Revisiting the Rigid Distal Carpal Row Assumption for Measuring Thumb Motion

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Summary

Thumb carpometacarpal (CMC) joint motion occurs as the first metacarpal moves relative to the trapezium. When analyzing thumb motion in patients who have received common treatments for thumb CMC osteoarthritis, the trapezium can be either missing or fused. The purpose of this research was to determine which carpal, or metacarpal bone had the most similar movement to the trapezium in participants with healthy wrists. We found that the capitate moves most similarly to the trapezium, making it a good candidate to examine thumb motion in patients.

Introduction

The most common treatments for thumb CMC osteoarthritis are ligament reconstruction and tendon interposition (LRTI) and CMC fusion. LRTI's remove the trapezium bone and aim to preserve thumb motion while CMC fusion preserves the bone but removes motion [1]. Despite limited motion it seems that patients who have undergone CMC fusion maintain some thumb mobility. Our long-term goal is to understand where the motion occurs in these patients. We hypothesize that motion occurs at adjacent carpal joints, but we require a good candidate reference bone to compute overall thumb motion because patients with LRTI do not have a trapezium and patients with fusion have a locked trapezium.

Previous studies have used sequential CT scans (accuracy ~0.5 mm and ~0.5°) to show that the distal carpal row and metacarpals 2-5 largely move as a single rigid body [2], [3]. From this perspective, any of these bones would be a good candidate bone for assessing how the first metacarpal moves relative to the hand after surgery. However, these joints undergo small motions and have different tracking accuracies. Therefore, this study aimed to characterize the motion of the distal carpal row and metacarpals relative to the first metacarpal in individuals with healthy wrists, with the goal of identifying a suitable substitute for the trapezium.

Methods

We used a previously collected dataset consisting of 10 participants (21-34, 5M and 5F) with CT scans of 11 different hand positions that sampled the spectrum of wrist motion and also contained substantial thumb CMC motion [2]. We computed the motion of each bone in the distal row and metacarpals 2-5 relative to the first metacarpal for all combinations of the 11 positions (55 total motions per participant). We quantified kinematics using the helical axis of motion. The rotation about the helical axis of each bone was subtracted from the trapezium's rotation, meaning the bone would show 0° if it moved identical to the trapezium. To determine if the rotation of each bone was like the trapezium, we computed the standard deviation and performed a one-population t-test with a hypothetical mean of zero.

Results and Discussion

The mean trapezium-corrected rotation ranged from -0.15 ± 5.0° (capitate) to 2.3 ± 9.3° (fifth metacarpal). Capitate rotation was not statistically different than trapezium motion ($p = 0.5$), making it the ideal candidate for examining the motion of the first metacarpal with respect to the hand and wrist when the trapezium is either not present or fused. Interestingly, the fifth metacarpal exhibited non-zero rotation relative to the trapezium ($p < 0.0001$), which calls into question whether it moves rigidly with the distal row.

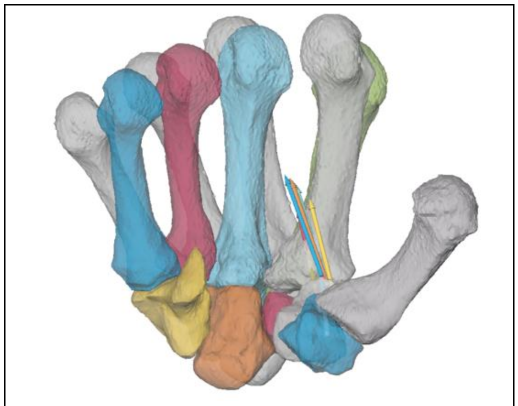

Figure 1: Example of the helical axis analysis. Here the participant is moving from maximum ulnar deviation (gray) to a dart thrower's radial-extension pose. The first metacarpal is mathematically fixed. The helical axes of each bone correspond to bone colour.

Conclusions

We found that the capitate moves most similarly to the trapezium across a wide range of positions. This analysis will allow us to proceed with our study to determine where the motion occurs in patients with LRTI and CMC fusion.

Acknowledgments

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References

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