BIOMECHANICAL EVALUATION OF GEL-SPUN POLYETHYLENE FIBERS IN FLEXOR TENDON REPAIR

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Introduction: The strength of conventional flexor tendon repairs is limited by the choice of available suture materials and suturing techniques. This is of concern since immediate mobilization of the injured tendon is necessary to maximize patient outcome. Various repair techniques have been devised which provide improved mechanical strength. These methods are technically difficult, however, and may ultimately interfere with tendon healing by increasing the amount of material at the repair site. Using a suture that is stronger than any currently used material, but is still easy to work with, may result in repairs that are of sufficient tensile strength to permit early, active, unprotected motion. A stronger material can also be employed in a smaller size to make complex repairs technically easier. The purpose of this study was to evaluate industrial gel-spun polyethylene (GSPE) fibers as a potential new suture material for flexor tendon repair.

Materials and Methods: Three different GSPE fiber configurations were chosen for evaluation; a 4-0 size micro dyneema™ monofilament (Fireline™), a 4-0 size spectra ™ braid (Spiderwire™), and a 6-0 size micro dyneema™ braid (Gorilla Braid™). For comparison, three commercially available suture materials were selected; 4-0 Ethibond Excel™, 4-0 Supramid™, and 4-0 steel suture. In the first phase of the experiment 9 samples of each specimen were tested in accordance with the 1990 USP standards for the physical testing of suture materials. For the second phase of the experiment, 27 flexor tendon samples were obtained by harvesting the profundus tendon from the middle, index, and ring finger of 9 cadavers. The tendons were then divided at the level of the A2 pulley and a separate suture was passed through each half using a Kessler stitch. One half of each tendon received a GSPE suture, while the other half received one of the commercial sutures. Thus, 54 tendon-suture constructs (9 of each material) were produced. The free ends of the suture were tied using the tubing specified by the USP code. Using this novel approach, as opposed to performing a full repair of the cut tendon using a single suture, it was felt that testing error would be reduced as knot tension would be uniform, and each tendon specimen would be paired with both a GSPE and conventional suture. Mechanical testing was performed using an MTS servo-hydraulic testing apparatus operating in stoke control at a rate of 25 mm/min for each phase of the experiment. Each test sample was pre-tensioned to 1N to remove slack, then tested to failure in tension. Load displacement data was recorded simultaneously by a chart recorder and an electronic data acquisition system. Maximum force to failure and stiffness were calculated and analyzed using one-way ANOVAS and Scheffe's post-hoc tests. Statistical significance was determined at $p \leq 0.05$.

Results: As seen in figure 1, the results of the first phase of the experiment showed that all three GSPE materials and steel were significantly stronger than both Ethibond and Supramid ($p \leq 0.019$ for all comparisons). Additionally, both the Fireline and Gorilla materials failed at significantly higher forces than did the steel suture ($p \leq 0.0003$). Comparing the stiffness of the sutures showed that all three GSPE materials were statistically stiffer than Supramid ($p \leq 0.039$), however, only Spiderwire was statistically stiffer than Ethibond ($p < 0.001$). Steel suture was significantly stiffer than both Gorilla and Fireline ($p \leq 0.037$) but equal to Spiderwire ($p = 0.88$). The data from the second phase of the experiment demonstrated that only Fireline and Spiderwire were significantly stronger than both the Ethibond and Supramid suture ($p \leq 0.039$), as seen in figure 2. Interestingly, the maximum failure load of the steel suture was statistically equal to that of the Ethibond, Supramid, and Gorilla Braid materials. No differences were found between the stiffness of the materials in this phase of the experiment. The mode in which the suture-tendon construct failed was notable between the different materials. Eight of the nine Fireline samples experienced complete pullout of the repair without any knot or suture failure. Similarly, four of the nine Spiderwire samples sustained pullout of the suture. In contrast, the conventional suture materials and the Gorilla Braid demonstrated either material or knot failure in the overwhelming majority of tests.

Discussion: The results of this study indicate that GSPE materials may serve as suitable sutures for the repair of flexor tendons. When tested in accordance with USP standards, the GSPE was consistently stronger than steel and statistically stronger than both Ethibond and Supramid suture. In the simulated tendon repair portion of this study, the GSPE materials maintained their significant improvements in mechanical strength when compared to conventionally used Ethibond and Supramid sutures of similar caliber. Only Gorilla Braid, which was available in 6-0 caliber, failed to provide significant improvement in tensile repair strength. However, despite the smaller size, it performed identically to the conventional sutures. The additional observation that the Fireline and Spiderwire specimens often pulled out of the tendon, rather than failing at the material or knot level, indicates that these materials exceeded the strength of the Kessler repair. This means that even greater increases in tensile repair strength may be obtained by utilizing complex suture techniques that permit enhanced tendon purchase. Clearly, the next step in the evaluation of these materials should involve in vitro and/or in vivo testing for biocompatability and biodegradability. These materials may also find applicability in other situations requiring tendon repair such as patella, rotator cuff, and Achilles tendon ruptures.

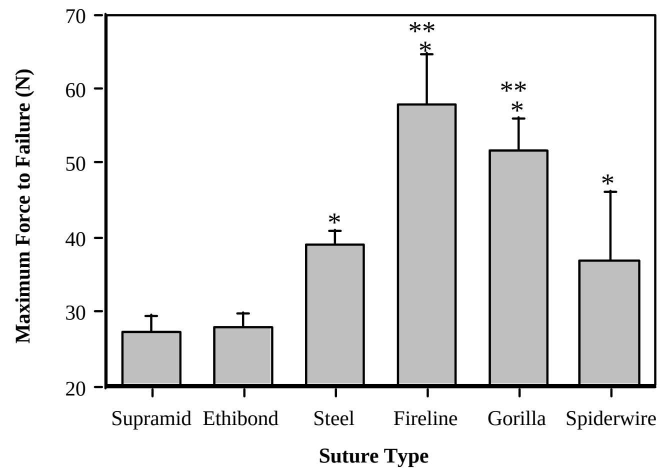

Figure 1: Maximum failure force (mean ± S.D.) of the suture material itself. (* = sig. diff. from Ethibond and Supramid, ** = sig. diff. from steel)

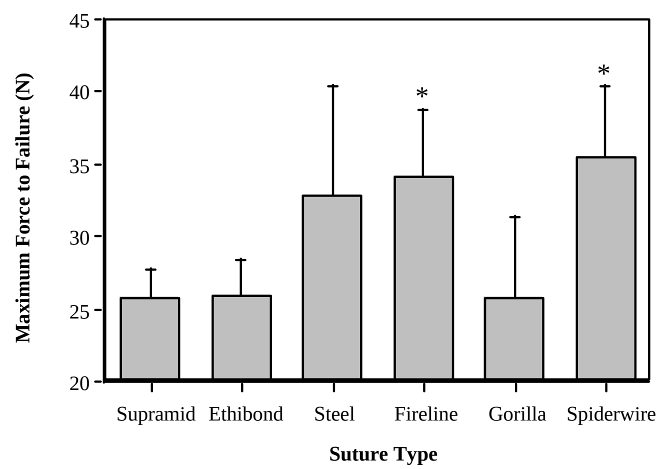

Figure 2: Maximum failure force (mean ± S.D.)of the tendon-suture constructs. (* = sig. diff. from Ethibond and Supramid)

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