THREE-DIMENSIONAL MOTION KINEMATICS OF TYPE I VS TYPE II LUNATE

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PURPOSE:
Two types of lunate have been recognized: type I lunate, which has no facet articulation with the hamate, and type II lunate, which has a facet articulation with the hamate. A previous study found that there was a significant incidence of cartilage erosion at the proximal pole of the hamate in the type II lunates (38%) but a low incidence (2%) in the type I lunates. It is unknown, however, whether the cartilage erosion was a result of differences in cumulative trauma, motion or abnormal loads between the two different types of lunates. The purpose of this study is to define the kinetics of the two different lunate types by three-dimensional motion analysis techniques.

MATERIALS AND METHODS:
Four fresh-frozen cadaver upper extremities without visible or radiographically identifiable abnormalities (1 male, 3 female; age: 55 – 82, av. = 69) were used. Two of the lunates were type I and 2 were type II. Triad pins were placed in the wrist, lunate, capitae and hamate. The upper arm was fixed in a special jig with the elbow flexed 90 degrees and the forearm maintained in a neutral pronation/supination position to allow wrist motion. The flexor carpi ulnaris, flexor carpi radialis, and extensor carpi ulnaris tendons of the wrist were then dissected and each of their ends sutured to form a loop. The extensor carpi radialis brevis and longus were looped together to form their own loop. Transverse images of the wrist and triad pins were obtained with a GE 9800 CT scanner generating 1.5-mm thick contiguous slices. The data was processed using a locally developed software program (UTMB, Galveston, TX). In each CT section, the outer boundary of each bone and triad pin were tracked to make a contour. Then each contour of a bone and triad pin were connected to create a 3-dimensional object. The wrist was moved through a passive flexion/extension and radio/ulnar deviation arc by a Steinmann pin inserted in the third metacarpal bone. Four cameras arranged around and above the wrist, tracked the triad pins reflective surfaces throughout a motion arc, creating motion path files. The 3-dimensional geometric reconstruction and the kinematic path information were combined to create an animation of the actual carpal motion. From the kinematic analysis, the motion was analyzed and compared between the two different types of lunate in both radio / ulnar and flexion / extension motion.

Results:
Radial and Ulnar deviation motion
The capitae-lunate angle was analyzed during global wrist motion from 20 degrees radial deviation to 20 degrees ulnar deviation. In the X axis, a positive angle is extension and a negative angle is flexion. Type I lunates averaged 8.4±6.2° in radial deviation, –9.7±3.8° in ulnar deviation and range of motion (ROM) was 18.2 ±22.3°. Type II lunates averaged 7.5±0.4° in radial deviation, –25.3±9.2° in ulnar deviation and ROM was 32.7±8.9°. The type II lunates had greater extension than type I lunates in ulnar deviation, and the ROM of type II lunates was greater than type I lunates. In the Y axis, a positive angle is radial translation and a negative angle is ulnar translation. Type I lunates averaged 11.7±1.6° in radial deviation, –9.7±0.9° in ulnar deviation and ROM was 21.4 ±2.5°. Type II lunates averaged 18.3±1.9° in radial deviation, –13.6±2.5° in ulnar deviation and ROM was 32.0±0.5°. The type II lunates had greater radial and ulnar translation than the type I lunates, and ROM of the type II lunates was greater than the type I lunates. In the Z axis, a positive angle is pronation and a negative angle is supination. Type I lunates averaged 1.5±2.8° in radial deviation, –1.3±0.6° in ulnar deviation and ROM was 4.6 ±1.9°. Type II lunates averaged 7.6±4.4° in radial deviation, –3.3±6.6° in ulnar deviation and ROM was 11.8±9.5°. There were no significant differences between type I and II lunates in the Z axis.

Flexion and Extension motion
The capitae-lunate angle was analyzed during global wrist motion from 40 degrees extension to 60 degrees flexion. In the X axis, a positive angle is extension and a negative angle is flexion. Type I lunates averaged 22.3±0.6° in extension, –39.9±17.3° in flexion and ROM was 62.3 ±18.0°. Type II lunates averaged 21.7±2.7° in extension, –37.9±13.5° in flexion and ROM was 59.6 ±16.2°. In the Y axis, a positive angle is radial translation and a negative angle is ulnar translation. Type I lunates averaged 5.2±2.7° in extension, –2.5±8.6° in flexion and ROM was 10.2 ±3.8°. Type II lunates averaged 2.0±5.7° in extension, –7.1±4.2° in flexion and ROM was 10.2±0.2°. In the Z axis, a positive angle is pronation and a negative angle is supination. Type I lunates averaged 7.7±9.8° in extension, –2.5±2.1° in flexion and ROM was 13.6 ±3.3°. Type II lunates averaged 4.2±4.0° in extension, –4.7±4.0° in ulnar deviation and ROM was 9.6±1.2°. There were no significant differences between type I and II lunates in flexion/extension.

Axis of rotation (AOR)
The AOR from maximum radial deviation to maximum ulnar deviation was located in the capitae. However, the AOR location was different between type I lunates and type II lunates. The AOR of type I lunates was oriented from the radial-volar side to the ulnar-dorsal side of the capitae at an angle of almost 50 degrees relative to the transverse plane, and located in the distal aspect of the capitae body. While, the AOR of type II lunates was oriented from the radial-volar side to the ulnar-dorsal side of the capitae at an angle of almost 15 degrees relative to the transverse plane, and located in the proximal aspect of the capitae head. The AOR from maximum extension to maximum flexion was located in the capitae. The AOR of the type I and type II lunates were located in the same aspect of the capitae and had the same spatial orientation. The AOR of extension / flexion were oriented from the ulnar-volar side to the radial-dorsal side of the capitae at an angle of almost 10 degrees relative to the transverse plane, and located at the proximal aspect of the capitae head.

CONCLUSIONS:
This study showed that the carpal kinematics of a wrist with a type I lunate was different than that of a wrist with a type II lunate in radio / ulnar deviation motion. However, the carpal kinematics of a wrist with a type I lunate was the same as that of a wrist with a type II lunate in extension / flexion motion. The total range of radio / ulnar translation and volar / dorsal flexion of type II lunates was greater than that of type I lunates.

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Fig.1
a) An illustration of the radio /ulnar deviation AOR of a type I lunate
b) The location of the radio / ulnar AOR of a type I lunate
c) An illustration of the radio /ulnar deviation AOR of a type II lunate
d) The location of the radio / ulnar AOR of a type II lunate
e) An illustration of the extension / flexion AOR of both type of lunate
f) The location of the extension / flexion AOR of both type of lunate