New Technique for Evaluation of Retrieved Total Hip Arthroplasty

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Statement of Purpose: Since the introduction of synthetic hip joint replacements in 1962, wear of the articulating surfaces has been a major concern (1). To reduce wear, hard bearing materials, as well as crosslinked ultra-high-molecular-weight-polyethylene acetabular cups, are being investigated. While these options are promising, early failures have been reported. Quantitative analysis of these early failures is typically beyond the abilities of standard techniques. Three-dimensional laser micrometry (3DLM) provides a quantitative description of the wear surfaces of such a retrieval.

Methods: A clinically retrieved crosslinked ultra-high molecular weight polyethylene (UHMWPE) acetabular cup and CoCr femoral head were analyzed. 3DLM was carried out using a laser micrometer having an accuracy of 0.5 μm and a scan rate of 400 scans/sec (Laserlinc, Yellow Springs, OH). The laser unit functions via transmission where the length of the beam blocked by the object is measured. A specimen mount was constructed from a manual, dual axis tilt stage mounted to the center of a computer controlled rotational stage having a rotational accuracy of 0.005 degrees (Parker Hannifin, Irwin, PA). A vertical actuator (Aerotech, Pittsburgh, PA) is used to move the specimen through the laser beam.

While the wear of the femoral components was measured directly, a cast was created from the acetabular cup. The femoral head or cast is mounted on the tilt stage. Tilt corrections are made to provide the best presentation to the laser. It is then moved linearly through the beam of the laser. The linear position and dimension of the head are recorded simultaneously from the stage encoder and laser micrometer controller, respectively. This data represents a single profile. The sample is rotated a small step (i.e. 1.0°) and the linear motion and collection of data repeated. After 180° of rotation the entire surface is sampled. This collection of profile lines must then be reconstructed into a 3-D point cloud using an automated "reconstruction algorithm." The resulting xyz point cloud (≥140,000 pts) is rendered as a surface utilizing triangulation methods (2). Alignment and comparison of the resulting surface "map" to an ideal sphere of the specified component dimension is performed to determine linear wear across the entire map. SEM (Philips, XL-30 ESEM) and optical profilometry (VEECO, WYKO NT3300) were also utilized.

Results / Discussion: 3DLM allowed both detection and visualization of micron level wear in both the acetabular cup and the femoral component. Figure 1 shows the results from a scan of a femoral head compared to an ideal 32 mm sphere. Gradual differences of approximately 9 μm in sphericity can be seen. The polar region, C, is raised in comparison to an immediate peripheral "ring". SEM analysis of regions C, D, and E confirmed less "polishing" type wear at region C. Optical profilometry yielded R_a values of 16, 22, and 18 nm, respectively. However, the overall head surface roughness calculated from 3DLM was 3 μm, indicating that small area profilometric analysis provides an incomplete assessment of overall wear. Analysis of the cup showed a more worn area (more positive y axis) in the region corresponding to region C of the femoral head. The raised region of the head could result from preferential wear of the surrounding area *in vivo* or from manufactured imperfections in the virgin surface.

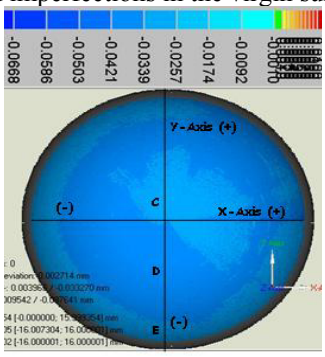

Figure 1: Linear wear color map of CoCr femoral head. (Scale is mm, deviation is negative relative to an ideal sphere)

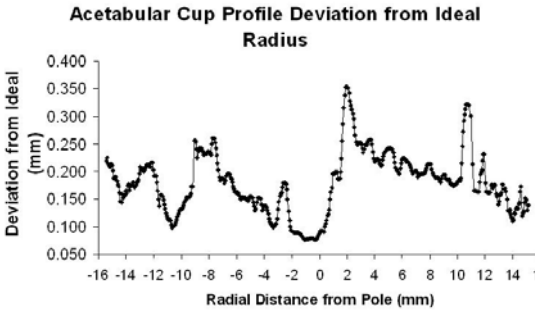

Figure 2: 2-D profile of linear wear of acetablular cup vs. radial position relative to pole (y-axis of figure 1). Scanned surface is a cast, therefore positive wear is actually tunneling

Conclusions: The ability to map and quantify short term damage in next generation materials has not been previously reported. 3DLM should prove to be a useful tool in the analysis of retrieved implants.

References:.

1. Charnley J. Physiotherapy. 1963;41:79-86.
2. Dey TK. J Comp and Inf Sci Eng. 2003;4(3):302-307.