SCIENTIFIC ARTICLE

Effect of Radial Head Implant Shape on Radiocapitellar Joint Congruency

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Purpose Radial head arthroplasty is indicated in displaced fractures in which comminution precludes successful internal fixation. Many types of radial head implants have been developed varying in material, methods of fixation, and degrees of modularity and geometry. The purpose of this study was to investigate the effect of radial head implant shape on radiocapitellar joint congruency.

Methods Joint congruency was quantified in 7 cadaveric specimens employing a registration and inter-surface distance algorithm and 3-dimensional models obtained using computed tomography. Forearm rotation was simulated after computer-guided implantation of an axisymmetric radial head, a population-based quasi-anatomic radial head implant, and a reverse-engineered anatomic radial head implant. Inter-surface distances were measured to investigate the relative position of the radial head implant and displayed on 3-dimensional color-contour maps. Surface area was measured for inter-surface distances (1.5 mm) and compared for each radial head geometry.

Results There were no statistical differences in the contact surface area between radial head implants during active or passive forearm rotation. The joint was more congruent (larger contact surface area) during active forearm rotation compared with passive forearm rotation.

Conclusions This study investigated the effect of implant geometry on the radiocapitellar joint contact mechanics by examining a commercially available radial head system (axisymmetric), a quasi-anatomic design, and an anatomic reverse-engineered radial head implant. We found no statistical differences in radiocapitellar joint contact mechanics as measured by 3-dimensional joint congruency in cadaveric specimens undergoing continuous simulated forearm rotation.

Clinical relevance The importance of choosing an implant that matches the general size of the native radial head is recognized, but the degree to which it is necessary to create an implant that replicates the native anatomy to restore elbow stability and prevent cartilage degenerative changes remains unclear. This study concluded that the geometry of the implant did not have a statistically significant effect on joint contact mechanics; therefore, future work is needed to examine additional factors related to implant design, such as material choice and implant positioning to investigate their influence on joint contact mechanics. *(J Hand Surg Am. 2017;■(■):1.e1-e11. Copyright © 2017 by the American Society for Surgery of the Hand. All rights reserved.)*

Key words Radius, arthroplasty, 3-dimensional reconstruction, computed tomographic imaging, joint contact mechanics.

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RADIAL HEAD ARTHROPLASTY IS INDICATED for displaced fractures in which comminution precludes successful internal fixation. A variety of radial head implants have been developed that vary in material,[1–7] methods of fixation,[1,2,5–7] and degrees of modularity.[1,2,5] Current radial head designs also vary in geometry.[1,2,4]

Previous anthropometric studies showed that the radial head is not only circular, it is consistently elliptical.[8,9] The radial head articulates with the capitellum of the distal humerus as well as the lesser sigmoid notch of the proximal ulna. As such, alterations in the articular geometry of the radial head implant are likely to have implications for the joint mechanics. Previous studies showed that radial head implants can induce degenerative,[4–7] erosive,[10] and osteopenic changes in the capitellum.[5,6] Degenerative changes are thought to occur as a result of altered joint contact area and stresses caused by the implant. Erosion of the cartilage may occur because of the introduction of a stiff metal implant articulating with the native capitellum and overstuffing of the joint with an improperly sized radial head implant.[5,10]

The importance of choosing an implant that matches the general size of the native radial head is recognized, but the degree to which it is necessary to create an implant that replicates the native anatomy to restore elbow stability and prevent cartilage degenerative changes remains unclear. A previous experimental study employed casting techniques to examine the effect of radial head geometry on radiocapitellar joint contact area after computer-assisted implantation of a reverse-engineered anatomic implant, a quasi-anatomic population-based implant, and a commercially available axisymmetric implant.[11] That previous study was limited to a statically loaded forearm model. More recently, noninvasive imaging techniques have been developed to quantify joint congruency using novel inter-surface distance and registration.[12]

The purpose of this study was to investigate the effect of implant shape on radiocapitellar joint congruency using a forearm motion simulator under continuous forearm rotation.

MATERIALS AND METHODS

Radial head implants

The radial head implant system designed for this study consisted of a generic stem and 3 radial head implant designs. The custom-made generic stem was previously described[9] and had a squared base with fiducial marks indented into the surface that could be used for navigation. The radial head implants were formed of ABS M30 plastic using a rapid prototyping machine.[11,13] A tracked stem implantation device with an optical tracker was used to position the generic stem before fixation.

Reverse-engineered anatomic implant

To create the reverse-engineered anatomic implants, 3-dimensional computed tomography (CT) bone models were obtained from each cadaveric specimen and used along with the rapid prototyping machine to fabricate a reverse-engineered radial head implant specific for each elbow.[9,11,13]

Population-based quasi-anatomic

A previously developed population-based radial head implant was used in this study. We obtained morphologic measurements ($n = 50$) using 3-dimensional CT bone models obtained from cadaveric specimens (aged 73 years; 34 males and 16 females). The shape of the radial head was estimated by fitting ellipses on serial cross-sections on 3-dimensional bone models.[9,11,13]

Axisymmetric implant

The commercially available axisymmetric radial head implant examined in this study is manufactured in cobalt chromium (Evolve Modular Radial Head System; Wright Medical, Arlington, TN).[9,11,13] The reverse-engineered and quasi-anatomic implants were rapid prototyped and therefore were fabricated in ABS M30 plastic. To ensure that the material properties were consistent among the 3 types of implants, the commercially available implant was replicated in ABS M30 plastic such that comparisons in joint congruency among implants were a result of differences in implant geometry and not the material.

Specimen preparation and experimental protocol

Figure 1 shows an overview of the experimental protocol and data analysis. Volumetric images were obtained for each specimen using a 64-slice x-ray (CT) scanner (Discovery CT750HD; GE, Waukesha, WI) (field of view: 20×20 cm, 512×512 reconstruction matrix, 200 mA and 120 kVp). Voxel size was approximately $0.40 \times 0.40 \times 0.623$ m.

Seven right fresh-frozen cadaveric specimens (aged 73 years [range, 57–84 years], male) were thawed at room temperature for approximately 20 hours and then were surgically prepared for the elbow motion simulator. The tendons of the triceps, biceps, and pronator teres were isolated and sutured to cables that attached to servo motors and actuators on the motion simulator. The specimen was then mounted to the elbow motion simulator, which was positioned in the

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