THE EFFECTS OF RECONSTRUCTION OF THE METACARPALPHALANGEAL JOINT OF THE THUMB DURING TIP PINCH FOR INTRINSIC MUSCLE LOADING

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Introduction

The metacarpalphalangeal joint (MCP) connects the metacarpal bones with the proximal phalanx and is a diarthrodial joint. There are several extrinsic and intrinsic muscles that contribute to the motion and stability of the MCP to facilitate our specialized grasp and tip pinchers. Electromyographic studies have found that the intrinsic abductor pollicis brevis (AbPB) is active during abduction, opposition and extension of the thumb and the intrinsic adductor pollicis (AdP) is active during opposition and flexion. These intrinsic muscles act together with the flexor pollicis longus (FPL), the extrinsic muscle that flexes the MCP joint, to produce tip pinch. Patients with injuries to the stabilizing structures of the MCP joint usually will have altered kinematics. Damage to the ulnar collateral ligament (UCL) of the MCP joint of the thumb has been reported to be the most common upper extremity ski injury. This can lead to constant subluxation of the joint, pain and decreased strength during pinch of the thumb. We hypothesized that 1) the AdP would adduct the MCP joint when loaded together with the FPL, 2) the AbPB would abduct the MCP joint when loaded together with the FPL, 3) transection of the UCL would increase MCP laxity and 4) reconstruction of the UCL would return laxity to normal.

Methods

Eleven human cadaver hands were tested. The mean (SD) age of the donors at death was 79 ± 10 years. Nylon threads were secured to the tendons of the FPL and the extensor pollicis longus (EPL) proximally and to the AbPB and AdP distally. Threads attached to the AdP passed through Teflon tubing which was inserted below the skin along the line of action of the AdP. The interphalangeal (IP) joint of the thumb was immobilized in 15° of flexion, chosen to mimic the pinch configuration of the thumb, with a K-wire so that all motion would take place at the MCP joint. A hemispherical plastic dome (6 mm diameter) was secured to the volar surface of the distal end of the thumb with a screw driven through the dorsal phalanx at the base of the cuticle in a dorsal-volar direction. Two K-wires were inserted radioulnarly through the second, third, fourth and fifth metacarpal bones proximally and distally for additional stability and mounting the hand in the apparatus.

The spatial positions of the metacarpal bone and proximal phalanx and the anatomic geometry of the MCP joint were measured with the 3Space Fastraq (Polhemus Navigation Sciences, Colchester, Vt), a six-degree-of-freedom digitizer. The specimen was mounted onto a specially designed apparatus. The hemispherical dome rested on the polished surface of a plastic plate for nearly frictionless contact. The position of the plate was adjusted to obtain the desired flexion angle of the MCP joint, to constrain the joint only in flexion, and to ensure that the point of contact of the plastic plate with the dome would be reproducible from test to test and from specimen to specimen. The angle of flexion of the MCP joint was measured with a goniometer. External forces of 4.9 N were applied through nylon threads attached to the FPL, AdP and AbPB and directed along the muscles’ anatomic directions.

Two sets of static loads were applied to for MCP flexion angles ranging from 0° to 45° in 15° increments: 1) passive loading the MCP joint and 2) simulated active muscle loading. Muscle loading tests were performed for three experimental states on each specimen: 1) the FPL was loaded alone, 2) the FPL and AdP were loaded together, and 3) the FPL and AbPB were loaded simultaneously. These same loading tests were then applied to the joint after transecting the UCL and then again after surgically repairing the UCL. To perform the active muscle loading test, a dead weight of 0.98 N force was first applied to the FPL through a nylon thread attached to the tendon to preload the joint, and the MCP joint was positioned at the desired angle of flexion. Next, external loads were applied by hanging dead weights of 4.9N through nylon threads attached to the tendons for each of the four experimental states. With the joint passively positioned or loaded and in equilibrium at the desired angle of flexion, the spatial positions of the metacarpal bone and proximal phalanx were digitized.

After testing was completed, the MCP joint was dissected and bony landmarks on the metacarpal bone and proximal phalanx were then digitized for construction of coordinate systems to represent the bones. The autogenous extensor digiti quinti proprius was used as the graft to reconstruct the UCL according to standard procedures. Each hand served as its own control. For each specimen, the three-dimensional positions of the proximal phalanx with respect to the metacarpal bone as a function of flexion angle were computed for each of the four experimental states during simulated muscle loading. Each three-dimensional position (i.e., each translation and rotation) was normalized with respect to the corresponding position of the passively placed intact joint for each of the flexion angles at which the joint was tested.

Two-way ANOVA with repeated measures, one-way ANOVA with repeated measures and univariate F-tests were performed to determine significant differences between test states for each of the flexion-angles. Statistical significance was defined as p < 0.05.

Essential results

In the intact MCP joint, the FPL caused an ulnar shift of the proximal phalanx of 0 to 2 mm, an ulnar deviation of 2.7° to 5.9°, and pronation of 0.9° to 1.7° when compared to the reference (i.e, passive loading) state for all angles of flexion. When loaded together with the FPL, the AdP caused small and statistically insignificant changes in radial-ulnar shift, radial-ulnar deviation and pronation-supination when compared to the FPL alone for all angles of flexion. However, when loaded together with the FPL, the AbPB caused statistically significant radial shifts of 2.5 to 6.5 mm, radial deviations of 1.6° to 4.8° and pronations of 7.2° to 11.2° when compared to the FPL alone for all angles of flexion.

When the FPL was loaded alone, both transection and reconstruction of the UCL resulted in statistically insignificant changes in radial-ulnar shift, radial-ulnar deviation and pronation-supination when compared to the intact state. When the FPL was loaded together with the AdP, both transection and reconstruction of the UCL resulted in statistically insignificant changes in radial-ulnar shift and radial-ulnar deviation when compared to the intact state. Transection of the UCL resulted in a significantly pronated proximal phalanx for 30° and 45° of flexion when compared to the intact state. However, reconstruction of the UCL returned pronation-supination to a level not significantly different from the intact state at 30° of flexion.

When the FPL was loaded together with the AbPB, both transection and reconstruction of the UCL resulted in statistically significant changes in radial-ulnar shift for all angles of flexion when compared to the intact state. Reconstruction of the UCL returned radial-ulnar shift to levels not statistically significant from the intact state for all angles of flexion. Transection of the UCL produced changes in radial-ulnar deviation that were significantly different from the intact state only at 30° of flexion; reconstruction of the UCL returned this to a level not significantly different from the intact state. Neither transection nor reconstruction of the UCL resulted in statistically significant changes in pronation-supination when compared to the intact state.

Dorsal-volar translation was not significantly affected by any of the load or experimental states.

Discussion

We found that the AdP had little effect on the MCP joint when loaded together with the FPL, failing to support our hypothesis, and that the AbPB ab ducted the MCP joint when loaded together with the FPL in support of our hypothesis. Furthermore, transection of the UCL increased laxity in radial-ulnar shift when the AbPB was loaded together with the FPL, in support of our hypothesis; however, reconstruction of the UCL returned laxity to normal. Thus, the AdPB has a much larger affect on joint stability than the AdP. Furthermore, radial-ulnar shift was the measurement primarily affected by rupture of the UCL. However, reconstruction returned this to within normal levels. When diagnosing an UCL injury or assessing the efficacy of surgical reconstruction of the UCL during tip pinch, radial-ulnar shift should be carefully examined.