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ORIGINAL ARTICLE

Isolated ligamentous injury can cause posteromedial elbow instability: a cadaveric study

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Background: Elbow posteromedial rotatory instability (PMRI) is known to occur with fracture of the anteromedial coronoid and injury to the posterior bundle of the medial ulnar collateral ligament (pMUCL). However, whether instability results from isolated pMUCL injury remains unclear. The purpose of this study was to quantify displacement about the ulnohumeral joint to evaluate whether isolated sectioning of the pMUCL results in elbow PMRI.
Methods: Nine cadaveric elbows underwent movements simulating PMRI by application of axial compression with varus and internal rotation moments. Gapping values at both the proximal and distal aspects of the medial ulnohumeral joint were then recorded for "intact" and "pMUCL-sectioned" elbows at positions of 30°, 60°, and 90° of flexion.
Results: After pMUCL transection, torsion increased by 2.6° ± 0.7° ($P = .054$) at 30° and 4.5° ± 1.2° ($P = .039$) at 60° of flexion. Proximal ulnohumeral joint gapping also increased at 30° (1.4 ± 0.4 mm; $P = .039$), 60° (1.5 ± 0.6 mm; $P = .039$), and 90° (1.5 ± 0.7 mm; $P = .017$), respectively. No increases in distal ulnohumeral gapping occurred at any angle of flexion.
Discussion: Sectioning of the pMUCL results in significant increases in torsion and displacement about the proximal ulnohumeral joint. Our findings demonstrate that elbow PMRI can occur secondary to isolated ligamentous injury. Clinicians mindful of this previously unrecognized role of the pMUCL as a stabilizer may wish to consider methods of restoring pMUCL integrity when treating medial elbow instability.
Level of evidence: Basic Science Study; Biomechanics

Keywords: Elbow instability; ligamentous injury; elbow posteromedial rotatory instability; posterior bundle; medial ulnar collateral ligament; biomechanical study

Of the components of the elbow's medial ulnar collateral ligamentous complex, the role of the posterior medial ulnar collateral ligament (pMUCL) has not been characterized. The anterior medial ulnar collateral ligament (aMUCL) is considered a primary stabilizer to valgus instability,[4] with the posterior bundle (pMUCL) deemed a secondary restraint.[2] Whereas several studies have suggested that the pMUCL does play an important role in elbow stability, this assertion has classically been made in the absence of a functioning aMUCL.[1,2,4,7,8] However, more recent data have implicated a new role for the pMUCL in contributing to elbow stability independent of the aMUCL, demonstrating increased rotation between the distal humerus and proximal forearm after isolated pMUCL sectioning.[10] These findings suggest that

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isolated pMUCL injury may represent a previously unrecognized cause of clinically relevant elbow instability, consistent with our clinical observation of persistent posteromedial rotatory instability (PMRI) despite reduction and repair of the coronoid, lateral ulnar collateral ligament (LUCL), and aMUCL in some cases.

Originally described by O'Driscoll et al,[9] PMRI of the elbow has often been described as occurring in the setting of pMUCL injury. However, current descriptions of elbow PMRI have been noted to occur in the setting of fracture, most classically of the anteromedial coronoid facet,[5,9,11,13,14] along with injury of the LUCL. Furthermore, the current literature contains no description of posteromedial-type instability resulting from a purely ligamentous insult, with the possibility of an isolated ligamentous cause of elbow PMRI remaining unclear.

The purpose of this biomechanical cadaveric sectioning study was to assess the potential for isolated pMUCL injury to cause posteromedial-type rotatory instability by employing a custom testing method designed to evaluate gapping about the medial ulnohumeral articulation. We hypothesized that in elbows undergoing a movement pattern simulating a PMRI event, isolated transection of the pMUCL will result in clinically significant gapping and instability at the medial ulnohumeral joint.

Methods

Specimen preparation

Eleven fresh frozen cadaveric elbows were transected at mid-diaphyseal humerus and forearm, with the soft tissue then dissected by layer to the level of the capsule and collateral ligaments. Two specimens were lost during pilot testing, with the remaining 9 cadaveric elbows employed for data collection. Care was taken to sharply remove all muscle tissue while preserving the common extensor origin, with the underlying lateral collateral ligamentous complex remaining intact. Both the humerus and the radius and ulna of each specimen were then secured into custom-made cylindrical aluminum pots and fixed with a polymethyl methacrylate polymer. Direct visualization of the articular surface was achieved by a small anterior capsulotomy to ensure appropriate positioning of the specimen within the pot and to ensure joint congruity at the start of each testing cycle. After secure fixation, a radial osteotomy was performed in each specimen at a point just distal to the bicipital tuberosity to prevent any possible hinging around a fixed radius during testing. Care was taken to ensure that the entire LUCL, including its insertion on the crista supinatoris, remained intact.

Specimen mounting

Each forearm was secured into a dynamic testing apparatus actuator, allowing application of an axial load along with varus and internal rotation in a predefined sequence designed to mimic testing for posteromedial elbow instability.[8] The actuator was located on the top of the machine to execute motion. Elbow specimens were affixed with a clamp to a low-friction X-Y stage, which in turn was mounted to a 6-axis load cell (ATI Industrial Automation, Apex, NC, USA). A custom jig was employed to allow adjustment of elbow flexion, in 15° increments ranging from 0° to 90°. Four 6.4-mm infrared markers were rigidly affixed to the humeral and ulnar sides of the medial elbow to allow real-time tracking of ulnohumeral torsion and displacement. Each marker, labeled A to D, was mounted onto a K-wire drilled into 1 of 4 bone landmarks. Marker A was affixed to the medial epicondyle, with marker B secured to the distal medial trochlea, just proximal to the ulnohumeral joint line. Markers C and D were placed along the ulna, just distal to the joint line at the proximal (marker C) and distal (marker D) extent of the sigmoid notch. These marker positions allowed a composite of 4 measurements to be taken between the 4 respective marker "gaps."

Force application

Figure 1 depicts an elbow specimen just before a testing cycle. After it was confirmed that all markers were detected by each of the 4 system cameras, a posteromedial elbow instability event was simulated by a servohydraulic Materials Testing Machine (Eden Prairie, MN, USA). Each testing cycle consisted of a 25 N · m axial load, followed by 5° of varus bending and 2.5 N · m of internal rotation torque, with programming mandating continued application of each respective force until the defined load was achieved. Forces were applied by an actuator located at the top of the machine that allowed axial loading, torsional rotation, and bending in both the X and Y planes. The collar-clamp containing the radius and ulna of each specimen was secured directly to this actuator, and the humeral collar-clamp was affixed to a jig at the bottom of the testing apparatus.

To ensure the accuracy of each measurement, the calibration was checked before the initiation of each testing cycle. Each specimen was again checked to verify that the joint was congruent and seated in its natural resting position. This was accomplished first through direct visualization and then by performing minor, computerized adjustment of resting rotation of both the forearm and humeral collars. Real-time output from load cells verified that joint reactive forces were as close to zero as possible, with no testing cycle beginning until all torque readings were <0.05 N · m.

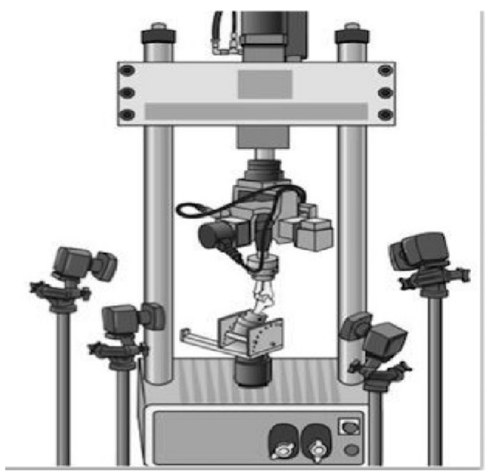

Figure 1 Diagram of a potted elbow specimen secured within the custom collar, positioned within the camera field just before a testing sequence.