SCIENTIFIC ARTICLE

Effect of Radial Head Implant Shape on Joint Contact Area and Location During Static Loading

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Purpose To examine the effect of implant shape on radiocapitellar joint contact area and location in vitro.

Methods We used 8 fresh-frozen cadaveric upper extremities. An elbow loading simulator examined joint contact in pronation, neutral rotation, and supination with the elbow at 90° flexion. Muscle tendons were attached to pneumatic actuators to allow for computer-controlled loading to achieve the desired forearm rotation. We performed testing with the native radial head, an axisymmetric implant, a reverse-engineered patient-specific implant, and a population-based quasi-anatomic implant. Implants were inserted using computer navigation. Contact area and location were quantified using a casting technique.

Results We found no significant difference between contact locations for the native radial head and the 3 implants. All of the implants had a contact area lower than the native radial head; however, only the axisymmetric implant was significantly different. There was no significant difference in contact area between implant shapes.

Conclusions The similar contact areas and locations of the 3 implant designs suggest that the shape of the implant may not be important with respect to radiocapitellar joint contact mechanics when placed optimally using computer navigation. Further work is needed to explore the sensitivity of radial head implant malpositioning on articular contact. The lower contact area of the radial head implants relative to the native radial head is similar to previous benchtop studies and is likely the result of the greater stiffness of the implant.

Clinical relevance Radial head implant shape does not appear to have a pronounced influence on articular contact, and both axisymmetric and anatomic metal designs result in elevated cartilage stress relative to the intact state. *(J Hand Surg Am. 2015;40(4):716–722. Copyright © 2015 by the American Society for Surgery of the Hand. All rights reserved.)*

Key words Biomechanics, elbow, radial head arthroplasty, computer-assisted orthopedic surgery, joint contact.

THE RADIAL HEAD HAS A COMPLEX and variable shape.[1,2] Numerous elbow morphology studies have reported that the radial head is elliptical[3–5]; however, most commercially available radial head implants are symmetric about a central axis, or axisymmetric. Only one anatomical asymmetric design is currently commercially available.[6] In some systems, the implant stem is smooth and purposely placed loosely, because small amounts of stem movement in the radial neck may compensate for the non-anatomic shape.[7] Other axisymmetric implants have a bipolar

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articulation, containing a joint between the stem and the radial head to optimize joint contact, but have a potential risk of polyethylene wear and provide less contribution to radiocapitellar stability.[6,8,9] Another group of axisymmetric implants aims for secure stem fixation, most commonly with uncemented ingrowth stems.[6] When anatomic asymmetrical designs are used, it is essential that they be positioned and fixed in the correct location to ensure proper joint alignment and hence optimize radiocapitellar contact.[10]

The contact of a metallic radial head on articular cartilage can be expected to alter joint contact patterns owing to the stiffness of the implant.[11,12] Changes in implant alignment with respect to the capitellum owing to incorrect positioning or differences in the implant shape relative to the native radial head may also contribute to changes in contact patterns and hence alter articular cartilage loading. Collectively, like any hemiarthroplasty, these changes in stiffness, alignment, and shape have a potential to cause degenerative changes in the opposing cartilaginous surface.[11,12]

The focus of the current study was on evaluating the effect of radial head implant shape on radiocapitellar contact using computer-assisted surgical techniques to ensure optimal implant positioning and a whole elbow model to mimic a clinically relevant loading environment. The objective of this study was to compare the radiocapitellar contact patterns of 3 radial head implant designs that included axisymmetric, population-based quasi-anatomic, and reverse-engineered patient-specific devices. We hypothesized that anatomically shaped radial head implants would have greater contact area than the axisymmetric radial head implants and demonstrate radiocapitellar contact patterns similar to the native radial heads.

MATERIALS AND METHODS

Design of implants

The radial head implant system designed for this protocol consisted of 2 components: a custom-made generic stem and the radial head (Figs. 1, 2).[13] All radial head implants were formed out of acrylonitrile butadiene styrene (ABS) M30 plastic (Stratasys, Eden Prairie, MN) using a rapid prototyping machine with an accuracy of ± 0.127 mm (400MC, Stratasys). We performed a benchtop study to determine whether the plastic implants would produce a contact area similar to that of traditional metal implants. Three casts were made using a cadaveric humerus with one plastic axisymmetric implant and one metal axisymmetric implant of the same size.

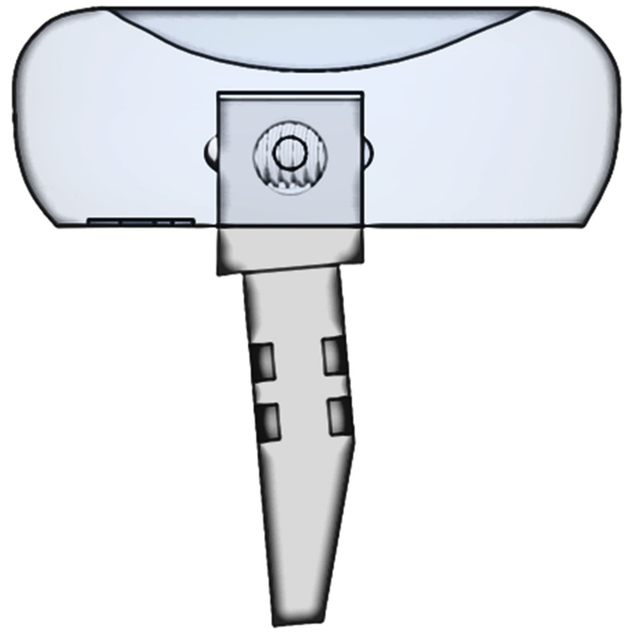

FIGURE 1: Customized stem. View of the stem inside the implant.[13]

We used custom-made axisymmetric radial head implants in this study in lieu of a commercially available implant so that it would match our custom stem. In this case, the axisymmetric implant was modeled after the Evolve Proline Radial Head System (Wright Medical Technology, Inc, Arlington, TN) and included 20-, 22-, 24-, and 26-mm implant sizes. An experienced upper extremity orthopedic surgeon compared the size of the excised native radial head with the axisymmetric implants as is performed clinically. The minor diameter of the elliptical native radial head was used to select the diameter of the axisymmetric implant. If the radial head was judged to be between sizes, the smaller sized prosthesis was selected.

To design a series of population-based, quasi-anatomic radial head implants, we measured computed tomographic scans of 34 male elbows. These specimens were sorted by maximum diameter into 3 groups representing the specimens within 1 SD of the mean (QM) (n = 24), above 1 SD (Q+) (n = 5), and below it (Q−) (n = 5). All specimens were within 3 SD of the mean. Implants were then generated for each of these groups by averaging a large number of measured parameters in these specimens.[13] The size of the excised native radial head was compared with the population-based elliptical implants. The population-based implant that most closely matched the maximum diameter of the native radial head was used. If the radial head was judged to be between sizes, the smaller sized prosthesis was selected. We applied the same measurement techniques to the scans of each