INTRODUCTION

Radial head arthroplasty is currently accepted for the treatment of unreparable radial head fractures with elbow instability. The bipolar radial head prosthesis has been shown to maintain full contact between the prosthesis and capitellum throughout the full range of motion using dynamic radiography. The goal of this continuous contact is reduce the stress at the implant bone interface.

Radiocapitellar stability provides resistance to translation of the radial head on the capitellum by concavity compression. Biomechanical studies have confirmed these effects of the normal and fractured radial heads on the stability of the radiocapitellar joint. The effects of a radial head prosthesis on radiocapitellar joint stability have been previously studied by Moon et al. In the absence of soft tissues they have shown that the monoblock radial head prosthesis and native radial head have intrinsic resistive translation through concavity compression but the bipolar prosthesis actually promotes translation. However, the soft tissues of the elbow joint may contribute to radiocapitellar stability. The present study was conducted to examine the effect of the soft tissues on radiocapitellar stability with bipolar and monoblock radial head prostheses. We hypothesized that a monoblock implant is more effective in stabilizing a radiocapitellar joint than a bipolar radial head prosthesis even with the soft tissues in place.

MATERIALS AND METHODS

All work done in this study was approved by our Institutional Review Board.

Specimen preparation: 12 fresh frozen elbows from deceased donors with no evidence of radiocapitellar joint pathology were used. The average of age of the donor at the time of death was 82 years (range, 61-101 years) 6 donors were men. Each specimen was thawed overnight at room temperature before preparation.

Surgical preparation: All skin muscle and tendon was carefully removed layer by layer; leaving the joint capsule and ligament around the elbow intact (intact condyle). A surgical approach by condylar osteotomy and longitudinal cut at the anterior and posterior capsule were performed for the flipping the condyle to expose the radial neck area.

Radial head replacement: The Radial Head System (RHS) bipolar implant (Tornier SA, Saint-Ismier, France) was used. The straight neck enables ±10° bipolar tilt. We were able to effective convert this into a monoblock prosthesis by adding a custom-made metal collar in the radial neck area to prevent tilt of the head.

Mechanical Testing: Intrinsic joint stability was measured using a custom mechanical device. The device consists of a 6 degree of freedom load cell (JR3 Inc, Woodland, CA) mounted on a motorized X-Y stage (DCI Design Components, Franklin, MA). Each specimen was tested under 5 conditions in 4 directions of translation (Table 1).

<table>
<thead>
<tr>
<th>Table 1: Soft Tissue Not Detached</th>
<th>Soft Tissues Modified</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radial Head</td>
<td>Intact Condyle Condylectomy Detached Repaired</td>
</tr>
<tr>
<td>Native Monoblock Bipolar</td>
<td>√         √           √          √</td>
</tr>
</tbody>
</table>

To prevent variation resulting from the test sequence of the prostheses (i.e. monoblock first then bipolar vs. bipolar first then monoblock), the testing order of the prostheses was randomized. There were 6 specimens that were tested with the monoblock prosthesis first then the bipolar prosthesis and 6 specimens tested with this order reversed.

Each specimen/head was tested at 30° elbow flexion angles under axial 50 N compression loads, and in 4 directions (anterior, posterior, posterolateral and lateral). The radial head was translated 6 mm from the starting position at a speed of 2 mm/s. The subluxation force during the dynamic movements in each test was measured at a frequency of 45 Hz.

Data analysis: The force data were smoothed using a fourth order, bidirectional Butterworth filter. The greatest force in the direction of travel between the components before subluxation was defined as the peak subluxation force. All data are reported as the mean ± standard error of the peak subluxation force. Data analysis focused on comparing 1) the effect of condylectomy on native radial head, 2) the effect of various radial heads (i.e. native, monoblock or bipolar) and 3) the effect of soft tissue status (i.e. non-detached, detached, or repaired) with various radial head prostheses (i.e. monoblock or bipolar). The data were modeled with the use of MANOVA (i.e. repeated measures analysis), ANOVA, Student-t test, and Tukey HSD post-hoc testing where appropriate with a significance level of p < 0.05.

RESULTS

The diameter of radial head prosthesis used in the study were 20 mm in 3 specimens, 22 mm in 3 and 24 mm in 5 specimens. Mean peak subluxation force of Intact condyle elbow (78 ± 4.5 N) was significantly higher than that seen in the condylectomy elbow group (59 ± 4 N) (p < 0.0001). Although there was a statistically significant reduction in the mean peak subluxation force post-condylectomy, this force in the condylectomy group was still over 75% of that seen in the intact elbow. Given this, we felt it reasonable to proceed with the additional tests conditions for each specimen.

Native Radial Head vs. Radial Head Prostheses

The native radial head (condylectomy) and monoblock radial head both showed the force-displacement curves characterized by steep increments until a peak was reached. The bipolar head had an opposite pattern in the initial stages. The force to resist subluxation of the radiocapitellar joint became negative (less than initial force). As translation increased, the force pattern became similar to that seen with the monoblock and native radial heads (Fig. 1). The radial head tested (native, monoblock or bipolar) had a significant effect on the mean peak subluxation force (p < 0.0001). Tukey HSD post-hoc testing showed that the mean peak subluxation force of the native radial head (59 ± 4 N) was significantly greater than that of the monoblock (26 ± 2 N) which was in turn significantly greater than that of the bipolar prosthesis (16 ± 2 N) (p < 0.05, Fig. 2).

Radial head prosthesis with different soft tissue management

The mean peak force in intact soft tissue group (21 ± 1 N) was significantly better than in the detached group (10 ± 1 N) (p < 0.05). The repaired the soft tissue group (17 ± 1 N) was significantly improved over the detached group, but was still not as good as the intact group (p < 0.05).

DISCUSSION

The soft tissue improved the radiocapitellar stability of the bipolar radial head prosthesis. This may be due to a buttressing effect that is present while these tissues are under tension. However, the overall mean peak subluxation force still significantly lower than that seen with the monoblock radial head prosthesis and native radial head. The results suggest that with the bipolar prosthesis, repairing the soft tissues may not restore the radiocapitellar stability that is seen when a monoblock prosthesis is used. This may be especially important in cases where adequate soft tissue repair is questionable.

ACKNOWLEDGEMENTS

This study was funded by the Mayo Foundation.