https://doi.org/10.31705/FOMAAS.2025.012

Kinematic Analysis of the Scaphoid-Trapezium-Trapezoid (STT) Complex in Scapholunate Instability Using Dynamic CT Imaging

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Introduction - Scapholunate Instability (SLI) disrupts the mechanical continuity of proximal row of the wrist. While scaphoid malalignment and abnormal proximal-row behavior have been well documented, the kinematic response of the scapho-trapezio-trapezoid (STT) complex remains poorly defined. This study describes the six degrees of freedom (6-DoF) motion of the STT complex during ulnar-to-radial deviation using dynamic computed tomography (4D-CT).

Materials and Methods - Dynamic CT was acquired during active ulnar-to-radial deviation at 4 frames per second with a slice thickness of 0.6 mm. Datasets were acquired from eight non-arthritic SLI wrists and six normal right wrists. Each time-resolved dataset was processed in 3D Slicer to create segmentations of the radius, capitate, scaphoid, lunate, trapezium and trapezoid. Bone motion was quantified by applying a radius-based coordinate system and using rigid registration (iterative closest point algorithm) to measure 3D angular rotations and centroid translations for each bone.

Results - Compared to normal wrists, SLI wrists showed a characteristic decrease in scaphoid flexion arc. The trapezium and the trapezoid had a decreased translations in the Dorso volar direction compared with normal wrists. These differences indicate measurable changes in the mobility and directional behavior of the distal-row elements when scapholunate stability is compromised.

Discussion - Findings indicate that SLI alters STT kinematics and normal multi-planar mobility. These kinematic signatures emphasize the mechanical interdependence of the distal row in SLI and may refine future approaches to ligamentous reconstruction and carpal instability management.

Keywords - Scapholunate instability, STT complex, dynamic CT, carpal kinematics, ulnar-radial deviation