INTRODUCTION:

Techniques have evolved for quantifying human tendon and ligament forces in the lower extremity; however, custom developed systems for the upper extremity, particularly the elbow, are not well described. Consequently, ligament forces of the human elbow joint have not been reported. Knowledge of the magnitudes of tension of the primary valgus stabilizer, the anterior bundle of the medial collateral ligament (AMCL)\(^1,2,3\), would allow for an improved understanding of the load borne by the ligament.

The purpose of this in vitro study was to quantify the magnitude of tension in the native AMCL through the arc of elbow flexion for different arm orientations. We hypothesized that tension in the AMCL would increase with elbow flexion, and that AMCL loads would be greater with the arm oriented in the valgus position relative to the dependent (i.e. vertical) position.

METHODS:

Five fresh-frozen cadaveric upper extremities (mean age 72 ± 10 years) were amputated at mid-humerus and maintained frozen at -20°C prior to use. To produce active muscle loading in a motion simulator, stainless steel cables were affixed to the distal tendons of the brachialis, biceps brachii, triceps brachii, and brachioradialis and attached to actuators. The wrist was fixed in neutral flexion/extension and the forearm in neutral rotation.

The humerus was mounted into a motion simulator\(^4\) which allowed unconstrained elbow motion. The simulator permitted orientation of the arm in the valgus gravity-loaded position, as well as in the dependent (i.e. vertical) position. The medial aspect of the elbow was exposed, and the common flexor origin was elevated to identify the AMCL. A custom designed E-form frame buckle ligament load transducer (instrumented with strain gauges) was then inserted into the AMCL (Figure 1).

Active simulated flexion was achieved via computer-controlled actuation while passive elbow flexion was achieved by an investigator directly guiding the arm through its full range of motion. Motion of the ulna relative to the humerus was measured in six-degrees-of-freedom using an electromagnetic tracking device (Flock of Birds; Ascension Technology, USA). Testing was conducted with the arm oriented in the dependent and valgus positions, with the elbow under both passive and active motion. The AMCL tension and elbow kinematic data were analysed using a one-way and two-way repeated measures analysis of variance (ANOVA) with \(\alpha = 0.05\), and post hoc paired t-tests using the Bonferroni correction.

RESULTS:

With the arm in the valgus orientation, both the active and passive motion pathways showed an increase in AMCL tension with increasing angles of elbow flexion (\(p < 0.05\)). There was no difference in AMCL tension levels between active and passive elbow flexion (\(p = 0.2\)). (Figure 2).

With the arm in the dependent orientation, there was no difference in AMCL tension levels between flexion angles for both active and passive motion (\(p = 0.06\) and \(p = 0.08\), respectively). There was no difference in the AMCL tension levels between active and passive elbow flexion (\(p = 0.7\)). (Figure 3).

The AMCL tension levels in the valgus orientation were greater that those measured in the dependent orientation (\(p < 0.05\)).

DISCUSSION:

For all test conditions, AMCL tension levels were observed to increase with elbow flexion, indicating that other structures (such as the joint capsule and the shape of the articulation) are likely more responsible for joint stability near full extension, and that the AMCL is recruited at increased angles of elbow flexion.\(^4\) This finding is consistent with previously reported data by Morrey et al.\(^1\), who reported that valgus stability was observed to be equally divided among the MCL, anterior joint capsule, and joint articulation (31%, 38%, and 31%, respectively) when the elbow was extended; whereas, at 90° of elbow flexion, the MCL, anterior joint capsule, and joint articulation were found to resist approximately 54%, 10%, and 33% of valgus stress, respectively. Our tension results are consistent with previously reported data by Pribyl et al.\(^5\) and Lin et al.\(^6\), who reported that strain in the AMCL increased with elbow flexion. Pribyl et al.\(^5\) observed the maximum AMCL strain to be 30% at 130° of elbow flexion. Similarly, our study found, for both the valgus and dependent positions, greater AMCL tension levels in flexion.

In summary, this in vitro cadaveric study demonstrated that tension in the AMCL increases with elbow flexion, and tension levels are greater when the arm is oriented in the valgus position relative to the dependent position; both of these observations are consistent with our hypotheses. Of particular importance is our new understanding of the magnitudes of AMCL tension through the arc of elbow flexion, as this has important implications with respect to the desired target strength of repair and reconstruction techniques. These findings will also assist in the development and validation of computational models of the elbow.

REFERENCES: