Three Dimensional Laser Micrometry Analysis of Clinically Retrieved Acetabular Cups

Jeremy Gaumer[a], John Lannutti[a], Jon Dyce[a], Laura Nelson[a], Paul Pavka[a], Andrew Kohm[b], Vishnu Ravula[a], Tamal Dey[a], Gang Li[a]

a. The Ohio State University, Columbus, OH

b. University of California Berkeley, Berkeley, CA

Statement of Purpose: Quantification of material removal across orthopedic implant surfaces that undergo articulating wear is largely limited to single value measurements. The influence of a broad range of factors on wear remains frustratingly enigmatic. Our development of three-dimensional laser micrometry (3DLM) introduces an easy, accurate means of 'mapping' material removal. Using this novel technique, not only can the amount of wear be precisely determined, but its spatial distribution as well. We show that this proves to be particularly interesting in examining the wear of explanted acetabular cups. Comparison of the surface map to a reference surface can be used to both discover and provide detailed positional information on the location of small wear features. Such features may otherwise go unnoticed due to the relatively large overall size of the implant upon which these features exist. Using this technique specific wear features discussions relating observed wear patterns to rotational wear caused by third-body particles can be initiated.

Methods: Four surgically retrieved conventional ultra-high molecular weight polyethylene (UHMWPE) canine acetabular cups were analyzed following 3, 16, 37 and 79 months of *in vivo* exposure that also represent a range of significant clinical complications. Casts of these surfaces were created using Protemp™ 3 Garant™ (3M ESPE, St. Paul, MN) which accurately and repeatedly reproduces even submicron features in these wear surfaces. The casting of such cups is performed in an Ar atmosphere glove box to eliminate the effects of water and oxygen on the curing process. The resin (~2.75 g for a 17 mm cup) is dispensed into the cup rapidly with minimal perturbations. Small marks on the back of the cast are used to record the biomechanical relationship of the cast to the original cup. Although the material hardens in 1-2 minutes it is not removed until after 24 hours have passed to ensure complete curing of the resin. A three-dimensional laser micrometer was constructed using a laser micrometer having an accuracy of 0.5 µm and a scan rate of 400 scans/sec. A full 3-D surface map of the cast/head is triangulated from a point cloud consisting of approximately 140,000 individual points. 3DLM was able to accurately map the fine scale surface features and corresponding amount of wear. The 0.5 µm (or greater) accuracy of the laser allows us to image wear with a high degree of confidence. Comparison to a perfect sphere was then performed to determine radial wear over the entire surface map. Histograms of wear were constructed from these scans and were summarized along with the case histories.

Results / Discussion: Following 3 months of exposure, the wear appears as a high density of relatively small overlapping arcs that may represent an initial wearing in morphology associated with either machine line degradation or creep. At 16 months a transition to larger-scale, deeper wear is evident as a series of developing pits in the direction of the expected biomechanical rotation. The explant surface following 79 months of *in vivo* exposure shows that the pits have increased in both area and depth and have become more defined. In all cases rotational wear appears to be a major component of defect generation. In the latter two cases these highly localized wear patterns could be due to third body generation that subsequently remains in a localized area leading to the observed pitting. A less likely possibility is that the head surface has acquired localized damage that results in a similar morphology. In all cases the 3DLM allows for easy 'discovery' and quantification of these features

Conclusions: We anticipate that this advance will prove to be valuable in establishing that while each head and cup combination emerging from a given clinical environment has unique wear patterns, intuitively expected wear patterns correlated to patient factors (weight, age, activity level) will finally be observed. For the immediate future follow on studies showing before-and-after behavior utilizing in vitro simulator wear will assist in quantifying the immediate values of creep and wearing in of pre-existing machine lines

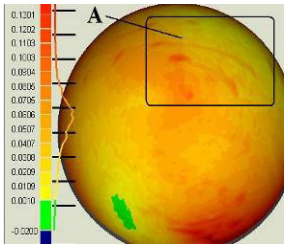

Figure 1: Linear wear color map of canine cup retrieval. This failure was due to aseptic loosening after 16 months. (Scale is mm, deviation is positive relative to an ideal sphere)

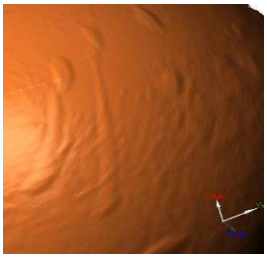

Figure 2: Section A (rotated ~90 degrees clockwise) from figure 1 showing greater detail of individual wear features.

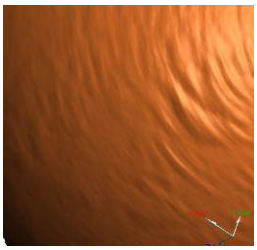

Figure 3: Highly detailed surface map region of the 3-month in-vivo cup associated with implant infection.

Figure 4: Another small section of surface features from the 79 month retrieval associated with ventral luxation.