PRELIMINARY ASSESSMENT OF FLEXOR TENDONS CONTRIBUTION IN REQUIRED FINGER JOINT MOTION: A NOVEL RESEARCH METHOD

Tai-Hua Yang1,6,7, Szu-Ching Lu1, Wei-Jr Lin1,5, Kristine D Zhao7, Chunfeng Zhao7, Li-Chieh Kuo3, I-Ming Jou4, Kai-Nan An7, Fong-Chin Su1,5

1Institute of Biomedical Engineering, 2Department of Computer Science & Information Engineering & Institute of Medical Informatics
3Department of Occupational Therapy, 4Department of Orthopedics, 5Medical Device Innovation Center, National Cheng Kung University, Taiwan, R.O.C.
6Department of Orthopedics, China Medical University Hospital, Taiwan, R.O.C.
7Orthopedic Biomechanics Laboratory, Division of Orthopedic Research, Mayo Clinic Rochester, Rochester, Minnesota

Email address: fcsu@mail.ncku.edu.tw

INTRODUCTION
Pulley system is a series of intermittent ligaments along the flexor side of the digit. The function and biomechanics of pulley system has been well demonstrated. It plays a critical role in hand function, supports accurate tracking route of the tendon, and maintains apposition of the tendon to bone in order to reduce a bowstring phenomenon and ultimately raise arcs of joint motion per unit of tendon excursion. Most of research methods were founded in an open system and investigated on the kinetics and kinematics changes of individual flexor tendon. There was no clearly demonstration about synchronized and continuous excursion change between flexor digitorum superficialis (FDS) and flexor digitorum profundus (FDP). This study created a novel research model, a synchronized close system, to investigate biomechanical changes in normal pulley system and to assess characteristic excursion relationship between FDS and FDP in individual and combined joint motion.

MATERIALS & METHODS
Ten fresh-frozen human cadaveric hand specimens were used. After thawing, FDS, FDP and extensor digitorum communis (EDC) tendons of the 3rd finger were exposed. Each wrist joint of specimen was fixed and mounted on custom-made fixation frame. These 2 flexor tendons were linked by Dacron through a mechanical pulley which connected with a load cell for acquired force record to build up a synchronized close system and to make sure an equal force was applied at each tendon. A 500gm weight was secured at EDC for a counter-force (fig.1). A motion analysis system was used to capture the motion trajectories of finger. The finger was moved manually from resting position to maximal flexion in 10 seconds. 4 different joint motion statuses (DIP only, PIP only, MCP only and free combined joints movement) were measured. Kinematical and kinetic variables including joint range of motion (ROM), tendon excursion and loading force were analyzed. In addition, moment arms calculation followed the equation: M = E/θ (E = tendon excursion, θ = joint angle) for individual joint motion.

RESULTS & DISCUSSION
Based on the individual joint motion data, the linear moment arms (mm) of FDP, FDS were 12.56±1.09, 13.62±1.05 at MCP joint, and 12.30±1.82, 9.02±1.34 at PIP joint; and FDP at DIP joint was 10.43± 0.23 mm. These results were similar to previous studies. With the increase of flexor tendon forces, the joint motion trajectories revealed a gradual ascending S-curve pattern (Figure 2). Both the PIP and MCP joints initiated the movement at low force. The PIP joint moved faster to reach the limit, while the MCP was still moving. The DIP movement delayed slightly, but more or less synchronized with that of PIP. The characteristics of the excursions of FDP and FDS were also interesting (Figure 3). Both excursions are highly correlated in either individual joint motion or combined joints motion. For PIP and MCP joint movement along, the excursions of FDP were greater and slightly small than those of FDS respectively. It reflected the nature of moment arms of these two tendons at these two joints. For the combined joint movements, the excursion of FDP was greater than FDS which reflect the contribution of IP movement.

CONCLUSIONS
In this study, we design a novel research model to create a close synchronized system which different from previous studies of loading the individual tendon alone. With the validation of moment arm and angle change by potential force, it determined this close synchronized system can be not only explained individual flexor tendons behavior similar to that of open system strategy but also revealed the characteristics of the excursions between two flexor tendons which could be a useful way to illustrate the pulley injury and repair in the future.

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