AN IN VIVO 3D ARTICULAR MODEL OF THE RADIOSCAPHOCAPITATE (RSC) LIGAMENT DURING WRIST FLEXION/EXTENSION AND ULNAR/RADIAL DEVIATION

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INTRODUCTION
The stability and function of the wrist are dependent on the ligaments that traverse the carpus. The ligaments stabilize the wrist by tightly approximating the congruent surfaces of neighboring bones, while at the same time allowing limited relative motion.

The radioscaphocapitate ligament (RSC) is an important extrinsic ligament of the wrist. It originates from the palmar surface of the radial styloid, and the majority of its fibers traverse obliquely to insert on the waist of the capitate (Berger, 1990). The RSC passes beneath the waist of the scaphoid, forming a supporting sling as the scaphoid flexes and extends during wrist motion.

There is limited data on the mechanical properties of the RSC, and the data that has been reported differs substantially from the properties of other ligaments. For example, the failure strain of the RSC has been reported to be 20 to 50% (Mayfield, 1979), which is much higher than that of other skeletal ligaments (the major knee ligaments fail at 12%-15% strain). We question whether the ligaments of the wrist are fundamentally different than those of the knee, or whether these findings were secondary to differences in testing methodologies.

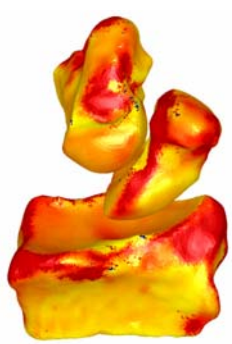

Figure 1: The radius scaphoid and lunate's color maps correspond to distance from the surrounding soft tissue. This Micro-CT model combined with dissection and anatomy texts provides a map of the insertion regions

This study was performed to estimate the elongation of the RSC at various wrist positions. To do so we analyzed an extensive database of 3-D *in vivo* carpal kinematic data using a computer algorithm designed to compute ligament fiber path lengths, with the constraint that the ligaments wrap over the bone surfaces. In particular, we tested the hypothesis that RSC elongation would change as a function of wrist position.

METHODS
Following IRB approval and informed consent, a comprehensive digital database of bone surfaces and carpal kinematics was generated from serial CT scans of 27 healthy subjects (mean age 24.6; range 21-34).

Anatomy texts, wrist dissections, and micro-CT (Fig. 1) were used to define the insertion sites of the RSC on the radial styloid and capitate of the average-sized subject from our database. A central fiber was placed at the centroid of the insertion sites and 12 other fibers were distributed around the periphery. The path of each fiber was computed as the shortest straight-line distance between its insertion sites, constrained to wrap around the bone surfaces, avoiding penetration. These paths were computed based upon distance-field maps and the tessellated scaphoid surface. The assembled wrist model was animated using the 3-D kinematic data from 80 different positions of wrist flexion/extension and 41 different positions of wrist ulnar/radial deviation. The 3-D kinematic data for each subject was scaled to remove the effect of carpus size.

At each wrist position, fiber elongation was defined as the percent change in length relative to the neutral wrist position. Linear regression was used to determine if elongation of the central fiber differed with wrist position ($P < 0.05$).

RESULTS AND DISCUSSION

The central fiber of the RSC significantly ($P<0.01$) lengthened as the wrist moved from full flexion to full extension, and as the wrist moved from radial deviation to ulnar deviation (Fig. 2a). The elongation of the central fiber ranged from -15% to 25%, relative to its length at the neutral wrist position. The maximum elongation was observed in ulnar deviation and the maximum shortening was observed in radial deviation. There was a positive linear relationship between the elongations of the each of the 12 peripheral fibers and the central fiber. This relationship varied only slightly with insertion location and extent of wrapping (Fig 2b).

SUMMARY/CONCLUSIONS

Elongations of the RSC during wrist flexion/extension and radial/ulnar deviation were computed using kinematic data and bone surface models of the capitate, scaphoid and radius from an extensive *in vivo* digital kinematic database. The range of elongation was approximately 40%. While our findings are generally consistent with previous *in vitro* studies of RSC failure strains, they are still much greater than values typically reported for other ligaments (i.e. those around the knee). It is important to emphasize that our ligament elongations were derived computationally and that our results do not necessarily reflect actual ligament strain values. This is because we do not know precisely how the RSC fibers traverse the scaphoid, and because we arbitrarily selected our "zero" elongation at the neutral wrist positions. Therefore, negative elongations reflect decreased length relative to the length at the neutral wrist position, not necessarily a state of negative strain or "slack". The large range of elongations, however, does suggest either highly elastic structure or slack or both. *In vitro* biomechanical testing data will be required to resolve this issue.

REFERENCES

1. Beger and Landsmeer, *J Hand Surg [Am]* **15**: 847-854, 1990. 2. Mayfield et al. *Ortho. Trans*. 143-144, 1979. *IEEE Trans Biomed Eng* 79-799, 2004.

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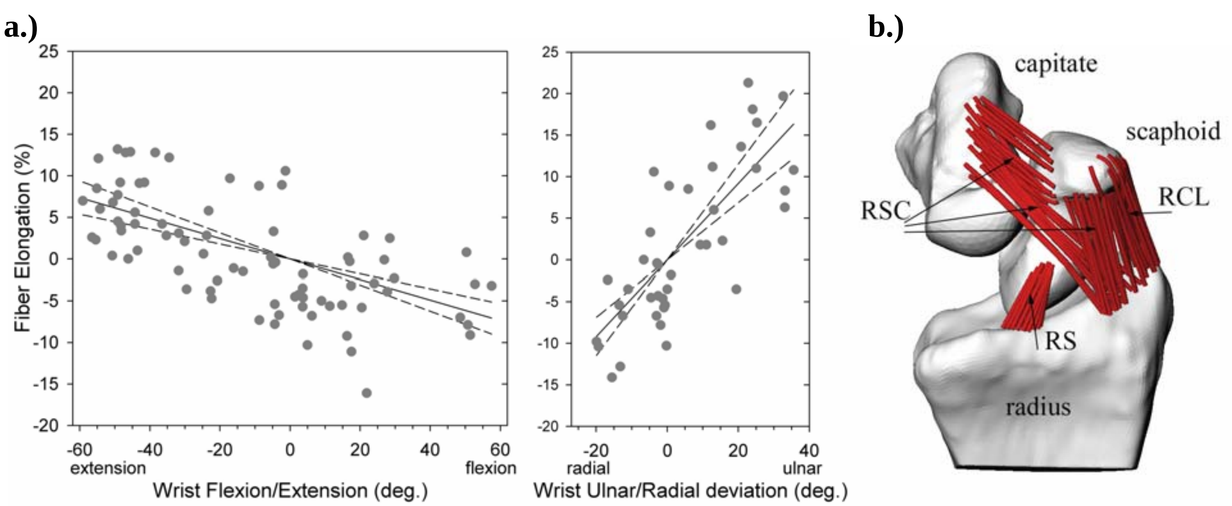

Figure 2. a.) Elongation of the central fiber of the RSC, relative to neutral wrist position, and constrained to wrap over the scaphoid bone surface. Each datum corresponds to a single wrist position. **b.)** Multiple fiber models of various ligaments. Radioscaphocapitate (RSC), radio collateral (RCL), radio scaphoid (RS). Note that the RSC forms a supporting sling around the waist of the scaphoid.