MODELING EXTRINSIC FINGER FLEXOR TENDON KINEMATICS

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INTRODUCTION

Trauma to the tendons and nerves of the hand and wrist has been attributed to chronic tissue stress experienced during their interactions with surrounding osseous and soft tissues. Biomechanical modelling has become a common non-invasive method to estimate tissue and joint forces. While a number of models of the hand and wrist exist, recent evidence suggests improved joint kinematics are needed to increase the accuracy of predicted force transmission [1]. Tendon excursion for the same finger motion has been shown to vary depending on wrist posture using both an analytical model [2] and in canine limbs *in vivo* [3]. In addition to excursion itself, the effects of tendon motion also require investigation, as movement of the tendons relative to each other, as well as bone surfaces, likely alter tissue loading (tensile, compressive and shearing forces). The purpose of this study was to develop a model of finger flexor tendon motion that incorporates the interactions between the tendons and their surrounding tissues during finger motion.

METHODS

A three-dimensional dynamic model of the hand was developed using Maya™ v5.0 software (Alias®, Toronto, Canada). Each of the fingers was constructed as a series of four rigid body segments, sculpted to represent the metacarpal and phalangeal bone surfaces (Figure 1). A coordinate system positioned at each of the MCP, PIP and DIP joint centres defined locations and orientations of the tendons and bone segments, and defined joint posture. Scalable relationships were used to determine segment lengths, joint centre locations, and tendon centre locations of the flexor digitorum profundus and superficialis muscles proximal and distal to each finger joint space [4,5]. The annular pulley system of each finger was modelled as a series of modified rigid body cylinders attached to the palmar surface of each phalanx, to constrain palmar and mediolateral displacement of the flexor tendons. In order to utilize the mechanics of solid materials inherent in the software, each tendon was defined as a string of rigid body spheres, affixed to one another via pin joints. Tendon excursion and resultant joint motions were dependent on the interactions between the spheres, as well as with the pulleys surfaces. Initial testing focused on tendon excursion and changes in moment arm magnitude during isolated joint movements in the flexion-extension plane, allowing results to be compared to those found in the literature. For this communication, analyses were limited to the deep (FDP) and superficial (FDS) flexors of the index finger.

RESULTS AND DISCUSSION

While model development and testing are ongoing, this study represents one step in the development of a biomechanical model of the hand and wrist. Flexor tendon excursions for the index finger are in agreement with those in the literature with greater FDS than FDP excursion during MCP flexion [4]. DIP flexion of 90° resulted in 6.7 mm of FDP excursion. In addition, the physical interactions between the tendons resulted in slight FDS movement when tension was applied to the FDP tendon (1-2 mm depending on condition). And, with tension applied to both FDS and FDP, concurrent flexion of all three finger joints resulted.

While the hand and wrist model is still in its relatively early stages, the benefits are readily visible. This method enables tendon thickness and natural restraints created by the bone, tendon and pulley surfaces to predict tissue interactions and force transmission. In the future, the shape and cross-sectional area of each tendon can be incorporated from existing MRI data to improve the anatomic fidelity. By incorporating tendon excursion and changes in moment arm lengths into our existing model of the carpal tunnel [6], a more realistic and complete understanding of three-dimensional tendon movement through the carpal tunnel will result. This will enable investigation of soft tissue interactions within the carpal tunnel, including median nerve compression. A model that includes differential tendon excursion and interaction, with the potential to add frictional effects, is an important step in understanding injuries at the wrist, such as carpal tunnel syndrome and tenosynovitis.

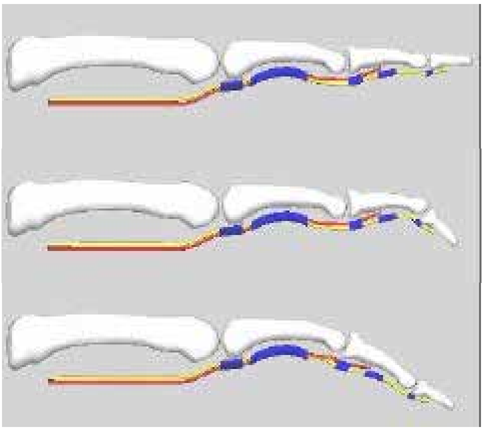

Figure 1. Excursions were measured from the straight finger (top) and included DIP (middle) and PIP (bottom) joint flexion.

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