Primary Tendon Sheath Enlargement and Reconstruction in Zone 2: An *In Vitro* Biomechanical Study on Tendon Gliding Resistance

Robert E. Bunata, MD, Victor Kosmopoulos, PhD, Sara Simmons, MD, Tristan J. Tayag, PhD, Matthew Roso, BA, Heather Carlson

Purpose To investigate our hypothesis that primary pulley enlargement and repair using an extensor retinaculum graft will reduce tendon repair gliding resistance. The benefit of pulley enlargement has been tested in experimental animals, but its effect on gliding resistance *in vitro* using human fingers is not known.

Methods *In vitro* gliding resistance in the proximal tendon sheaths (A1 through A3) was measured and compared in 7 cadaver fingers using the method of Uchiyama and colleagues at a fixed 50° over the proximal sheath under 3 conditions: (1) intact tendons with intact proximal sheath; (2) laceration and 2-strand core plus running epitenon repair of the tendons with intact sheath; and (3) repaired tendons with enlargement of the A2 pulley and adjacent proximal sheath by incision and repair with an extensor retinacular graft. Results were analyzed statistically.

Results Gliding resistance increased from an average of 0.44 N ± 0.07 in the intact condition to an average of 1.51 N ± 0.23 (a mean increase of 243%) when the tendons were cut and repaired. Enlarging the proximal sheath by sheath incision and graft repair reduced the gliding resistance from the repair condition to 1.04 N ± 0.15 (a mean decrease of 31%). These changes are statistically significant.

Conclusions *In vitro*, repaired tendons had a greater resistance to gliding than that of the intact tendons through the proximal sheath when tested by the method of Uchiyama and colleagues. Enlargement and repair with an extensor retinacular graft of the A2 pulley and adjacent sheath significantly reduced resistance to repaired tendon gliding. These findings support further investigation into the concept that primary pulley enlargement may improve tendon function after repair. *(J Hand Surg 2009;34A:1436–1443. Copyright © 2009 by the American Society for Surgery of the Hand. All rights reserved.)*

Key words Flexor tendon injuries, flexor tendon sheath, gliding resistance, sheath and pulleys, zone 2.

MANAGEMENT OF THE tendon sheath during zone 2 flexor tendon repairs continues to be controversial. Before tendon repair combined with protected early motion was developed, limited sheath resection was advocated.[1,2] In the 1970s and early 1980s, when the intrinsic healing ability of tendons was established and use of early postoperative motion regimens was popularized, the sheath was me-

From the Bone and Joint Research Center, Department of Orthopaedic Surgery, University of North Texas Health Science Center, Fort Worth, TX; the Department of Orthopaedic Surgery, John Peter Smith Hospital, Fort Worth, TX; and the Department of Engineering, Texas Christian University, Fort Worth, TX.

The authors wish to acknowledge the help of Rene' Cote', MS, Department of Engineering, Texas Christian University, for his help in creating the data collection system and in data collection and analysis.

Received for publication November 19, 2008; accepted in revised form May 13, 2009.

No benefits in any form have been received or will be received related directly or indirectly to the subject of this article.

Corresponding author: Robert E. Bunata, MD, 4054 Hildring Dr. West, Fort Worth, TX 76109; e-mail: rbunata@hsc.unt.edu.

0363-5023/09/34A08-0009$36.00/0
doi:10.1016/j.jhsa.2009.05.005

ticulously repaired. Closing the sheath isolated the repair from adhesions, encouraged synovial tendon nutrition, molded the tendon, and guided the tendons into and through the sheath avoiding the catching of the repair on an exposed edge of sheath.[3,4] In the 1980s, concern was expressed that sheath closure might result in a constricting, tight sleeve that could impair tendon gliding.[5,6] Making a limited incision (referred to as venting)[7] of a tight sheath, including the pulleys, is one method of dealing with the tendon sheath to improve free tendon movement and prevent the repair from catching on an edge of the sheath.[8–10] However, rupture of repaired tendons may indicate that control of gliding resistance and/or triggering remains a problem.[9] Reporting on their series of 126 consecutive cases, Kwai Ben and Elliot stated that they "vented" either the A2 or A4 pulley in 64% of zone 2 tendon repairs.[8,9] Although the worldwide incidence of venting is not known, this gives one center's perspective on the occurrence of sheath problems.

In 1985, Lister, in addition to recommending primary sheath closure, advocated use of fascial graft in cases of an extensively damaged, deficient sheath to accomplish closure for the purpose of isolating the repair from adhesion formation and to provide mechanical guiding of the tendon through the sheath.[4] In 1988, Manske, expressing concern that closure could result in a sheath that was too tight to allow free tendon gliding, expanded Lister's concept by offering the suggestion that enlargement and repair with a fascial graft might prevent a sheath closure from being too tight.[5] In 1993 Tang et al. reported using sheath enlargement, preserving pulleys if possible, in 21 digits.[11]

Several authors have reported laboratory animal studies with improved gliding resistance after enlargement of the sheath adjacent to the pulley[12–17] and some after enlargement of the pulley itself.[13,18] Palliard et al. reported improved gliding in cadaver fingers after a pulley plasty.[19] This study measures the effect of pulley enlargement by incision and grafting in a controlled experimental setting in human anatomic specimens, by measuring flexor tendon gliding resistance using the method of Uchiyama et al.[20] at a fixed 50° angle at "time zero" under 3 conditions. Our hypothesis is that sheath enlargement with graft repair will reduce tendon gliding resistance and thereby improve tendon repair gliding through the proximal sheath, including the A2 pulley.

MATERIALS AND METHODS

Seven fresh human index, middle, and ring fingers from the base of the metacarpal to the finger tip from 3 different cadavers were frozen and stored in sealed bags at −20°C. The fingers had no visible evidence of previous injury or arthritis and had full passive joint motion. On the day of testing, they were thawed and prepared by removing soft tissues except the flexor tendon sheath, the flexor tendons, and the extensor tendons and joint capsules. With the entire flexor mechanism intact, 2 marks were made on the flexor digitorum profundus (FDP) tendon at the proximal edge of the carefully dissected A1 pulley; one with the 3 finger joints in full extension and the other with the metacarpophalangeal joint extended and the interphalangeal (IP) joints fully flexed from tension on the FDP tendon. The distance between the marks was measured and recorded as the FDP excursion. The marks also identified the normal location of the FDP within the sheath and were used to maintain the placement of the tendon in the sheath during testing. The length of the A2 pulley was measured and recorded by placing a probe in the sheath to see and feel the beginning and end of the pulley. All measurements were made with a handheld caliper (model no. 17; General Tools, New York, NY; error ±0.5°).

We then removed the tendon sheath distal to the A3 pulley and opened a small flap at the C1 level. This small flap was outside the excursion of the tendon repair but meant the sheath was no longer, strictly speaking, "intact." The FDP tendon was detached from the distal phalanx, and figure-of-eight silk holding sutures were placed in its proximal and distal ends. The flexor digitorum superficialis (FDS) tendon insertion was left intact and a holding suture placed in its proximal end. The vincula of the FDP were cut from the middle phalanx through the C1 flap. The specimen was mounted in a custom-built frame, which locked the metacarpophalangeal joint at 0° and the proximal interphalangeal joint at 20° of flexion according to the frame construction, and was submerged in a saline bath.

We placed the FDS tendon holding suture under 2 N of tension at 35° above the horizontal level of the proximal phalanx. Angle measurements were made using a hand held goniometer (Mitutoyo, Kawasaki, Japan; error ±0.02 mm). The distal FDP was attached at 20° above horizontal through a force transducer (F1) and then to a 4.9 N weight, and the proximal FDP was attached through a second transducer (F2) at 30° above horizontal to our material testing system (MTS 858; MTS Systems Corp., Minneapolis, MN) (Fig. 1). We carefully followed the technique of testing tendon resistance to gliding described by Uchiyama el al.[20] The resistance force to tendon gliding was measured using the 2 ring load cell transducers. The ring force recorded