INTRODUCTION:
Dart-throw motion (Fig. 1) is the most frequent and natural wrist motion in activities of daily living. It is used for high and low-demand tasks that require strength and fine-motor control in many occupational and recreational situations. We have developed a system with which in vivo three-dimensional (3D) measurement of rotation angle of carpal bones can be calculated, and the purpose of this study was to clarify the 3D rotation of each carpal bone during dart-throw motion in vivo.

MATERIALS and METHODS:
Seven wrist joints of healthy male volunteers were included in this study. We developed two original software based on Matlab, and one of them is for the reconstruction of the 3D image of the target bone, and the other is for the measurement of their rotation angle around three axes. At first, we took CT data from the distal forearm to the palm in 2 positions of active and maximum radial extension and ulnar flexion. During the CT examination, the forearm was fixed in 45 degrees pronated position. Then, the CT data was transferred to a personal computer, and the outline of radius, ulna, capitate, lunate, and scaphoid were extracted manually with a use of a commercially available software. After that, the reconstruction of the 3D image of each bone was performed automatically. For the measurement of the 3D rotation angle of carpal bones, we used matching technique. At first, the outline of radius and ulna was matched to set three axes, and then the gravity center and the outline of each carpal bone was matched to measure the rotation angle.

The theory of Euler’s angle was used for the matching technique with which the rotation angle was calculated. The Euler’s angle is used for the orientation of a rigid body in the 3D space, and is calculated by the rotation of the coordinate axes and the molecular axes. It is usually used in the robotics. For the measurement of rotation angle three-dimensionally, the z-axis was defined as the long axis of the distal part of the radius, the y-axis was defined as a line passing both edges of the sigmoid notch of the radius and being perpendicular to the z-axis. The x-axis was defined as a line perpendicular to the other two axes (Fig. 2).

RESULTS: (Fig. 3)
The average rotation angle of capitate was 37 degrees around x-axis, 39 degrees around y-axis, and 1 degree around z-axis. That of lunate was 23 degrees around x-axis, 12 degrees around y-axis, and -2 degrees around z-axis. That of scaphoid was 19 degrees around x-axis, 19 degrees around y-axis, and 10 degrees around z-axis. It was only scaphoid that rotated certainly around z-axis. There was statistically significant difference in the rotation angle around z-axis between lunate and scaphoid.

DISCUSSION:
In the literatures of the kinematic study, scaphoid and lunate move minimally during dart-throw motion, and the possibility of early postoperative rehabilitation along the dart-throw path was described. However, the difference of the rotation around z-axis among carpal bones was not focused on in these studies.

In the present study, capitate rotated almost same around x- and y-axes, and little around z-axis. Lunate rotated mainly around x-axis and little around z-axis. Scaphoid rotated moderately around z-axis. The results mean that during dart-throw motion, capitate and lunate are moving on plain, which means 2-dimensionally, however scaphoid is moving out of plain, which means 3-dimensionally. Scaphoid twists even during dart-throw motion. In other words, partial arthrodesis around scaphoid, with which scaphoid movement is limited, may have large effect on the wrist motion. And care must be taken for the early rehabilitation after the treatment of lesions around scaphoid.

The limitations of this study are, 1. the number of subjects may be limited, 2. this is not a biomechanical study, and is just measuring the rotation angle between two positions, 3. the accuracy of this measurement system is not confirmed yet. However, the movement of capitate was approximate to that of wrist joint, and the error may not be large.

CONCLUSION:
Scaphoid moves peculiarly even during dart-throw motion, and may be the corner stone (bone) for the wrist motion.

REFERENCES: