Biomechanical Evaluation of the Ligamentous Stabilizers of the Scaphoid and Lunate: Part II

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Purpose: This study is a continuation of our previous investigation of the ligaments stabilizing the scaphoid and lunate. We evaluated the effects of sectioning the scapholunate interosseous ligament, radioscaphocapitate ligament, and scaphotrapezial ligament in 3 sequences.

Methods: Three sets of 8 cadaver forearms were placed in a wrist simulator and moved in continuous cycles of flexion–extension and radial–ulnar deviation. Kinematic data for the scaphoid and lunate were recorded for each wrist in the intact state, after the 3 ligaments were sectioned in various sequences and after the wrist was moved through 1,000 cycles of motion.

Results: Sectioning only the scaphotrapezium ligament (ST) or the radioscaphocapitate ligament (RSC) resulted in minimal angular changes to the motion of the scaphoid and lunate. Sectioning of the scapholunate interosseous ligament (SLIL) or 1,000 cycles of repetitive wrist motion after ligament sectioning altered scaphoid and lunate kinematics.

Conclusions: Based on these findings it was concluded that the SLIL is the primary stabilizer and the RSC and ST are secondary stabilizers of the scapholunate articulation. Repetitive motion after ligament injury probably results in further carpal instability. (J Hand Surg 2005;30A:24–34. Copyright © 2005 by the American Society for Surgery of the Hand.)

Key words: Scapholunate instability, scaphoid, lunate, wrist, kinematics.

Ligamentous injuries in the region of the scaphoid and lunate are common. Diagnosis is sometimes difficult owing to inconsistencies in the physical examination and imaging studies. Treatment outcomes also are variable because of the uncertainties as to the function of the various wrist ligaments and the exact anatomic location of the soft-tissue injury.

The anatomy of various ligamentous stabilizers has been described by Berger[1] for the scapholunate interosseous ligament (SLIL), by Berger[2] and Berger and Landsmeer[3] for the radioscaphocapitate ligament (RSC), and by Moritomo et al[4] and Drewniany et al[5] for the scaphotrapezium ligament (ST). Dorsally the dorsal intercarpal ligament and the dorsal radiocarpal ligament also help to stabilize the wrist.[6–9]

In previous studies we[10] and others[11,12] have shown that the SLIL is a primary stabilizer between the scaphoid and the lunate. The specific roles of the RSC and ST, however, are not defined clearly, resulting in a variety of treatment recommendations

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and less than ideal clinical outcomes for many patients.[13–19]

The purpose of this study was to continue our previous investigation[10] to evaluate the stabilizing function of the SLIL, RSC, and ST ligaments on the scaphoid and lunate in a biomechanical cadaver experiment. This methodology is similar to our previous study[10] but the ligaments were sectioned in different sequences because changes in the motion of the scaphoid and lunate may be dependent on the order in which these ligaments are sectioned. The primary aim was to study the effect of sequential sectioning of these ligaments on scaphoid and lunate motion during cyclic wrist flexion–extension and wrist radial–ulnar deviation. The additional effect of repetitive cyclic motion after sequential ligament sectioning also was evaluated. This was performed to mimic the effect of continued use after ligament injury.

Methods

The method used in this experiment was the same as in a previously published study.[10] Twenty-four fresh-frozen cadaver right upper extremities were determined by fluoroscopy and arthroscopic examination to be free of traumatic and systemic defects that potentially could result in altered wrist biomechanics. The age range of the specimens was from 31 to 87 years with an average age of 67 years. There were 12 men and 12 women. All specimens were amputated at the midhumerus level.

Sensors (Polhemus Fastrak sensors; Polhemus, Colchester, VT) were attached indirectly via support posts to the scaphoid, lunate, and distal radius, and directly to the third metacarpal to measure each bone's motion or position relative to an electromagnetic source. The motion of the third metacarpal sensor relative to the fixed radius was defined as global wrist motion. After these sensors (Fastrak) were attached the specimen was placed in the wrist joint simulator.[20] This is an apparatus that produces repetitive, reproducible cycles of motion in both flexion–extension, radial–ulnar deviation, as well as complex motions such as circumduction by applying physiologic forces on both the wrist flexor and extensor tendons. To permit a smooth reversal of motion each desired and actual cycle of wrist motion was sinusoidal.

The elbow was fixed in the simulator at 90° of flexion by multiple Steinmann pins and the forearm was positioned in neutral position. A rectangular acrylic platform then was passed between the radius and ulna at the level of the interosseous membrane and fastened to the proximal ulna so that it was perpendicular to the long axis of the ulna and parallel to the floor. Two electromagnetic sources (Fastrak) then were attached to this platform. One source was mounted dorsally and was used with the sensor on the third metacarpal that monitored global wrist motion. The other source was mounted palmarly and was used with the scaphoid, lunate, and radial sensors.

Table 1. Sequence of Ligament Sectioning

Group 1	Group 2	Group 3
RSC	ST	SLIL
SLIL	RSC	RSC
ST	SLIL	ST

Static position data were collected for the scaphoid, lunate, distal radius, and third metacarpal in the neutral wrist position in the simulator with load applied to the tendons. The wrist then was moved cyclically under computer control by the wrist simulator from 30° wrist extension to 50° wrist flexion for 6 consecutive cycles while force data from the simulator and positional data from the sensors (Fastrak) were collected. Data also were collected during a cyclic motion from 10° radial deviation to 20° ulnar deviation. These motion extremes were chosen because some cadaver wrists occasionally were incapable of further extremes of motion.

The 24 forearms were randomly put into 1 of 3 groups (Table 1), each containing 8 forearms. In the first group data were collected with the carpus intact, for the scaphoid, lunate, distal radius, and third metacarpal in static neutral, cyclic flexion–extension, and cyclic radial–ulnar deviation. The RSC then was sectioned and static and cyclic data again were collected. The SLIL, including the dorsal, palmar, and membranous portions of the ligament, then were sectioned and data again were collected in static neutral and the 2 cyclic motions. The ST then was sectioned and data again were collected. Finally, after these 3 ligaments had been sectioned and data were recorded, the arm was moved through 1,000 cycles of a 30° flexion to 30° extension motion. The purpose of this was to mimic the condition of continued use after ligament injury. On conclusion of 1,000 cycles the static and cyclic motion data again were recorded. During the entire experiment the specimen was kept moist by spraying normal saline onto the tissues. Details on how these 3 structures were sectioned has been described previously.[10] In