Evaluation of A2 and A4 Hand Pulley Reconstruction Using Tendon Graft Rings

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Introduction

The main function of hand pulleys is to maintain a desired moment arm, between the flexor tendon and the axis of joint rotation. This ensures optimal joint motion and tendon excursion. Total or partial pulley absence increases the moment arm resulting in what is viewed clinically as tendon bowstringing and limited range of motion. Pulley damage frequently occurs in rock climbing, where a crimp grip is used to support a climber’s body and the flexed digit becomes subject to large and rapidly increasing force, forcing the finger into quick extension. The A2 and A4 pulleys are believed to be the most important pulleys in preventing bowstringing, ensuring optimal force transmission and tension throughout the flexor tendon. Although various surgical techniques for reconstruction of the digital pulley system exist, there is no consensus on an optimal procedure partially due to paucity of supporting kinematic data. Although both A2 and A4 pulleys are needed for optimal PIP joint function, the A2 pulley is critically important in preventing bowstringing at the PIP joint [1,2,4,5].

Repair of the distal portion of A2 contributes to improved PIP flexion more significantly than repair of the A4 pulley. Although the contribution of the A4 pulley to achieve complete finger flexion is indisputable, it may not always be feasible or necessary to reconstruct. Furthermore, kinematic studies and clinical reports indicate that release of the A4 pulley in the context of flexor tendon repair may be mechanically well-tolerated and in some cases can lead to a better outcome [1-3]. In deciding on the optimal surgical technique for an individual patient, the surgeon should choose one that is experimentally justified while aiming to achieve range of motion at the finger joints that closely approximates the kinematics of a finger with an intact pulley. The length of the graft harvested to repair A2 and A4 pulleys as well as the surgical site created by harvest and repair are extensive, making pulley repair challenging and unpopular.

Therefore, the purpose of our study was to determine whether repair of the A4 pulley along a digit having A2 and A4 pulley damage will lead to sufficient functional outcome based on kinematic results. We also aimed to determine the number of graft rings necessary to achieve optimal kinematics.

Methods

We tested digit kinematics in eleven cadaveric fingers secured to a rigid frame permitting measurement of tendon excursion, tendon force, and finger range of motion. The flexor digitorum profundus tendon of each measured finger was sutured to a cord connected to a drive pulley attached to a servo motor. Joint movement and kinematics were recorded using potentiometers placed laterally on the MCP and PIP joints. The hardware was controlled by a LabView virtual instrument. After control (undamaged pulleys) testing, we recorded tendon excursion and finger angular rotation after each of the following interventions: 1) complete damage of A2 and A4 pulley, 2) repair of distal part of the A2 pulley with one ring of tendon graft, 3) repair of the A2 pulley with two rings of tendon graft, 4) repair of the A2 pulley with two rings of tendon graft and the A4 pulley with one ring. To reconstruct the A2 and A4 pulleys, we utilized the single loop technique using FDP tendon as a free tendon graft.

Results

Repair of distal part of A2 with one ring (loop) had a 14% decrease in PIP rotational angle compared to control, while the use of three rings, that is, two at A2 and one at A4, had a decrease of only 5%. The results of the MCP joint showed that with one ring the decrease in rotational angle was only 12% whereas the 3 ring scenario resulted in a 14% decrease in rotational angle when compared to control. Using a two ring pulley repair at A2 and no repair at A4, showed inferior results compared to the alternative repairs, ANOVA analysis was performed, and no statistically significant difference among the experimental groups was detected (p = 0.26, f = 1.49). Two-sample t-test assuming unequal variances was performed and there was a significant difference between the group with damaged but un repaired A2 and A4 pulleys and the group with one ring repair.

Discussion/Conclusion

Our study showed that ring positioning and the number of rings used to repair the pulley have an influence on the rotational displacement angle at finger joints. A one loop construct placed at the distal part of the A2 pulley site gives more favorable results on the MCP joint than on the PIP joint. The results further showed that the average percent decrease in rotational angle was about 2% smaller with one ring repair than with three ring repair.

Our kinematic data for the three ring configuration showed the PIP joint performs better than the MCP joint (9%) when compared to one ring configuration at the A2 site. The PIP and MCP joint with two ring pulley repair at the A2 site in the presence of A2 and A4 pulley damage showed a decrease in rotational angle (Fig. 1). We hypothesize that a two ring graft repair at the A2 site may create a greater amount of tension impeding excursion resulting in less efficient digital flexion.

Our results also show that the A4 pulley enhances kinematics of the PIP joint since the rotational angle improved at the PIP joint with a three ring configuration versus a one ring configuration. It also showed that the A2 pulley does not contribute to optimal MCP joint function, since the results showed that MCP joint angular rotation did not improve after A4 pulley repair.

At the same time, reconstruction of the distal portion of the A2 pulley with a single ring contributes to both improved MCP and PIP flexion significantly. We further conclude that repair of the distal portion of the A2 pulley in the context of A2 and A4 pulley damage is more important than repair of the A4 pulley. From the results of our study, it appears that the difference in the average percent decrease in rotational angle for one ring reconstruction and the previous hypothesis may not be clinically relevant.

Our study suggests that in the presence of complete A2 and A4 pulley damage, one ring at A2 compares the kinematics of a pulley system reconstructed with two rings at A2 and one ring at A4, and may be considered in certain clinical situations as the treatment of choice. Our findings support previous studies and clinical reports indicating that release of the A4 pulley may be mechanically well-tolerated [1-3].

References