Trapeziometacarpal Joint Space Changes with Different Thumb Orientation Directions

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INTRODUCTION: The trapeziometacarpal (TMC) joint is a biconcave-convex saddle joint located at the base of the thumb between the first metacarpal and trapezium. The TMC joint is the most important joint of the thumb and allows for the thumb to carry out its important executive functions of grasping and manipulating objects. The TMC joint can be prone to pathological diseases which can hinder the kinematic and structural integrity of the joint. The kinematic functionality of the joint is defined by the complex range of motion, describing the capability and extent to which the joint can move in different directions. These directions can include flexion, extension and abduction [1]. The structural integrity of the joint can be defined by the joint space, which is a frequently used metric in the experimental and clinical evaluation of joint health [2, 3]. Being able to define the relationship between the joint range of motion and the joint spacing in healthy TMC joints can allow for future comparisons to different pathological states that commonly affect the TMC joint. The purpose of this study was to quantify the space of the TMC joint with the thumb oriented in maximal flexion, extension and abduction. The hypothesis was that the integrity of the TMC joint spacing would be maintained across the executed range of motion.

METHODS: Five full-arm male cadaveric specimens were used for the study. The specimens were secured onto a custom fixation device, with the four fingers secured around a cylinder. The specimens were placed inside a CT machine and scanned with the thumb in the natural orientation. A custom device was used to position the thumb into three additional orientations. These orientations were maximum abduction, maximum flexion and maximum extension. A CT scan was taken for each orientation (Figure 1). The articular surfaces of the metacarpal and trapezium were manually selected and a fifth order polynomial was fit to each surface and the location of the metacarpal saddle point was approximated [4]. A sphere of 2 mm radius centered at the metacarpal saddle point was defined and the intersection of the sphere with the metacarpal articular surface defined a boundary, within which the minimum distance between the articular surfaces of the metacarpal and trapezium was calculated as the joint space. The points inside this boundary were projected onto the articular surface of the trapezium (Figure 2). A two-dimensional coordinate system was anatomically defined with one axis in the dorsal-volar direction and one axis in the radial-ulnar direction. The dorsal and radial directions were define as positive, respectively. The location of the joint space region was measured with respect to the center point of the trapezium articular surface projection. A two-tailed t-test was used to compare the joint space in the natural orientation with the joint space in the maximum abduction and maximum flexion orientations ($\alpha = 0.05$).

RESULTS: The minimum joint space when the thumb was oriented in the natural, maximum abduction, maximum extension and maximum flexion orientations was 3.367 ± 0.573 mm, 3.369 ± 0.759 mm, 3.432 ± 0.789 mm and 3.229 ± 0.714 mm, respectively. There were no significant differences between the joint space in the natural and maximum abduction orientation ($p = 0.997$); or between the natural and maximum flexion orientations ($p = 0.745$). The location of the joint space region on the trapezium articular surface was different for different thumb orientations (Figure 2). In the dorsal(+)/volar(-) direction, the location of the joint space region with respect to the trapezium center point was -2.56 ± 2.39 mm, -0.04 ± 3.05 mm, 2.24 ± 3.03 mm and -1.04 ± 1.13 mm for the natural, maximum abduction, maximum extension and maximum flexion thumb orientations. In the radial(+)/ulnar(-) direction, the location of the joint space region was 0.95 ± 2.99 mm, 0.32 ± 3.22 mm, 1.96 ± 4.23 mm and -2.22 ± 3.14 mm, respectively.

DISCUSSION: The TMC joint space was well-maintained, with respect to the joint space in the natural orientation, when the thumb was oriented in the maximum orientation arrangements. This was evidenced by the negligible magnitude of specimen-specific changes in joint space. The minute changes in TMC joint space may be a characteristic of the healthy TMC joint, showing that the structural integrity of the joint is able to be well-maintained, even at the extremes of the thumb range of motion. At these extremes, the visual and quantitative results for the joint space region location show that the region can be located differently for the different thumb orientations. Continued experimentation on a larger sample size and future in-vivo experimentation for healthy and pathologically afflicted joints could help to substantiate and expand the current findings by defining distinctive relationships between the thumb orientation, the motion of the joint and the joint space magnitude.

SIGNIFICANCE/CLINICAL RELEVANCE: This study provides a baseline for changes in healthy TMC joint spacing with maximum thumb deviations and can be used for comparative analyses against pathologically afflicted joints, which may display smaller or larger differences in the deviation of the TMC joint space for similar motions.

REFERENCES: [1] Crisco et al., J Hand Surg Am., 40, 2015. [2] Halilaj et al., J Biomech, 48, 2015. [3] Kennedy et al., Clin Orthop Rel Res, 474, 2016. [4] Halilaj et al., J Biomech, 46, 2013.

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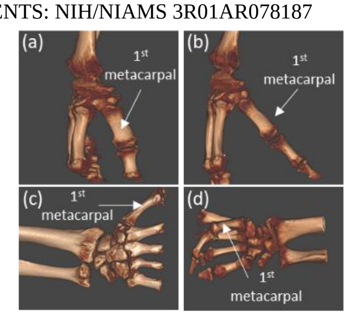

Figure 1: Example of thumb orientations for the (a) natural, (b) maximum abduction, (c) maximum extension and (d) maximum flexion orientations.

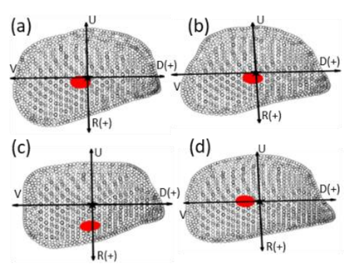

Figure 2: Example of joint space region location on trapezium articular surface for the (a) natural, (b) maximum abduction, (c) maximum extension and (d) maximum flexion orientations with anatomical coordinate system; dorsal (D), volar (V), radial (R) and ulnar (U).