Zirconia Ceramic Femoral Heads in the USA

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Introduction

As of today approximately 400,000 zirconia ceramic hip joints have been implanted throughout the world as an alternate to alumina ceramic femoral heads. Zirconia ceramic exhibits fracture strength over 1500MPa accompanied by a fracture toughness value at least double to that of alumina ceramic.

Since their inception for THR in 1985, their global fracture rate up until 1996 has been that of 0.01%; however in the past 10 years their fracture rate has been reduce to 0.002% due to proof testing. However reports from three countries were not encouraging towards zirconia’s clinical performance. The French report presented survivorship analysis down to 63% level at only 8 years follow up. These poor results have lead to the abandonment of zirconia heads. The Korean study found that the mean wear-rate was higher with 22mm zirconia diameter femoral heads compared to corresponding CoCr heads in bilateral THR cases. A Japanese retrieval study of two zirconia femoral heads noted that the monoclinic content had risen from about 1% to about 30% on the surface of the heads with the SEM revealing considerable cratering of the surface. These issues raised the question of zirconia’s metastability, i.e. ageing while in vivo. Given the clinical uncertainties raised by these studies and the scarcity (lack) of zirconia retrieval information, we formed an international team to study these implants.

In this study a total of 23 retrieved zirconia ceramic femoral head implants have been compiled for analysis. The retrieved heads range from 2 months to 10 years in vivo, from four different manufacturers compiled of 28 and 32mm diameter ball size. The study is aimed at characterization of the ball heads through surface roughness, SEM, XRD and Raman microprobe Piezo-spectroscopy.

Materials and Methods

A set of 23 retrieved zirconia ceramic femoral heads was contributed by the University of California San Francisco (UCSF). These had been implanted over the range of 1990 to 2001, representing four ceramic vendors. Surface roughness measurements were carried out on a Feinprüf Perhometer S8P analyzer using a 5µm rad. diamond tip stylus. Measurements were taken at (0, 15, 30, 45, 60, 90, 105 and 120º) relative to the pole. Neutral change was predominating from 10 year to 2 months follow up.

Conclusion

The zirconia ceramic femoral heads examined appeared pristine to the naked eye apart from the black like metallic contamination. Surface roughness did not vary along the arc of the head as reported by other investigators. These data suggests that phase transformation from tetragonal to monoclinic has not occurred. Raman microprobe Piez-o-spectroscopy for the femoral head retrieved after a period of 10 year follow-up revealed predominate compressive stresses upon the surface, indicating no monoclinic to tetragonal transformation. These heads contrasted dramatically with literature that claimed surface changes in the zirconia femoral heads created higher UHMWPE wear. Therefore, we conclude that’s these zirconia balls had produced no deleterious changes in vivo.

Acknowledgments

Thanks to Dr. P. Campbell and Ms C. Buffone at the Joint Replacement Institute, Los Angeles Orthopaedics Research Hospital for use of their Feinprüf Perhometer S8P for surface roughness measurements.

References


Table 2 – Surface Roughness of retrieved heads – as a function of arc angle

<table>
<thead>
<tr>
<th>Specimen</th>
<th>Follow up yrs.</th>
<th>0º nm</th>
<th>15º nm</th>
<th>30º nm</th>
<th>45º nm</th>
<th>60º nm</th>
<th>90º nm</th>
<th>105º nm</th>
<th>120º nm</th>
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<tbody>
<tr>
<td>R56</td>
<td>0.2</td>
<td>70</td>
<td>70</td>
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<tr>
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<td>70</td>
<td>50</td>
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</table>

The scans by Raman microprobe Piezo-spectroscopy revealed there to be minimal tensile stresses upon the surface of the heads, through the arcs of (0, 15, 30, 45 60, 90, 105 and 120º) relative to the pole. Neutral to compressive stress was predominating from 10 year to 2 months follow up.

Surface roughness measurements revealed no significant change in Ra value from the pole of the head (0º) to the base (120º) refer to Table 1.

SEM analysis predominately showed scratch marks from initial polishing and residual wear. Evidence of pitting, pores and grain pullout was not observed in these samples.

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