2.3 Hip Resurfacing – a superior articulation concept?

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Introduction

Hip Resurfacing is an idea and concept dating back to the end of 1800's and restarted with metal components by Wiley around 1938. The concept of using a thin bearing only covering the affected surface of the hip instead of a total hip arthroplasty (THA) is intriguing. The big diameter implant restores the normal anatomy. Compared to a THA it increases the range of motion and reduces the risk for impingement. The overall stability of the hip joint is improved and the stemless femoral component of the arthroplasty saves bone stock for a later revision. Several attempts with Surface Replacement (SR) arthroplasty have been made historically with various designs and materials, an example shown in Figure 1. First metal-on-metal (MoM) was used, then plastic- or ceramic-on-metal and even ceramic-on-ceramic. All these historic couples failed already in the short-term, either due to surgical issues, lack of permanent fixation, necrosis, deformation with high friction and reaction to wear particles.

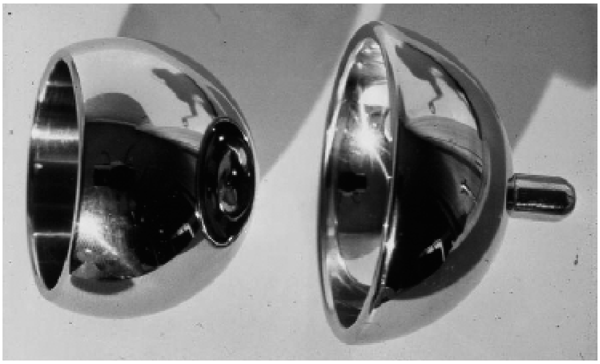

Figure 1:
Historic metal-on-metal Resurfacing (Müller) from 1967.

The renaissance of the resurfacing concept has been started after the re-introduction of the MoM articulation for THA in 1989 [1]. Because the low wear and the high strength and stiffness of the CoCr alloy allowed for thin components the concept of SR was re-evaluated. Apart from improved joint stability it was thought that tribological a large diameter bearing would allow developing a permanent lubrication film to separate the articulation metallic surfaces during the patient's activity from each other and, thereby reducing the friction and also the wear.

Permanent and continuous lubrication in a human joint is difficult to achieve with its varying force and velocity, a turning point at zero velocity and the individual lubrication regime during a walking cycle and tiny wear particles are released into the local tissue. If a MoM concept is used metal wear products can be detected not only in the peri-prosthetic tissue but also in distant organs like liver, spleen and lymph glands [2,3]. Due to the dissolution of the metal in the body environment ions are released, distributed throughout the body creating potential biological issues. A reduction in the wear rate, especially the high running in wear in the early phase of the ambulation is, therefore important for the long-term success of THA and SR.

Material and Methods

A series of hip joint simulator studies with various MoM couples was conducted. The specimens were manufactured from Co-28Cr-6Mo-0.2C alloy. A total of 27 MoM combinations were fabricated and investigated using two different hip joint simulators and test protocols.

The first set of experiments was conducted using a MTS 8 station hip joint simulator in 50% diluted bovine serum. First, two conditions (cast and cast/solution annealed) of the CoCr-alloy with 40 mm diameter articulation were compared and a second generation MoM THA with 28 mm diameter used as control in a short 1 million cycle test. The as-cast components had an average grain size of 1-2 mm with hard $M_{23}C_6$ and M_7C_3 (M = Co+Cr+Mo) carbides of approximately 20 µm diameter embedded in the matrix. The 28mm articulations were manufactured from hot worked (WF) CoCr-alloy with an average grain size of 20 µm and carbides of 2-3 µm.

Subsequent experiments tested the consistency of the early results using a set of as-cast 40 mm diameter articulations with a radial clearance of 50-90 µm for 5 million cycles. The test was repeated then with another set of 40 mm diameter articulations with a lower radial clearance of 25-50 µm.

A final experiment was conducted using a commercial SR implant of 50 mm in a physiological anatomical Leeds I PA simulator for 5 million cycles. Comparative wear control data was obtained from a previous test using the same simulator and protocol for a commercial 28 mm THA bearing [4].

Results

The result of the comparison between two different types of cast 40 mm diameter MoM articulations and conventional MoM THA of 28 mm is depicted in Figure 2. The average wear rate at 1 million cycles for the solution treated 40 mm bearings was about four times that of the as-cast bearings, indicating that the presence of carbides plays a significant role in the wear performance of MoM joints. Interestingly, the second generation MoM (28 mm) wore less only a non significantly different rate compared to the first generation as-cast bearings (p = 0.29) despite the difference in the diameter and material.

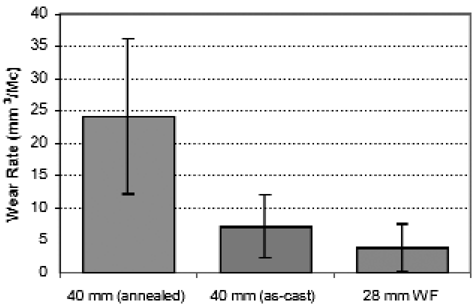

Figure 2:
Hip simulator wear rate of MoM articulations.

The subsequent test for the as-cast 40 mm bearings exhibited inconsistent, erratic wear behaviour, depicted in Figure 3a. While several of the tested bearings showed the well known running in period with a steady-state wear rate later of less than 1 mm^3/million cycles, 38% of the bearings showed excessive wear with two bearings exhibiting a run-away wear pattern after 1 and 4 million cycles, respectively.

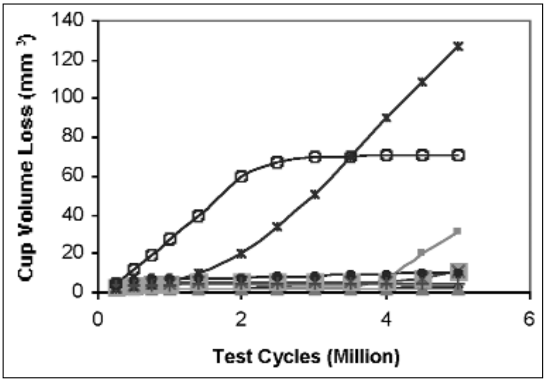

Figure 3a:
Wear rates of 40 mm MoM bearings, showing erratic behaviour.

The run-away wear rates were 30 and 40 mm^3/million cycles and the serum of the chamber was discoloured by the high amount of wear particles, shown in Figure 3b.

Figure 3b:
Lubricant during the run-away wear regime.

The subsequent tests with the reduced clearance of the 40 mm bearings yielded similar results with 25% of the bearings exhibiting run-away wear. No reason for this behaviour could be detected.

On the 50 mm SR the wear scars appeared on the head and cup early in the test and were located in the superior quadrant. Figure 4 shows the volumetric wear as a function of the number of cycles for the SR and the comparative data for the 28 mm MoM THA pairings [4]. The running in wear was far higher for the large diameter SR than for the comparative MoM THA. Following the running in period the wear rate of the SR decreased but remained still higher than for the 28 mm THA. At 5 million cycles the total volumetric wear of the SR was 3.27 mm^3, and was higher on the cup, making up 62% of the total wear.

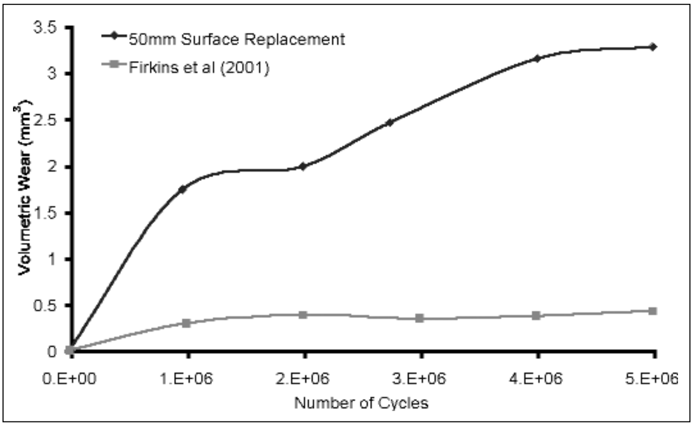

Figure 4: MOM - Surface Replacement versus THA 28 mm.

Discussion

The increase in diameter for MoM Resurfacing changes the tribological system of the hip joint. Assuming a similar clearance for the articulations, a bigger diameter decreases the surface pressure and increases the velocity, both being advantageous for the formation of a fluid film formation resulting in reduced friction and wear. Nevertheless, no favourable tribological results were found in our tribological investigations for the bigger diameter SR bearings. The wear rate under identical conditions in the laboratory was generally higher than for smaller diameter THA bearings but also inconsistent. Given this in vitro evaluation, Surface Replacement does not seem to be a superior tribological concept.

Some comparative in vivo studies have evaluated the metal ion release of a normal 28 mm THA versus a SR. In general it has been observed that Resurfacing articulation releases a higher amount of Co and Cr ions compared to standard THA. The values reported show an increase of 5 to 350% [5,6,7,8]. It has been speculated that these higher levels of metal ions are due to a higher activity of the SR patients but this has not been proven yet. On the contrary, a recent study has shown no relationship between the patient activity and the serum metal ion level [9]. Another possible explanation is the creation of smaller wear particles with bigger diameters, leading to relatively more debris and, therefore a higher ion concentration in blood and urine. On the contrary, at the recent ORS two posters have been presented with comparable clinical wear results between MoM THA and SR [10,11].

Despite the low amount of MoM articulation wear particles in general the amount of Co and Cr ions detected in blood or urine are elevated up to a tenfold over controls [12] and metal sensitivity has been reported as a reason for revisions [13,14,15]. The long-term pathological significance with potential carcinogenicity and metal sensitivity issues are of concern, especially because the main indication for a big diameter or SR MoM bearings is the young and active patient. This has to be weighted against the benefit of these popular bigger diameter bearings with a documented higher joint stability with fewer dislocations [8] and a better range of motion.

References

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