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Hemiarthroplasty of the elbow: the effect of implant size on joint congruency

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Background: Distal humeral hemiarthroplasty is a treatment option for elbow joint disease that predominantly affects the distal humerus, including distal humerus fractures, nonunions, and avascular necrosis. The effect of hemiarthroplasty implants on joint contact has not been reported. The purpose of this in vitro study was to quantify the effects of hemiarthroplasty and implant size on ulnohumeral joint congruency.

Methods: Five fresh frozen cadaveric upper extremities were mounted to a custom elbow testing system. Active and passive motion were performed in dependent, horizontal, varus, and valgus positions. A registration and interbone distance algorithm was used to quantify ulnohumeral joint congruency throughout elbow flexion.

Results: The optimally sized hemiarthroplasty implant demonstrated the greatest joint congruency with the ulna, followed by the oversized implant, then the undersized implant. Joint congruency was greater during active vs. passive flexion, indicating that the elbow joint is more reduced in active flexion than in passive flexion.

Conclusion: This study demonstrates that undersized distal humeral hemiarthroplasty implants have the lowest joint congruency compared with an optimally sized or oversized implant.

Level of evidence: Basic Science Study, Kinesiology, Cadaver Model.

Keywords: Elbow hemiarthroplasty; joint congruency

There has recently been an increased interest in distal humeral hemiarthroplasty as a less invasive alternative to total elbow arthroplasty. Distal humeral hemiarthroplasty may be ideal in situations in which only the distal humeral articular surface is affected. This includes distal humerus fractures not amenable to open reduction and internal fixation, avascular necrosis, and nonunions. Distal humeral

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hemiarthroplasty has the advantage of being a less invasive surgical procedure, decreasing patient morbidity, avoiding concerns surrounding polyethylene wear, and preserving the bone stock for future reconstructive procedures.[13,20]

The current literature on distal humeral hemiarthroplasty is limited. Clinical studies to date have small samples sizes, variable implants, short-term follow-up, and inconsistent indications for surgery.[1,2,13,21,25,27-31] Articular wear from abnormal contact of the metallic implant on the proximal radius and ulna is a long-term concern.[29] A recent biomechanical study on distal humeral hemiarthroplasty demonstrates its limitations in restoring normal elbow kinematics.[5] The purpose of this study was to determine the influence of distal humeral hemiarthroplasty and implant size on ulnar joint congruency in vitro.

Methods

This in vitro study examined the effect of distal humeral hemiarthroplasty on joint congruency using 5 fresh, previously frozen male cadaveric arms (74.1 ± 6.4 years) amputated at the midhumerus. A 64-slice computed tomography (CT) scan was performed on each arm (GE LightSpeed Ultra; General Electric, New Berlin, WI, USA). A 3-dimensional (3D) surface model was generated of the distal humerus and proximal ulna (Visualization Toolkit, VTK; Kitware Inc, Clifton Park, NY, USA) from CT scan Digital Imaging and Communications in Medicine data. A preoperative surgical plan was conducted using the 3D reconstructed bone model. The distal humerus hemiarthroplasty component size was selected using the geometric center of the capitellum and trochlea based on the 3D model. Points were identified on the capitellar and trochlea surface, and a semiautomated algorithm created a point cloud over the capitellum and trochlear groove. The geometric center was found using a sphere-fit of the capitellum and a circle-fit of the trochlear groove. The size of the native distal humerus was based on the distance between these 2 points and then compared with the 6 available implants to determine the optimal implant size (Latitude Anatomic; Tornier, Inc, Stafford, TX, USA).

Before testing, specimens were thawed at room temperature (mean, 22°C ± 2°C) for 18 hours. Normal saline was used throughout the testing protocol to keep the specimen well hydrated. The tendons of the biceps, triceps, and brachialis were sutured with a locking Krackow technique.[14] A Steinmann pin was placed through the third metacarpal into the distal radius to fix the wrist in neutral flexion and extension. The forearm was also fixed in neutral rotation by placing 2 fully threaded 3.5-mm cortical screws across the distal radioulnar joint.

An in vitro unconstrained elbow simulator was used (Fig. 1).[10] The humerus was mounted in the simulator. The sutures from the tendons were connected to servomotors by braided Dacron cords. The servomotors applied forces to the tendons that moved the elbow from full extension to full flexion and vice versa at a controlled rate (10°/s). The motion simulation was based on electromyographic data and muscle cross-sectional area.[11,15] Elbow motion was simulated with the humerus in the horizontal position. Two optical position sensors were used. One sensor was rigidly fixed to the ulna using a bone-fixated mounting pedestal; the other sensor was mounted on the base of the simulator adjacent to the humerus.

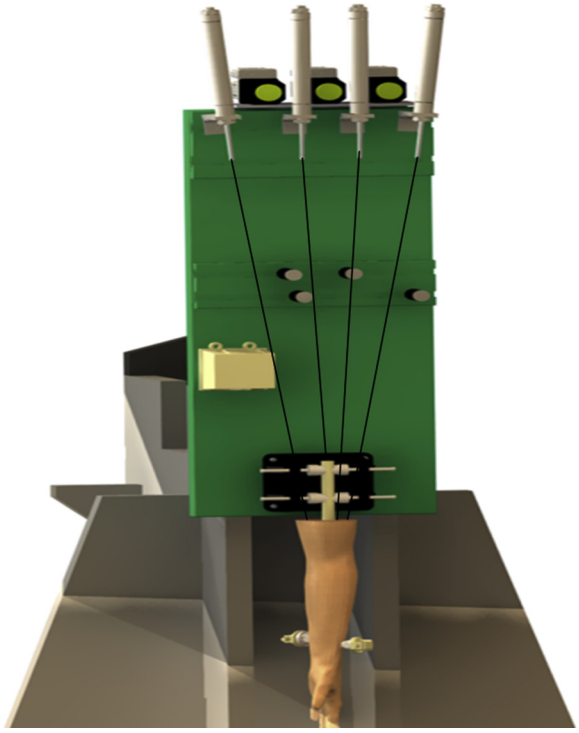

Figure 1 Schematic diagram of the elbow motion simulator in the dependent position.

The distal humeral hemiarthroplasty stem was then surgically implanted. The elbow was approached through a midline posterior incision. The subcutaneous border of the ulna was identified, and a chevron-type olecranon osteotomy was performed to access the distal humerus while maintaining the integrity of the collateral ligaments. The distal humeral cuts were made per the manufacturer's protocol. A medium humeral stem (Latitude, Tornier) was shortened for ease of placement into the humeral canal. The stem was cemented under computer navigation as previously described,[5] to maximize the accuracy and reproducibility of stem placement.[23] The optimally sized implant and the implants that were 1 size too small and 1 size too large were tested in random order. The stem was cemented and used for the entire testing protocol. The stem had a custom locking mechanism that allowed the various humeral articular components to be locked to the same stem. The osteotomy was secured with a