

EXPERIMENTAL INVESTIGATION OF FINGER JOINT FLEXION AND FDP EXCURSION BEFORE AND AFTER MCP JOINT ARTHROPLASTY

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ABSTRACT

The purpose of this study is to assess the kinematical changes in the flexion of the finger joints after MCP arthroplasty. Angular joint position in relation to its corresponding excursion was used to quantify the kinematics of the finger. The assessment uses real time data acquisition and fresh-frozen cadaver hands.

INTRODUCTION

Because of its short operative time and predictable postoperative function [1] silicone arthroplasty is used to treat deformities of the hand caused by rheumatoid and osteoarthritis. Arthritis primarily affects MCP joints, making them the most widely used implants of all upper extremity prosthetics [2]. Arthroplasty addresses ulnar deviation and subluxation of the joint. It further corrects flexion contractures of the MCP joint allowing a more functional range of motion while improving grasp. Factors such as fatigue life [3] and implant center of rotation [4] are important to consider when studying the success of finger joint arthroplasty. However, little work has been done on the effect of the MCP joint arthroplasty on the overall motion of the digit. Initial starting angle, joint initiation order, and general joint movement are all factors that can be used to describe the successful imitation of a normal, healthy finger. The MCP prosthesis we tested is a silicone design that is pre-flexed at 30 degrees of flexion (Figure 1).

METHODS

Index, middle, and ring fingers of several fresh-frozen cadaver hands were utilized. The hand was attached (palmar side up) to a custom test apparatus (Figure 2) using two 5/64 Steinmann pins, one in the forearm and the other in the metacarpals. In order to maintain consistency between specimens the hand was placed in neutral wrist flexion. The flexor digitorum profundus (FDP) tendon was drawn with constant force and velocity by a small winch-type servomotor. In previous studies, lower and higher tendon velocities were shown not to have a significant affect on the excursion and joint displacement [5]. Feedback from the encoder on the motor was used to monitor the tendon excursion. Micro-potentiometers were attached to the centers

of rotation of the MCP, DIP, and PIP. Voltage drops across the potentiometers measured the angular displacement of the joints. As the motor pulled the tendon, real-time data acquisition was used to simultaneously acquire joint angles and excursion. Motor control and feedback from the encoder and potentiometers was obtained using a data acquisition card and custom software created in Labview (National Instruments Corp., Austin, TX). Specimens were taken through a full range of motion starting in the "at rest" position and ending when the fingertip touches the palm. Several trials were run preoperatively (intact hand) and postoperatively for each finger. Data from the trials was inserted into a spreadsheet and the appropriate graphs were generated for data analysis. The MCP was the only joint replaced.

Figures 3 and 4 show a sample joint flexion vs. excursion plot for a single digit. Graphs such as these were plotted and used to analyze the data for all specimens. The analysis included order of initiation MCP starting angle, MCP initiation delay, and total MCP flexion.



Figure 1. MCP Silicone Prosthesis with 30° of Flexion

RESULTS

In the native finger, the order of initiation was DIP, PIP, and MCP. After arthroplasty the order was maintained in all specimens.

However, there was delay in initiation of MCP flexion. Further, the post-operative start angle for the MCP flexion (at rest) was equal to or greater than the pre-operative angle in four of five specimens. Finally, the average total maximum MCP flexion was less in the post-arthroplasty finger than in the natural digit.

DISCUSSION

The post arthroplasty MCP joint showed delayed initiation and decreased overall flexion when the fingertip touched the palm. We attribute this to increased stiffness imparted to the MCP joint by the arthroplasty. In reconstruction of the contracted MCP joint this tends to maintain the MCP joint in a functional position for activities requiring fine manipulation.

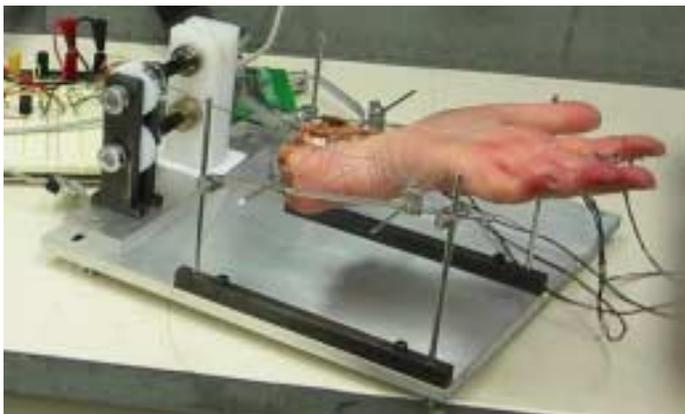


Figure 2. Experimental Setup with Custom Test Apparatus

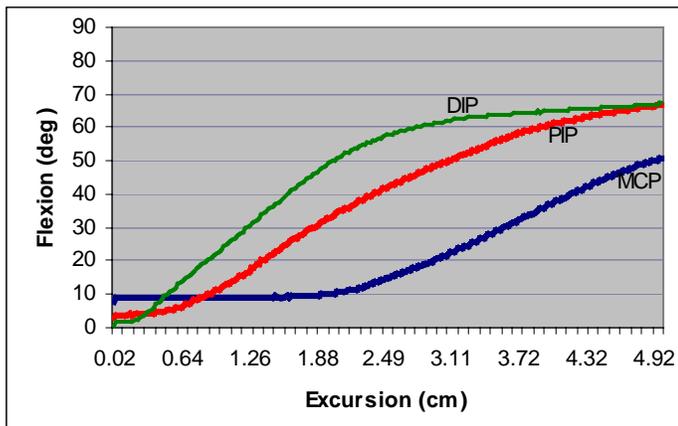


Figure 3. Pre-Arthroplasty Analysis

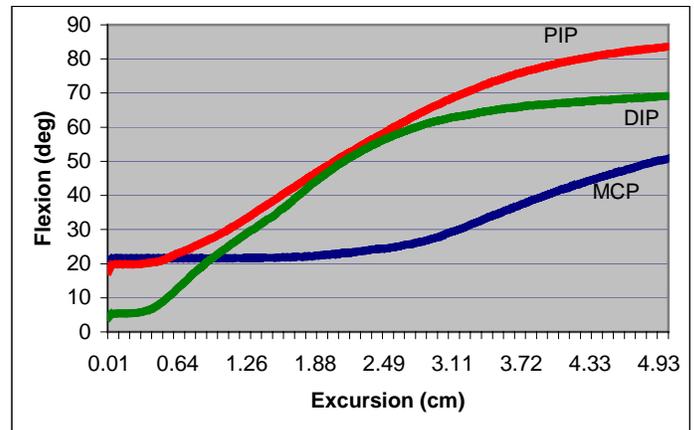


Figure 4. Post-Arthroplasty Analysis

CONCLUSIONS

Evaluation of the kinematics of the digit before and after MCP arthroplasty showed two salient changes. Initiation of MCP flexion was delayed and overall MCP flexion was diminished. The MCP joint is pre-bent and stiffer than the native joint. We believe that the stiffness of the arthroplasty caused this change in kinematics. This arthroplasty is commonly utilized in reconstruction of the contracted MCP joint. The stiffness and pre-bent position of the arthroplasty tends to maintain the MCP joint in a functional position during fine manipulation. A decrease in MCP flexion was compensated by increased flexion at the DIP and PIP joint.

REFERENCES

1. Bass, R.L., Stern, P.J., Nairus, JG, 1996, "High Implant Fracture Incidence with Sutter Silicone Metacarpophalangeal Joint Arthroplasty," *Journal of Hand Surgery*, 21A, pp. 813-18.
2. Foliart, D., 1996, "Synovitis and Silicone Joint Implants: A Summary of Reported Cases," *Plastic and Reconstructive Surgery*, 99(1), pp. 245-252.
3. Alsheik, Nila, H., 2000, "Effect of Lateral Bending Stress on Fatigue Life of Anatomically Neutral NeuFlex Metacarpophalangeal (MCP) Joint Implant," Orthopaedic Research Laboratories, Rhode Island Hospital, Providence, RI.
4. Weiss, Arnold-Peter, C., 1999 "Mechanics of Silicone Metacarpophalangeal Joint Replacements in Finger Flexion and Extension,"
5. Amirouche, F., Gonzalez, M., Koldoff, J., Tioco, J., Ham, K., 2002, "A Biomechanical Study of the Finger Pulley System During Repair," *Technology and Health Care: Official Journal of the European Society for Engineering And Medicine*, Vol 10, Issue 1, pp 25.

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