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ORIGINAL ARTICLE

Coronoid reconstruction using osteochondral grafts: a biomechanical study

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Hypothesis: The purposes of this study were to test the hypothesis that coronoid deficiency in the setting of posteromedial rotatory instability (PMRI) must be reconstructed to restore articular contact pressures to normal and to compare 3 different osteochondral grafts for this purpose.

Methods: After creation of a anteromedial fracture, six cadaveric elbows were tested under gravity varus stress using a custom-made machine designed to simulate muscle loads and to passively flex the elbow. Mean articular surface contact pressure data were collected and processed using TekScan sensors and software. After testing of the intact specimen (intact condition), a PMRI injury was created (PMRI condition). Testing was repeated after reconstruction of the lateral collateral ligament (LCL) (LCL-only condition), followed by reconstruction of the coronoid with 3 different osteochondral graft techniques (reconstructed conditions).

Results: Contact pressure was consistently significantly higher in the PMRI elbow compared with the intact, LCL-only, and reconstructed conditions ($P < .006$). The LCL-only elbow contact pressure was significantly higher than that of the intact and reconstructed conditions from 5° to 55° of flexion ($P = .018$). The contact pressure of the intact elbow was never significantly different from that of the reconstructed elbow, except at 5° of flexion ($P \leq .008$). No significant difference was detected between each of the reconstructed techniques ($P \geq .15$). However, the annular surface of the radial head was the only graft that yielded contact pressures not significantly different from normal at any flexion angle.

Conclusion: Isolated reconstruction of the LCL did not restore native articular surface contact pressure, and reconstruction of the coronoid using osteochondral graft was necessary. There was no difference in contact pressures among the 3 coronoid reconstruction techniques.

Level of evidence: Basic Science Study; Biomechanics

Keywords: Elbow; posteromedial rotatory instability; coronoid deficiency; osteochondral graft; lateral collateral ligament; contact pressure; congruity

This cadaveric study was conducted under protocol number 10-008186, which was approved by the Mayo Clinic Biospecimen Committee on December 17, 2010.

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Coronoid deficiency is one of the most challenging scenarios even for the most experienced and skilled elbow surgeon. It is typically a chronic condition, often associated with subluxation, persistent dislocation, and/or early ulnohumeral degenerative changes.[11,36,43,47] Several surgical methods have been described to treat it, such as techniques using the soft tissue around the elbow,[21,40] coronoid replacement,[2,15] or bone grafts,[7,9,10,13,16,18,22-24,34,42,43,47,49,50] with the orthopedic community's interest mostly focused on the latter. However, because this condition is uncommon, few data are available in the literature, which consists mostly of case reports and small case series.

Some biomechanical studies have been performed to test coronoid reconstruction using grafts, with particular focus on the tip of the olecranon graft.[1,39,45] However, to our knowledge, only 2 studies have compared different graft types. Schneeberger et al[45] tested the use of a coronoid graft and tested the use of the olecranon tip in a biomechanical model simulating a terrible-triad injury with a coronoid deficiency of 70%; the first technique restored elbow stability. However, the aim of the study was not to perform a comparison of different grafts but rather to investigate the function of the radial head and the coronoid in posterolateral rotatory instability. Kataoka et al[20] compared the articular coronoid facet configuration between the olecranon tip, the lateral radial head, and the proximal radial head. Their study concluded that the olecranon graft was most suitable for defects involving the tip of the coronoid. However, this was a 3-dimensional computed tomography scan study performed on normal elbows.

Posteromedial rotatory instability (PMRI) of the elbow is characterized by an anteromedial coronoid fracture associated with tears of the lateral collateral ligament (LCL) and the posterior bundle of the medial collateral ligament (MCL).[5,31,33,37,48] If these injuries are left untreated, early-onset arthritic changes have been reported.[11,33,41,44,47,48] Therefore, they represent the most common situation in which coronoid reconstruction would be needed.

This study has 2 aims: (1) to test the hypothesis that, in the elbow affected by coronoid deficiency with PMRI, an isolated LCL reconstruction is not sufficient to adequately restore articular contact pressure and that a further reconstruction of the coronoid using osteochondral grafts is necessary and (2) to compare the articular contact pressure of the elbow after 3 different coronoid reconstructions—2 radial head graft methods as conceived by Ring et al[42] and O'Driscoll and colleagues[6] and a third method that uses the posteromedial portion of the olecranon.

Materials and methods

Specimen preparation

Eight fresh-frozen cadaveric male limbs from fingertip to midhumerus were thawed at room temperature overnight prior to the experiment (average age, 85 ± 2 years). All data are presented as mean ± standard error. None of the specimens had a flexion contracture of more than 10°, a pronation-supination rotation arc of less than 140°, or radiologic evidence of arthritis or deformity. The skin and subcutaneous fat were removed from the midhumerus to 5 cm distal to the elbow joint. The biceps, brachialis, and triceps muscle bellies were removed, while their tendon insertions were preserved and prepared with locking Krackow stitches using a 36-kg test braided polyester fishing line. The humeral origins of the flexor-pronator and the extensor supinator muscles were preserved. Any specimen with cartilage erosion to the subchondral bone was excluded; however, specimens exhibiting only shallow erosion with fibrillation and fissuring with normal joint contact were included. Any specimen with ligament insufficiency, detected by either direct visualization of the ligaments or performance of the posterolateral rotatory drawer test,[32] was excluded. The proximal humeral end of the specimen was then potted into a cylindrical metal sleeve in parallel to its long axis using polyurethane resin (Smooth-Cast 65D; Techno-Industrial Products, Hartland, WI, USA) to fix and load the specimen onto the testing machine.[4] A transverse olecranon osteotomy was made at the apex of the ulnar bare spot to allow the insertion of the pressure transducer.

Pressure transducer

A TekScan 5051 thin-film pressure transducer (TekScan, South Boston, MA, USA) with a saturation pressure of 8.3 MPa (1200 psi) was prepared and inserted into the joint from anterior to posterior as previously reported.[5] To permit placement of the pressure transducer while minimizing the wrinkles therein, the anterior capsule was excised. The anterior bundle of the MCL (medially) and the radial portion of the LCL (laterally) were used as landmarks to perform the anterior capsulectomy. The sensor was inserted from anterior to posterior, until the end of the sensor reached the olecranon osteotomy line and covered both the ulnohumeral and radiocapitellar articulations. Then, an olecranon plate (Olecranon Plate LCP, 3.5 mm; AO Synthes, Oberdorf, Switzerland) was used to fix the osteotomy. Rigid fixation of the olecranon osteotomy prevented macroscopic movements across the olecranon fracture site. The thin-film TekScan sensor has been validated for measuring pressure in rounded contact areas[12] and used in earlier reports of joint contact pressures,[8,30] specifically including use within the elbow.[4,5] Each 5051 sensor has one 56 × 56–mm matrix (196 mm^2), comprising 1936 sensels (individual detection units of pressure) located on conductive ink grids. The 5051 sensors were preconditioned and calibrated according to the manufacturer's recommendations. The calibration was performed with TekScan I-Scan software using an MTS machine (MTS Systems, Eden Prairie, MN, USA) to apply 8 sequential loads to the sensor while it was sandwiched between 2 layers of 1.6-mm rubber membrane, which was in turn sandwiched between 2 polished aluminum plates. The calibration loads ranged from 690 to 5520 kPa (100 to 800 psi) and were applied in 690-kPa (100-psi) increments. Because it is recommended that sensors be calibrated under conditions that mimic those encountered during testing,[46] the membrane-aluminum calibration construct was chosen to mimic the cartilage–subchondral bone conditions of the elbow joint. The TekScan contact pressure data were captured at a frequency of 100 Hz.

Specimen mounting, motion simulation, and flexion-extension angle detection

The specimen was mounted on a custom-made machine (Fig. 1) designed to test the elbow while it was passively flexed from 0° to