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The effect of coronoid fractures on elbow kinematics and stability

Daphne M. Beingessner [a,*], Cynthia E. Dunning [b], Rebecca A. Stacpoole [c], James A. Johnson [b], Graham J.W. King [d]

[a] *Department of Orthopaedics and Sports Medicine, Harborview Medical Center, University of Washington, 325 9th Avenue, Box 359798, Seattle, WA 98104, USA*
[b] *Department of Mechanical and Materials Engineering, The University of Western Ontario, London, Ont., Canada*
[c] *Department of Biomedical Engineering, The University of Western Ontario, London, Ont., Canada*
[d] *Division of Orthopedic Surgery, The University of Western Ontario, London, Ont., Canada*

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Abstract

Background. Coronoid fractures often occur in the setting of more complex elbow trauma. Little is known about the influence of coronoid fracture size on elbow kinematics, particularly in the setting of concomitant ligament injuries. The purpose of this study was to determine the effect of coronoid fractures on elbow kinematics and stability in ligamentously intact and medial collateral ligament deficient elbows and to determine the effect of forearm position on elbow stability in the setting of coronoid fracture.

Methods. Eight cadaveric arms were tested during simulated active dependent elbow motion and gravity-loaded passive elbow motion. Kinematic data were collected from an electromagnetic tracking system. The protocol was performed in ligament origin repaired and medial collateral ligament deficient elbows with radial head arthroplasty. Testing was carried out with the coronoid intact, and with 10% (Type I), 50% (Type II), and 90% (Type III) removed. Varus-valgus angulation of the ulna relative to the humerus and maximum varus-valgus laxity were measured.

Findings. With repaired ligament origins and medial collateral ligament deficiency, there was increased varus angulation and increased maximum varus-valgus laxity following simulation of a Type II and Type III coronoid fracture. There was less kinematic change with the forearm in supination than in pronation.

Interpretation. Elbow kinematics are altered with increasing coronoid fracture size. Repair of Type II and Type III coronoid fractures as well as lateral ligament repair is recommended where possible. Forearm supination may be considered during rehabilitation following coronoid repair. Valgus elbow positioning should be avoided if the medial collateral ligament is not repaired.
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Keywords: Coronoid fracture; Elbow stability; Biomechanics

1. Introduction

Coronoid fractures are uncommon in isolation (Hanks and Kottmeier, 1990), typically occurring in the setting of more complex elbow trauma (Morrey, 1998; Terada et al., 2000; Josefsson et al., 1989; Hildebrand et al., 1999). They commonly occur with injuries to the collateral ligaments and may be associated with the "terrible triad": elbow dislocation, radial head fracture and coronoid fracture (Morrey, 1998; Hildebrand et al., 1999; Pugh et al., 2004). Clinical experience with these combined injuries has demonstrated the importance of repair or replacement of the radial head, ligament repair, and fixation of larger coronoid fragments (Ring et al., 2002; Pugh et al., 2004).

Currently, the influence of coronoid fracture size on elbow stability and kinematics, particularly in the setting of concomitant injuries to the ligaments, is not known. There are little biomechanical data available to direct

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[*] Corresponding author.
E-mail address: daphneb@u.washington.edu (D.M. Beingessner).

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clinical practice (Closkey et al., 2000; Schneeberger et al., 2004). The first objective of the current study was to determine the effect of coronoid fractures on elbow kinematics and stability in ligamentously intact and medial collateral ligament (MCL) deficient elbows, combined with radial head replacement. The second objective was to determine the effect of forearm position on the kinematics and stability of the coronoid-deficient elbow. We hypothesized that increasing coronoid fracture size would decrease elbow stability and that elbows would be further destabilized when coronoid fractures were combined with MCL disruption.

2. Methods

Eight unpreserved cadaveric upper extremities (mean age 72 years, [range 61–80]) were amputated at mid-humerus and stored at −20 °C prior to use. The specimens were thawed for 18 h at room temperature (22 ± 2 °C) and prepared for mounting on an elbow testing apparatus (Milne et al., 2001; Johnson et al., 2000) (Fig. 1). Stainless steel cables were sutured to the distal tendons of the biceps, brachialis, brachioradialis, triceps, and pronator teres. The cables for pronator teres and brachioradialis were routed through the humeral canal via Delrin® (Dupont, Wilmington, DE, USA) sleeves inserted into the medial and lateral supracondylar ridges. Skin incisions were closed and the specimen was kept moist using 0.9% normal saline solution throughout testing.

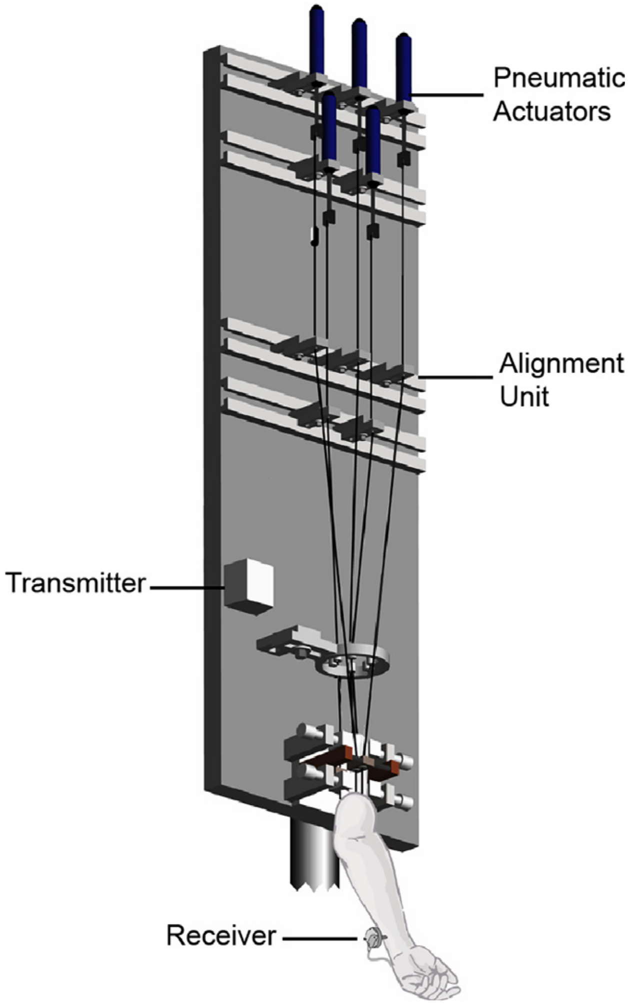

Fig. 1. Custom elbow jig used for testing kinematics and stability.

The humerus was mounted in the testing apparatus in neutral position using a clamp that rigidly held the arm while allowing unconstrained elbow motion (Milne et al., 2001; Rath, 1997). To simulate active joint motion, the tendon cables were attached to computer-controlled pneumatic actuators. The lines of action for the biceps, brachialis, and triceps cables were controlled using an alignment unit previously described (Dunning et al., 2001a,b; Johnson et al., 2000). While the positions of the force vectors that occur anatomically could not be precisely duplicated, they were kept constant throughout testing and were similar to those published by An (An et al., 1981). A hinge on the base plate of the testing device allowed placement of the arm in the dependent position for active elbow simulation and in varus and valgus gravity-loaded positions. To simulate active elbow motion in the dependent position, the pneumatic actuators applied prescribed forces to the tendons, to position the arm in pronation or supination and the elbow then moved through an arc from full extension to full flexion. The muscle loading protocol was based on electromyographic data and an in vitro testing system developed in our laboratory (Johnson et al., 2000; Dunning et al., 2001a,b). We tested varus-valgus laxity by placing the elbow in the varus or valgus gravity-loaded position. For each motion, the tester (DMB) maintained the forearm in full pronation or supination and passively flexed the elbow from full extension to full flexion by grasping the wrist.

Medial and lateral epicondyle osteotomies were performed to simulate MCL deficiency and to gain access to the radial head and coronoid, respectively. Care was taken to leave the ligaments and common flexor/extensor origins attached to the osteotomy fragments. The osteotomies were securely repaired using 3.5 mm cortical screws (Synthes Canada, Mississauga, ON, Canada) to reattach the collateral ligaments and muscle origins. The screw-holes were reinforced with bone cement to ensure consistent rigid anatomic osteotomy repair throughout testing.

Dependent-position active testing was performed in the fully intact elbow, stable elbow (both osteotomies repaired) with radial head replacement, and the MCL deficient elbow (osteotomized lateral collateral ligament (LCL) origin repaired) with radial head replacement. Gravity-positioned varus-valgus testing was performed in the intact, stable and MCL deficient elbows with radial head replacement. For each elbow, the radial head was removed to facilitate coronoid osteotomies and it was replaced with a metallic radial head arthroplasty (Evolve®, Wright Medical Technology, Arlington, TN, USA) for testing. Four coronoid states were tested based on the classification of Regan and Morrey (Regan and Morrey, 1992). The base of the

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