The Novel Semilunar Pulley Orthosis (SPOrt) Decreases Flexor Tendon-Phalanx Distance in Climbers with Chronic A2 Pulley Ruptures

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Introduction

As modern rock climbing has become increasingly popular, there is an increase in the incidence of pulley ruptures. Pulley ruptures are one of the most common injuries sustained by rock climbers with a prevalence of 26% in elite climbers (1-4).

A2 pulley ruptures are associated with the "crimp grip" used by climbers when grasping small holds. In the "crimp grip" position, the distal interphalangeal joints are hyperextended, the proximal interphalangeal (PIP) joints are flexed beyond 90 degrees, and the metacarpophalangeal (MCP) joints are slightly flexed. Disruption of the pulley results in an increased tendon-phalanx distance (TPD), which can cause bowstringing of the flexor tendons and lead to flexion contractures and loss of function. Complete A2 pulley rupture is defined as TPD greater than 2mm, with distances less than 1mm defined as normal (5-8). Biomechanically, an increased TPD decreases the strength of the digit, especially in the crimp position and decreases the amount of finger flexion possible.

The senior author developed a novel, custom finger splint, called the Semilunar Pulley Orthosis (SPOrt), which is easily fabricated and applied (Figure 1A). We hypothesized that when the SPOrt was used by climbers with chronic A2 pulley ruptures, it would reduce the TPD in a statistically significant manner.

Methods

Participant Enrollment

Climbers with a suspected pulley injury were recruited from local climbing gyms to participate in the study. Inclusion criteria consisted of self-described rock climbers over 18 years of age with no prior fractures, surgeries, or injuries to their fingers other than the suspected A2 pulley injury greater than 4 weeks prior to presentation. Institutional Review Board approval was obtained and all climbers involved in the study signed the informed consent form prior to ultrasound imaging.

Ultrasound Screening

This prospective series of climbers with a suspected history of a pulley injury were screened with an ultrasound (Philips CX50, Philips Healthcare, Inc, Bothell, WA) using a 5-12 MHz linear transducer. Those with TPD at the middle of the proximal phalanx greater than 2 mm were included in the study (5,7). TPD on the equivalent digit of the contralateral hand was measured to serve as a control.

SPOrt Fabrication

The SPOrts were fabricated from 1/12", 13% microperforated thermoplast splint material (Prism Medical, Inc, Maryland Heights, MO) and those used for testing were windowed to permit for ultrasound measurement of TPD (Figure 1B). They are fabricated to be 5/6th the circumference at P1 and cover 2/3rd the distance between the palmar digital crease and the proximal interphalangeal joint crease with the PIP joint extended.

Ultrasound Testing

The ultrasounds were done both at rest and in a custom testing jig that allowed the digit to be stressed in a slightly flexed position. Climbers pulled with at least 30N of force measured by a tensiometer (Shenzhen Times Fishing Tackle Co., Ltd., Guangdong, China) while in the testing jig (Figure 2) (9). The SPOrt is placed on the volar aspect of the finger, just distal to the palmar digital crease and snuggly secured by the wearer with six circumferential wraps of cloth athletic tape, 2/3rd the width of the SPOrt. Measurements of TPD of the affected digit were obtained both in the stressed condition in the jig and at rest.

Statistical Analysis

A paired t test was performed after verifying normal distribution using the Kolmogorov-Smirnov test (Excel 2016, StataCorp 2015). A Wilcoxon Signed-Rank test was performed when the data was not normally distributed.

Results

47 fingers were scanned in 43 climbers and 15 fingers in 15 climbers were diagnosed with a complete unilateral A2 pulley rupture. One patient was excluded who had an acute rupture of his A2 pulley (less than 2 weeks old). Average age of the climbers was 43 years (range 27 to 66 years) and 80% were male. The middle finger was injured in 53% of climbers, the ring finger in 40% and the index in 7%.

Average TPD at rest, in the unstressed condition, was 2.47±0.67 mm without the SPOrt and 2.05±0.48 mm ($p<0.005$) with the SPOrt applied. Average TPD in the stressed condition was 3.02±0.67 mm without the SPOrt and 2.25±0.45 mm ($p<0.0001$) with the SPOrt applied. Average decrease in TPD was 0.78±0.45 mm for a 26% reduction in TPD in the stressed condition.

Discussion

Historically, non-operative treatment of pulley ruptures involved a period of immobilization followed by a gradual increase in loaded finger exercises with circumferential cloth tape around the digit. Prior studies have shown that circumferential taping does not prophylactically protect against pulley injuries and is minimally effective in relieving the force on the A2 pulley (10,11). Taping in an H pattern has been shown to reduce TPD by 16% (12). A study by Schneeberger et al. reports on a custom pulley-protection splint as a conservative method to treat pulley ruptures (13). The investigators found that patients treated in this splint for two months had a decreased TPD after treatment, from 4.4±1.0 to 2.3±0.6 mm. The authors found that the smallest TPD attainable with their splint was 2 mm in forced flexion. While the pulley-protection splint is an effective treatment for pulley ruptures, the convexities

Figure 1: (A) Custom SPOrt. (B) SPOrt with window for ultrasound testing correctly positioned on a finger.

protruding into the interphalangeal spaces to avoid vessel compression are bulky and cumbersome. The SPOrt is comfortable to wear, is low profile to diminish discomfort while climbing, and can be easily adjusted by reapplying the tape to minimize constriction of digital nerves and vessels.

The SPOrt effectively decreases the TPD in climbers with A2 pulley injuries by 26%, an average of 0.78 mm while in the stressed condition. The SPOrt is better able to decrease TPD in the stressed condition than at rest, indicating that it is effective in decreasing the amount of bowstringing of the flexor tendons while climbing.

Limitations to this study include the inability to study the finger under stress in the crimp position. While the crimp position is the most important grip to study since it places the most stress on the pulley system, there was insufficient space for the ultrasound probe to image the pulley in this position. Therefore, imaging was done with the finger in a slightly bent position approximating the crimp position as closely as possible while still allowing ultrasound access as in other studies (12,14). Measurements were made through the SPOrt window which limited the ability to determine exactly where along the phalanx the ultrasound caliper was placed. However, an identical SPOrt was used on the contralateral finger and the measurement was taken at the middle of the window on both fingers to control for this. Furthermore, measurements done "without the SPOrt" were in fact done with the SPOrt in position but not secured to ensure measurements were done at the same location on the affected digit.

The SPOrt decreases the TPD in climbers with A2 pulley injuries and is effective in decreasing the amount of bowstringing of the flexor tendons while climbing. This may in turn decrease the stress on the remaining intact pulleys and prevent subsequent injuries in the remainder of the tendon sheath. The SPOrt is custom-sized, easily fabricated, facile to apply, readily adjustable, and comfortable to wear while climbing, which should increase compliance with wear and allow the climber to return to climbing with support to the pulley sheath.

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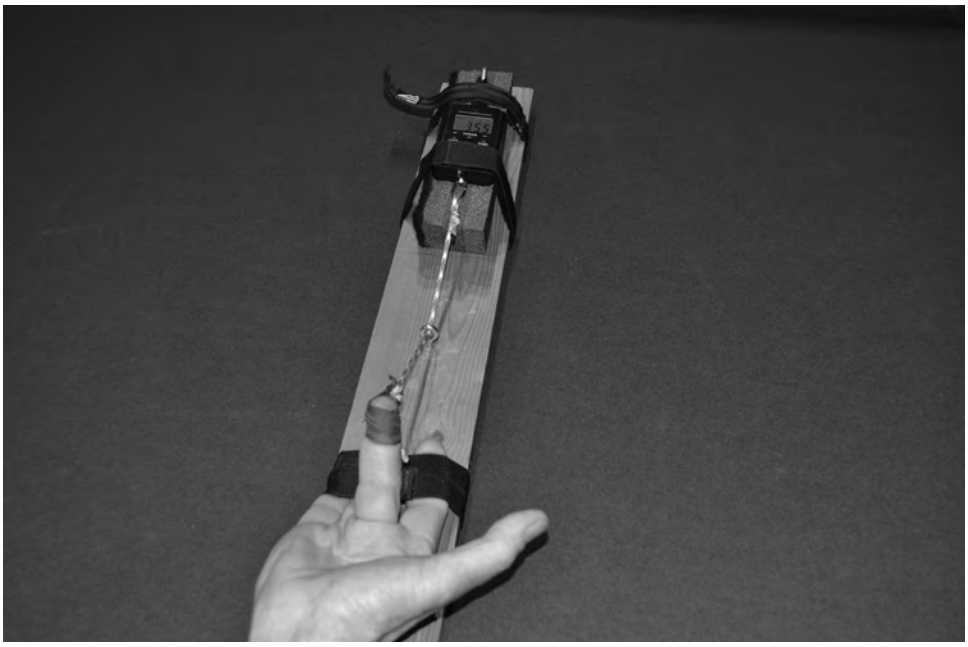

Figure 2: Testing jig used to ensure the digits were tested with the MCP and PIP joints in a flexed position and loaded with at least 30N.

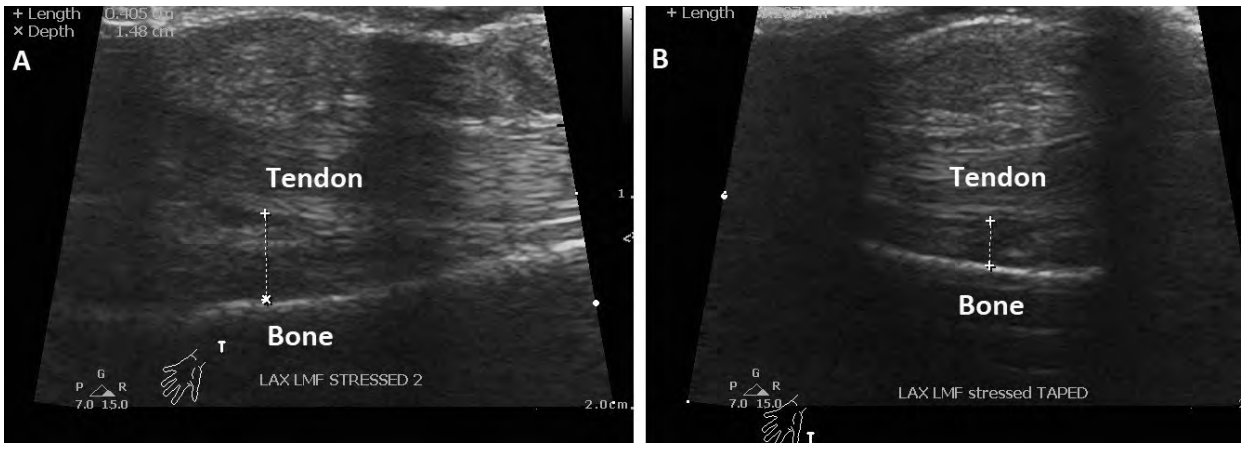

Figure 3: Representative US images (A) without and (B) with the SPOrt secured showing a decreased TPD.

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