The Characterization of Damage Modes in Retrieved Metal-on-Metal Hip Implants

INTRODUCTION
Clinical concerns have been raised regarding adverse reactions to metal debris (ARMD) involving metal-on-metal (MoM) total hip arthroplasty (THA) [1]. Damage modes on other implant systems have been described [2], but characterization of damage to MoM hips has not. Hip simulator studies measure the amount of metal worn from the surface of these implants but do not adequately describe the damage [3]. Our aim was to develop a characterization system of MoM damage modes to hopefully suggest the mechanisms causing the damage and to determine clinical factors that affect failure.

MATERIALS AND METHODS
Forty-six THA implants (45 heads, 44 cups, 44 patients, 7 designs) and 25 Hip Resurfacing (HR) implants (32 heads, 21 cups, 25 patients, 5 designs) from an IRB-approved retrieval system were analyzed. Average age and BMI at revision were 54.4 yrs and 27.9, respectively. Each implant was examined by light microscopy at 6–31x magnification, and individual damage modes were investigated with SEM at 100–5000x magnification. Damage was mapped onto 2D polar charts with the pole assigned 0° longitude and the equator 90°. Linear measurements of surface damage were made using an electronic caliper. Abduction angle was measured for each implant on AP x-rays using the pre-revision x-rays closest to the revision date. When appropriate x-rays were available, anteversion angle was similarly measured.

Eight damage modes were classified: scratching, dulling, pitting with discoloration, pitting without discoloration, discoloration alone, etched microstructure, rim scratching, and circular areas of congruent scratches (CACS) [4]. Surface scratching is self-explanatory. Dulling is a patch stripped of its luster but absent of any signs of damage. Pitting without discoloration (Fig. 1A) is visible grossly as a clouded irregularly shaped area, and under microscopic examination appears as densely packed pits with little or no metallic sheen between them. Discored areas have a gold, rust, or “oil-slick” rainbow surface coloration, but maintain a surface luster. Pitting with discoloration appears similar to discoloration alone but includes surface pitting with a loss of surface luster. The microstructure of the CoCr alloy (Fig. 1B), including gr. boundaries and dendrites, is visible on some implants; the microstructures vary in size and morphology among manufacturers, and between head and cup of a single manufacturer. Rim scratching (Fig. 1C) consists of short (≈0.1mm) scratches oriented roughly parallel to each other forming a thin (≤5.5mm) strip at the rim. On SEM analysis, corrosion was found within the strip of rim scratching. CACS (1.5-2.5mm diam) consist of geometrically similar scratches within a circular area (Fig. 1D).

RESULTS
Scratches were multidirectional or unidirectional. 100% of the implants had scratches, often extending over the entire bearing surface. Dull patches were found on 12% of heads, but on only 1 cup (1.5%); they were always within ~20° of the pole.

Figure 1. A. Pitting without discoloration (15x) B. Exposed microstructure (15x) C. Rim scratches (15x) D. CACS (8x)