INTRODUCTION:
Digital flexor tendon pulleys are critical to maintain normal finger flexion based on the limitations of flexor digitorum profundus (FDP) muscle force and excursion. Prior studies suggest that the A2 and A4 pulleys are the most critical for preventing bowstringing and loss of finger flexion [1]. However, repair of a lacerated FDP tendon (tenorrhaphy) often necessitates the release of a pulley to allow adequate surgical exposure, permit smooth gliding of the repaired tendon, or prevent postoperative scarring [2]. In contrast to prior studies that demonstrated a significant increase in work of flexion with loss of either the A2 or A4 pulley, recent studies suggest that partial pulley release may actually reduce the work of flexion, maintain normal tendon excursion, or maintain near normal range of motion [3]. However, these studies were performed in normal functioning tendons undisturbed by laceration and subsequent repair. Given that in humans, tendon repair under or distal to the A4 pulley is often technically challenging, and the outcome is sometimes compromised by triggering of the repair, these findings suggest a beneficial effect of pulley release associated with flexor tendon repair. Thus, the purpose of this study was to quantify the effect of partial and complete A4 pulley release in the context of a lacerated and repaired FDP tendon just distal to the A4 pulley.

METHODS:
Tendon biomechanics were tested in six fresh frozen cadaveric hands thawed overnight to room temperature. With the exception of the FDP tendon to each digit, all skin and soft tissue were removed proximal to the midpalmar crease. Two Steinman pins were drilled through three or four metacarpals, and hands were secured to a rigid frame, palm up, to permit excursion, force, and range of motion testing of the FDP tendon to each digit. Hands were rested on an adjustable solid support to prevent digital hyperextension.

Each FDP tendon was clamped to a dual mode servo-motor (Aurora Scientific, Inc., Model 310), which allowed continuous recording of length and force. The initial position was defined with the finger fully extended, and the tendon was pulled proximally (simulating active flexion) at a rate of 300 mm/min to the point of full flexion, confirmed by visual contact between the finger tip and palmar skin. Prior to any intervention, an initial trial was performed to provide the baseline values of excursion, force of flexion, and work needed to flex the finger. The finger then underwent the same testing protocol after each of the following interventions: 1) Laceration of the FDP tendon just distal to the A4 pulley and subsequent repair using a six-strand technique with 4-0 fiber-wire and a 6-0 prolene epitendinous suture; the A4 pulley was left intact, 2) Release of the distal half of the A4 pulley, 3) Complete release of the A4 pulley, and 4) Continued proximal release of the sheath to the distal edge of A2 (release of C2, A3, and C1 pulleys). The skin was reapproximated and sutured with 4-0 nylon after each intervention.

Data collected for each finger, under each condition, included excursion (mm), force required for full digital flexion (N), and work of flexion (mJ; calculated as the area under the force-distance curve). Data were analyzed by two-way ANOVA (finger and treatment as grouping factors) with significance level (α) set to 0.05. For purposes of analysis, fingers within each hand were treated as a repeated measure. All data are presented as a mean ± SEM.

RESULTS:
A total of 18 tendons were successfully tested and are included in the analysis (4 index, 4 long, 5 ring, 5 small). Average excursion for all intact digits was 37.9 ± 1.5 mm (range: 24.6-46.7) and average work of flexion was 69.5 ± 8.8 mJ (range: 13.2-141.9). Tendon repair resulted in tendon shortening of 1.6 ± 0.4 mm (range: -1.4-3.8). Due to abstract space limitations as well as the variability between size and mechanical forces on digits, the reported changes in excursion and work are summarized as percent change from the intact condition.

DISCUSSION:
The main result of this study is that, after FDP laceration and repair in the region of the A4 pulley, work of flexion did not increase by more than 3% from baseline after either partial or complete release of the A4 pulley (Fig. 2). These results are in contrast to the findings reported for subhuman primates by Peterson et al. that release of the A4 pulley results in a significant 20% increased work of flexion [4]. However, other studies similarly noted that loss of the flexor tendon pulleys, including A4, does not necessarily result in a complete functional loss of motion [3, 5]. The results of this study provide strong support for the idea that either partial or complete sacrifice of the A4 pulley may be considered to assist with surgical exposure, improve tendon gliding, and prevent adhesion and scar. Previously, it has been considered heresy to sacrifice the A4 pulley due to its presumed importance in flexor tendon function. However, our results suggest that if the surgeon anticipates that a repair distal to the A4 pulley will be compromised due to technical difficulty or triggering, sacrifice of the A4 pulley is a legitimate intraoperative solution preventing the need for later tenolysis. Furthermore, because the FDP muscle has relatively long fibers and large force generating capacity, it can overcome the increased excursion (Fig. 1) and work (Fig. 2) that result from A4 pulley release.

REFERENCES:

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