SCIENTIFIC ARTICLE

Intrinsic Hand Muscle Function, Part 1: Creating a Functional Grasp

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Purpose Regaining hand function has been identified as the highest priority for persons with tetraplegia. In many patients, finger flexion can be restored with a tendon transfer of extensor carpi radialis longus to flexor digitorum profundus (FDP). In the absence of intrinsic function, this results in a roll-up finger movement, which tends to push large objects out of grasp. To enable patients to grasp objects of varying sizes, a functional grasp is required that has a larger excursion of fingertip-to-palm distance than can be supplied without intrinsic function. The aim of this study was to quantify the role of intrinsic muscle force in creating a functional grasp.

Methods Finger kinematics during grasp were measured on 5 cadaveric hands. To simulate finger flexion, the FDP was activated by a motor and intrinsic muscles were loaded at various levels (0, 125, 250, 375, or 500 g). Finger movement was characterized by the order of metacarpophalangeal, proximal interphalangeal, and distal interphalangeal joint flexion and by the maximal fingertip-to-palm distance during finger closure.

Results Without any intrinsic muscle contribution (0-g load), FDP activation resulted in flexion of all 3 joints, whereby flexion began at the proximal interphalangeal joint, followed by the distal interphalangeal joint, and then the metacarpophalangeal joint. With increasing intrinsic muscle load, finger flexion was initiated at the metacarpophalangeal joint, followed by the proximal interphalangeal and distal interphalangeal joints. This altered joint flexion order resulted in a larger maximal fingertip-to-palm distance during finger flexion. The difference between the 2 extreme conditions (0 g vs 500 g of intrinsic muscle load) was 19 mm.

Conclusions These findings demonstrate that simultaneous activation of the FDP and the intrinsic muscles results in an apparently more functional hand closing compared with FDP activation alone because of altered kinematics and larger fingertip-to-palm distances.

Clinical relevance These findings suggest that intrinsic muscle balancing during reconstruction of grasp in tetraplegic patients may improve function. *(J Hand Surg 2013;38A:2093–2099. Copyright © 2013 by the American Society for Surgery of the Hand. All rights reserved.)*

Key words Grasp, hand, intrinsic muscles, tendon transfer, tetraplegia.

Additional material is available online.

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Regaining arm and hand function has been identified as the highest priority for persons with tetraplegia.[1,2] Recovering even partial function can have an enormous impact on independence, which enhances quality of life.[3] Restoration of finger flexion is an achievable goal in reconstructive surgery of many tetraplegic hands. It can be performed if both the extensor carpi radialis longus and brevis are fully innervated, in which case the extensor carpi radialis longus is transferred to the flexor digitorum profundus (FDP),[4] which enables patients to grasp and hold objects. However, by restoring FDP function only, fingertips coming into full flexion approach the bases of the fingers rather than the center of the palm.[5] This happens because finger flexion begins at the distal interphalangeal (DIP) joint, and fingers curl into flexion rather than following a large arc, which would provide a broad sweeping movement.[6] The roll-up finger flexion tends to push large objects out of grasp[5] and is, therefore, considered less functional in daily life.

In normal hand function, the intrinsic muscles, both the lumbricals and the interosseus muscles, balance finger movement[7] and create this broad sweeping movement. Besides abducting and adducting the fingers, they are responsible for coupling metacarpophalangeal joint (MCP) flexion with interphalangeal (IP) joints extension.[8,9] For 2-dimensional finger movement during grasp, the lumbricals and the interossei provide the same function, as shown by Leijnse et al.[10] Because their function is redundant in the sagittal plane, we refer to them as 1 entity, the intrinsics. Intrinsic function is so important that even when patients have neither functional intrinsic muscle nor a sufficient number of transferable muscles to reconstruct them with an active tendon transfer, passive tenodeses are used to substitute for intrinsic muscle function.[11,12]

We characterize functional hand movement for tetraplegic persons as a large fingertip-to-palm distance during flexion because this enables them to grasp objects of varying sizes and shapes necessary for activities of daily life. The exact contribution of the intrinsic muscles to this function is incompletely understood. Therefore, the purpose of this study was to quantify the role of intrinsic muscle force in creating a functional grasp. We hypothesized that increasing intrinsic muscle contribution would result in a more functional grasp.

MATERIALS AND METHODS

Sample preparation

Five fresh-frozen hands were used for the experiment (3 male, 2 female; average age, 75 y; range, 59−88 y). Hands had been amputated at the level of the radiocarpal joint. For each hand, dissection and data collection were performed on the same day. During preparation and testing, hands were maintained at room temperature, and tendons were kept moist with Ringer solution.

The thumb was amputated at the MCP joint to permit clear video recording. The volar skin was excised distally to the level of the middle phalanx, and the palmar aponeurosis was resected. The FDP tendons were identified at the level of the carpal tunnel and the ends individually sutured proximally with 2-0 suture. The palmar carpal ligament remained intact. Each lumbrical was identified by its origin on the FDP and insertion into the radial lateral band. For our purposes, intrinsic muscle insertion was defined as the tendinous insertion of the lumbricals into the radial lateral bands and were tagged with 2-0 suture. The lumbrical and interossei origins were left intact. All volar tendons and affixed sutures were then passed proximally through the carpal tunnel. Dorsal skin was excised entirely. Tendons of the extensor digitorum communis (EDC) were sutured individually with 2-0 suture at the level of the wrist. Owing to the scarce contribution of EDC to the extensor apparatus of the little finger in most hands, the extensor digiti quinti tendon was sutured for this digit.

Kirschner wires (1.1 mm) were drilled into each metacarpal and phalanx dorsally to mark motion. The angle between the wire and its respective bone was measured for later analysis. To facilitate data collection (ie, prevent markers from obscuring one another), each intrinsic muscle loading condition was performed once with wires in the index and ring fingers and once with wires in the middle and little fingers. The order was randomized. Two Schanz pins were drilled into the base of the third metacarpal dorsally to affix and stabilize the hand during experimentation.

Mechanical testing

The hand was positioned palm up with fingers fully extended (Fig. 1). The FDP sutures were attached to a single dual-mode servo-motor (Aurora Scientific, Model 310, Aurora Inc., Ontario, Canada). To approximate passive resistance, we affixed EDC sutures to a 50-g mass, which was allowed to move via a pulley and created a fixed resistance. Intrinsic muscle sutures were affixed via a pulley to 0, 125, 250, 375, and 500 g masses, which were also allowed to move. The order in which these intrinsic loads were trialed in each hand was randomized. Five hundred grams represented the maximal weight that