Wear of ceramic-on-carbon fibre reinforced PEEK hip replacements
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Introduction

Total hip replacement has been a successful surgical intervention for many years. However, concerns regarding UHMWPE wear particle induced osteolysis [1], have led to alternative bearing materials to be sought. Carbon-fibre reinforced poly-ether-ether-ketone (CFR-PEEK) is a fibre-reinforced polymer which has shown reduced wear in hip and knee configurations compared with conventional polyethylene [2-4].

The aim of this study was to investigate the wear performance of a ceramic-on-CFR PEEK total hip replacement bearing through in-vitro wear simulation.

Methodology

Five 36mm diameter Biolox Delta heads were paired with ram-extruded CFR-PEEK cups (material supplied by Invibio, UK; nominal clearance 100µm) and tested in a hip wear simulator (Simulator Solutions, UK). The heads used were off-the-shelf, clinical products (DePuy International, UK). Prior to testing, the cups were soaked in deionised water for a period of 20 weeks, cleaned and weighed at intervals to examine fluid uptake. Geometric and surface measurements were taken for all components using a CMM (Kemco) and a contacting profilometer (Talsysurf, Taylor Hobson)

Hip simulator testing was conducted for 10 million cycles (Mc). Tests were performed in a Prosim hip simulator, which applied a twin peak loading cycle, with a peak load of 3kN. Flexion-extension of -15 to +30 degrees was applied to the head and internal-external rotation of +/- 10 degrees was applied to the cup, components were mounted in the anatomical position. The lubricant was 25% (v/v) calf serum supplemented with 0.03% (w/v) sodium azide and was changed approximately every 0.33Mc.

Wear was assessed gravimetrically at 1, 3, 5, 7 and 10Mc and moisture uptake was assessed using a mean value from unloaded and loaded soak controls. Volumetric wear was calculated using a density of 1.4g/cm3.

Results

The fluid uptake of the cups was monitored over a period of weeks prior to the wear study, and the weights were found to have stabilised after a 12 week period. The clearance and the mean surface roughness for the samples were measured prior to the study (Table 1). Surface roughness of the CFR-PEEK cups decreased by approximately 35% over the period of the study, with polished regions noted on the cup surface corresponding with the wear region. No change was noted in the surface roughness of the ceramic femoral heads during the study.

Table 1: Bearing details

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<tr>
<th>Mean diametric clearance/mm</th>
<th>Mean head Ra/μm</th>
<th>Mean Cup Ra/μm</th>
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<tr>
<td>0.108</td>
<td>0.006</td>
<td>0.540</td>
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The volumetric wear of the CFR-PEEK cups was calculated from weight loss, corrected for fluid uptake by a mean value of the loaded and unloaded soak controls. The CFR-PEEK bearings exhibited step-like wear behaviour throughout the study (Figure 1), with periods of ‘higher’ wear rate (between 0.4mm – 1.4/mm/Mc) and periods of ‘lower’ wear rate (less than 0.4mm/mm/Mc), a phenomenon that has previously been observed with this material [3].

Figure 1: Mean cumulative wear, corrected for fluid uptake (+95% confidence limits)

The mean wear rate over the 10 million cycle study was very low at 0.30 ± 0.003mm3/Mc, which was comparable with previously reported studies [2, 3].

Discussion

The wear of a novel ram-extruded CFR-PEEK cup, articulating with a Biolox Delta ceramic head was assessed through a 10Mc experimental wear study. The mean wear rate over the period of the study was very low, with less than 1mm3/Mc measured. The wear rates observed for this polymeric material are within the same order of magnitude as reported wear rates for 36mm diameter hard-on-hard bearings [5], and lower than wear rates measured for highly cross-linked polyethylene bearings [6]. It should be noted the methodology used to calculate the wear differs between studies, and for very low wearing bearings, such as this material, where fluid uptake may affect the results observed, further development of wear analysis techniques may be required to increase confidence in the results achieved.

The wear rates reported in this study are lower than those previously reported by Scholes et al [3], however, as CFR-PEEK operates within a boundary lubrication regime, the reduced head diameter within the present study would result in reduced sliding distance and hence lower surface wear. This study demonstrates ceramic-on-CFR PEEK to be a promising low wear bearing option for total hip replacement.

Acknowledgements

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References
[1] Ingham and Fisher