Metal-on-Metal Hip Wear Patterns of Explanted Components Do Not Match Simulator Results

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Statement of Purpose: Hip simulators are intended to assess the wear performance of metal-on-metal artificial hip components, typically using the ASTM F1714 or ISO 14242 standards. The wear patterns generated by hip simulators are concentrated near the load axis on the fixed component and more distributed on the moving component.[1] Here we present a comprehensive evaluation of the wear patterns from retrieved components and compare them to the wear patterns observed from hip simulators. This *ex vivo* validation is needed to identify whether current test methods are sufficient for generating physiologically-relevant wear patterns. In this study, the wear patterns of 196 pairs of retrieved heads and cups, including eleven different designs from six different manufacturers, were compared to simulator predictions.

Methods: In order to assess the wear pattern of retrieved components, the coordinates of the surface need to be measured and compared to nominal dimensions. In this study, 163 pairs of retrieved heads and cups were measured using a Contura G2 (Zeiss, Oberkochen, GER) coordinate measurement machine (CMM), and 33 pairs of retrieved heads and cups were measured using a Global 9158 Advantage Silver (Hexagon Metrology, North Kingstown, RI) CMM, both utilizing a 1.5 mm radius, ruby probe tip to scan the articulating surface of each component.

Approximately 30,000 coordinates were collected per component for analysis using a custom MATLAB (Mathworks, Natick, MA) algorithm, which identified the original, unworn surface of each component using linear least squares sphere fits and compared it to the measured surface, thereby creating linear wear depths at each measured coordinate. The linear wear depths were used to create a 3D model of the measured component, with color representing the linear wear depth at each measured coordinate.

A gravimetric comparison was performed for validation of this method. Material was physically removed from never-implanted components, weighed, and converted to volume based on the density of the material used in this device. A wide range of physiologically-relevant volumes were measured, up to 95 mm^3. These gravimetric volumes were compared with the CMM-measured volumes. Using linear regression, the slope of the gravimetric comparison, a measure of accuracy of the measurement and analysis method, was 0.987 and 0.971 for heads and cups, respectively. This linear fit resulted in $R^2 = 0.998$ for both heads and cups independently.

Results: Thirty eight (38) percent of the retrieved cups exhibited gross wear patterns. The maximum linear wear depth for every cup in this subset was non-polar in location. Seventy eight (78) percent of the retrieved heads which had measurable wear had wear ellipses which did not cross the pole of the head. Furthermore, the maximum linear wear depth was not centered at the pole for any of the retrieved heads.

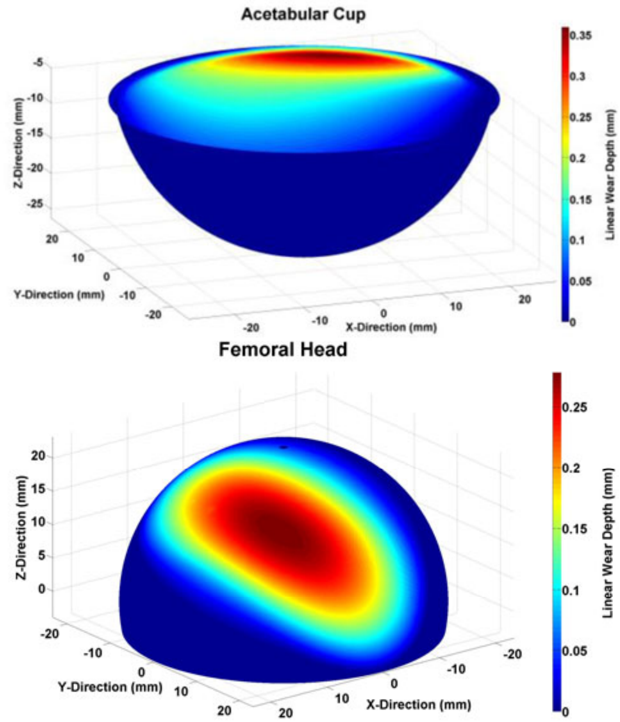

Figure 1. The maximum linear wear depth of a retrieved acetabular cup (top) was located away from the pole of the cup. The maximum linear wear depth of the femoral head (bottom) of the same retrieved hip system was also located away from the pole of the cup.

Conclusions: The wear patterns observed on retrieved metal-on-metal hip components does not match the wear pattern anticipated by hip simulator testing. The retrieved heads and cups exhibited non-polar maximum linear wear depth locations, while hip simulator components have exhibited maximum linear wear depths located near the pole of the fixed component.[1]

References: [1]Park SH. ASTM STP 1346. 1998;129-143.