# Changes in Contact Site of the Radiocarpal Joint and Lengths of the Carpal Ligaments in Forearm Rotation: An *In Vivo* Study

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**Purpose** To examine the contact site of the radiocarpal joint and lengths of carpal ligaments at different forearm rotations *in vivo*. Rotation of the forearm could exert noteworthy influence on mechanics of the wrist, and understanding how forearm rotation influences wrist mechanics may help treat carpal disorders because wrist position closely relates to forearm rotation.

**Methods** We obtained computed tomography scans of the wrists of 8 volunteers at the following 7 positions of forearm rotation: neutral; 30°, 60°, and 90° of pronation; and 30°, 60°, and 90° of supination. Three-dimensional images of the carpals and distal radius and ulna were reconstructed with software. Subsequently, the contact site of the scaphoid and lunate on the radial articular surface and the lengths of 8 carpal ligaments between their respective origin and insertion points were measured and compared among different positions of forearm rotation.

**Results** We found that the contact site of the scaphoid on the distal radius moved between 0.2 and 2.0 mm during forearm rotation. The lengths of the 3 ulnar carpal ligaments (ie, ulnocapitate [UC], ulnolunate [UL], and ulnotriquetral [UT] ligaments) showed the greatest and significant change. From neutral position to pronation, the UC, UL, and UT ligaments shortened significantly. From neutral position to supination, the UT ligament lengthened significantly, but the radioscaphocapitate, UC, UL, and dorsal intercarpal ligaments decreased significantly.

**Conclusions** During forearm rotation, the contact site of the scaphoid and the lunate on the distal radial articular surface changed minimally. The lengths of 3 ulnar carpal ligaments (UC, UL, and UT ligaments) changed substantially.

**Clinical relevance** Our findings will help elucidate carpal biomechanics during forearm rotation. The findings may inform decisions about how to reduce the load to these carpal ligaments when treating the carpal disorders. *(J Hand Surg 2013;38A:712–720. Copyright © 2013 by the American Society for Surgery of the Hand. All rights reserved.)*

**Key words** Carpal joint, *in vivo* kinematics, ligaments, distal radius, forearm rotation.

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Received for publication September 27, 2012; accepted in revised form January 14, 2013.

No benefits in any form have been received or will be received related directly or indirectly to the subject of this article.

Supported by grants from the Health Bureau of Jiangsu Province, the Department Fund of the Affiliated Hospital of Nantong University, and the Natural Science Foundation.

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0363-5023/13/38A04-0012$36.00/0
http://dx.doi.org/10.1016/j.jhsa.2013.01.021

 

How to place the forearm at appropriate rotation position is an essential question that surgeons face after surgery for carpal disorders. The rotational position may be particularly important after ligament repair or reconstruction because forearm rotation could subject different carpal ligaments to significantly different levels of tension.[1–3]

Forearm rotation likely influences multiple aspects of carpal kinematics.[1–3] The contact site of the proximal carpal row on the distal radius is the principal linkage between the carpus and forearm. The lengths of the carpal ligaments depend on anatomical relations of the origin and insertion points of ligaments and their paths over intervening bones. We sought to address the effects of forearm rotation on the contact site of the scaphoid and lunate on the distal radius and the length changes of carpal ligaments associated with forearm rotation. A method was developed to determine the center of contact of the radiocarpal joint based on 3-dimensional image reconstruction from computed tomography (CT) scans,[4] and *in vivo* data of ligament lengths have provided insight into length changes of carpal ligaments at different carpal positions.[5–8] We used these methods to investigate the carpal contact centers and lengths of carpal ligaments at different positions of forearm rotation.

## MATERIALS AND METHODS

We recruited 8 healthy volunteers (4 men and 4 women) for this investigation. The institutional review board approved this study. Subjects' average age was 22 years (range, 20–29 y). The volunteers were free of systemic diseases or any symptoms of disorders of the right hands or wrists. Subjects with a history of wrist trauma were excluded. Plain x-ray films were taken before the CT scan to confirm the absence of degenerative changes or skeletal abnormalities in the wrist.

### Collection of computed tomography images at different forearm rotations

The hand of each volunteer was placed in a custom-designed nonmetallic supporting frame before CT scanning. The frame held the forearm in place, and marks on the surface controlled positions of forearm rotation. We acquired CT images in 7 positions during forearm rotation: neutral, 30° of pronation, 60° of pronation, 90° of pronation, 30° of supination, 60° of supination, and 90° of supination. These 7 positions were chosen to represent the entire range of forearm rotation, and all the wrists could achieve 90° of pronation and supination. At all 7 positions of forearm rotation, the wrist was held at 0° of flexion and extension, and 0° of radial or ulnar deviation. The finger and thumb were fully extended during the test. During CT scanning, the elbow was flexed to 90°, and the shoulder was abducted to 90°. We used a high-speed, 16-slice, spiral CT scanner (Somatom Sensation 16; Siemens Medical Solutions, Forchheim, Germany) to obtain images at a maximum of 120 kVp and 80 mA. Contiguous 0.75-mm images were acquired from the distal forearm to the distal carpal row at each designated forearm position, typically resulting in more than 70 image slices for each forearm position. Radiographic exposure from the scan at 7 positions was half of the maximum allowed to extremities per year.[5–7] The pixel dimensions of each slice ranged from $0.2 \times 0.2$ mm$^2$ for scans made with the wrist in the neutral position to $0.9 \times 0.9$ mm$^2$ for scans made in all other forearm positions. The resolution of the measurement system was approximately 0.5 mm.

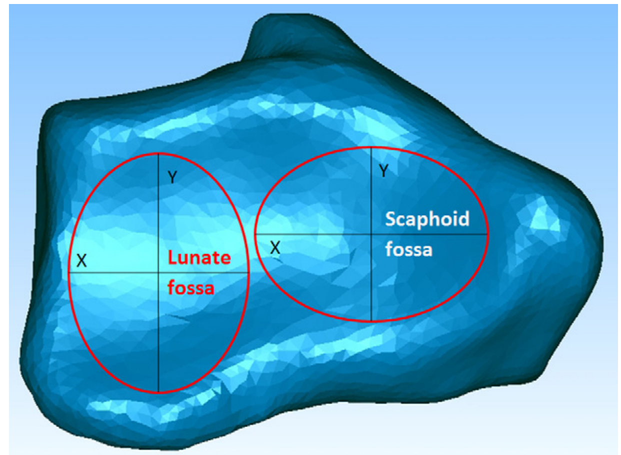


**FIGURE 1:** The image of the distal radial articular surface from a 3-dimensional reconstructed image of the distal radius, showing the scaphoid and lunate fossas, x and y planes of 2 fossas in which percentage shifting of the center of the joint contact is calculated.

### Three-dimensional reconstruction of carpal joint and contact site mapping

The 3-dimensional structures of the entire carpus—including the distal radius and ulna—at 7 positions of forearm rotation were reconstructed for each volunteer using an analytic software program (Mimics 10.01; Materalise, Leuven, Belgium) and an established method of 3-dimensional bone reconstruction.[5–10]

The contours were then grouped to form separate 3-dimensional surfaces of each bone. We determined the center of the contact region using a method applied to identify the joint contact site in previous investigations.[11–13] The contact region map obtained at the