The Relationship of Metal-On-Metal Wear and Metal Ion Release in the Serum Lubricant

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Statement of Purpose: It is challenging to obtain an accurate measurement for low wear implants, such as metal-on-metal, especially when the amount of wear is close to the limits of the scale. Factors affected weighing results include the precision of the scale, the operating procedures, and the environment variables (humidity, temperature and barometric pressure) [1].

The metal ions released in the serum lubricant during wear testing may be an alternative wear indicator, if there was a correlation with the total volumetric wear. The dissolved metals can be measured effectively using inductively coupled plasma mass spectrometry (ICPMS).

This study investigated the relationship of metal-on-metal implant wear and the metal ions released into the serum lubricant in a hip simulation study.

Methods: Femoral head components and acetabular inserts made of CoCrMo (ASTM F1537) with 28 and 36 mm nominal diameter were used. All articulating surfaces were polished to an Ra of 0.01 µm. The wear test was performed on a simulator (AMTI, Watertown, MA) under a 2000N, Paul type hip-load at one Hz in 90% bovine serum (Hyclone, Logan, UT), containing sodium azide and EDTA, and synchronized with physiological kinematic inputs (with the range of abduction/adduction = ±8.5°, flexion/extension = ±23°, and internal/external rotation = ±10°). Load soak controls were utilized with same hip-load and lubricant but without motion. Wear was determined by weight loss method every half million cycles after the cleaning procedure. The weight loss was converted to volumetric wear using a density of 8.86 g/cm3 [2]. The test was performed for 2.5 million (M) cycles.

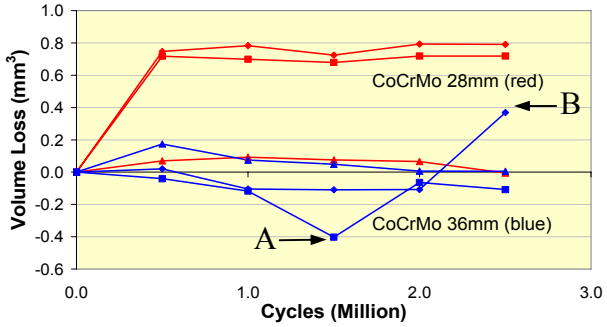
Serum samples were collected at 0.5M, 1M, 1.5M and 2.5M for ion analysis. The samples were centrifuged at 3000 rpm (2000g) for 15 minutes. The supernatant was then collected and analyzed for the Cobalt, Chromium and Molybdenum ions using ICPMS (WCAS, Santa Fe Springs, CA). The detection limit for Cobalt, Chromium and Molybdenum were 0.0005, 0.0004 and 0.003 µg/ml, respectively. Correlation coefficients between interval combined wear vs. [Co], [Cr] and [Mo] were calculated.

Results / Discussion: Figure 1 shows the accumulated wear of each metal-on-metal pair for the period of 2.5M testing cycles. In a typical metal-on-metal wear test, a weight gain sometimes occurred (arrow A in Figure 1), such fluctuation of values might attribute to the factors mentioned above. However, a sudden wear increase (arrow B in Figure 1) may be due to other events, such as broken bag or misalignment of implants during the test.

When comparing the metal ion concentration, the data point A in Figure 1 became obviously an outlier because there were still metal ions released in the serum lubricant (left side in Figure 2). However, the data point B in Figure 1 may represent true wear because it reflected in the increase of metal ions (Figure 2). Each measured metal element followed a linear relationship with the combined interval wear. The ratios between the three metal ions remained reasonable values. The correlation coefficients of cobalt, chromium and molybdenum concentration with the combined interval wear were 0.9578, 0.9082 and 0.9379, respectively (Figure 2).

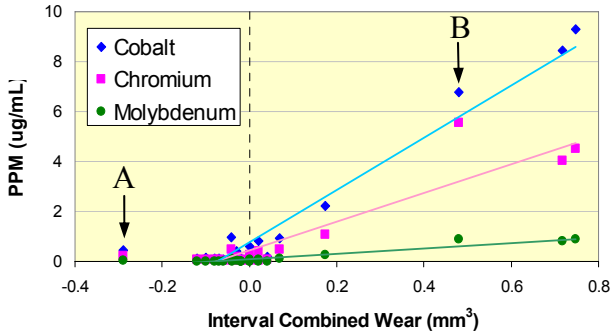
The metal ions released into the serum lubricant in the load soak stations remained very low or non-detectable. The fresh serum lubricant showed [Cobalt] of 0.0068 µg/ml, and non-detectable for [Chromium] and [Molybdenum]. The serum from load soak station showed an average [Cobalt] of 0.0357 ± 0.0483 µg/ml, and non-detectable for [Chromium] and [Molybdenum].

Figure 1. Wear Test Result



Conclusions: The results showed that metal ions released in the serum lubricant were proportional to the implant wear. Using ICPMS to measure metal ions may be an effective method to estimate implant wear than the conventional weighing method, which usually involved time-consuming cleaning and drying procedures. The similar approach may also be applied to evaluate the serum/urine ion level for the patients who use the metal-on-metal implants.

Figure 2. [Ion] vs. Interval Combined Wear



References:
[1] Lower et al, 1989, ASTM STP 1025, p233-239
[2] Liao et al, ORS 2004, p1454

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