ABSTRACT

A wear testing machine was designed to simulate the loading and motion of the wrist joint resulting from flexion, extension, radio-ulnar deviation and axial rotation that an individual may experience during normal daily activity. This machine was then used to evaluate a newly developed total wrist joint replacement prosthesis. Six prosthesis specimens underwent 5 million cycles at a frequency of 1.5 Hz while a compressive axial load of 20 lb was constantly applied to the articulating surface. Weight and dimensional changes due to wear were examined. The result showed a maximum wear loss rate of 0.0006 inch per year, which corresponds to an implant life as 65 years from a structural standpoint.

METHODS

Implant Description

The total wrist joint replacement prosthesis (Avanta Orthopaedics, San Diego, CA) is made up of three primary articulating components and two screws (Figure 1). The elliptical surface of the polyethylene ball and the radial component articulate against each other along two perpendicular axes of rotation replicating flexion-extension and radio-ulnar deviation. An additional degree of freedom is incorporated on the carpal side of the implant where the articulating ball is allowed to rotate against the carpal component with a rotation angle of ± 5°. The head of each screw governs the rotational extremes. The articulating ball and carpal component are joined using an interference snap fit spherical stem. The radial, carpal, and screw components are fabricated from implantable grade cobalt chrome alloy per ASTM F-1537. The articulating ball component is fabricated from implantable grade extruded ultra-high molecular weight polyethylene (UHMWPE) per ASTM F-648. Each metallic component is machined from wrought material and is ultrasonically cleaned and passivated in accordance to ASTM F-86. The articulating ball is machined from wrought material and is ultrasonically cleaned in de-ionized/distilled water. The articulating surfaces of the metallic components are polished to a mirror finish with a maximum of a 4 micro inch surface finish. All components that make up the total wrist joint prosthesis are sterilized using ethylene oxide gas (EO).

Test Description

The wear test was performed using a custom made six station reciprocating machine (Figure 2). The prosthesis was cyclically actuated in a circular fashion at a rate of 1.5 Hz creating a conical envelope of 40° while a constant compressive force of 20 lb was applied to the bearing surfaces of the prosthesis via a compressive spring housed on the top of each station. An uni-axial compression load cell was incorporated into the base of each station to monitor the implant loading during the course of testing. The test specimen underwent 5 million cycles. A non-contact reed switch was used to record the number of cycles. Force data and number of cycles was collected with a custom data acquisition program in a personal computer. Implants were submerged in a properly sterilized 25% bovine serum (Grottkau, 2002) at 37 °C. Solution was replaced weekly. Three UHMWPE control samples were submerged in the
bovine solution for a time period equivalent to the wear test. After test completion, the mass of each articulating UHMWPE ball was weighed on a microscale. The radii and exterior features were measured with an optical comparator (Jones & Lamson EPIC 30E, 20X Lens, Springfield, VT). Diameters and internal features were inspected with a coordinate measuring machine (SmartScope, Rochester, NY). The spherical diameter features were inspected with a contour measurement (Mitutoyo Contour Tracer CV-500, Aurora, IL).

Figure 2. Wear testing machine

RESULTS
Weight and dimensional changes of the test and control samples were compared to eliminate the effect of water absorption. The pre- and post-test weights and dimension of the articulating balls were compared to determine the weight and dimensional loss (Tables 1 and 2) due to wear. Visually no wear nor scratch on the metal components. The range of motion required for daily activity is dependent upon the specific task that each individual may be performing. The orthopaedic hand surgeons participating in the design of this prosthesis determined that restoring 40° of flexion, 40° extension, 10° radial deviation, and 20° ulnar deviation would satisfy the needs for performing most tasks (Ryu, 1991). Therefore, the relative positions used in this study replicate common limits of daily motion.

![Image](image_url)

Table 2. Pre- and post-wear weight of the articulating ball samples

<table>
<thead>
<tr>
<th>Sample</th>
<th>Pre-test weight (g)</th>
<th>Post-test weight (g)</th>
<th>Percentile change</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>2.1893</td>
<td>2.1831</td>
<td>0.2832%</td>
</tr>
<tr>
<td>II</td>
<td>2.2077</td>
<td>2.2010</td>
<td>0.3035%</td>
</tr>
<tr>
<td>III</td>
<td>2.2070</td>
<td>2.2000</td>
<td>0.3172%</td>
</tr>
<tr>
<td>IV</td>
<td>2.2047</td>
<td>2.1893</td>
<td>0.6985%</td>
</tr>
<tr>
<td>V</td>
<td>2.2004</td>
<td>2.2000</td>
<td>0.0182%</td>
</tr>
<tr>
<td>VI</td>
<td>2.2040</td>
<td>2.1997</td>
<td>0.1951%</td>
</tr>
</tbody>
</table>

* Average weight gain (0.0008 g) of soak samples subtracted

**REFERENCES**


2003 Summer Bioengineering Conference, June 25-29, Sonesta Beach Resort in Key Biscayne, Florida