Comparison of Barbed Sutures in Porcine Flexor Tenorrhaphy

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Abstract

Background: Barbed suture use has become more popular as technology and materials have advanced. Minimal data exist regarding performance of the 2 commercially available products, V-Loc™ and Stratafix™ in tendon repairs. The purpose of this study was to compare gap resistance and ultimate tensile strength of both suture materials and nonbarbed suture in a porcine ex vivo model. **Methods:** Porcine flexor tendons were harvested and divided into 3 groups of 10 of varying suture material (3-0 PDS™, 3-0 V-Loc 180™, or 3-0 Stratafix™). A modified 4-strand cruciate technique was used to repair each tendon. Knotless repair was performed using barbed suture, whereas a buried 6-throw square knot was done using conventional suture. A servohydraulic tester was used for biomechanical testing of linear 2-mm gap resistance and maximum tensile strength. **Results:** No difference was found in 2-mm gap resistance among the 3 groups. No difference was found in ultimate tensile strength between V-Loc™ (76.0 ± 9.4 N) and Stratafix™ (68.1 ± 8.4 N) repairs, but the ultimate strength of the PDS™ control group (83.4 ± 10.0 N) was significantly higher than that of Stratafix™. **Conclusions:** Barbed (knotless) and nonbarbed suture repairs demonstrate equivalent 2-mm gap resistance. Stratafix™ repairs show slightly inferior performance to nonbarbed repairs in ultimate tensile strength, although this occurred at gap distances far beyond the 2-mm threshold for normal tendon gliding. Both barbed and nonbarbed 4-strand cruciate flexor tendon repairs may require peripheral repair to withstand physiologic loads.

Keywords: tendon repair, barbed suture, knotless, gap, tensile strength

Introduction

Flexor tendon repair technique has improved as studies have demonstrated benefits in functional results from early, active mobilization.^{1,24,25} Various aspects of tenorrhaphy have been studied in an effort to maximize tensile strength, such as multiple strands,^{1,3,8,22} suture materials,¹¹ locking constructs,^{2,6} purchase length,^{5,17} and supplemental peripheral repair.^{7,8}

Although barbed suture use in tenorrhaphy was first reported in 1967,¹⁶ the material, first created using 3-0 nylon, fell out of favor due to low tensile strength and poor construction. In 2009, however, advances in materials and geometry enabled the birth of a new generation of barbed sutures and renewed interest in applying the technology in flexor tendon repair.²³ Barbed suture tenorrhaphy theoretically allows smoother gliding under pulleys by decreasing cross-sectional area under load, better load distribution along the entire suture length, and improved tendon flow by reducing constricting forces.¹⁰ Currently, 3 commercial barbed sutures are available: V-Loc™ (Covidien, Dublin, Ireland), an absorbable monofilament polydioxane suture;

Quill SRS™ (Angiotech Pharmaceuticals, Inc., Vancouver, BC, Canada), an absorbable unidirectional barbed polydioxane suture; and Stratafix™ (Ethicon, Johnson & Johnson, USA), a form of Quill SRS modified with proprietary needles. Most studies have compared one of the commercially available barbed sutures with conventional nonbarbed sutures^{10,11,13,14,18,19,23,27,28} but minimal data exist in comparing the barbed sutures with each other. The purpose of this study was to determine if any differences exist between conventional nonbarbed, V-Loc™, and Stratafix™ barbed suture core repairs in gap resistance or ultimate tensile strength in an established biomechanical ex vivo model of flexor tenorrhaphy.

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Methods

Thirty porcine flexor digitorum profundus tendons were harvested and separated into 3 groups. A power assessment done previously using a significance level of 5% and a power of 80% indicated a minimum sample size of 7 in each arm.^{9,25}

As described in prior studies, the tendons were harvested from the 2 central rays of each forelimb and transected 5 mm proximal to the long vinculum, within the Zone II region.^{4,12,17,21} Tendons were visually inspected, and those with grossly deviating size or deformities were excluded. The 3 test groups consisted of the following:

- Group 1: absorbable monofilament polydioxane suture (PDS™ 3-0; Johnson & Johnson). PDS was chosen as a control over braided nonabsorbable suture to minimize differences in suture materials and geometries.
- Group 2: absorbable unidirectional barbed glycolic-carbonate suture (V-Loc 180™ 3-0; Covidien).
- Group 3: absorbable unidirectional barbed polydioxane suture (Stratafix™ 3-0; Johnson & Johnson).

Adelaide type core repair was conducted using the suture with 4-mm cross-locks and 1-cm suture purchase with a buried 6-throw square knot in PDS™ repairs, and a knotless, modified Adelaide repair was performed using the barbed sutures, terminating in a reverse throw per manufacturer recommendations.¹⁰ All repairs were performed by a single surgeon (A.S.).

Repaired tendons were mounted into serrated soft tissue clamps at a 2.0-cm distance from the repair site. Tendons were preloaded to 3 N and then stretched linearly by the Instron™ machine (Model 8521; Instron Corp., Canton, MA) at a rate of 20 mm/min until failure, similar to protocols used in similar studies.^{10,13,27,28} Trials were recorded using a digital video camera and a ruler was positioned next to the tendon to provide a reference of length.

To look for differences in gap resistance, frame-by-frame analysis was conducted, and we recorded the load at which a 2-mm gap was measured at the midpoint of tendon ends. Kruskal-Wallis one-way analysis of variance (ANOVA) with Tukey tests was used to evaluate significance for 2-mm gap resistance with significance set at $P < .05$. Saline spray was used throughout testing to avoid dehydration of samples.

Similarly, to evaluate maximum tensile strength, frame-by-frame analysis was conducted, and we recorded the load at which the suture ruptured, pulled out, or unraveled. One-way ANOVA was again used to compare group means with significance set at $P < .05$.

Figure 1. Conventional PDS and barbed V-Loc and Stratafix suture repairs produced similar 2-mm gap resistance. Note. PDS, polydioxane suture.

Results

Two-Millimeter Gap Resistance

Suture type did not affect gap resistance, although barbed sutures performed slightly better than conventional PDS™. The loads at 2 mm measured gap formation were 22.6 ± 3.8 N in PDS™ repairs (Group 1), 25.1 ± 4.0 N in V-Loc™ repairs (Group 2), and 27.1 ± 5.4 N in Stratafix™ repairs (Group 3) as shown in Figure 1; all differences were insignificant ($P > .05$).

Maximum Tensile Strength

Barbed sutures of both types had equivalent ultimate tensile strength ($P = .133$), but the Stratafix™ had lower ultimate tensile strength than the PDS™ control ($P = .003$), whereas the V-Loc™ was equivalent to PDS™ ($P = .086$). The maximum tensile strengths were measured to be 83.3 ± 10.0 N in PDS™ repairs (Group 1), 76.0 ± 9.4 N in V-Loc™ repairs (Group 2), and 68.1 ± 8.4 N in Stratafix™ repairs (Group 3) as shown in Figure 2.

Mode of Failure

The most common mode of failure was suture rupture, present in 90% of samples. One suture pullout was seen in each of the 3 groups. No cases of knot unraveling were seen. Because all groups had the same proportion that ruptured (90%) and pulled out (10%), no further statistical comparison was performed.

Discussion

In this study, we found no difference between V-Loc™ or Stratafix™ repairs in 2-mm gap resistance. These results concur with previously published findings.⁹ Although V-Loc™ and Stratafix™ are created from different core

Figure 2. Barbed V-Loc and Stratafix repairs produced similar maximum tensile strength, but conventional PDS produced higher ultimate strength than Stratafix.

Note. PDS, polydioxane suture.

* $P = .003$.

materials and possess different shaped barbs (dual-angle cut in V-Loc™, deeper single-angle cut in Stratafix™),³⁰ the similar geometries still produced statistically equivalent results. Furthermore, we demonstrated that barbed and non-barbed repairs possessed equivalent 2-mm gap resistance, also in accordance with prior reports,¹⁴ indicating minimal benefit to the use of barbed suture in flexor tenorrhaphy from a purely biomechanical standpoint. These results must be interpreted with care, however, as the theoretical benefits of barbed knotless repair in load distribution, tendon gliding, and improved tendon circulation over conventional repairs^{10,18} would need to be further studied.

Our results differed from a prior study comparing V-Loc™ with Stratafix™ in that we also found no difference between barbed suture types in maximum tensile strength, whereas the V-Loc™ was previously shown to have significantly higher ultimate tensile strength.⁹ This may be due to differences in repair constructs, as we opted to use a modified 4-strand Adelaide repair over the modified Kessler due to improved performance of the cross-stitched locked construct in other studies.^{2,3,26} Consequently, our measured values for maximum load averaged 60% higher. The clinical relevance of maximum tensile load, however, is debatable as these values were reached when gap distance reached grossly 10 mm, far beyond the accepted range of 2 or 3 mm for flexor tenorrhaphy.²⁹

Prior studies have measured digital flexor tendon forces up to 34 N during active unresisted finger motion in vivo.²⁰ Although all 3 suture types outperformed this figure in ultimate tensile strength, they also reached a gap distance greater than 2 mm under a 34 N load. This could indicate potential gliding or healing problems in vivo without further supplementation by a circumferential repair.

Several limitations in our study must be acknowledged. First, by linear testing, we considered only the initial

mechanical performance of repair constructs. Cyclical testing of tendon repairs might better mimic better physiologic loads to failure and should be further studied. Second, although the barbed and conventional core repair geometries were similar, they were not completely identical. We opted for the modified Adelaide repair terminating in a reverse throw because of its similarity to the Adelaide repair while in accordance with manufacturer recommendations. Third, as alternative suture materials become available, further studies will need to be performed examining strength over time and absorption profiles. Theoretically, adequate repair strength must be present throughout the tendon healing process to support active mobilization.

In conclusion, barbed and nonbarbed suture repairs demonstrate equivalent 2-mm gap resistance and are equally viable options for use in flexor tenorrhaphy. Regardless of the suture material chosen, however, it is accepted that 4-strand cruciate flexor tendon repairs require peripheral supplementation to withstand physiologic loads.⁸ Neither of the two commercial barbed sutures demonstrates a clear clinical advantage over the other or over conventional PDST™ suture within the defined parameters, but further studies are needed to optimize repair geometries, suture materials, and compare tendon gliding in vivo.

Ethical Approval

This study was approved by our institutional review board.

Statement of Human and Animal Rights

This article does not contain any studies with human or animal subjects.

Statement of Informed Consent

Informed consent was obtained when necessary.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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