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Original Article

A novel method for reducing gap formation in tendon repair

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ABSTRACT

Background: This study investigates gap formation in tendon repair using a novel tensioning method.
Hypothesis: The novel stitch will demonstrate less gap formation than the other suture configurations tested.
Methods: Porcine tendons stitched with classic Krackow stitch configurations were compared to a Krackow stitch modified with a proximal Tension-Assist Loop. Each group was cyclically loaded followed by analysis of the tendon-suture construct for gap formation.
Results: The Tension-Assist Loop group produced significantly less gap formation than each of the other stitch groups.
Conclusion: Decreasing early gap formation may be beneficial in allowing early rehabilitation and range of motion.

1. Introduction

Surgical repair of tendons is common practice in orthopaedics. Secure fixation between the tendon and bone is critical for clinical success of the tendon repair.[1,2] In addition, early rehabilitation protocols, which allow early weight bearing and range of motion, are dependent on resistance to gap formation.[1,2,3,4]

Various studies have been performed to identify the suture technique that provides the greatest resistance to gap formation. These studies compare new suture configurations as well as varying the number of throws in known suture configurations. These studies assess gap formation, load to failure, and failure mode.[4,5,7] The Krackow stitch is recommended due to its greater resistance to gap formation.[4]

Mechanisms of gap formation include suture tear-out,[4] suture material elasticity,[8] knot failure[9] and suture slack.[10,11] Suture slack is the laxity that exists in a tendon suture construct. When a suture-tendon construct is tensioned, a decrease of tendon width occurs due to the constricting effects of the suture loops.[4] As the constriction occurs, suture is extruded from the tendon end, resulting in gap formation between tendon and fixation site. Due to the compressible properties of tendon tissue, suture slack exists even with meticulous technique. This concept is demonstrated below (Fig. 1), with foam exaggerating the compressible nature of tendon.

The purpose of our study was to quantitate and subsequently reduce gap formation due to suture slack. Current methods to reduce suture slack are limited to distal tensioning of suture-tendon constructs by hand before proceeding to final fixation. We describe a method which allows for simultaneous proximal and distal tensioning. We hypothesized this method would demonstrate less gap formation than the other suture configurations tested.

2. Materials and methods

2.1. Tendon preparation

A total of 32 equally sized fresh 6 mm porcine flexor digitorum tendons were obtained and randomly assigned into 4 groups, each with a sample size of 8 tendons (Fig. 2). The first 3 groups were prepared with the same stitch configuration, an 8-throw Krackow[K], each with different suture material: No. 2 FiberWire[FW], 2 mm FiberTape[FT], and 1.5 mm LabralTape[LT]. For each of these groups, the Krackow stitch was constructed in the classic Krackow fashion, starting 10 mm from the free end of the tendon. The pitch between the suture throws was 5 mm.[12,13] Each stitch loop throughout the process was tensioned by hand to eliminate suture material and the finished construct was robustly tensioned by hand to a minimum of 25 N (confirmed by linear tensiometer), simulating operating room technique.

The fourth, experimental, group consisted of a modified 8-throw Krackow Tension-Assist Loop (TAL) Stitch using No. 2 FiberWire. The stitch was identical to the Krackow stitch described above with the following exception: a 15 cm loop of suture was left at the most proximal aspect of the configuration, between the 4th and 5th throw

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[1] Where the work was done.

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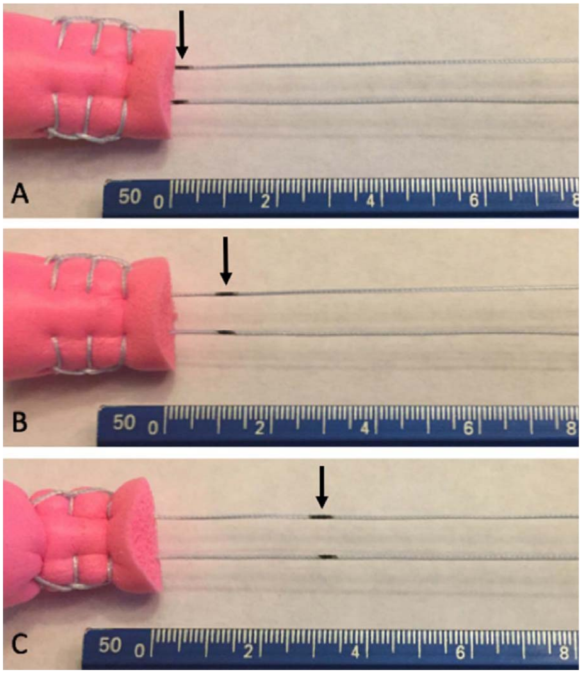

Fig. 1. This image depicts the concept of suture slack. As greater tension is applied, the foam (which represents tendon) is compressed. This results in movement of the suture with resultant gap formation. Movement is demonstrated by the black indicators advancing to the right.

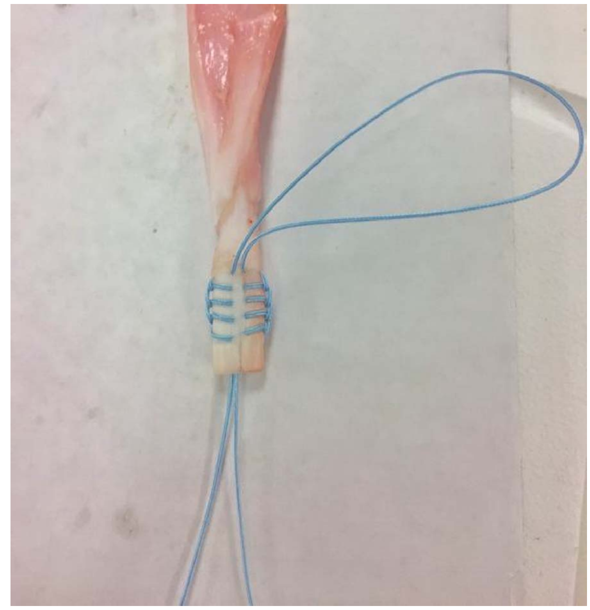

Fig. 3. The TAL Stitch configuration. The 15 cm loop allows for tensioning the suture from the proximal end.

(Fig. 3). This loop is able to be tensioned, effectively creating an anchor allowing for suture tensioning in the proximal direction.

The specimen was transferred to the Hughston Auburn Rotational Testing (HART) machine for "slack-removal." The loop just constructed was placed on the actuation arm of our tensioning machine and the suture free ends were affixed to a rigid vice directly below the actuation arm (Fig. 4).

The machine then applied tension at 1 mm displacement per second until 250 N (56 lbs) was reached. This was repeated 5 times for each TAL Stitch tendon. 250 N was chosen as the pre-tensioning load as it was substantially lower than the ultimate strength of the suture material.[4] It is important to note that once the suture pattern was complete, the tension was applied between the proximal suture loop and the distal suture free ends. This is in contrast to the other tested models, where tension is applied through the distal suture free ends alone (which mimic the clinical scenario).

Once 5 cycles were reached, the construct was removed from the HART machine. The loop was then cut and tied with 5 square knots (Fig. 5).

This concluded the "slack-reduction" process. From a testing configuration, it now had the same construct pattern as the traditional Krackow of first three groups, yet by tensioning in this method, higher constricting effects led to greater slack reduction. This was made possible by the simultaneous proximal and distal force applied as well as the high magnitude of the force.

2.2. Biomechanical testing

Tests were performed by use of the validated Hughston Auburn Rotational Testing (HART) machine.[6] This machined applies and measures torque via an actuation arm. For this loading application, torque was converted to tension by dividing the torque measurement by the radius of the actuation arm (Fig. 6). This conversion was verified by the use of a linear tension gauge prior to testing.

The free ends of prepared tendons were placed in a vice below the actuation arm. The vice was fixed and submerged in 0.15 M saline bath with temperatures maintained between 90 and 110 (mean 100) degrees Fahrenheit to approximate physiologic conditions.[14] The free ends of the sutures were affixed around a post on the actuation arm and tied with 6 square knots. Prior to placing tendons in the testing machine setup, gap formation indicators were placed on each free suture end. These markers consisted of metal loops crimped on both suture leads directly adjacent to the midsubstance of the tendon, where the suture exited. One was placed on each side in the event that gap formed unevenly between the 2 suture ends. The placements of the indicators were marked with permanent marker to ensure that any slippage of the

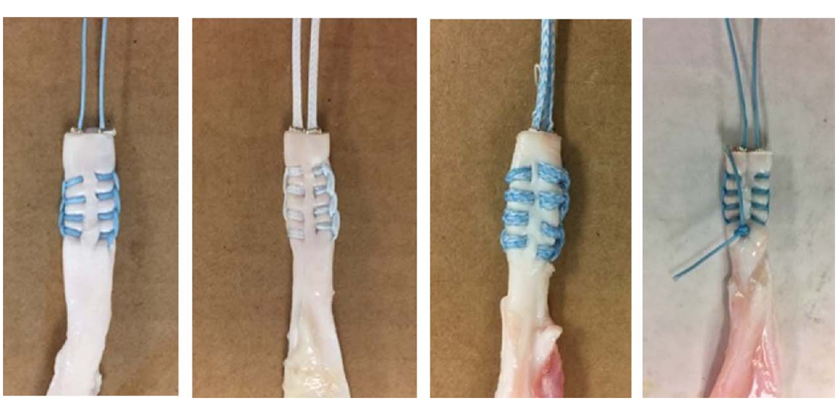

Fig. 2. Groups 1–4 stitch configurations (Right to Left).

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