INTRODUCTION: Anatomic coordinate systems are widely used in biomechanics research and have found some applications in orthopaedic surgical procedures such as joint arthroplasty. With respect to the elbow, coordinate systems for the humerus and ulna are often derived from surface scans or digitizations of specific anatomical features.

In 2005, the International Society of Biomechanics (ISB) expressed the need for standardized joint coordinate systems (JCS) and proposed definitions of various JCS including the elbow by means of anatomical features. The ISB acknowledged that “it cannot be assured that the [humerus and forearm] Z axis is equal to the joint rotation axis” and that “the numerical and practical inaccuracies in defining the lateral and medial epicondyles may swamp the accuracy of the JCS definition”.

In some applications, anatomy-derived JCS may be difficult or impractical to produce if access to the required anatomy is not available or not warranted due to a resulting increase in morbidity. Furthermore, there is a dependency on accuracy and repeatability of an investigator’s selection of anatomical features.

The aim of this study was to develop JCS for the humerus and ulna which are derived solely from passive elbow motion, and compare their accuracy and repeatability to established anatomy-derived JCS. We hypothesized that a motion or kinematic derived coordinate system would yield more consistent and less variable motion pathways.

METHODS: Twenty fresh-frozen cadaveric upper extremities, amputated at mid humerus (mean age: 69 ± 15, 11 male, 8 left), were mounted with a humeral clamp. A 6DOF electromagnetic tracking system was used to record kinematic data (Flock of Birds, Ascension Technologies Inc., VT, USA). Tracking system receivers were rigidly fixed to the ulna and radius. The transmitter was rigidly mounted with respect to the humeral clamp, and thus fixed relative to the humerus.

In the dependent portion of the study, an investigator manually rotated the forearm and flexed the elbow in the following sequence: forearm pronation → elbow flexion → forearm supination. The sequence was conducted 5 times to evaluate repeatability.

Average SDAs (Screw Displacement Axes) were calculated for elbow flexion and for forearm rotation representing their axes of rotation. These SDAs, along with their intersection and cross products, were used to construct motion-derived JCS for the humerus and ulna.

Active flexion trials were performed on ten of the twenty specimens (mean age: 65 ± 11, 5 male, 8 left). Active flexion was simulated with a custom elbow motion simulator. Tendons were connected with sutures to computer-controlled actuators. Pronated elbow flexion was produced in the valgus and horizontal positions and evaluated for varus angle and external rotation kinematics of the ulna relative to the humerus.

Following testing of the elbow and wrist, the elbow and wrist were disarticulated in order to digitize various anatomical features including the capitellum, trochlea, humeral shaft and ulnar styloid. The digitizations were performed using a stylus mounted to a tracking receiver. Anatomy-derived JCS for the humerus and ulna were generated as established in previous studies.

In order to compare the anatomy-derived and motion-derived JCS, a common reference was created for each arm. This was formed by a flexion plane and perpendicular axis calculated using the principle component of motion of the distal ulnar styloid. These are essentially the average plane and axis of flexion.

Varus and external rotation angles were calculated for each motion trial using both anatomy-derived and motion-derived JCS. The location of each JCS was calculated relative to the reference.

RESULTS: Repeatability of creating motion-derived JCS for the humerus and ulna was 0.36°&0.46° varus angle, 0.72°&0.64° internal rotation, 0.39°&0.29 mm proximal, and 0.39°&0.36 mm anterior, respectively.

The position and orientation of both types of JCS was measured with respect to the reference for all 20 specimens (Figure 1). The motion-derived JCS were closer to the reference for all cases except for humerus external rotation (p<0.05). The standard deviations for the motion-derived JCS were significantly less than for the anatomy-derived JCS in all cases (p<0.05).

REFERENCES: