Articular Contact Pressures During Prosthetic Radial Head Subluxation

Dipit C. Sahu, MBBS, James S. Fitzsimmons, BSc, Andrew R. Thoreson, MS, Daniel R. Bachman, MD, Kai-Nan An, Ph.D., Shawn W. O’Driscoll, PhD, MD.
Mayo Clinic, Rochester, MN, USA.


Introduction: Metallic radial head prostheses are often used in the management of comminuted radial head fractures and complications following radial head excision (1, 2). Radial head prostheses restore significant stability in the elbow joint, but they have also been associated with radiocapitellar joint subluxation, capitellar cartilage erosion and degeneration (3-5). Furthermore, mismatch between the design of a radial head prosthesis and the native radial head anatomy may result in radiocapitellar joint subluxation or malpositioning which may cause cartilage degeneration (6). However, it is not currently known how the radiocapitellar contact pressures and areas change with radiocapitellar instability and malpositioning of a prosthesis. Anatomic radial head implants have been designed to mimic certain anatomic aspects of the native radial head (7). Thus, an anatomic radial head design should theoretically mimic the pattern of change in radiocapitellar contact pressures of the native radial head during radiocapitellar subluxation or malpositioning. While bipolar implants have been designed to maintain improved contact with the capitellum and compensate for inaccuracies in the design (8), it is not known how the contact pressures and areas may change with subluxation. The purpose of this study was to compare the changes in radiocapitellar contact pressures with 3 different types of radial head prostheses. We hypothesized that the contact pressure characteristics of a monopolar anatomic radial head prosthesis will more closely mimic those of the native radial head as compared to a monopolar circular or a bipolar circular radial head design.

Methods: 8 fresh frozen elbows were obtained, thawed and had all surrounding soft tissues, including the capsule and ligaments removed. The radius and the humerus bone were disarticulated and dissected free of all soft tissues. These two bones were then potted separately in cylindrical tubes using methylmethacrylate. Using a previously published technique (9), a Tekscan pressure sensor was used to measure the mean radiocapitellar contact pressures, contact areas of the native radial head were at 0, 2, 4 and 6 mm of posterior subluxation (Fig. 1). These assessments were repeated after the native radial head was replaced with 3 different radial head designs: 1) the Anatomic Radial Head (Acumed, Hillsboro Oregon, USA), 2) the circular RHS™ Radial Head System with the “floating articulation” locked (10) (Tornier SA, Saint-Ismier, France) and 3) the circular RHS™ Radial Head System with the “floating articulation” unaltered (8).

Results: At the stable 0-position, the native and anatomic radial heads demonstrated significantly higher contact areas than those observed with the circular monopolar and bipolar radial heads (p < 0.0001, Fig. 2A, Table 2). However, with further subluxation, the contact areas with the anatomic radial head decreased significantly (p < 0.0005), mimicking the pattern of significant decrease seen with native radial head (p < 0.0001), while the contact areas seen with the monopolar and bipolar circular prostheses stayed low and relatively unchanged (p > 0.21, Fig. 2A). In the native radial head, the mean contact area decreased significantly from its initial max-value of 180 ± 11 mm² at 0 mm to 55 ± 5 mm² at
6 mm of subluxation - a 69% decrease (p < 0.0001). The mean contact area with the anatomic prosthesis decreased from its initial max-value of 140 ± 6 mm² at the 0 mm stable position to 55 ± 9 mm² at the 6 mm position - a 61% decrease (p < 0.0001). The mean contact areas did not change significantly from their baseline values for the monopolar (55 ± 6 mm²) or the bipolar (61 ± 5 mm²) prostheses with subluxation from 0 to 6 mm (p > 0.25 and p > 0.21, respectively). As compared to the native radial head, at the 0-position, the contact areas with the prostheses were as follows: decreased by 22% with the anatomic prosthesis, decreased by 69% with the monopolar and decreased by 66% with the bipolar prostheses (p<0.0001, Fig. 2A, Table 2). At the 6 mm subluxated position the contact areas of all the prostheses and the native radial head were not significantly different from each other (p > 0.41).

**Discussion:** This study showed that joint contact pressures increase during prosthetic radial head subluxation, and the pattern of increase in contact pressures depends on the design of the radial head prosthesis. The contact pressures with the anatomic prosthesis mimicked those of the native radial head by starting low and then increasing progressively and significantly with increasing subluxation. The contact pressures with the monopolar prosthesis did not behave at all similarly to those of the native radial head. Instead, the monopolar prosthesis started out with contact pressures that were very significantly elevated at baseline and which displayed only a small but significant increase with 6 mm of subluxation. The contact pressures with the bipolar prosthesis were also significantly elevated at baseline and did not change significantly with subluxation. The pattern and magnitude of the increase in contact pressures with the anatomic prosthesis more closely followed the pattern of increase with the native radial head, because the design of the anatomic prosthesis more closely approximates the native radial head anatomy (11). For example, the depth of articular dish is 2.3 mm and has a variable radius of curvature(7). The circular designed prostheses that we tested had a shallow dish depth (1 mm) which does not conform well with the capitellum. Therefore the contact pressures with the circular monopolar or bipolar prostheses were high even at the reduced 0 position and changed very little with subluxation. As expected, the bipolar contact pressures did not change significantly with further subluxation due to its self-aligning mechanism. However, with this particular design, the contact pressures were excessively high at all positions, possibly due to the shallow articular surface design. We also found that the native radial head and all the three prostheses frequently exceeded the “damage threshold” contact pressures at 4 and 6 mm of subluxation. This would be consistent with reports of joint degeneration with chronic and persistent instability of the radial head(12). However, the circular monopolar and bipolar prostheses also showed contact pressure elevations above the “damage threshold” value even at the 0 mm and 2 mm subluxation positions. Contact pressures before and during subluxation of the anatomic prosthesis closely resembled those of the native radial head. Pressure started out low in the reduced resting position, and then significantly and progressively increased. A very different and abnormal pattern was seen with the non-anatomic, circular prostheses tested in this study. This was attributable to its shallow dish depth and non-conforming design. When the head geometry was converted for use as a bipolar prosthesis, no improvement in radiocapitellar contact pressures was seen.

**Significance:** The articular surface design of a radial head prosthesis is an important determinant of joint contact pressures.
Figure 1: Testing Machine Schematic. The specimens were positioned in 30° of flexion and contact parameters (pressures and areas) were recorded at from 0 to 6 mm of subluxation in 2 mm increments.

Figure 2: Contact Area (A) and Mean Pressure (B) results. There were significant differences seen between the different radial head types and with different displacement distances. Key statistical comparisons are indicated with circles and lowercase letters. Data points within the same dotted circle are not significantly different from one another ($p > 0.05$). Dotted circles labeled with different lowercase letters are significantly different ($p < 0.05$).
Table 1: # of specimens with contact pressures above the threshold value of 5 MPa (n=8)

<table>
<thead>
<tr>
<th>Subluxation</th>
<th>Native</th>
<th>Anatomic</th>
<th>Monopolar</th>
<th>Bipolar</th>
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<tr>
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<td>0</td>
<td>6</td>
<td>4</td>
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<td>4</td>
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<tr>
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