ends of the biceps tendons. Samples were cyclically loaded between 5 and 20 N for 100 cycles, followed by a pull to failure at 33 mm/s. Load and displacement data were recorded at 500 Hz.

Power and Statistical Analysis

An a priori power analysis showed that 8 specimens per group would provide 80% power to detect a significant difference in mean construct stiffness between groups with an effect size of 1 and significance level of $P < .05$. All statistical comparisons were made with paired t tests, and $P < .05$ was considered significant. Post hoc power calculations were carried out for all detected significant differences using a 2-tailed matched pairwise comparison, with effect size calculated from the respective means and standard deviations. Chi-square calculations were used to analyze the mode of failure. Power calculations were carried out with G*Power 3.1.[4]

RESULTS

There were no statistically significant differences between the 4 groups in terms of ultimate load to failure (Tables 1 and 2). With regard to mode of failure (Figure 4), the Loop 'n' Tack groups with No. 2 SutureTape and No. 2 FiberLink failed by suture breakage 72% and 64% of the time, respectively. All (11/11) of the double half-racking and 90.9% (10/11) of the Krakow samples failed by suture pullout from the tendon. One of the Krakow samples failed because of graft failure. Chi-square analysis revealed that the frequency of the modes of failure was significantly different between groups ($P < .001$). Stiffness values for each group can be found in Tables 3 and 4. The double half-racking technique was the stiffest construct with a mean stiffness of 66.8 N/mm, which was significantly greater than that of the Loop 'n' Tack with SutureTape (46.2 N/mm; $P = .002$), Loop 'n' Tack with FiberLink (49.6 N/mm; $P = .012$), and Krakow (22.5 N/mm; $P < .001$) groups. Both the Loop 'n' Tack with SutureTape ($P < .002$) and Loop 'n' Tack with FiberLink ($P < .012$) groups had significantly higher mean stiffness measures than the Krakow group.

DISCUSSION

The aim of this study was to compare the mechanical properties of a simple tendon suture-grasping technique for tendon tenodesis with other standard techniques. The current study specifically looked at ultimate load to failure as well as failure mode and stiffness. There was no statistically significant difference in terms of ultimate failure load with the Loop 'n' Tack construct compared with the double half-racking stitch or the Krakow stitch. The main advantage of the arthroscopic Loop 'n' Tack tenodesis is that the fairly simple stitch configuration can be performed completely arthroscopically, involving piercing a tendon only once (unlike the double half-rack). In addition, only 1 limb of a suture needs to be inserted within an anchor, making anchor placement significantly simpler. Unlike the commonly used Krakow stitch, the Loop 'n' Tack technique does not require the surgeon to exteriorize the tendon. These advantages allow for a significant decrease in operative time without compromising outcomes. The technical ease of the procedure combined with the use of only a single anterior portal is an additional advantage compared with other reported tenodesis techniques.[5] This does provide an advantage to the Loop 'n' Tack, especially in the setting of an all-arthroscopic tenodesis if there is no biomechanical advantage to the use of a double half-racking or Krakow stich.

Several other all-arthroscopic biceps tenodesis techniques have been described.[1,9,10] The first technique utilizes a transtendinous all-suture anchor with a suture wrap technique to secure the tendon for fixation.[10] Compared with the Loop 'n' Tack, this technique is similar in that operative time is reduced, but the wrapping suture technique requires knot tying over the long head of the biceps (LHB) tendon, which can lead to irritation. The Loop 'n' Tack avoids this specific issue because the suture construct requires no knot tying for fixation. The second technique utilizes placement of 2 suture anchors in the intertubercular groove, which are used to secure the tendon before cutting the suture.[9] Both of the abovementioned techniques permit fixation of the tendon before surgical detachment, which helps to preserve the length-tension relationship, theoretically improving the biomechanical outcomes of the tenodesis. The Loop 'n' Tack technique does not permit anchoring before cutting the LHB tendon, which may demonstrate an advantage of the other 2 techniques. The last all-arthroscopic tenodesis technique utilizes a "lasso-loop" suture configuration, which requires 2 anchors placed roughly 3 to 5 cm apart within the intertubercular groove.[1] One end of the suture is used to form the lasso loop around the LHB tendon, while the other pierces directly through the tendon itself. The free ends of the suture are externalized, and knots are tied using an arthroscopic knot pusher.[1] Theoretical advantages include multiple points of fixation, but this technique leads to increased operative time and

TABLE 1
Ultimate Load-to-Failure Values by Suture Construct

Technique	Ultimate load, N
SutureTape Loop 'n' Tack stitch	382.545
Double half-racking stitch (No. 2 FiberWire)	426.636
Krakow stitch (No. 2 FiberWire)	364.455
FiberLink Loop 'n' Tack stitch	352.909

TABLE 2
Ultimate Load-to-Failure Tukey HSD Post Hoc Analysis by Suture Construct[a]

Suture Technique 1	Suture Technique 2	Mean Difference	95% CI Lower Bound	95% CI Upper Bound	P Value
SutureTape Loop 'n' Tack stitch	Double half-racking stitch (No. 2 FiberWire)	44.091	–90.871	179.053	.817
	Krakow stitch (No. 2 FiberWire)	–18.091	–153.053	116.871	.984
	FiberLink Loop 'n' Tack stitch	–29.636	–164.598	105.325	.935
Double half-racking stitch (No. 2 FiberWire)	Krakow stitch (No. 2 FiberWire)	–62.182	–197.143	72.78	.609
	FiberLink Loop 'n' Tack stitch	–73.727	–208.689	61.234	.468
Krakow stitch (No. 2 FiberWire)	FiberLink Loop 'n' Tack stitch	–11.546	–146.507	123.416	.996

[a]HSD, honestly significant difference.

carries a risk of overtensioning.[1] The Loop 'n' Tack stitch helps to avoid this, as its simple technique helps to decrease operative time, and its use of 1 free suture end for fixation assists in tensioning.

The mode-of-failure analysis did demonstrate different mechanisms of failure when comparing the Loop 'n' Tack configuration with the double half-racking and Krakow stitch. The Loop 'n' Tack stitch failed via suture breakage, whereas the double half-racking stitch and Krakow stitch failed via the suture pulling out of the tendon. The ability of the Loop 'n' Tack technique to achieve such strong fixation suggests that it may be a preferred option in cases of poor tendon quality. In this situation, failure of the tendon-suture construct would depend solely on the strength of the suture, not on the quality of the tendon. Additionally, our study demonstrated that there were no differences in ultimate load to failure, stiffness, or mode of failure between the Loop 'n' Tack technique with FiberLink and Loop 'n' Tack with SutureTape constructs, suggesting that the Loop 'n' Tack knot technique, not the type of suture, provides the biomechanical strength to the construct. However, while not statistically significant, the Loop 'n' Tack with SutureTape group had an overall higher load to failure and a lower percentage of suture pullout than the FiberLink group. The broader SutureTape suture may give the Loop 'n' Tack construct a stronger grasp of the tendon owing to the increased area of contact. Further studies evaluating these specific biomechanical differences are needed to determine the best overall options for the Loop 'n' Tack technique.

These results indicate that the biomechanics of the Loop 'n' Tack technique as at least equivalent to commonly used techniques in terms of failure strength and demonstrate that it is a viable option for tenodesis surgery, especially in the proximal biceps. Prior work by Brady et al[2] and Duerr et al[3] has shown that suprapectoral proximal biceps tenodesis is an acceptable treatment option with acceptable outcomes, and we believe our work adds to the validity of the proximal tenodesis while potentially limiting its downside. A retrospective analysis of the Loop 'n' Tack proximal biceps tenodesis technique demonstrated high patient satisfaction and shoulder outcome scores with minimal postoperative complications.[3]

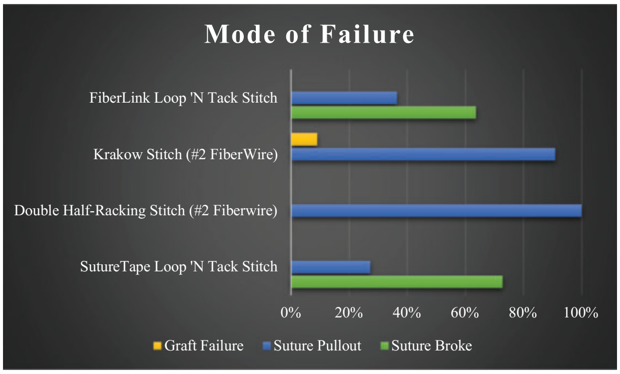

Figure 4. Mode of suture construct failure (%).

TABLE 3
Stiffness Values of Each Suture Construct

Technique	Stiffness, N/mm
SutureTape Loop 'n' Tack stitch	46.200
Double half-racking stitch (No. 2 FiberWire)	66.773
Krakow stitch (No. 2 FiberWire)	22.518
FiberLink Loop 'n' Tack stitch	49.564

Limitations

This study had several limitations. First, owing to the cadaveric nature of the study, the data may not adequately represent the in vivo response to this procedure regarding aspects such as the healing process and rehabilitation. Second, this study did not use anchors, knots, or other options for tenodesis, which essentially limited this study to an analysis of suture construct only. Future studies incorporating anchor or knot fixation with the Loop 'n' Tack suture technique are required for a more accurate analysis of this construct. Last, although our a priori power analysis calculated that 8 specimens per group would allow for statistical power of at least 80%, the sample size of 11 per group was relatively small.

TABLE 4
Stiffness Tukey HSD Post Hoc Analysis by Suture Construct[a]

Suture Technique 1	Suture Technique 2	Mean Difference	95% CI Lower Bound	95% CI Upper Bound	P Value
SutureTape Loop 'n' Tack stitch	Double half-racking stitch (No. 2 FiberWire)	20.572	6.425	34.720	.002
	Krakow stitch (No. 2 FiberWire)	–23.681	–37.830	–9.534	<.001
	FiberLink Loop 'n' Tack stitch	3.363	–10.784	17.511	.919
Double half-racking stitch (No. 2 FiberWire)	Krakow stitch (No. 2 FiberWire)	–44.254	–58.402	–30.107	<.001
	FiberLink Loop 'n' Tack stitch	–17.209	–31.357	–3.061	.012
Krakow stitch (No. 2 FiberWire)	FiberLink Loop 'n' Tack stitch	27.046	12.898	41.193	<.001

[a]HSD, honestly significant difference.

CONCLUSION

Based on biomechanical analysis, the Loop 'n' Tack knot allowed for efficient, secure grasping of tissue without the need for externalization of the tendon.

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