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Effect of suture material on gap formation and failure in type 1 FDP avulsion repairs in a cadaver model

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Abstract

Background. An in vitro cyclical testing simulating a passive mobilisation protocol was used to compare repair of flexor digitorum profundus tendon with modified-Bunnell two-strand pullout technique using a monofilament (Prolene), braided polyester (Ethibond) and a synthetic polyfilament ensheathed by caprolactan (Supramid) sutures.

Methods. Eighteen fresh-frozen cadaveric fingers were randomly divided into three repair groups ($n = 6$); modified-Bunnell technique with 3/0 Prolene, Ethibond or Supramid. After repair, specimens were cyclically loaded from 2 to 15 N at 5 N/s, for a total of 500 cycles. Gap formation at the tendon–bone interface was assessed every 100 cycles. Samples were tested to failure at the completion of 500 cycles.

Findings. All sutures held in all specimens during cyclic testing. The gap formation after 500 cycles was greatest with Prolene suture (6.8 mm, SD 1.2) followed by Supramid suture (4.0 mm, SD 1.1) and Ethibond suture (1.7 mm, SD 1.7) ($P < 0.05$). Repairs with Supramid displayed higher failure load (52.7 N, SD 5.5) as compared to Prolene (37.6 N, SD 4.7) ($P = 0.001$) but not compared to Ethibond (44.9 N, SD 7.1). The failure loads between Prolene and Ethibond did not differ ($P = 0.130$).

Interpretation. Gap formation with Ethibond was significantly lower compared to Supramid and Prolene. The four strand nature of the Supramid repair was superior to Prolene but did not differ compared to Ethibond with respect to failure load. Prolene is the least favourable suture when considering gap formation and failure load, while Ethibond is the most favourable.

Keywords: Flexor digitorum profundus tendon; Suture; Tendon; Biomechanical testing

1. Introduction

Flexor digitorum profundus (FDP) tendon avulsions, although not common, typically occur in young adults involved in sporting activities (Strickland, 1999). Avulsion of the profundus tendon has been classified by Leddy and Packer into three types: in type 1 avulsions the tendon is avulsed from its attachment at the base of the distal phalanx without a concomitant avulsion fracture; type 2 avulsions are associated with a small avulsion fragment disrupting the volar cortex; type 3 avulsions involve avulsion of a large bony fragment from the base of the distal phalanx (Leddy and Packer, 1977). Unfortunately, the clinical results published for this type of injury are often less than satisfactory (Moiemen and Elliot, 2000). In the majority of FDP avulsion injuries, the conventional repair technique comprises reattachment of the FDP tendon to the distal phalanx using a pullout suture over a tendon button (Leddy, 1985; Mangus et al., 1971). Potential problems associated with use of the button include nail plate deformities, nail fold

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necrosis and infections tracking along the sutures. In addition, when using this technique it is not easy to achieve multiple-strand repairs. It is well documented that the strength of a tendon repair depends upon the number of strands crossing the repair site and on the nature of the suture material being used (Savage and Risitano, 1989; Silva et al., 1998).

The Supramid suture (a non-absorbable synthetic polyfilament ensheathed by caprolactan) comes prepacked as a looped suture (B. Braun, Sydney, Australia). When it is used in the conventional pullout suture technique, it is possible to achieve a four strand repair with a single suture and still can be removed similar to monofilaments. In this study, we performed type 1 FDP avulsion tendon reattachments in cadaveric specimens with a looped 3/0 Supramid suture (B. Braun, Sydney, Australia) compared to a standard a monofilament polypropylene suture (3/0 Prolene, Ethicon, North Ryde, Australia) or a braided polyester (3/0 Ethibond (Ethicon, North Ryde, Australia)) over a tendon button. Our aim was to examine the ability of the sutures to withstand a simulated passive mobilisation protocol (Latendresse et al., 2005). The criteria for comparison included the development of any gap formation at the tendon–bone interface during cyclical loading and ultimate load to failure of the repairs.

2. Methods

Eighteen non-randomised fresh-frozen cadaveric fingers (mean age 72.6 years, SD 4.5) were used from six cadaver hands. A sample size of $n = 6$ for each repair method was used based on previous experiments and power calculations on load to failure data to provide a minimum power of 0.8 (Latendresse et al., 2005). Specimens from the ring, middle and index fingers were harvested through the level of the PIP joint preserving a maximum length of the FDP tendon (all >15 cm). Bruner skin incisions were used and dissection carried out to the flexor sheath. The A5 pulley was sacrificed and the FDP insertion was sharply dissected from the base of the distal phalanx, leaving the volar cortex intact and simulating a type 1 FDP avulsion. The flexor digitorum superficialis tendon was removed, and all adhesions between the FDP tendon and surrounding tissues liberated to allow free excursion of the FDP in the remaining flexor sheath.

Group 1 had the FDP tendon reattached using a tendon button with a 3/0 Prolene suture, while the specimens in group 2 had the FDP reattached using a tendon button with a 3/0 Ethibond suture. The specimens in group 3 had the tendons reattached with a looped Supramid suture. In all three groups, the suture was woven into the tendon using a modified Bunnell unlocked core suture. Due to the looped nature of the Supramid suture, there were four strands crossing the site of repair in this repair while the other two groups had two strands across the repair site.

The specimens were tested in uniaxial tension for gap formation and load to failure following a previously developed protocol (Latendresse et al., 2005). Each specimen was prepared for mounting with an anteroposterior 1.5 mm K-wire through the tuft of the distal phalanx. Marker sutures of 6/0 Prolene were placed superficially at the most proximal extent of the suture repair to allow measurement of gap formation in the most consistent manner. A small portion (<3 mm) of the A4 pulley was vented to allow visual measurement with our markers. The repaired fingers were mounted on a material testing machine using pneumatic clamps (MTS 858 Mini Bionix, MTS Testware software, MTS Systems Corp., Eden Prairie, MN, USA). In the first part of the testing, the specimens were cyclically loaded and unloaded from 2 to 15 N, at a rate 5 N/s, for a total of 500 cycles (Latendresse et al., 2005). Specimens were carefully irrigated with physiological solution periodically throughout the procedure. Gap formation at the tendon–bone interface was measured every 100 cycles using a Series 500 Digimatic ABSolute Caliper (0.02 mm accuracy, Mitutoyo UK Ltd., Andover, Hampshire, UK) at a standard load of 2 N. The second part of the testing involved a static elongation at 20 mm/min. Failure load and modes of failure were determined. Gap formation at 500 cycles and failure load data was analyzed using a one way analysis of variance and a Tukey HSD comparison using SPSS for Windows (SPPS, Chicago, IL, USA).

The tensile stiffness of six samples of 3/0 Supramid suture was measured using a Mach 1 Micromechanical Testing Machine (Biosyntech, Montreal, Canada) immersed in phosphate buffered saline at room temperature using a gauge length of 10 mm and a displacement of 0.1 mm/s (Latendresse et al., 2005). The linear stiffness in the initial part of the load versus displacement graph was used to determine the stiffness based on a linear regression analysis. This data was compared to published values for 3/0 Ethibond and 3/0 Prolene using the same testing protocol (Latendresse et al., 2005) using an analysis of variance followed by a Tukey HSD post hoc test using SPSS for Windows (SPPS, Chicago, IL, USA).

3. Results

All repairs completed cyclic loading and testing to failure in this study. Gap formation increased only by approximately 10% from 100 to 500 cycles for all suture types. The gap formation after 500 cycles was greatest with Prolene suture (6.8 mm, SD 1.2) followed by Supramid suture (4.0 mm, SD 1.1) and Ethibond suture