

Extensor Pollicis Longus Tendon Relocation: Evaluation of the Biomechanical Effects

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Introduction

The Extensor Pollicis Longus (EPL) muscle is located within the forearm and is used primarily for thumb extension. Following a dorsal approach to access the radiocarpal joint, for example during fixation of a distal radius fracture, the extensor retinaculum is cut, freeing the EPL which has to be relocated radially to Lister's tubercle to achieve adequate exposure. Reconstruction of this sheath is not feasible due to the development of scar tissue that would inhibit proper tendon motion.

This study evaluates the effect of EPL tendon relocation on thumb extension. A rigid body mathematical model was developed to simulate thumb extension for both the natural and relocated positions. A cadaveric experiment was conducted to obtain calibration parameters and to validate the mathematical model. This pilot research uses a mathematical model to improve biomechanical understanding of thumb extension following EPL relocation that could potentially serve as future basis of improving surgical techniques and therefore functional outcome.

Methods

Mathematical Model

A mathematical model was developed to simulate thumb extension movement resulting from force applied to the EPL tendon. It consisted of the EPL tendon and five rigid body segments; distal phalange, proximal phalange, first metacarpal, and two carpal (wrist) segments.

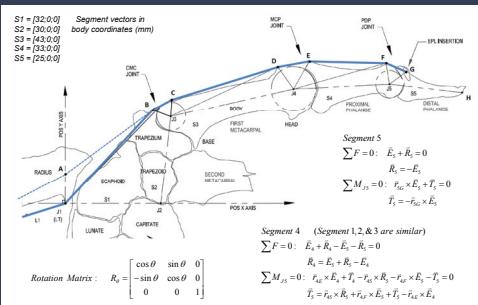


Figure 1: Model of the distal thumb segment. Force applied to the EPL tendon results in thumb extension, as the distal phalange rotates about the distal interphalangeal joint (P5).

Torsional springs were employed at each joint to represent joint stiffness due to elasticity of the joint capsule, ligaments, and other passive tissues spanning the joint. Using MATLAB software, the applied EPL force was incrementally increased and static equilibrium was evaluated to determine the unique set of joint configurations at each step. Equilibrium equations were solved starting with the most distal segment and working proximally. Using this quasi-static approach all the full movement of the thumb was simulated.

Cadaveric Experiment

Eight fresh, or fresh frozen and thawed, cadaveric limbs were positioned on a fixture that maintained the natural positions of the radius and ulna. A Kirschner wire (K-wire) was inserted through the distal interphalangeal joint (J5) of the thumb. A suture was secured to the proximal end of the tendon and several forces were applied using weights. The thumb angle at each applied force was measured visually using a calibrated scale (Figure 2). Following this testing, the EPL was surgically released from its ligamentous sheath (relocated) and the test was repeated.



Figure 2: A K-wire through the distal interphalangeal joint was used to indicate thumb extension.

Results

Torsional spring stiffness at each joint was modified to calibrate the mathematical model with experimental data (Figure 3 – green line). EPL relocation was simulated in the model by a vertical shift in the path of the EPL tendon from around Lister's tubercle to a point 14 mm laterally (0,14,0). With only this change, the new thumb movement (dashed red line) was simulated and found to approximate the results obtained experimentally (red circles).

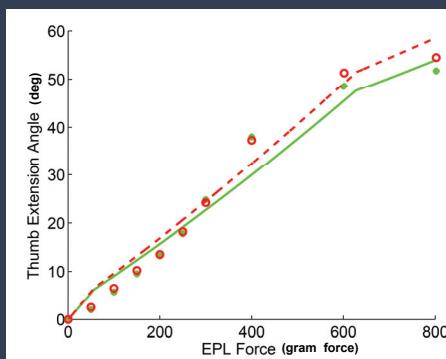


Figure 3: Mathematical model of natural thumb extension (solid) correlates well with the experimental data (circles). Furthermore, after tendon relocation, the model (dashed) also accurately predicts data found experimentally (stars).

Extended Results

In addition, the calibrated model was expanded to also include the EPL muscle. Muscle activation was simulated from zero to 100% at 0.1% increments. The muscle force generated was a function of the length of the muscle and the activation level. A quasi-static method was again utilized. Relocation of the tendon caused 4.4 mm of slack to develop due to the shorter path. The results (Figure 4) show that this slack caused the muscle to be shorter (4b) at each level of activation and as a result of lower muscular efficiency (4a), produce less force (4c). However, the movement of the thumb was actually increased due to an increased moment arm at joint 3.

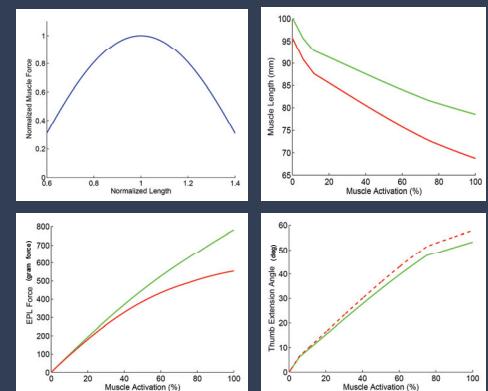


Figure 4: Simulation expanded to include EPL muscle. Muscle force length curve (a). Muscle length (b), muscle force (c), and thumb extension (d) as a function of muscle activation level.

Conclusions

The mathematical model was able to simulate the motion of the thumb during extension and results closely approximated those found experimentally. Releasing the EPL tendon shortened the path and resulted in tendon slack. In the model, this slack caused the muscle to function in a contracted state reducing the amount of force that could be generated. However, the line of action of the tendon was also changed to a more advantageous angle. When these two effects were combined, thumb extension actually increased with tendon relocation, contrary to our original hypothesis. However, it should also be noted that thumb extension force was decreased with relocation which may make it difficult to use tools (e.g. scissors) associated with thumb extension following EPL tendon relocation. Future work will further investigate the force length relationship of the EPL muscle and quantify how removal of EPL tendon slack may increase performance during thumb extension.

References

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Tang J, Zhang X, and Li Z. *Ergonomics*, 51:7, 1109 – 1118, 2008.