DYNAMIC vs. QUASI-STATIC COLLECTION OF CARPAL BONE KINEMATICS

Michael E. Hahn, Kok P. Looi, Min J. Park and Kai-Nan An
Orthopedic Biomechanics Lab, Mayo Foundation, Rochester, Minnesota
Email: An.kainan@mayo.edu

INTRODUCTION

Carpal bone kinematics have typically been collected in a quasi-static fashion using either biplanar radiography or electromagnetic tracking devices. While this allows for an intuitive collection setup, it has been suggested that the true nature of carpal kinematics may only be detected in dynamic collection (Short, et al., 1995), specifically when discrete instability is being investigated. Studies that have pursued dynamic collection have chosen Eulerian angles to describe carpal motion. This leaves the investigator without linear displacement data. The purpose of this study was to determine which components of carpal motion as described by screw displacement axes (SDA) were most affected by collection type. It was thought that a significant difference would exist between dynamic and quasi-static collection.

METHODS

Four fresh frozen cadaver forearms (mean age = 70.75 yrs) were dissected, leaving ligaments and tendons intact. The ECRL, ECRB, ECU, FCR, FCU, and APL were loaded according to physiological cross-section area (Brand, et al., 1981). Wrists were pre-conditioned for full flexion/extension (F/E) and radial/ulnar deviation (RUD) prior to data collection. The 3Space Fastrak electromagnetic system (Polhemus, Inc., Colchester, VT) was used to track the scaphoid, lunate and capitate. A local coordinate system was defined by the SDA describing the extreme ends of flexion/extension and radial/ulnar deviation. The X-axis was defined as the long axis of the forearm, the Y-axis described RUD and the Z-axis described F/E. Data was first collected with the wrist in static positions of rotation (Neutral, 40° flexion, 40° extension, 15° radial deviation, 30° ulnar deviation) as determined by planar fluoroscopic images. The capitate was assumed to indicate global hand position. Quasi-static kinematic data was then calculated as the motion from neutral to the four end positions.

Each wrist was then moved through a custom-made jig that allowed planar motion. Dynamic position and orientation data were collected at 30 Hz for all sensors. Kinematic data was calculated as the motion from neutral to each data point. A spline was fit to the raw data so that discrete points were selected where the global wrist angle value (based on the capitate position relative to the forearm) matched that of the desired quasi-static angle value.

Quasi-static and dynamic results were expressed using the concept of SDA and transformed into the local coordinate system. A one-way ANOVA and a Tukey-Kramer post-hoc test were used to determine significant differences between the collection techniques, for rotations about and linear displacement along the X, Y, and Z axes.

RESULTS

Linear displacement along the X and Z-axes proved to be significantly different between collection techniques (p=.006 and p=.019, respectively). No other measurements were found to be significantly different (α=.05). In X-axis translation, the static collection showed a greater translation than that shown by the dynamic collection, indicating a more proximal position (Fig. 1). In Z-axis translation, the static collection also showed a greater translation than that of the dynamic collection. This would indicate a greater ulnar shift of the carpus (Fig. 2).

DISCUSSION

These results support the theory that collecting carpal kinematics in a quasi-static fashion may limit the ability to detect subtle carpal instabilities, including subluxations of the scaphoid and/or lunate. When position of the carpal bones is recorded in a static orientation with muscles loaded, it is possible that the constant pull at the tendon attachment causes the individual bones to sublux from where they would be at a discrete point in the time-series of a dynamic collection. This indicates an inherent laxity in the wrist joint that is exacerbated when held in a static position with load applied. If conclusions are drawn from kinematic studies where the motion is quasi-static and the muscles are loaded, the authors feel that errors may be made in judging the degree of instability existing between the carpals. Furthermore, it can be assumed that the discrete point in a wrist's rotation where subluxation does occur will likely be missed in kinematic studies of quasi-static design. The present study has put forth a method for dynamic carpal kinematic collection that can determine the discrete point of instability and quantify the amount of instability in three dimensions.

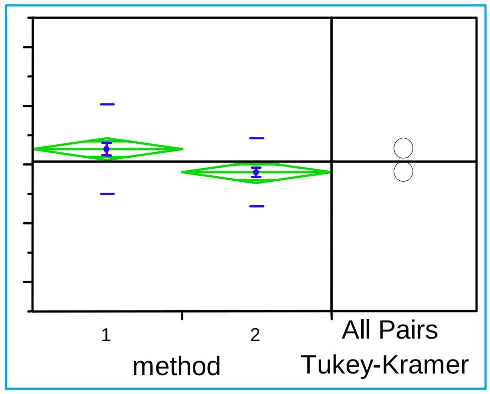

Figure 1. Significant difference in X-axis linear displacement. Methods 1 and 2 indicate the quasi-static and dynamic methods, respectively.

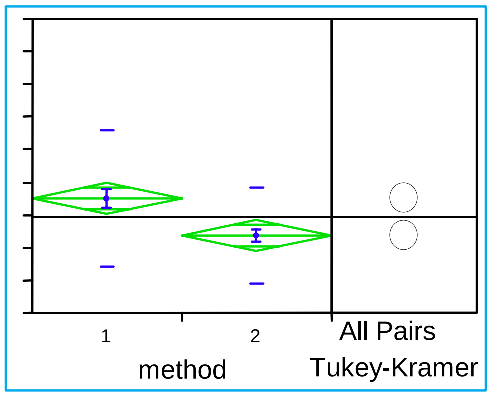

Figure 2. Significant difference in Z-axis linear displacement. Methods 1 and 2 indicate the quasi-static and dynamic methods, respectively.

REFERENCES

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