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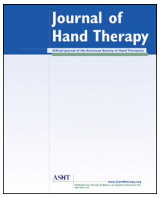

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Scientific/Clinical Article

Effect of wrist and interphalangeal thumb movement on zone T2 flexor pollicis longus tendon tension in a human cadaver model

Patricia O. Rappaport PT, CHT[a], Andrew R. Thoreson MSc[a], Tai-Hua Yang MD[a], Ramona L. Reisdorf BS[a], Stephen M. Rappaport PhD[b], Kai-Nan An PhD[a], Peter C. Amadio MD[a,*]

[a] *Tendon and Soft Tissue Biology Laboratory and the Biomechanics Laboratory, Mayo Clinic, Rochester, MN, USA*
[b] *School of Public Health, University of California, Berkeley, Berkeley, CA, USA*

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ABSTRACT

Introduction: Therapy after flexor pollicis longus (FPL) repair typically mimics finger flexor management, but this ignores anatomic and biomechanical features unique to the FPL.

Purpose of the study: We measured FPL tendon tension in zone T2 to identify biomechanically appropriate exercises for mobilizing the FPL.

Methods: Eight human cadaver hands were studied to identify motions that generated enough force to achieve FPL movement without exceeding hypothetical suture strength.

Results: With the carpometacarpal and metacarpophalangeal joints blocked, appropriate forces were produced for both passive interphalangeal (IP) motion with 30° wrist extension and simulated active IP flexion from 0° to 35° with the wrist in the neutral position.

Discussion: This work provides a biomechanical basis for safely and effectively mobilizing the zone T2 FPL tendon.

Conclusion: Our cadaver study suggests that it is safe and effective to perform early passive and active exercise to an isolated IP joint.

Level of evidence: NA.

Introduction

Extensive study of treatment following repair of finger flexor tendons has continued to enhance rehabilitation and outcomes.[1] Although knowledge gained from study of finger flexors is relevant to treating the flexor pollicis longus (FPL), features unique to the opposable thumb[2–4] challenge straightforward extrapolation. Since limited scientific research has been devoted specifically to the FPL,[5–7] the scientific basis for early-phase mobilization following FPL repair may not be fully optimized.

As compared to the fingers, thumb motion involves highly complex patterns of flexion/extension, abduction/adduction, and circumduction. The FPL harnesses this mobility by providing stability, strength, and dexterity.[8–10] As the sole flexor of the interphalangeal (IP) joint, it is essential to thumb opposition and — being independent from the flexors of the fingers — enables the hand to perform highly precise movements crucial to daily function.[8,10] However, lack of interconnections to the fingers leads to higher incidence of proximal tendon retraction following laceration, complicating repair and rehabilitation.[5,7,11,12] Furthermore, while early mobilization is known to enhance healing and tensile strength,[13] the most effective means for introducing early active motion remains controversial[14] and appears to be better established for the finger flexors than for the FPL.

Study of the FPL by Sirotakova, Elliot, and Southgate [5,15,16] has informed surgical techniques and orthosis design, but optimal mobilization methods remain elusive. Using dividers and a 0.5-mm calibrated ruler, Brown and McGrouther[17] found a 70% increase in tendon excursion in zone T2 with isolated passive IP flexion when compared to simultaneous flexion of the IP and metacarpophalangeal (MCP) joints. Although this confirmed that isolating the IP joint produces greater tendon glide, it is unclear whether the forces generated by passive IP flexion can overcome gliding resistance at the site of repair, or whether force generated by active IP flexion might exceed repair strength.

Conflict of interest: All named authors hereby declare that they have no conflicts of interest to disclose.

[*] Corresponding author. Department of Orthopedic Surgery, Mayo Clinic, 200 1st Street SW, Rochester, MN 55905, USA. Tel.: +1 507 538 1717; fax: +1 507 284 5392.

E-mail address: pamadio@mayo.edu (P.C. Amadio).

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It is well understood that wrist position is crucial to treating a repaired tendon.[18] Yet, forces associated with various wrist positions, specifically in combination with isolated thumb IP motion, have not been investigated. Lastly, synergistic motion has been recognized to offer low finger flexor force with high tendon excursion,[19–24] but the influence of synergistic wrist motion on the thumb flexor has not been reported.

To better understand how joint position and mobilization methods optimize the mechanics of FPL rehabilitation, we utilized the concept of a 'safe and effective zone' (SEZ) where the forces applied (actively or passively) are great enough to achieve tendon movement while remaining below those that disrupt the suture repair.[22,25,26] The lower SEZ limit represents the viscoelastic drag of the repaired tendon within its sheath,[27–29] while the upper SEZ limit represents the force a repair can withstand before gapping.[30] Using a modified Kessler suture technique, the SEZ for the FPL was reported to be between 1.3 N[31,32] and 7 N.[22,26] Additionally, it has been suggested that a minimum of 2 mm of tendon excursion at the repair site is needed to minimize adhesions and thus maintain adequate tendon glide for functional motion.[33–35]

In this cadaveric study, we measured the forces acting on the FPL in zone T2 as induced by the tenodesis effect of wrist position while passively moving the isolated IP joint and passively performing a synergistic arc of wrist motion. Then, we experimentally induced a simulated active IP motion while blocking the MCP, carpometacarpal (CMC), and wrist in neutral. We hypothesized that measuring the forces generated under these conditions would identify safe and effective motion, and thereby provide a biomechanically-based guide for post-surgical rehabilitation.

Materials and methods

Subjects

This study was approved by Mayo Clinic Institutional Review Board (IRB) and Biospecimens Subcommittee (Study # 13-008747/Bio00011478). Eight fresh-frozen human forearms (four right and four left), consisting of all tissue distal to the mid-humerus, were obtained from eight different cadavers with a mean age of 77 years (range 55–94 years) through our institution's anatomical bequest program. Specimens were screened for arthritic changes as well as hand and wrist injury. No thumb IP limitations related to arthritis or otherwise, were noted. The sample size of 8 specimens was selected based on a previous study[22] which had 80% power to detect a difference of 15 N in mean tendon forces with a significance level of $\alpha = 0.05$.

Experimental setup

The elbow was fixed at 90° by inserting a K-wire (2.3 mm) through the intramedullary canal of the humerus and the olecranon of the ulna while simultaneously securing the mid-forearm in neutral pronation/supination with K-wire through the radius and ulna. The arm was oriented vertically on a wrist joint kinematic table with the mid-forearm K-wire secured to the table and the distal humerus firmly locked onto the table. To maintain wrist motion in the desired plane, K-wires (1.5 mm) were inserted into the distal, middle, and proximal phalanges and metacarpals of the long and ring fingers. The K-wires were then secured to an arched Plexiglas guide (Fig. 1).

A 2.0-mm K-wire fixed the MCP joint at 0° flexion/extension/abduction/adduction. An external fixator was attached at the CMC joint allowing for reliable adjustment of CMC radial abduction/adduction angles. To mark the IP axis of rotation, a pin was driven into the head of the proximal phalanx at a right angle to the plane of flexion and used to locate the goniometer for measuring IP angle during excursion data collection. A mid-volar incision between the A1 and A2 pulleys allowed for access to the FPL tendon without disrupting the pulley system. With the wrist in a neutral position, IP and MCP joints at 0°, and CMC at 30° radial abduction, a marker suture (6-0 polypropylene) was inserted into the tendon in line with a reference suture placed in tissue firmly attached to the bone. To further assist with visual alignment, an additional reference suture was place in the skin. As seen in Fig. 2, all three sutures were located just proximal to the IP joint. Tendon excursion between the marker and reference sutures was measured with a digital caliper calibrated to 0.5 mm.

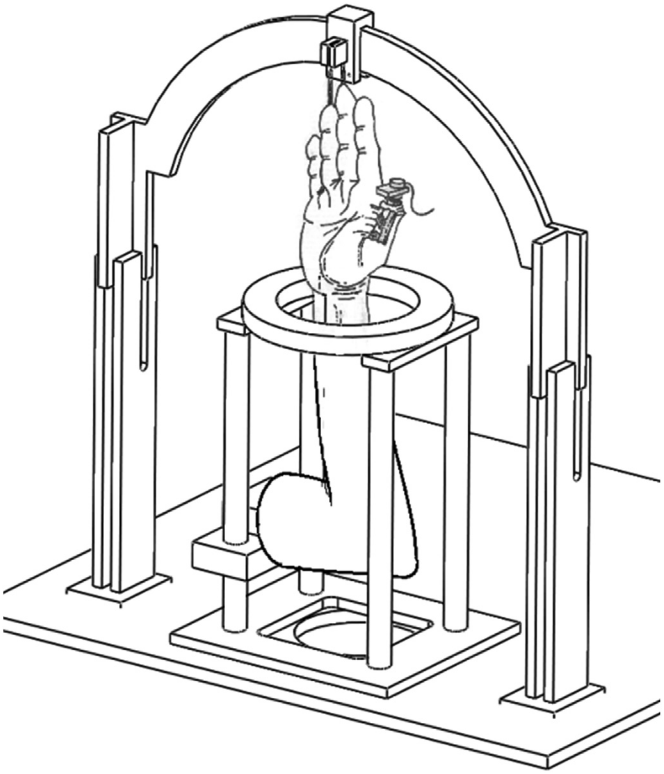

Fig. 1. Kinematic wrist table with load-cell transducer in place on the thumb.

Approximately 1.5 cm of the distal phalanx was removed so that a custom-fabricated platform could be press-fit into the intramedullary canal of the remaining distal phalanx. After securing a small button load cell transducer (10804 50 lb. capacity, Entran, Hampton, VA) to the platform, the FPL tendon was cut near its bony insertion and connected to the transducer with 2-0 braided polylactic acid suture (Vicryl; Ethicon, Somerville, NJ). To achieve resting tendon tension, care was made to maintain alignment of the marker and reference sutures.

Thumb IP and wrist joint positions were measured with a three-dimensional motion analysis system (Motion Analysis Corporation, Santa Rosa, CA). For IP motion, two spherical (3-mm diameter) retro-reflective markers were secured to the transducer platform in a parallel orientation to the long axis of the distal phalanx. Two additional reference markers were secured vertically along the proximal phalanx. For wrist motion, three (5-mm diameter) markers in a triangular configuration were secured into the 4th metacarpal and a similar configuration into the distal radius (Fig. 3). Wrist angles and thumb IP flexion angles were captured using three motion capture cameras placed perpendicular to the long axis of the third metacarpal and oriented to maintain focus on the retro-reflective markers during testing.