INFLUENCE OF SIMULATOR KINEMATICS ON THE WEAR OF METAL ON METAL HIP PROSTHESES

Introduction

There is now considerable interest in the wear of metal on metal hip prostheses. Clinical studies of retrieved first and second generation metal on metal hip prostheses have shown linear penetrations of approximately 5 µm per year (1). This can be related to a wear volume of 1 mm³ per year, two orders of magnitude less than conventional polyethylene acetabular cups. Hip joint simulator studies have shown steady state wear rates as low as 0.1 mm³ per million cycles (2). The difference between low in vitro wear rates and in vivo has been investigated by some centres through studies with elevated loads and stop start motion (3). In this study we postulate that the kinematics of the joint simulator are a critical determinant of volumetric wear. The aim of the study was to compare the wear of metal on metal hip prostheses in two simulators with different kinematics.

Materials and methods

Both hip joint simulators tested the prostheses in the anatomical position with the cup located superiorly inclined at 45° to the vertical loading axis. A double peak load of 3 kN was applied as defined by Paul. The first simulator PA3 had three motions, flexion-extension, internal-external rotation and abduction-adduction as defined by Paul (4). This produced an open elliptical wear track. The second simulator PA2 had two motions flexion extension and internal external rotation which were out of phase and also produced an open elliptical wear track. On some areas of the cup, the two axis elliptical motion had a greater degree of eccentricity compared to the 3 axis motion. Studies with polyethylene acetabular cups in both simulators had previously shown similar wear rates of 32 ± 4 mm³/million cycles (5). Tests were run with size 28 mm cobalt chrome alloy heads and cups with 60 µm diametrical clearance in 25% bovine serum for up to 5 million cycles. Three prostheses were tested in each simulator. Wear of heads and cups were measured gravimetrically every 25% million cycles and wear surfaces analysed by profilometry. Wear debris was characterised by SEM and TEM. Wear results were analysed as initial bedding in wear and steady state wear from 1 to 5 million cycles.

Results

The wear in both simulators was in the superior quadrant of the cup with an approximately circulate wear scar and with an elliptical wear scar on the heads, elongated in the AP direction.

The two simulators with different kinematics produced different wear rates, with the wear rate being significantly higher in the two axis machine. Table 1 shows the initial bedding in wear rate for the first million cycles and the steady state wear rate for the remainder of the test.

Discussion

Low wear rates in metal on metal hip prostheses in vitro may be achieved through a self-polishing action of the two surfaces with the fine wear debris 30 nm in size acting as a polishing or solid phase self lubrication mechanism. This may substantially reduce the total surface wear. This study has shown that the motion and kinematics of the contact were a critical determinant of the wear, with the two axis simulator with the more eccentric elliptical motion producing significantly higher wear rates. One explanation for this is that an elliptical motion with increased eccentricity was not as effective in solid phase lubrication compared to an elliptical motion with low eccentricity. In vitro simulations apply standard patterns of motion to the prostheses, whereas in vivo a more extensive range of activities and motions are applied. This study indicates that gaits or activities which have a more eccentric wear path will lead to greater volumes of wear in metal on metal hip prostheses. This offers an explanation for the differences found between in vitro simulations and wear of ex vivo retrievals.

References


Acknowledgments

This study was supported by EPSRC in collaboration with Depuy International, a company of Johnson & Johnson.

Table 1 - Mean wear rates ± 95% confidence limits

<table>
<thead>
<tr>
<th>Simulator Kinematics</th>
<th>Mean Wear Rate ± 95% CL mm³/10⁶ Cycles</th>
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<tbody>
<tr>
<td>2 Axis</td>
<td>3.12 ± 0.45</td>
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<tr>
<td>3 Axis</td>
<td>0.31 ± 0.19</td>
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