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ORIGINAL ARTICLE

Three-dimensional scapular dyskinesis in hook-plated acromioclavicular dislocation including hook motion

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Background: The purpose of this study is to analyze the 3-dimensional scapular dyskinesis and the kinematics of a hook plate relative to the acromion after hook-plated acromioclavicular dislocation in vivo. Reported complications of acromioclavicular reduction using a hook plate include subacromial erosion and impingement. However, there are few reports of the 3-dimensional kinematics of the hook and scapula after the aforementioned surgical procedure.
Methods: We studied 15 cases of acromioclavicular dislocation treated with a hook plate and 15 contralateral normal shoulders using computed tomography in the neutral and full forward flexion positions. Three-dimensional motion of the scapula relative to the thorax during arm elevation was analyzed using a computer simulation program. We also measured the distance from the tip of the hook plate to the greater tuberosity, as well as the angular motion of the plate tip in the subacromial space.
Results: Decreased posterior tilting (22° ± 10° vs 31° ± 8°) in the sagittal plane and increased external rotation (19° ± 9° vs 7° ± 5°) in the axial plane were evident in the affected shoulders. The mean values of translation of the hook plate and angular motion against the acromion were 4.0 ± 1.6 mm and 15° ± 8°, respectively. The minimum value of the distance from the hook plate to the humeral head tuberosity was 6.9 mm during arm elevation.
Conclusions: Acromioclavicular reduction using a hook plate may cause scapular dyskinesis. Translational and angular motion of the hook plate against the acromion could lead to subacromial erosion. However, the hook does not seem to impinge directly on the humeral head.

This study protocol was approved by the institutional review board at Kangbuk Samsung Hospital (IRB No. #KBC12114).

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A hook plate without coracoclavicular (CC) ligament repair has been widely used because it can maintain accurate reduction without direct acromioclavicular (AC) joint surface injury.[13] However, limitations include the necessity of hook plate removal, persistent subluxation, acromial and/or clavicular fracture, impingement, and subacromial erosion due to superior displacement of the hook.[1,3-5,15] Meanwhile, we have little information about shoulder motion after AC reduction without CC ligament repair. A few studies using 2-dimensional methods had limitations in the analysis of rotation and translation of scapular motion.[2,7] Some studies have been published about 3-dimensional (3D) biomechanics and dyskinesis of the scapula using various methods, such as a vertically open magnetic resonance imaging unit or 3D computed tomography (CT) scan.[9,11,17,21] An in vivo study has been reported about AC motion in the case of a distal clavicular fracture treated with a hook plate.[12] However, there are few reports of 3D kinematics including scapular dyskinesis in AC dislocation patients treated with a hook plate.

Recently, we reported different patterns of scapular dyskinesis accompanied by clavicular and scapular fractures.[11] For extension of this study, we intended to analyze scapular motion in patients treated with a hook plate without CC repair. In addition, we investigated movement of the hook in the subacromial space quantifiably to evaluate subacromial erosion and impingement related to the hook plate.

The purposes of this study are to analyze the 3D kinematics of the scapula after hook-plated AC dislocation without CC ligament repair in vivo to evaluate scapular dyskinesis and to digitize the motion of the hook plate in the subacromial space. Through this study, we can present the factors affecting subacromial erosion and impingement, as well as data for developing the hook plate design.

Materials and methods

In this retrospective, parallel-design, open-label, observational study, we collected CT images from patients treated for AC dislocation by a hook plate at our institution between January 2012 and July 2014. CT images were obtained from 30 shoulders of 15 patients with AC dislocation who were able to elevate the arm forward to the same degree as the normal contralateral arm without pain. The mean age at evaluation was 48.2 years (range, 36-84 years). The mean time from operation to assessment was 11.2 months (range, 6-12 months). Patients with fractured contralateral upper extremities around the shoulder and shoulder stiffness were excluded.

All patients received a CT scan of the injured and contralateral shoulders including the thorax. Scans were performed in the prone position with soft padding on the chest to evaluate scapular motion accurately. This position avoided impingement of the scapula against the CT table.

Two CT DICOM (Digital Imaging and Communications in Medicine) images (LightSpeed Pro64; Siemens, Erlangen, Germany) were collected, including both shoulders and the thorax, in the neutral and full active forward elevation positions (Fig. 1, *A*). The scanning parameters were as follows: scan time, 60 seconds; scan pitch, 2 mm; tube voltage, 120 kV; tube current, 80 to 100 mA; and slice thickness, 0.5 mm. The CT images were revised in 3D surface models using a 3D simulation program (Bone Viewer and Bone Simulator; Orthree, Osaka, Japan) (Fig. 1, *B*). Two bone models were overlapped on the thorax and analyzed using a marker-less surface registration technique (Fig. 1, *C*), as described previously.[10,16,18]

The motion of each bone was analyzed using a voxel-based registration technique, which used overlapping voxels in the intersection region of the baseline and transforming images using a corresponding method based on correlation between voxel values. We located the surface corresponding to a user-specified value and created triangles. Then, to ensure a quality image of the surface, we calculated the normals to the surface at each vertex of each triangle.[16] Rotation and translation of the scapula were handled as 3D vectors using an anatomic orthogonal reference system modified from the scapular coordinate system of the International Society of Biomechanics.[23]

We defined the Z-axis as the line connecting the trigonum spinae scapulae (the midpoint of the triangular surface on the medial border of the scapula in line with the scapular spine) and the angulus acromialis (AA) (the most posterolateral point of the acromion). We defined the X-axis as a line perpendicular to the reference plane formed by the Z-axis (AA and trigonum spinae scapulae) and the angulus inferior (the most caudal point of the scapula) pointing from AA. Finally, we defined the Y-axis as a line perpendicular to the X- and Z-axes (Fig. 2).

We calculated the rotational movement of the scapula relative to the thorax using the anatomic coordinate system defined earlier. We prescribed the rotational values for upward (+) or downward (−) rotation around the X-axis in the coronal plane (YZ), external (+) or internal (−) rotation around the Y-axis in the axial plane (XZ), and posterior tilt (+) or anterior tilt (−) around the Z-axis in the sagittal plane (XY) in the Euler angle space.[8]

In addition, we measured translational movement along the 3 axes. Lateral (+) or medial (−) translation was measured along the Z-axis, which was the distance from the sagittal plane. Posterior (+) or anterior (−) translation was checked along the X-axis, which was the distance from the coronal plane. Finally, superior (+) or inferior (−) translation was measured along the Y-axis, which was the distance from the axial plane (Figs. 3-5).

The paired *t* test was used for the statistical analysis, and $P < .05$ was considered significant. Data were analyzed using IBM SPSS Statistics (version 24.0; IBM, Armonk, NY, USA).