A KINEMATICS-BASED METHOD FOR EVALUATING THE STABILIZING ROLE OF LIGAMENTS IN THE CARPAL JOINT

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INTRODUCTION:

The carpal ligaments are tough, passive bands of soft-tissue connecting the wrist bones. Their role is to stabilize the wrist joint during motion, although not all ligaments are active at any given pose. Unfortunately, the role of specific carpal ligaments is poorly documented, partly due to current in vivo measuring limitations.

We present a subject-specific computational method for estimating the passive/active state of specific carpal ligaments across the wrist range of motion. Understanding which carpal ligaments help stabilize a particular wrist pose may lead to improvements in treatment for injuries, as well as to a reduction in the number of wrist-related injuries.

METHODS:

The wrist bones of a male volunteer were CT-imaged (GE Hispeed Advantage, scan parameters: 80kV, 80mA, image resolution 0.94 x 0.94 x 1 mm^3) in seven different poses. The bone surfaces were segmented from the neutral pose scan.

Next, each bone surface was tracked accurately through the sequence of remaining CT volume images [1]. The tracking procedure reported relative bone motion from one articulation pose to another. Cartilage maps were reconstructed from the inter-bone distance information [2].

We generated ligament fiber paths for 15 ligament bundles, as follows. We manually identified ligament insertion sites [3]. We defined three to four equally spaced fibers per ligament bundle to account for the band-like structure of ligaments. For each fiber and joint pose, we automatically generated minimum-length paths constrained to avoid bone penetration [4]. The resulting fiber paths were visually validated against anatomy-book data.

To estimate the ligament rest length, we computed the maximum functional length l_{max} of the fibers across the range of motion. Extrapolating from knee ligament data and considering that the range of motion we used as input was unlikely to stretch ligaments to their maximum length, we estimated that the fiber rest length l_0 should be around 95% of the computed maximum length l_{max}. We considered a ligament to be lax in the poses in which its functional length was less than its estimated rest length l_0.

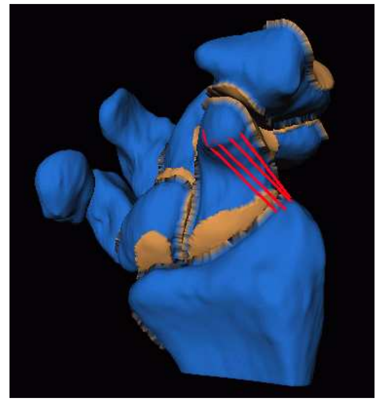

Figure 1: Palmar radial-scaphoid ligament fibers (ligament in red, bones in blue, cartilage in yellow).

Table 1: Wrist ligament fiber lengths across the range of motion (SLIM – scapho-lunate inter-median; PST – palmar scapho-trapezium; RSC - radio-scapho-capitate; DRC – dorsal radio-carpal)

Lig.	Min length across fibers	Max length across fibers	Active/ poses
SLIM	2.5 ± 0.2mm	3.3 ± 0.4mm	1/7
PST	3.2 ± 0.2mm	10.0 ± 0.9mm	1/7
RSC	23.1 ± 2.6mm	27.4 ± 2.2mm	3/7
DRC	24.5 ± 3.8mm	31.7 ± 2.4mm	1/7

RESULTS AND DISCUSSION:

Four computed ligament-fiber paths are shown in Fig. 1; note the fibers wrapping around the bone at the top insertion site. Evaluation of the computed fiber lengths across the range of motion (see Table 1 for sample results) indicates that most ligament fibers are active in only a few poses.

Subsequent observation of an in vitro dissected specimen confirms this finding: wrist ligaments appeared to be lax in most poses. We expect that the poses in which ligaments become active will indicate the functional role of specific ligaments.

REFERENCES:

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2.Marai et al., IEEE EMBC 2006:2079-82
3.Primal Pictures Inc.
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