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THE DETERMINATION OF HUMAN PULLEY TENDON STRESS AND SURGICAL TECHNIQUES FOR REDUCTION OF PULLEY AND TENDON DAMAGE: TESTING APPARATUS AND METHODS DEVELOPMENT

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By

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Purpose and Hypothesis I

Dr. Kennedy has developed a new technique using his invention, the Tendon Tensioning Device (TTD), which allows a surgeon to direct the forces in vectors along the axis of the tendon's normal movement. The TTD, which resembles a fork with two prongs, is expected to apply less stress on the pulley tendons than the currently used Tendon Hook (TH), which applies force perpendicular to the tendon's plane of movement. The goal of our study is to determine the difference between the tendon pulley stress associated with current hand surgery techniques and that of the new technique. The new technique is hypothesized to create less tendon trauma, and, potentially, reduce the sequelae (secondary consequences) associated with tendon surgery. My personal objective of this study was to design an apparatus that would measure precise tendon strains at three different points and allow for data collection.

Methods I

Apparatus – Description and Development of the Testing Apparatus

The apparatus was designed to collect the forces on the pulleys while applying an increasing measure of force on the horizontal tendon. The selection of the frame material was very crucial as the apparatus had to allow for sufficient room without compromising its sturdiness. Carbon fiber rods (Figure 2), often used in post-surgery orthotics were used along with titanium corner-connections (Figure 3) to make an apparatus (Figure 4), easily accessible from different angles, yet strongly fixed to minimize errors in data recordings. Two Teflon blocks were placed on the top of the apparatus in which the tendon samples

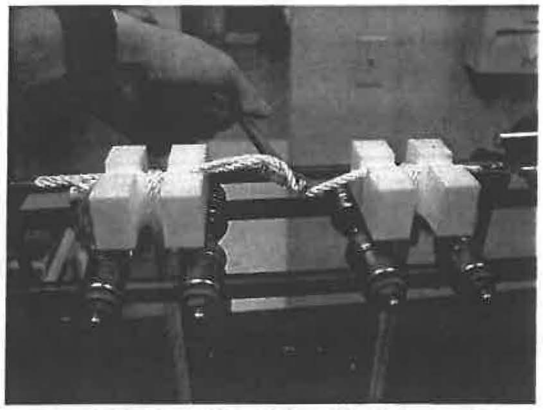

Figure 7 Teflon Blocks and Nylon Strings, Twisting Motion

Three S-shaped load cells were calibrated and strategically placed on the apparatus to measure the tendon forces during the experiments (Figure 8). A very precise calibration was necessary in order to obtain accurate readings. One of the load cells was replaced due to its unexpected frequent noise in the readings despite the multi-day calibration trials. The calibration process of the load cells involved the usage of the MTS 858 Mini Bionix® II machine and its associated software (Figure 9). A separately programmed set of MTS software processes was required for the execution and the data acquisition component of the calibration system.

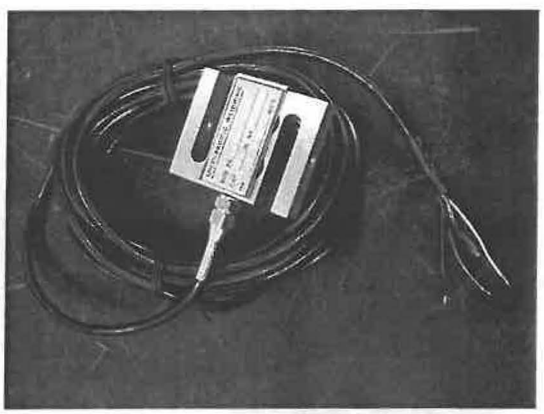

Figure 8 S-shaped Load Cell

Figure 9 MTS 858 Mini Bionix® II and Computer System

Figure 12 FDP Tendon Harvest

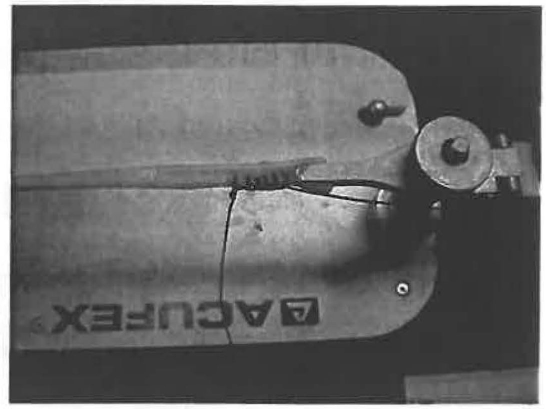

Figure 13 Tendon Suturing

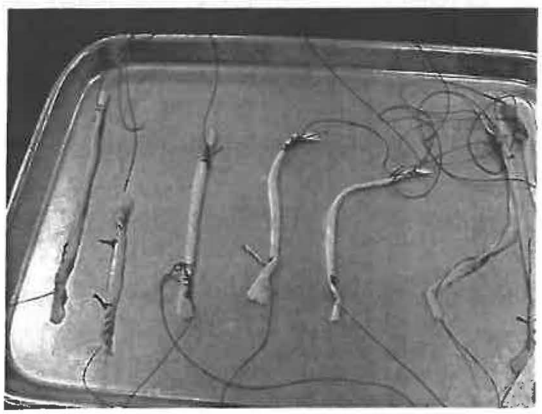

Figure 13 Trial Tendons

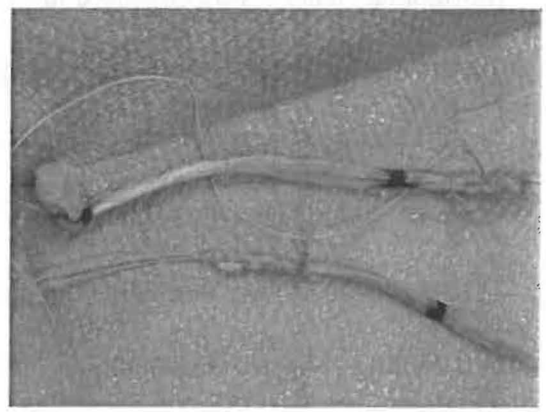

Figure 15 FDP with bone attachment (top)
FDS Mock Pulley (bottom)

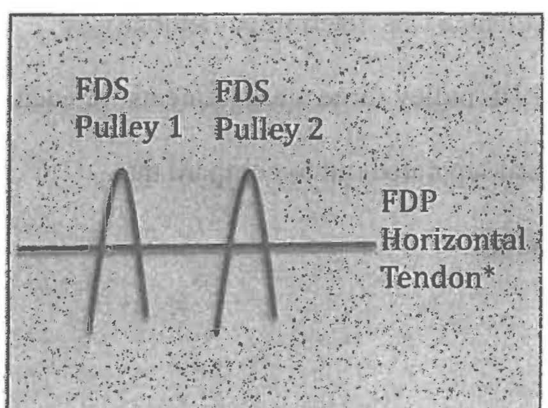

Figure 16 FDPs switched out after three trials

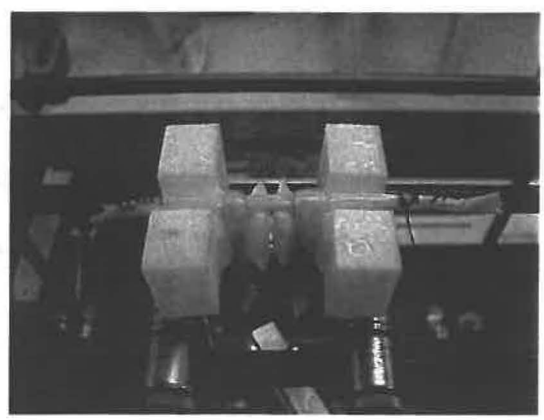

Figure 17 Modified Teflon Blocks

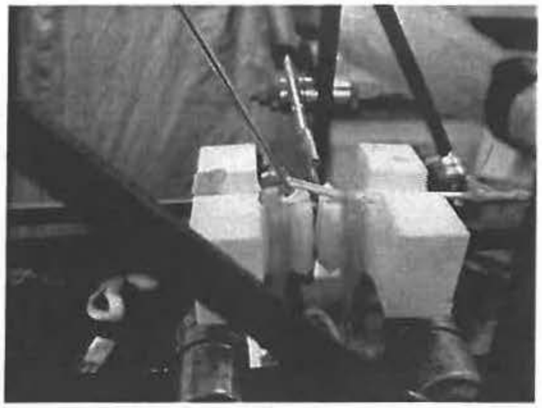

Figure 15 Tendon Hook, 60-Degree Pull

Figure 14 Tendon Hook, 90-Degree Pull

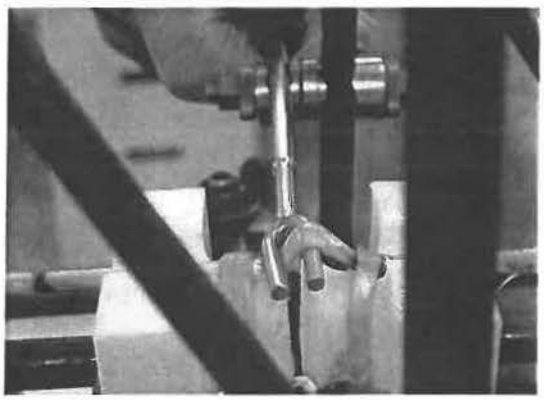

Figure 18 TTD, Clockwise Rotation

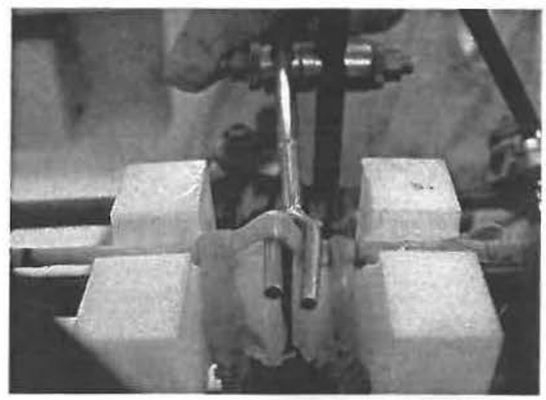

Figure 17 TTD Counterclockwise Rotation

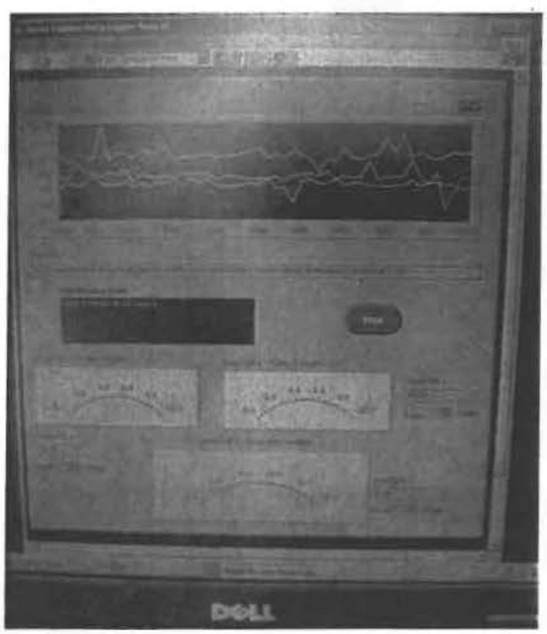

Figure 16 Data Acqusition Software

Results II

Table 4. Average force, standard deviation, and median values, Allis Clamp

	Pulley 1	Pulley 2
Average	1.8960	-0.0202
STDev	0.3041	0.1123
Median	1.9375	-0.0059

Table 5. Maximum Horizontal FDP and FDS pulley forces, standard deviation, and median values of Allis Clamp counterclockwise twist test.

	Horizontal FDP	Pulley 1	Pulley 2
Average	15.7929	6.6565	-0.4466
STDev	0.8834	1.6760	0.3377
Median	16.0208	6.2630	-0.4619

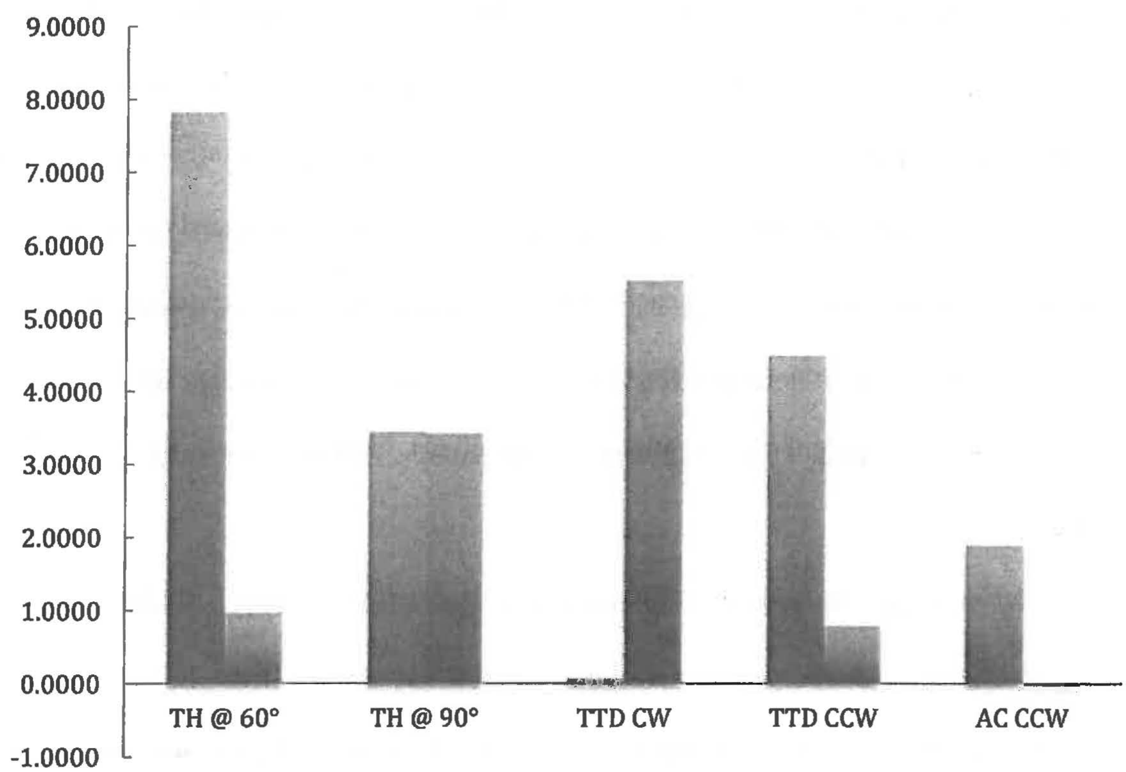

Figure 26 Pulley force comparison of five force-applying techniques, at horizontal FDP tendon force of 6.0000 lbs.

as shown in Figure 22, the higher forces of the clockwise and the counterclockwise twist still come out to be 5.5177 and 4.4908 pounds (P1: 5.5177 lbs., P2: 0.0702 lbs. and P1: 4.4908 lbs., P2: 0.7855 lbs.) at the horizontal force of 6.0000 pounds (Table 2). Using the twisting method with the Tendon Tensioning Device still requires the operator to apply 74.85 to 91.96 % of the horizontal force on one of the associated pulleys.

The Allis Clamp result gave some intriguing data that could help modify the current Tendon Tensioning Device. The consistently repeated force measurements with a small error also validate the accuracy and dependability of the testing apparatus. As shown in Table 4, the twist method using the Allis Clamps appears to significantly decrease the FDS pulley forces, compared to all four previous methods. The Allis Clamp twisting method showed a 44.59 - 75.76% decrease in the higher-stressed FDS pulleys and a 100.60 – 128.77% decrease in the lower-stressed FDS pulleys compared to the four previous methods (Figure 24, Tables 2 and 3).

Overall, the Allis Clamp twisting method seems to show the best result in minimizing vertical distraction forces on the pulley tendons while applying a horizontal force on the FDP tendons. However, the result of this study does not work to disprove the usefulness of the novel Tendon Tensioning Device. The Allis Clamp, although it produced reasonable data in this study, is not a highly reliable replacement for the Tendon Hook or the Tendon Tensioning Device. Allis Clamps are produced in many different sizes and only the select few smaller-sized clamps will produce reasonable results. They are difficult to hold and rotate (as the clamp frequently unclamps itself when rotated), and do not allow for a good range of motion or a smooth twisting due to the scissor-like design of their clamp handles. Also, the sharper edges of Allis Clamps are