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ORIGINAL ARTICLE

Effect of radiocapitellar Achilles disc arthroplasty on coronoid and capitellar contact pressures after radial head excision

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Background: Long-term radiographic arthritis has been commonly reported after radial head excision. Concern over radial head arthroplasty may arise in certain situations including capitellar arthritis, radiocapitellar malalignment, and in young and active patients. We hypothesized that radial head excision increases coronoid contact pressures, which may at least be partially reduced by radiocapitellar Achilles tendon disc arthroplasty.
Methods: Coronoid and capitellar contact pressure was measured on 6 human cadaveric elbows on a custom-designed gravity-valgus simulator under passive flexion from 0° to 90°. Sequential testing, starting with the intact specimen, resection of the radial head, and finally, radiocapitellar Achilles tendon disc arthroplasty were performed on each specimen.
Results: Mean contact pressure of the coronoid significantly increased after radial head excision ($P < .0001$) and significantly improved after Achilles disc arthroplasty ($P < .0001$). The pressure difference was most pronounced on the lateral coronoid. From 15° to 85° of elbow flexion, mean contact pressures on the lateral coronoid were 291 kPa and 476 kPa before and after radial head excision, respectively ($P < .0001$). Achilles disc arthroplasty significantly lowered coronoid contact pressures to 385 kPa ($P = .002$); however, they remained significantly higher than those in the intact radial head group ($P = .0009$).
Conclusions: Radial head resection increases contact pressure in the coronoid, especially the lateral coronoid. This study showed that radiocapitellar Achilles disc arthroplasty significantly improves contact pressures on the coronoid after radial head resection. Achilles disc arthroplasty could be considered in patients who are not candidates for radial head arthroplasty.
Level of evidence: Basic Science Study; Biomechanics

Keywords: Elbow; radial head; radiocapitellar joint; coronoid; contact pressure; Achilles tendon; radiocapitellar Achilles disc arthroplasty; biomechanics

Although radial head excision is often performed to treat comminuted radial head fractures and sometimes for radiocapitellar arthritis, there is the potential for multiple complications such as elbow instability, elbow stiffness, and proximal migration of the radius.[16,17] The radial head is

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considered to bear approximately 60% of the axial load across the elbow, depending on conditions such as varus or valgus loading.[11] Excision of the radial head alters the mechanics of load-bearing across the elbow, theoretically resulting in increased load on the coronoid, which might explain the high prevalence of late-term arthritis in such patients.[13,15,19] For this reason, there has been a growing interest in preserving or restoring the capacity of the radiocapitellar joint for load bearing.

Radial head prosthetic replacement can be problematic in patients with a damaged capitellar articular surface or radiocapitellar malalignment.[28] Radiocapitellar unicompartmental arthroplasty is another potentially attractive option, but concerns exist regarding implant longevity, especially on the radial side.[10,27] As an alternative to excision or prosthetic replacement, some surgeons have performed interposition arthroplasty using an anconeus muscle flap.[3,24] Concerns with this technique include violation of the lateral collateral ligament complex and atrophy of the transferred muscle. An alternative would be to use allograft tissue that might fit into the cavity created by radial head excision, without altering the lateral collateral ligament or the vascularity of the anconeus.

The present study tested the following hypotheses: (1) radial head excision results in an increase in ulnohumeral joint contact pressure with valgus loading, and (2) radiocapitellar Achilles tendon disc arthroplasty reduces the increased coronoid contact pressure after radial head excision.

Materials and methods

Specimen preparation

The study used 6 fresh-frozen cadaveric upper limbs (3 right and 3 left arms) from male donors who were a mean age of 80 ± 8 years. The specimens were thawed overnight for 12 hours at room temperature before the experiment. Each specimen was examined to have a normal range of motion. None of the specimens demonstrated a flexion contracture of more than 10°, a pronation-supination rotation arc of less than 140°, or radiologic evidence of arthritis or deformity under C-arm fluoroscopy.[5]

Each specimen was carefully dissected to remove the skin and subcutaneous fat from the middle humerus to 5 cm distal of 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 braided 36-kg test polyester fishing line. The humeral origins of the flexor-pronator and the extensor-supinator muscles were preserved.[5] To permit placement of the pressure transducer, the anterior capsule was excised, taking care not to injure the collateral or annular ligaments. Any specimen with cartilage erosion to the subchondral bone was excluded, but we did not discard specimens exhibiting shallow erosion with fibrillation and fissuring with normal joint contact.[5] Any specimen with ligament insufficiency was excluded using the posterolateral rotatory drawer test or the direct observation of ligaments.

The proximal humeral end of the specimen was potted into a cylindrical metal sleeve in parallel to its long axis using polyurethane resin (Smooth-Cast 65D; Techno-Industrial Products, Inc., Hartland, WI, USA) to fix and load the specimen onto the testing machine.[5] A lateral column humeral osteotomy was made, and a 2-mm groove created in the bare area of olecranon. A Tekscan 5051 thin-film pressure transducer (Tekscan, South Boston, MA, USA) was inserted, from anterior to posterior after anterior capsule excision, until the end of the sensor reached the olecranon bare area groove and covered both the ulnohumeral and the radiocapitellar articulations.

The lateral column osteotomy was fixed with 3 screws and washers (1 Arbeitsgemeinschaft für Osteosynthesefragen [AO] 3.5-mm cancellous screw for intercondylar fixation and 2 AO 3.5-mm cortical screws for distal humerus fixation). The 5051 sensors were preconditioned and calibrated according to the manufacturer's recommendations.

Pressure transducer

A Tekscan 5051 thin-film pressure transducer with a saturation pressure of 8.3 MPa (84.4 kg/cm^2) was prepared and inserted into the joint from anterior to posterior, as previously reported.[2] The osteotomized lateral humeral condyle was fixed with 3 screws, as stated above, and the sensor was secured in place by fixing to 2 proximal screws in the proximal posterior aspect of ulna. The thin-film Tekscan sensor has been validated for measuring pressure in rounded contact areas[7] and has been used in earlier reports of joint contact pressures,[6,22] specifically including use within the elbow.[2] Each 5051 sensor has one 56-mm × 56-mm matrix (196 mm^2), consisting of 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 the Tekscan I-Scan software using an MTS machine (MTS Inc., 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 (7 to 56 kg/cm^2) and were applied in increments of 690 KPa (7 kg/cm^2). Because it is recommended that sensors be calibrated under conditions that mimic those encountered during testing,[31] a rubber membrane-aluminum block 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 and testing

The specimen was mounted on a custom-made machine designed to test the elbow while it was passively flexed from 0° to 90° at 90° of humeral external rotation.[2] This places the medial epicondyle upward and the transcondylar axis perpendicular to the floor for gravity valgus loading (Fig. 1). The biceps, brachialis, and triceps were connected to Airpel pneumatic pistons (Airpot Corp., Norwalk, CT, USA) to simulate muscle loads intended to provide dynamic joint stability. Force was applied in a 1:1:2 ratio, with the brachialis, biceps and triceps receiving 25, 25, and 50 N, respectively.[2,8,18,20,26] These values were selected after pilot study tests were performed evaluating different loads.

The distance of each pulley from the joint line and humeral axis was set to simulate the physiologic position of the tendons[1] 5.5 cm proximal to the joint line. The brachialis, biceps, and triceps pulleys were set at 2, 3.5, and 2 cm away from the humeral axis, respectively. The elbow was passively flexed by pulling a braided 36-kg test polyester line perpendicular to the forearm over the range of