Wear Behaviour in Acetabular Metal-on-metal Components – Retrieval Analysis

ANTONIAC, IULIAN VASILE
University Politehnica of Bucharest
iulian@biomat.ro
LAPTOIU, DAN
Colentina Clinical Hospital Bucharest
danlaptoiu@yahoo.com
MICULESCU, FLORIN
University Politehnica of Bucharest
fmiculescu@sim.pub.ro
BUNEA, DANIEL
University Politehnica of Bucharest
dbunea@amcsit.ro

Abstract. The metal-on-metal implants are very low wear articulation systems. In special cases (heavy users - hip abusers), even after the running-in period of about one year in vivo, the wear rate can continue. We analyzed a series of explants, related to revision after traumatic events, at more than three years after initial implantation. The patterns found included large scratches (some millimeters in length and about 5 to 10 micrometers in width and depth) and a wear pattern of the classic polar loaded areas (micro-pits of 1 to 2 microns in diameter). This suggests a possible early failure for these special patients.

***Keywords**: metal-on-metal, explants, hip arthroplasty, wear, active patients*

1. Introduction

One puzzling aspect of the clinical experience in hip arthroplasty (THA) has been the large variability of wear within individual patient cohorts. Although most implants now perform satisfactorily for one or two decades, all reported clinical series in the literature include subsets of patients who, for special reasons, experience osteolysis and loosening.

For metal-on-polyethylene designs, which constitute the great majority of total hip replacement prostheses currently in clinical use, the primary source of osteolytic debris is submicron-size PE particles generated by adhesive or abrasive wear against the femoral head counterface. The good clinical results of some old metal-on-metal prostheses lead to reassessment of metal bearing surfaces by manufacturers as Sulzer Orthopedics - Switzerland in 1983 in an attempt to provide alternative bearing surfaces.

Other factors being equal, roughening of the counterface - especially as would occur from scratch damage after traumatic events – with third-body debris - is associated with dramatic elevation of wear in vitro tribologic experiments. Although the potential for accelerated in vivo wear from third-body damage is acknowledged within the clinical community and by implant manufacturers, this consideration is not clearly defined in nature.

2. Material and method

We analyzed cup explants of modular hip joint systems from Biomet (BiomEx), Sulzer (Allopro – Metasul) and Midland Medical Technologies (BHR) all in situ for more than three years. The implants have no dome holes (BiomEx and Allopro have apex hole to allow confirmation of correct seating, which can be sealed with a blanking screw and are articulated with 28mm heads; Birmingham Hip is a high carbide chrome cobalt alloy with 38 to 58 mm inner diameter). The selected patients are from one clinic that begun using metal-on–metal hips from end of 2001; in a three year interval there were four cases out of 127 “classic” implants and one in the 85 BHR – resurfacing group. All were young (39 to 52 years old), active, with a BMI around 30 kg/m2 and retrieval was related to a revision of the implant after a traumatic event. The patients had a normal clinical evolution before current revision.

Three of the cups were mobilized with ease, then handled with care by the surgeon and immersed in an isotonic solution of NaCl in order to be analysed by the laboratory. Sodium Hypoclorite 1,5% was used for removal of organic remnants.

ESEM analysis was the next step, using two types of electron detectors: LFD and BED - composition images on shell inner and outer surface. (ElectroScan XL30 ESEM-FEG; FEI Co, Hillsboro, OR) The scanning electrone microscope was focused on three distinct zones of the acetabular implants using a GW backscattered electron detector in topographic mode. First area was the main contact surface concentrated near the load axis; the non contact zone, which should be roughly similar to initial polishing status of the implant and finally, the external surface (with a focus on the rim of cup).

Figure 1 – clinical case: fracture of the femoral neck in a patient with a Birmingham Hip Resurfacing implant at more than 4 years, caused by a 2 meters fall – note the displacement in varus of the acetabular cup. At right, aspect of the explant femoral and acetabular components.

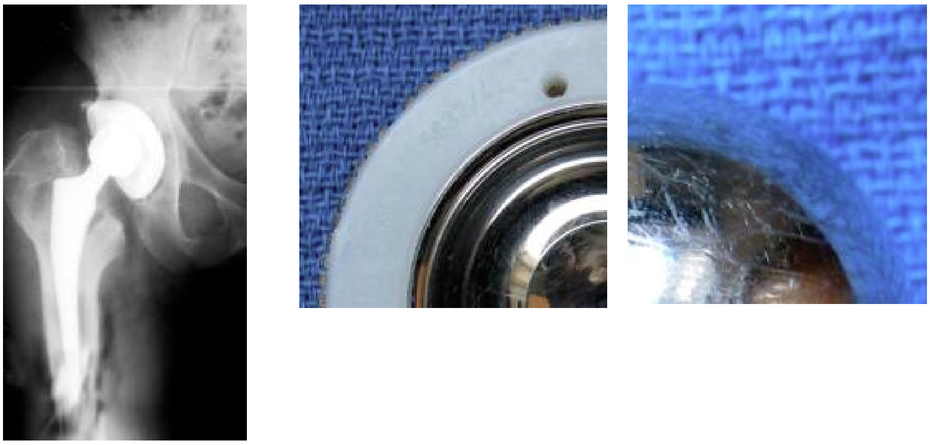

Figure 2 – clinical case: comminuted fracture that occurred distal to the stem tip after high velocity trauma. Both components were loose so revision was necessary. Note the discrete peri-acetabular radiotransparencies. At right aspect of the Allopro – Metasul cup associated to a cementless stem.

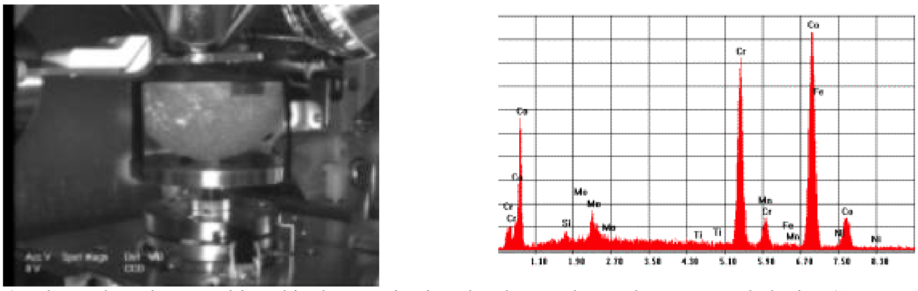

Figure 3 – the explanted cup positioned in the examination chamber. Probes underwent morphologic ESEM examination and photography with primary magnifications of 50X, 100X, 1000X and 5,000X, 1 Torr pressure, at 20kV and 10 to 22 mm WD . At right – the spectrum of alloys utilized in the implants was very similar.

Results

Implant retrievals show a wide range of damage patterns, suggesting that third-body particles access the bearing surface and scratch the femoral head in a seemingly random manner.

Typical observations included large scratches (some millimeters in length and about 5 to 10 micrometers in width and depth) and a wear pattern of the classic polar loaded areas (micro-pits of 1 to 2 microns in diameter). Image analysis evidenced the last findings on a minimal surface – less than 5% of total bearing area.

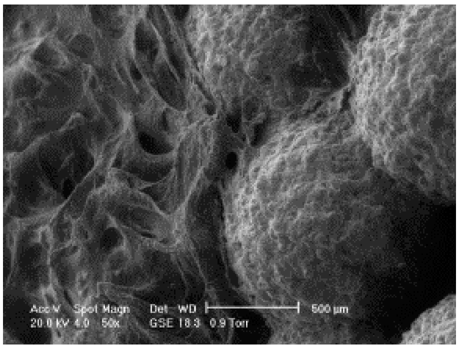

Figure 4 - GSE - Gaseous Secondary Electron Detector imaging of the external surface of the implant. Details of the sintered beads with attached bone tissue - BHR. (50X)

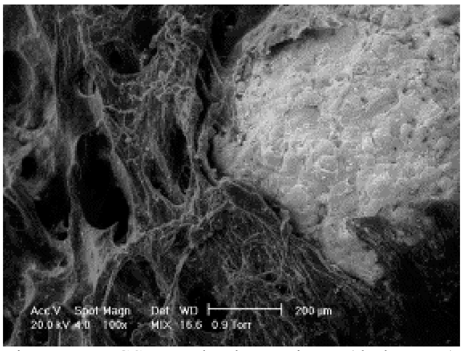

Figure 5 - GSE - The bone tissue (dark areas) in intimate contact with the hyrdroxyapatite (clear) on the external surface of the retrieved implant – BioMX. (100X)

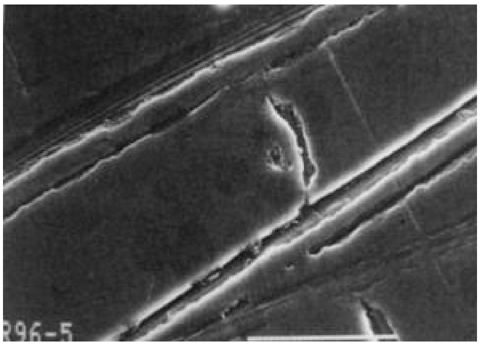

Figure 6 - Detailed image - scratches on the Metasul inner surface (5000X)

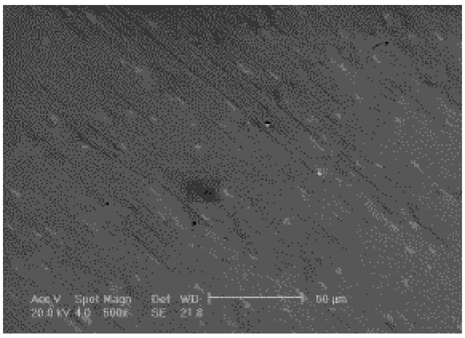

Figure 7 - Detailed image - Micro-pitting on the high stress contact area of the inner surface Metasul implant (500X)

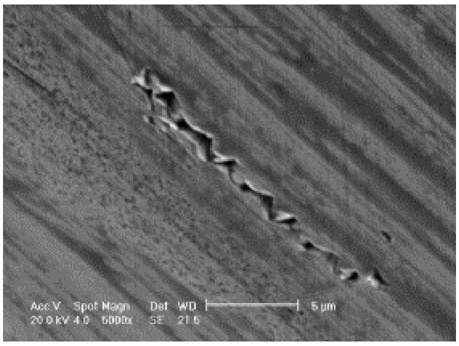

Figure 8 – details of scratches on inner surface of BHR. Area of particles of grit below the scratch. (5000X)

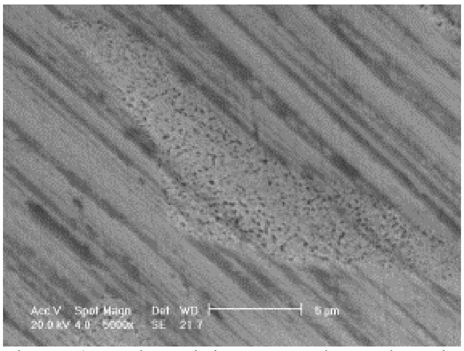

Figure 9 – micro-pitting areas observed on inner surface of BHR – sometimes in association with scratches as seen in figure 8

The particles of grit were discovered that were not initially detectable with secondary electron imaging of the original uncorroded surface. That is,probably the grit was found embedded several microns below the implant surface and revealed by ulterior wear. Macrophages filled with metallic particles were found in all tissues analysed at revision time, but in larger amounts in those with metallosis.

Discussion

Scientists expressed their concerns that unprotected total hip models consisting only of materials much harder than bone and cartilage will propagate these shock waves directly on bone and damage the coupling between the total hip and the skeleton. The cup component consists usually of three layers: the outer and inner layers are made of metal, and between these two layers, there is sandwiched a polyethylene layer. This is a complicated construction with possible risks of disintegration of the complicated cup component. There are, however, no published reports of such damage. Direct metal-on-metal coupling in an artificial hip has no soft cushion that might dampen the repeated shocks that appear from the contact of the leg with the floor during walking.

In the event of high surface stress, wear due to fatigue occurs even in modern metal–on-metal implants. The polyethylene inserts used in some implants may be interested by subsequent cracking and provide with third body particles. It may not be the weak link as in the classic metal-polyethylene pairing, but may be a factor that induces a biological reaction with the loosening of the implant – we mention that our clinical experience and current literature state the excellent fixation of these types of implants. Usually, revision of such implants is very technical demanding and lasts in some bone sacrifices. It was not the case with our patients were ablation was easily performed. At a closer look, radiotransparencies could be observed at the bone-implant interface. Could the initial source of debris be the handling of implants by the medical personnel? A well-known problem of implant manufacturers is that the ancillary for implantation is very expensive and rarely exchanged. Rasps, handles, guiding devices may also be potential sources of metal and plastic debris.

The literature quotes that occasional scratches on the metallic surfaces disappear with the continuous motion of the surfaces - the metal surfaces "polish" the scratches (Cobalt alloy with a good ductility). Literature (Chan and co, CORR 1999) state that accelerated wear occurres within the first 1 million cycles, followed by a marked decrease so, thevolumetric wear at 3 million cycles was small, ranging from 0.15 to 2.56mm3. One average person makes about 1 million steps per year so , the first one to five years could be crucial for the evolution of an artificial implant.
Our high demand patients may have not been the ideal “candidates” for this mechanism. The male, active patients are heavy users and the wear pattern found, may be related to these factors. It would be interesting to study but we could not measure the deviation from the ideal sphericity. Our findings confirmed the abrasive wear as the typical mechanism of wear even in these cases of second generation of metal-on-metal articulations. The micro-pitting, related usually to fatigue wear, was very small as incidence.

Conclusion

Wear appears even in modern metal-on-metal implants. “Wear is a function of use, not time”
Wear may be related and amplified by initial defaults in handling the implants in the operating room.

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