Using Dynamic Biplane Radiography to Assess the Relationship Between Post-trapeziectomy First Metacarpal Subsidence and Thumb Force During Functional Tasks

Edward Godbold[1], Joshua Setliff[2], Maria Munsch[1], John Fowler[1], William Anderst[1]
[1]Department of Orthopaedic Surgery and the [2]University of Pittsburgh School of Medicine, University of Pittsburgh
edg54@pitt.edu

Disclosures: E. Godbold (N), J. Setliff (N), M. Munsch (N), J. Fowler (N), W. Anderst (5; Smith and Nephew)

INTRODUCTION: The thumb carpometacarpal (CMC) joint is the most common site of osteoarthritis (OA) in the upper extremity.[1] Trapeziectomy alone was the historic surgical treatment.[2-3] More recently, concerns that the first metacarpal (MTC1) could subside into the trapezial space and contribute to a reduction in grip and pinch strength has led to the introduction of soft tissue modifications, such as ligament reconstruction and tendon interposition (LRTI) and suspensionplasty.[4-5] LRTI attempts to reconstruct the anterior oblique ligament (volar beak ligament), however, no biomechanical evidence supports the utility of reconstructing the ligament.[6] The long-term goal of this study is to quantify the relationship between three-dimensional (3D) MTC1 subsidence and thumb force during functional tasks after trapeziectomy, as no such *in vivo* data currently exists. The aim of this interim analysis is to assess the value of three functional tasks for revealing the relationship between post-trapeziectomy first metacarpal subsidence and thumb force.

METHODS: Thus far, 12 adults provided informed written consent prior to participating in this study. Participants scheduled for unilateral trapeziectomy followed by either LRTI or suspensionplasty (depending upon surgeon preference) were included. Visual Analogue Scale (VAS) scores and Quick Disabilities of the Arm, Shoulder and Hand (QuickDASH) outcome measures were collected both pre- and post-operatively to measure participant pain levels and physical function, respectively. Synchronized dynamic biplane radiographs of the thumb CMC joint were collected at 120 frames/second pre- and post-operatively while participants performed three functional tasks: can grasp, key pinch, and jar twist. Three trials of each task per hand were performed. Force was continually measured throughout the trials using a load cell (1200 frames/second). Pre-operative computed tomography (CT) scans of each participant's hands and wrists were collected and segmented to create 3D, subject-specific bone models of the first metacarpal, trapezium, scaphoid, and radius. A validated volumetric model-based tracking technique was used to track the bones with submillimeter accuracy during each trial of force application.[7] Participants returned six months post-operatively to perform the same functional tasks using the affected thumb CMC joint.

RESULTS: Data from 12 participants were analyzed (9 female; age = 62.3 ± 6.1 years), including three participants for whom post-operative data were available (2 female; age = 58.0 ± 5.3 years; 1 underwent LRTI, 2 underwent suspensionplasty). The average VAS score improved from 5.4 ± 2.1 pre-operatively (n = 12) to 1.3 ± 1.2 post-operatively (n = 3); the average QuickDASH score improved from 40.2 ± 18.5 pre-operatively (n = 12) to 9.1 ± 4.5 post-operatively (n = 3). Qualitatively, the peak force attained during key pinch decreased in all three participants' affected hands from pre-operative to post-operative testing (Figure 1). No other consistent trends in peak force were observed between pre- and post-operative affected hands, or between pre-operative healthy and affected hands. The pattern of change in gap distance between the MTC1 and scaphoid as force increased was inconsistent among subjects (Figure 2). The location of minimum gap between MTC1 and scaphoid was also variable across subjects (Figure 3). For the post-operative data, the average coefficient of variation (CV) in force was lower in the key pinch trials (25%) than in the can trials (34%) and jar trials (50%), and the average CV in post-operative minimum gap distance was lower in can trials (9%) and key trials (8%) than in jar trials (24%).

DISCUSSION: This interim analysis demonstrates that first metacarpal subsidence and thumb force can be measured simultaneously using dynamic biplane radiography, and that the effect of trapeziectomy on the relationship between peak force and subsidence may be dependent upon the functional activity. The key pinch task appears to be most reliable for testing this relationship between subsidence and force. Future work in this study will seek to relate any trends in force, subsidence, and location of minimum trapezial space to clinical outcomes.

SIGNIFICANCE: Key pinch appears to be the most reliable task for evaluating the relationship between force and MTC1 subsidence after trapeziectomy.

REFERENCES: 1) Van Heest AE et al. *JAAOS*. 2008. 2) Gervis WH et al. *JBJS Br*. 1973. 3) Murley A. *JBJS*. 1960. 4) Tomaino MM. *Hand Clin*. 2001. 5) Shonuga et al. *Hand.* 2021. 6) Lui et al. *J Hand Surg Eur.* 2023. 7) Munsch et al. *J Biomech.* 2022.

ACKNOWLEDGMENT: This ongoing research is sponsored by a grant from the National Institutes of Health under the award number R21AR081556.

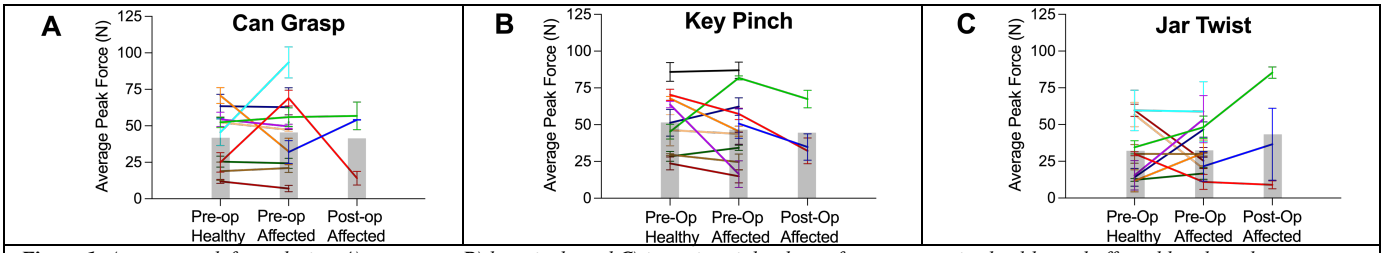

Figure 1. *Average peak force during* ***A)*** *can grasp,* ***B)*** *key pinch, and* ***C)*** *jar twist trials, shown for pre-operative healthy and affected hands and post-operative affected hand. Each color represents a different subject. Gray bars represent cohort averages. Error bars represent ± 1SD in the repeated trials for each participant.*

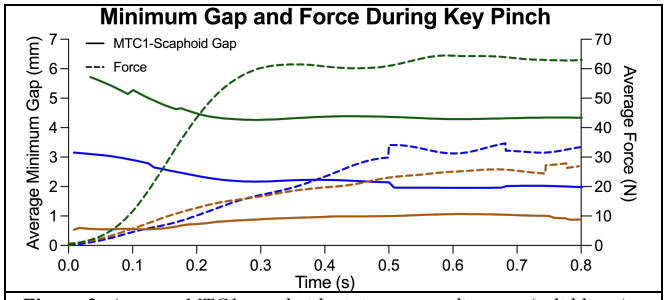

Figure 2. *Average MTC1-scaphoid minimum gap distance (solid lines) and average force (dashed lines) during post-operative key pinch trials. Each color represents a different subject.*

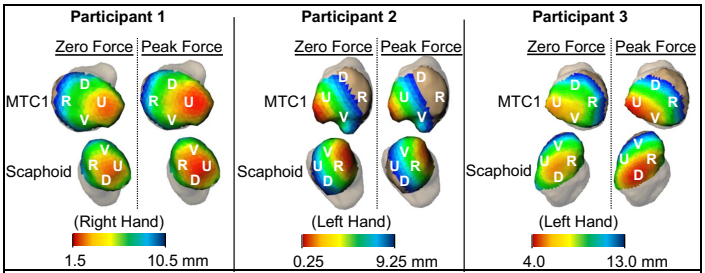

Figure 3. *Distance between the MTC1 and scaphoid bone at zero force and peak force during key pinch for 3 participants. Note color scale representing trapezial space is different among participants. D = dorsal, V = volar, R = radial, U = ulnar.*