**Risks Of Subluxation And Impingement In-vivo With Large-diameter Mom Bearings**

Ian C. Clarke, PhD¹, Michelle Burgett, BA², Thomas kent Donaldson, M.D.³, Alun John, MD⁴, Evert J. Smith, MD⁵, Edward McPherson, MD⁶, Christina Savisaar, PhD⁷, John G. Bowsher, PhD⁷

1Loma Linda University, Loma Linda, CA, USA, 2DARF Center, Colton, CA, USA, 3Loma Linda university, Colton, CA, USA, 4University of Cardiff, Cardiff, United Kingdom, 5University of Bristol, Bristol, United Kingdom, 6Orthopedic Institute ofLos Angeles, Los Angeles, CA, USA, 7FDA, Silver Spring, DC, USA.

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**Introduction:** Some MOM patients showed good results up to 30-years and some failed at less than 5-years.1 It is currently unknown which features could be responsible, i.e. design, surgical or patient related. CMM studies of MOM geometry have shown femoral-heads have a combination of circular and circumferential bands, presumed to represent ‘normal’ wear conditions.2 However a definition of ‘adverse’ wear is still elusive. Here it will be hypothesized that a ‘worst case’ scenario will be represented by ‘stripe’ damage, as commonly reported for ceramic-on-ceramic (COC) explants, i.e. due to a rigid ceramic cup rim impinging on an alumina ball. Therefore, we collected 45 large-diameter MOM retrievals to study ‘adverse’ wear. Our hypotheses were that large-diameter THA requiring revision surgery would consistently show a) stripe damage on heads and b) impingement patterns consistent with hip subluxation.3

**Methods:** Forty five large-diameter MOM bearings were studied and included 2 femoral stems (3 vendors, N =15 each). All components were examined for 3-D geometry (CMM: Legex 322, Mitotoyo). Implants were inspected for ‘normal’ and ‘adverse’ wear. Excluded were complex THA cases and implants likely damaged during revision surgery. Surfaces were inspected visually and by magnifying lens. Stripe wear was ink-marked to aid photography. Collateral surface features noted included protein layers, pitting and metal-transfer. Surface roughness was analyzed by white-light interferometry (NewView-600, Zygo Inc) and selected features analyzed by SEM and EDS (MA 15, Zeiss, Bruker x-ray analyser).

**Results:** In this review of 45 retrieved MOM bearings, it was rare to find a femoral head without multiples of macro-stripes. The ‘equatorial’ stripes paralleled the boundaries of normal wear patterns (Fig. 1). These extended up to 40mm long on occasion and typically followed the cup rim contour. Such stripes were < 1-10um deep and 0.1-2mm wide. The stripes crossing the area of habitual wear at the pole were labeled ‘polar’ (Fig. 1a) and outside the wear area were termed ‘basal (Fig. 1a: stripes #1, 2). Positioning the cup rim on polar and basal stripes invariably revealed impingement (Fig. 1a: stripe #1; Fig. 1b stripe #2). The basal stripes could be 1-10um deep and many were coated with metal contaminants 1-4um thick, the EDS imaging revealing elements of titanium alloy (Ti, Al and V). An example with four equatorial stripes (Fig. 2a) showed plastic-flow (arrows: A to D) directed away from the higher rims (H1, H2), into adjacent areas of fine surface grooves (E to G). At higher magnification, the plastic deformation (A) appeared superimposed on a striated or grooved topography (Fig. 2b: B = x2000mag). Fragmented Cr and Mo carbides were also exposed (Fig. 2b:at C). Imaging showed typical ‘saw-tooth’ profiles with 15-20um spacing and peak to valley height approximately 0.6um (Fig. 2c). Thus the CoCr damage hierarchy was represented by i) large macro-stripes, ii) micro-scratches inside stripes, iii) fine surface stirations transverse to linear grooves and iv) cold flow of scratch rims.

Fig. 1. Femoral head marked to show both equatorial and polar macro-grooves with cup positioned over polar/basal groove combinations, (a) on basal stripe #1, (b) on basal stripe #2.

Fig. 2. Equatorial grooving in femoral head (a) SEM imaging of four stripes exhibiting cold flow in CoCr surface, (b) Light microscopy of CoCr rippling damage, and (c) WLI imaging of ‘sawtooth’ grooving effects.

**Discussion:** Consistent patterns of ‘macro-stripes’ has not been reported previously in MOM retrievals, only in retrieved ceramic bearings. Nevertheless, a study of retrieved McKee-Farrar THA noted some large wear tracks and suggested these were i) consistent with 2nd and 3rd body wear, ii) were random, and iii) did not correspond to impingement.4 Nevertheless, the SEM image as published was consistent with the surface damage reported here. Our analysis showed that these were not random and were likely created under subluxation conditions.3 The basal and polar stripes (incidence = 96% of cases) appeared to be consistent evidence that these were created by the cup rim during impingement episodes. These ‘macro-stripes’ were 1 to 2 orders of magnitude larger than any damage reported for pitting or due to 3rd body wear by carbides (see Fig. 2b) as has been often reported. The basal stripes were unexpected, occurring in the so-called ‘non-wear’ regions of heads. These frequently showed a transfer of titanium onto the CoCr surface, suggestive of impingement against a Ti6AlV femoral neck. When the hip joint becomes destabilized at subluxation, the large hip muscles will drive the femoral head into the opposing cup rim, thereby creating (a) particulates of the alloys involved, (b) stripe wear and (c) cold flow. We can therefore hypothesize that macro-stripes form when MOM hip joints reach their terminal arc of motion and the patient reverses direction of the hip motion. Thus, the
MOM retrieval data satisfied two of our hypotheses. We can additionally theorize that no lubrication mechanism would be effective against (i) high magnitude of hip impact-loading and (ii) release of abundant fragments of metal into the joint space.

**Significance:** Our MOM retrieval study may provide new insight as to in-vivo hip performance and may have application to all THA. This is the first documentation of macro-grooves present in large-diameter MOM and clearly not due to instrument damage created during revision surgery. Such damage patterns may be similar to "stripe" wear frequently described on retrieved ceramic-on-ceramic bearings. These data also indicated that subluxation and/or impingement in-vivo was a risk that could lead to adverse MOM wear. Therefore the supposition that large-diameter femoral heads would minimize such subluxation/impingement risks may not be universally applicable.

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retrieved McKee-Farrar metal-on-metal total hip prostheses. J Arthrop.