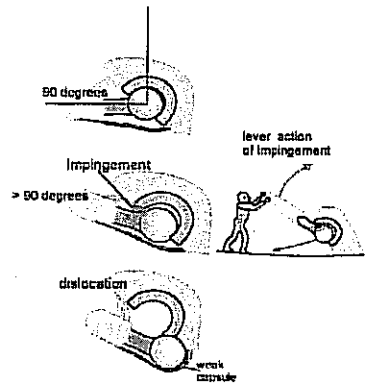
A BRIEF OVERVIEW OF SOME OF THE KEY DESIGN AND MANUFACTURING DEFECTS IN THE DePUY ASR HIP SYSTEM

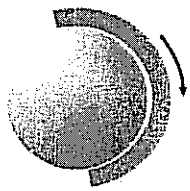
I. Coverage of the head: General Discussion

The DePuy ASR hip system was designed to have less coverage of the femoral ball in order to allow greater motion of the ball within the socket and thus greater motion of the hip joint after replacement surgery. DePuy designed their ASR cup to be shallow. Remember the ball is attached to a stem (in the ASR XL) and/or to the femoral head (in the ASR resurfacing). When the leg is fully flexed or extended or brought out to the side the leg's motion is ultimately limited as the neck hits the edge of the cup rim. The shallower the cup the more motion can occur before this impingement happens. It looks something like this:

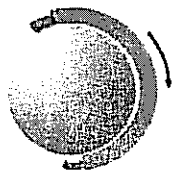


The problem with this design approach is, when taken to the extreme DePuy took it in the ASR design, there is not sufficient coverage to fully distribute the forces of the ball against the cup without over concentrating those forces – usually at the edge of the cup. There is a greater concentration of forces over the more limited area of contact between the ball and socket. With this more limited contact area we are seeing greater wear in general, and wear over the edge or periphery of the cup/ball contact in particular

A. Might represent the cup as designed in the ASR.

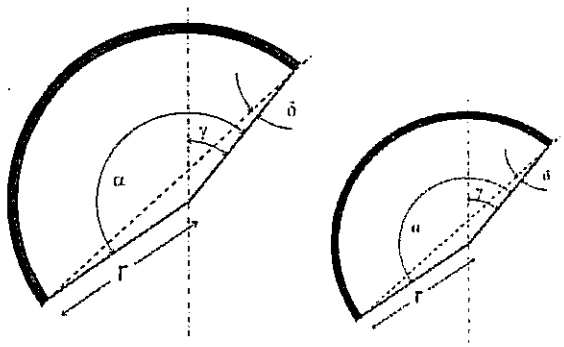


B. Might represent the cup if, as seen in the orange lines I drew, the cup was made deeper. In this cup, which is more like the cup design in the BHR and Conserve + models, there is more coverage and a greater distribution of force and as a result we do not see the extensive bearing surface wear in the BHR and the Conserve + like we see in the ASR.



II. Coverage of the head: ASR small cups v. larger cups

The smaller the cup the more shallow the cup. The smaller cup sizes end up having less coverage than the larger cup sizes. This is simply a function of the physics of the problem. The diagram below shows what is known as the alpha angle. In cups that are less than 55 degrees the coverage starts to get very small indeed.



Among those patients with ASR failures we see a preponderance of women. The cups used in women are usually smaller than those used in men since women are usually smaller than men. Smaller cups fail at a higher rate. If we look at the Australian hip registry data in general and adjust failure for age and gender we see the following: risk of revision for femoral components with a head size ≤44 mm is more than five times the risk for femoral components with a head size ≥55 mm. Similarly, the risk for revision of components 45 to 49 mm is more than three times the risk of revision of components ≥55 mm. Adjusting the data for age and stratifying by sex yields similar results.

For the smaller cups with less coverage the mechanism of failure is wear and we see this problem begin very early. With larger cups we don't seem to see as much very early bearing surface wear. However, the UK experience tells us that men with larger cups are definitely having failures and in these men we are seeing metal wear debris. These men are now presenting with painful hips requiring revision.

In the larger cups we do see bearing surface wear but we also see a slightly different mechanism of failue. The larger femoral heads are showing a corresion effect and metal on metal wear and corresion at the ball(head) neck taper junction. It is not well reproted in the US at this moment but it is a significant problem in the UK. We will likely see this same problem in the US since the ASR system in the US is the same design for the UK and the surgical technique is the same.

Thus the incidence of problems in men is likely under-reported and the overall problem with the ASR is likely under-reported. If you cosider the problem with both the larger and smaller implants you will see that the likely true projected incidence of failures with the ASR system will approach 30%. Mr. Nargol and Mr. Langton from Newcastle have related to me this week that the revision rate in the ASR implants they are seeing is, in fact, 30%.

The depth of a one-piece acetabular cup is a balance between range of motion (ROM) and coverage. Full hemisphere cups have greater coverage and would be less susceptible to edge effects but may have an increased risk of impingement and partial subluxation which would also lead to increased wear.

DePuy states that the clearances for the ASR has been validated with the use of hip simulator testing. There work has been summarized in the peer-reviewed Journal of Arthroplasty Journal of Arthroplasty. 2004 Dec;19 A hip joint simulator study of the performance of metal-on-metal joints: Part II: design Dowson D, Hardaker C, Flett M, Isaac GH. However we would

III. Clearance of the ball within the cup

The concept of fitting the ball within the socket is that the tighter the fit the less room there is for imperfect motion or "slop" if you will. The more perfectly matched the surfaces and the narrower the space between them the less wear there would be. The problem is that an perfect fit of the ball within the cup would cause the two metals to seize – there would be no room for any motion.

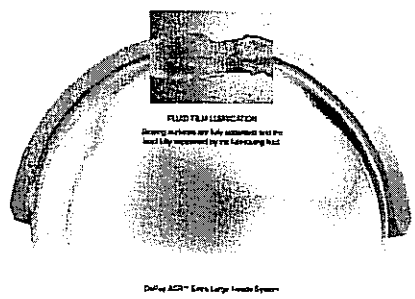
DePuy's theory in designing the ASR was to create a ball-in-cup clearance that was the lowest in the industry. DePuy claims that reduced the diametrical clearance of the ASR will reduce wear. DePuy further states that its studies have shown wear could be reduced up to 80% with the 70 to 100 micron clearance. DePuy's design goal of a very narrow 70 to 100 micron clearance goes against the design decisions used by the Birmingham Hip Resurfacing system and the Conserve + hip which have larger clearances of about 200 to 400 microns. Investigators including Dave Langton and Tony Nargol from Newcastle state that the problems with this design include but are not limited to:

a. As designed any deformation of the cup when it is implanted will cause clamping or complete loss of any space and direct metal on metal wear. We know cups tend to deform when hammered into the bone during the hip replacement surgery.

b. By designing the cup for a clearance of only 100 micrometers in a shallow cup with low coverage we actually see increase wear at the periphery of the cup. This peripheral wear seems predicable in light of the alpha angle analysis noted above and in light of the cup positioning anticipated at surgery.

c. If the cup is in an exact position of 45 degrees in a wear testing simulator you might have low wear – but few surgeons can place the cup exactly in 45 degrees and with increased tilt the wear of the ASR cup increases markedly. This is especially so given the very narrow clearance.

d. See DePuy's own publication depicting the concept of clearance and the fluid film layer that occurs between the ball and socket surfaces:



e. Example reference discussing this issue of clearance.

Lowry Barnes, MD, et. al Differential Hardness Bearings in Hip Arthroplasty. Journal of Surgical Orthopaedic Advances, Vol 17, Number 1, Apring 2008. stating (Optimum clearance between the bearing couples is essential to avoid problems with high frictional torque and equatorial seizing. This ensures polar contact between femoral head and acetabular cup. Chan et al. and others confirmed that this is the most influential factor in wear behavior. Too little clearance can result in congruent head-cup surfaces resulting in equatorial contact. Proper clearance is essential for the egress of the wear particles and ingress of lubricant to the articulating surfaces to maintain fluid film lubrication, a phenomenon by which a thick film is formed, thus reducing the wear. Wear and wear rates increase if the clearance between the component is too small or too large)

IV. Manufacturing Errors

Dave Langton and Tony Nargol from Newcastle UK have received and evaluated a large number of ASR explants – ASR implants removed from patients during revision surgeries. In many ASR explants they have measured clearances less than 70 micrometers. In several cases they have measured clearances less than 50 micrometers and in one case they documented a manufactured clearance of only 35 microns. In these particular cups there was no evidence of cup deformation at surgery. The markedly abnormal and extremely narrow clearance was actually manufactured by DePuy. As previously noted in the main discussion on implant clearance such an improperly manufactured implant would be likely doomed to failure by surface wear.

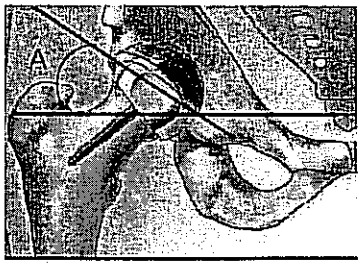
Further Dave Langton has sent DePuy several of these cups with abnormally low clearances and DePuy has confirmed that, in fact, his measurements are correct and it would seem the implant came off the production line with these dimensions.

We know that the laboratory at Newcastle used by Dave Langton would be correct in measuring the tolerance of the ASR implant since this lab uses a laser coordinate mapping system that measures over 6,000 surface points. This mapping is far more precise than other labs which measure on average 12 to 16 points for reference.

V. Surgeon Error?

DePuy designed the ASR cup to be placed in 45 degrees of vertical tilt. Vertical tilt is also known as "abduction." An illustration of vertical tilt:

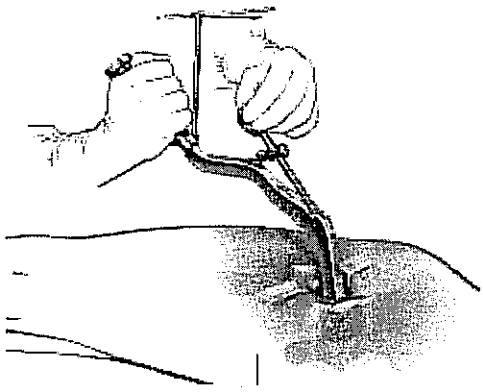
Issue of surgeon error 45 degree placement



A = inklination angle

In the operating room surgeons seek to obtain this angle by aligning the cup into the bone with the instruments provided by DePuy for the ASR system. As the surgeon looks into the patient's own acetabulum the one looks like this:

In general a surgeon uses his own eyes to align the cup in the desired position. This is also the case with the DePuy ASR. Example of generic alignment guide held in the surgeon's hand:



DePuy is stating that failure to position the ASR cup in a vertical tilt angle other than 45 degrees is not acceptable for this implant. The assertion would be that should a surgeon "malposition" a cup in an angle beyond 45 degrees there would be an increased likelihood of wear and failure. Unfortunately DePuy has, by definition, designed an implant that a very large number of well trained orthopaedic surgeons will not be able to properly (according to DePuy) insert. Note the relevant literature and comments as to cup positioning as achieved (and achievable) by US surgeons:

a. Henrik Malchau, et. al. Quality Imporvement of Use of Local Joint Registry: An Example Analysis of Cup Positioning in THA presented at AAOS annual meeting, New Orleans, LA, March 11, 2010. see also Callanan MC, Jarrett B, Bragdon CR, Zurakowski D, Rubash HE, Freiberg AA, Malchau H., Clin Orthop Relat Res. 2010 Aug 18, see also The John Charnley Award: Risk Factors for Cup Malpositioning: Quality Improvement Through a Joint Registry at a Tertiary Hospital. stating (From the 1823 hips, 1144 (63%) acetabular cups were within the abduction range, 1441 (79%) were within the version range, and 917 (50%) were within the range for both.)

b. Bosker BH, Verheyen CC, Horstmann WG, Tulp NJ. Poor accuracy of freehand cup positioning during total hip arthroplasty, Arch Orthop Trauma Surg. 2007 Jul;127(5):375-9. Epub 2007 Feb 13. stating (Based upon the inaccuracy of estimation, the group's chance on future cup placement within Lewinnek's safe zone (5-25 degrees anteversion and 30-50 degrees abduction) is 82.7 and 85.2% for anteversion and abduction separately. When both parameters are combined, the chance of accurate placement is only 70.5%.)

Further note that the ASR cup is a monoblock design i.e. it is on one piece and is not modular. You can't put in the shell first and then a modular insert thus you don't get as good a look at the position of the cup into the patient's bone as the cup goes into place. Designing surgeon Dr. Vail:

Thomas Parker Vail, For hip resurfacing arthroplasty prioritize exposure and cup insertion, Orthopedics Today, June 1, 2010, stating (When using a monoblock cup as part of a hip resurfacing or total hip procedure, it is important to note that a monoblock cup may be more challenging to insert than a modular cup with a dome hole and screw holes.)

VI. Metal Ions and Reaction to Metal Debris

From Dave Langton, Newcastle, UK:

> There is accumulating evidence to show that patients with MoM hips which wear at a greater than expected rate are more likely to develop adverse soft tissue reactions, including pseudotumours and extensive areas of necrosis. (**Kwon YM, Glyn-Jones S, Simpson DJ, Kamali A, McLardy-Smith P, Gill HS, Murray DW.** Analysis of wear of retrieved metal-on-metal hip resurfacing implants revised due to pseudotumours. *J Bone Joint Surg (Br)* 2010;92:356-61. **Langton DJ, Jameson SS, Joyce TJ, Hallab NJ, Natu S, Nargol AV.** Early failure of metal-on-metal bearings in hip resurfacing and large-diameter total hip replacement: A consequence of excess wear. *J Bone Joint Surg (Br)* 2010;92:38–46. **De Haan R, Campbell PA, Su EP, De Smet KA.** Revision of metal-on-metal resurfacing arthroplasty of the hip: the influence of malpositioning of the components. *J Bone Joint Surg (Br)* 2008;90-B:1158-63.
>
> The systemic effects of increases in metal ions are not fully understood but have been reported to include cerebral damage. **Rizzetti MC, Liberini P, Zarattini G, Catalani S, Pazzaglia U, Apostoli P, Padovani A.** Loss of sight and sound. Could it be the hip? *Lancet* 2009;373(9668):1052.

Serum concentrations >1 mcg/L indicate possible environmental or occupational exposure, and concentrations >5 mcg/L are considered toxic. Signs and symptoms of cobalt poisoning can include visual impairment, cardiomyopathy, cognitive impairment, auditory impairment, hypothyroidism, peripheral neuropathy, and rashes. Three prior case reports note blindness, deafness, heart failure, peripheral neuropathy, rashes, and hypothyroidism See < http://www.epi.alaska.gov/bulletins/docs/b2010_14.pdf>

Case Reports

Patient A, a fit, otherwise healthy, 49 year-old male received a MoMHA for osteoarthritis. An echocardiogram performed prior to his MoMHA showed normal myocardial function. At 3 months post-op, he complained of bilateral axillary rashes. At 8 months post-op, he reported unaccustomed shortness of breath. Pulmonary function tests and allergy testing for metals were normal. At 18 months post-op, he reported anxiety, headaches, irritability, tinnitus, and hearing loss. An audiogram confirmed high-frequency hearing loss. At 30 months post-op, he reported pain interrupting sleep, hip creaking, hand tremor, diminished coordination, slow cognition, poor memory, and lassitude. At 36 months post-op, a non-refractive loss of peripheral visual acuity was noted; at this time, his SCoL was 122 mcg/L.

The patient was indicated for revision surgery due to progressive hip pain and high SCoLs. An echocardiogram performed prior to the revision showed diastolic dysfunction. The revision was performed 43 months after the first surgery. At revision surgery, the periprosthetic tissues showed necrosis and staining with metal

debris and visible wear of the retrieved bearing. At 1 month post-revision, Patient A's SCoL was 14 mcg/L. At 6 months post-revision, he reported that all symptoms were improved except the visual changes.
Patient B, a fit, otherwise healthy, 49 year-old male received a MoMHA for a failed arthroplasty. At 12 months post-op, he complained of mental fog, memory loss, vertigo, hearing loss, groin pain, rashes, and breathlessness. At this time, his serum cobalt level was 23 mcg/L. At 18 months post-op, an echocardiogram showed diastolic dysfunction. He was observed until 40 months, when revision surgery was performed for progressive hip pain. Just before the revision, Patient B's SCoL was 23 mcg/L. At revision surgery, the periprosthetic tissues showed necrosis and staining with metal debris and his retrieved bearing showed visible wear. At 2 days post-revision, his SCoL fell to 11 mcg/L. At 3 months post-revision, his symptoms were improved. See < http://www.epi.alaska.gov/bulletins/docs/b2010_14.pdf>

We remain greatly concerned that patients who have the ASR hip implant in place will be at risk for complications from Chromium and Cobalt metal ions. In some of the ASR patients we are seeing some of the highest Chromium and Cobalt ion levels ever measured. There is a strong argument for surveillance and medical monitoring of these patients with an implanted ASR hip. The literature would suggest that this is so even if the patient is asymptomatic at this point.

Please feel free to give me a call at any point to help clarify some of these issues. I can point you to more precise references if you are interested. In the mean time we are working to put together the documentation form Dr. Graves we discussed earlier. My complete contact information is as follows:

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DePuy ASR Hip Prosthesis

Index to Research Materials

FILE 1			
No.	**Author & Title**	**Source**	**Date**
A. SAFETY NOTICES			
	MAUDE Adverse Event Report Reports	FDA	Various
	MedSun Reports	FDA	Various
	Urgent Field Safety Notice	MHRA	08.03.10
	Medical Device Alert	MHRA	25.05.10
No.	**Author & Title**	**Source**	**Date**
B. REGISTRY REPORTS			
	Annual Report 2007	Swedish Hip Arthroplasty Register	09.08
	Annual Report 2006	Australian Orthopaedic Association National Joint Replacement Registry	2006
	Annual Report 2007	Australian Orthopaedic Association National Joint Replacement Registry	2007
	Annual Report 2008	Australian Orthopaedic Association National Joint Replacement Registry	2008
	Annual Report 2009	Australian Orthopaedic Association National Joint Replacement Registry	10.09
No.	**Author & Title**	**Source**	**Date**

C. CONFERENCE REPORTS			
	17th Annual Fall Meeting	American Association of Hip and Knee Surgeons	2-4 November 2007
	75th Annual Meeting	American Academy of Orthopaedic Surgeons	March 2008
	76th Annual Meeting	American Academy of Orthopaedic Surgeons	February 25-28 2009
	2010 Annual Meeting	American Academy of Orthopaedic Surgeons	9-13 March 2010
No.	**Author & Title**	**Source**	**Date**
D. CLINICAL TRIALS			
	List of Clinical Trials for Device: DePuy ASR Hip System	ClinicalTrials.gov	25 March 2010
	Clinical Study Evaluating an Acetabular Cup System After Total Hip Replacement	ClinicalTrials.gov	October 2000 – June 2012
	A Multi-centre Study to Assess the Long-term Performance of the DePuy ASR™ System in Primary Hip Resurfacing Surgery	ClinicalTrials.gov	July 2003 – July 2020
	Metal Ion Release From an FDA-Approved Metal-on-Metal Total Hip Replacement Implant	ClinicalTrials.gov	October 2003 – November 2010
	A Single Centre Study to Assess the Long-term Performance of the DePuy ASR™ System in Primary Hip Resurfacing Surgery	ClinicalTrials.gov	November 2003 – February 2007
	A Randomised Study to Compare Metal Ion Release and Long-term Performance of the Pinnacle™ Cup With a Ceramic-on-Metal or a Metal-on-Metal Bearing	ClinicalTrials.gov	July 2006 – January 2012
	Multi-Center Comparative Trial of the ASR™-XL Acetabular Cup System vs. the Pinnacle™ Metal- on- Metal Total Hip System	ClinicalTrials.gov	August 2006 – December 2011
	A Multi-Centre Study to Assess the Long-term Performance of the DePuy ASR™ System in Resurfacing and Primary Total	ClinicalTrials.gov	September 2006 – June

	Hip Replacement		2015
	Efficacy of a New Resurfacing Hip Prosthesis	ClinicalTrials.gov	October 2006 – October 2011
	Metal-metal Articulations Versus Standard 28 mm Cementless Total Hip Arthroplasty	ClinicalTrials.gov	February 2007 – November 2011
No.	**Author & Title**	**Source**	**Date**
D. BUSINESS STUDIES			
	List of reports referencing "DePuy ASR"	Piribo	29 April 2010
No.	**Author & Title**	**Source**	**Date**
E. ARTICLES			
	Jacobs et al Cobalt and Chromium Concentrations in Patients With Metal on Metal Total Hip Replacements (abstract)	The Journal of Bone & Joint Surgery	August 1996
	Schmalzried et al Factors Correlating With Long Term Survival of McKee-Farrar Total Hip Prostheses (abstract)	The Journal of Bone & Joint Surgery	August 1996
	Szuszczewicz et al Progressive bilateral pelvic osteolysis in a patient with McKee—Farrar metal—metal total hip prostheses (abstract)	The Journal of Arthroplasty	October 1997
	H-P. Sieber et al Analysis of 118 second generation metal-on-metal retrieved hip implants	The Journal of Bone and Joint Surgery (Br)	July 1998
	Zahiri et al Lessons learned from loosening of the McKee-Farrar metal-on-metal total hip replacement (abstract)	The Journal of Arthroplasty	April 1999
	M. Böhler et al Adverse tissue reactions to wear particles from Co-alloy articulations, increased by alumina-blasting particle contamination from cementless Ti-based total hip implants	The Journal of Bone and Joint Surgery (Br)	April 2001

	C. Patrick Case Chromosomal changes after surgery for joint replacement	The Journal of Bone and Joint Surgery (Br)	November 2001
	Campbell et al Autopsy Analysis Thirty Years After Metal on Metal total hip replacement (abstract)	The Journal of Bone and Joint Surgery	2003
	Yorty et al Transplacental Transfer and Subsequent Neonate Utilization of Herpes Simplex Virus-Specific Immunity Are Resilient to Acute Maternal Stress	Journal of Virology	June 2003
	Daniel et al Metal-on-Metal resurfacing of the hip in patients under the age of 55 years with osteoarthritis	The Journal of Bone and Joint Surgery (Br)	March 2004
	Ladon et al Changes in metal levels and chromosome aberrations in the peripheral blood of patients after metal-on-metal hip arthroplasty (abstract)	The Journal of Arthroplasty	December 2004
	Dowson et al A hip joint simulator study of the performance of metal-on-metal hip joints: Part II: Design (abstract)	The Journal of Arthroplasty	December 2004
	Huk et al Induction of apoptosis and necrosis by metal ions in vitro (abstract)	The Journal of Arthroplasty	December 2004
	Bowsher et al Effect of ion implantation on the tribology of metal-on-metal hip prostheses (abstract)	The Journal of Arthroplasty	December 2004
	Willert et al Metal-on-Metal Bearings and Hypersensitivity in Patients with Artificial Hip Joints (abstract)	The Journal of Bone and Joint Surgery	January 2005
	Dumbleton and Manley Metal-on-Metal Total Hip Replacement: What Does the Literature Say? (abstract)	The Journal of Arthroplasty	February 2005
	Howie et al Metal-on-metal resurfacing versus total hip	Orthopaedic Clinics of North America	April 2005

	replacement-the value of a randomized clinical trial (abstract)		
	Clarke et al Current concepts of metal-on-metal hip resurfacing (abstract)	Orthopaedic Clinics of North America	April 2005
	Milosev et al Serum levels of cobalt and chromium in patients with Sikomet metal-metal total hip replacements (abstract)	Journal of Orthopaedic Research	May 2005
	Jin et al Deformation of press-fitted metallic resurfacing cups. Part 1: experimental simulation. Part 2: Finite Element Simulation (abstract)	Proceedings of the Institution of Mechanical Engineers, Part H: Journal of Engineering in Medicine	August 2005
	Dumbleton et al Metal on Metal total Hip replacement: What does the literature say? (abstract)	The Journal of Arthroplasty	September 2005
	William T. Long The Clinical Performance of Metal-on-Metal as an Articulation Surface in Total Hip Replacement	The Iowa Orthopaedic Journal	Vol 25, 2005
	Hart et al The association between metal ions from hip resurfacing and reduced T-cell counts (abstract)	The Journal of Bone and Joint Surgery (Br)	April 2006
	Jacobs and Hallab Loosening and Osteolysis Associated with Metal-on-Metal Bearings: A Local Effect of Metal Hypersensitivity (abstract)	The Journal of Bone and Joint Surgery	June 2006
	T Siebel et al Lessons learned from early clinical experience and results ASR hip resurfacing implantations (abstract)	Proceedings of the Institution of Mechanical Engineers, Part H: Journal of Engineering in Medicine	Vol 220(2), 2006
	National Medical Policy Subject: Hip Resurfacing	Health Net	February 2007
	Keegan et al Orthopaedic metals and their potential toxicity in the Arthroplasty patient (abstract)	The Journal of Bone and Joint Surgery (Br)	May 2007

	Jakobsen et al Cobalt-Chromium-Molybdenum Alloy Causes Metal Accumulation and Metallothionein Up-Regulation in Rat Liver and Kidney (abstract)	Basic & Clinical Pharmacology &Toxicology	October 2007
	Daniel et al Metal Ion Study Four Year Results	The Journal of Bone and Joint Surgery (Br)	December 2007
	Legenstein et al Metallosis in Metal-on-Metal PPF Total Hip Arthroplasties	Bioceramics and Alternative Bearings in Joint Arthroplasty	2007
	Randle and Gordiev Metal-on-Metal Articulation In Total Hip Arthroplasty: Preliminary Results in 57 Cases (abstract)	ANZ Journal of Surgery	January 2008
	Dunstan et al Chromosomal Aberrations in the Peripheral Blood of Patients with Metal-on-Metal Hip Bearings (abstract)	The Journal of Bone and Joint Surgery	April 2008
	Shimmin et al Metal-on-Metal Hip Resurfacing Arthroplasty	The Journal of Bone and Joint Surgery	May 2008
	Pandit et al Pseudotumours associated with metal-on-metal hip resurfacings (abstract)	The Journal of Bone and Joint Surgery (Br)	July 2008
	Antoniou et al Metal ion levels in the blood of patients after hip resurfacing: a comparison between twenty-eight and thirty-six-millimeter-head metal-on-metal prostheses (abstract)	The Journal of Bone and Joint Surgery	August 2008
	De Haan et al Revision of metal-on-metal resurfacing Arthroplasty of the hip (abstract)	The Journal of Bone and Joint Surgery (Br)	September 2008
	Langton et al The effect of component size and orientation on the concentrations of metal ions after resurfacing arthroplasty of the hip	The Journal of Bone & Joint Surgery	September 2008
	De Haan et al Correlation between inclination of the	The Journal of Bone and Joint Surgery (Br)	October

	acetabular component and metal ion levels in metal-on-metal hip resurfacing replacement (abstract)		2008
	Zijlstra et al Large head metal-on-metal cementless total hip Arthroplasty versus 28mm metal-on-polythene cementless total hip Arthroplasty: design of a randomized controlled trial	Biomed Central	October 2008
	Pandit et al Necrotic granulomatous pseudotumours in bilateral resurfacing hip arthoplasties: evidence for a type IV immune response (abstract)	Virchows Archiv : an international journal of pathology	November 2008
	Whittingham-Jones et al Immune responses in patients with metal-on-metal hip articulations: a long-term follow-up (abstract)	The Journal of Arthroplasty	December 2008
	Joyce et al Tribological analysis of failed resurfacing hip prostheses and comparison with clinical data	Proceedings of the Institution of Mechanical Engineers, Part J: Journal of Engineering Tribology	January 2009
	Dueul et al Alterations in femoral strain following hip resurfacing and total hip replacement (abstract)	The Journal of Bone and Joint Surgery (Br)	January 2009
	Daniel et al Six-year results of a prospective study of metal ion levels in young patients with metal-on-metal hip resurfacings (abstract)	The Journal of Bone and Joint Surgery (Br)	February 2009
	Hosman et al Metal-on-metal bearings in total hip arthroplasties: Influence of cobalt and chromium ions on bacterial growth and biofilm formation (abstract)	Journal of Biomedical Materials Research	March 2009
	Schnurr et al Is a valgus position of the femoral component in hip resurfacing protective against spontaneous fracture of the femoral neck?: A biomechanical study (abstract)	The Journal of Bone and Joint Surgery (Br)	April 2009
	Mark Bloomfield	Posted on 'hipsrus'	April 2009

	Hip Resurfacing vs THR	Message Board	
	Hart et al The painful metal-on-metal hip resurfacing (abstract)	The Journal of Bone and Joint Surgery (Br)	June 2009
	Grammatopolous et al Hip resurfacings revised for inflammatory pseudotumour have a poor outcome (abstract)	The Journal of Bone and Joint Surgery (Br)	August 2009
	Ollivere et al Early clinical failure of the Birmingham metal-on-metal hip resurfacing is associated with metallosis and soft tissue necrosis	The Journal of Bone and Joint Surgery (Br)	August 2009
	Patricia Walter High Metal Ions, Pseudotumours, Metallosis & ALVAL	Surface Hippy	September 2009
	A Kamali Metal Ion release following hip replacement not strongly related to patient activity medical study	Surface Hippy	September 2009
FILE 2			
No.	**Author & Title**	**Source**	**Date**
E. ARTICLES			
	Isaac et al Ceramic-on-metal bearings in total hip replacement (abstract)	The Journal of Bone and Joint Surgery (Br)	September 2009
	Langton et al The effect of component size and orientation on the concentrations of metal ions after resurfacing arthroplasty of the hip (abstract)	The Journal of Bone and Joint Surgery (Br)	September 2009
	Langton et al Blood metal ion concentrations after hip resurfacing arthroplasty: A comparative study of articular surface replacement and Birmingham hip resurfacing arthroplasties	The Journal of Bone & Joint Surgery	October 2009
	Young-Min Kwon et al Lymphocyte proliferation responses in patients with Pseudotumours following	Journal of Orthopaedic Research	October 2009

	metal-on-metal hip resurfacing Arthroplasty (abstract)		
	Robert Trace Soft Tissue reactions to metal-on-metal hip Arthroplasty are due mostly to surface wear	Orthopaedics Today Europe	November 2009
	Glyn-Jones et al Risk factors for inflammatory pseudotumour formation following hip resurfacing (abstract)	The Journal of Bone and Joint Surgery (Br)	December 2009
	Clinical Review Criteria Hip Resurfacing Metal on Metal Hip Resurfacing Systems	Group Health Cooperative	2010
	Langton et al The influence of implantation and component design on metal debris reactivity following hip resurfacing arthroplasty	The Journal of Bone and Joint Surgery (Br)	January 2010
	Jameson et al Articular Surface Replacement of the hip: a prospective single surgeon series (abstract)	The Journal of Bone and Joint Surgery (Br)	January 2010
	Langton et al Early failure of metal-on-metal bearings in hip resurfacing and large-diameter total hip replacement (abstract)	The Journal of Bone and Joint Surgery (Br)	January 2010
	Prosser et al Outcome of primary resurfacing hip replacement: evaluation of risk factors for early revision	Acta Orthopaedica	February 2010
	ASR – Articular Surface Replacement System by DePuy, a Jonson & Johnson Company	Surface Hippy	February 2010
	K. De Smet et al Metal-on-Metal hip resurfacing – A consensus from the Advanced Hip Resurfacing Course, Ghent June 2009	The Journal of Bone and Joint Surgery (Br)	March 2010
	Wik et al Increased strain in the femoral neck following insertion of a resurfacing femoral prosthesis (abstract)	The Journal of Bone and Joint Surgery (Br)	March 2010 (abstract only)

	Y-M Kwon Analysis of wear of retrieved metal-on-metal hip resurfacing implants revised due to pseudotumours (abstract)	The Journal of Bone and Joint Surgery (Br)	(March 2010 abstract only)
	ASR Hip Implant Failure – Depuy Orthopaedics	New York Times	March 2010
	Articles by Barry Meier	New York Times	March 2010
	Metal Ion Issues	Hip Resurfacing News	October 2008 – March 2010
	Study Finds Elevated Levels of Cobalt and Chromium in Offspring of Patients with Metal-on-Metal Hip Implants	Science Daily	March 2010
	Shinnin et al The influence of the size of the component on the outcome of resurfacing arthroplasty of the hip (abstract)	The Journal of Bone and Joint Surgery (Br)	April 2010
	Thomas Gross The controversy regarding adverse wear in metal-metal bearings by Dr. Goss	Surface Hippy	March 2010
	Patricia Walter Smith & Nephew Press Conference about the Safety and Effectiveness of BHR	Hip Resurfacing News	May 2010
	Matthew et al Acetabular Cup Malaignment After Total Hip Resurfacing Arthroplasty: A Case for Elective Revision?	OrthoSuperSite	Post 2008
	Dave Levitan Surgeons have many choices for hip surface replacements	OrthoSuperSite	Post 2004
	Thomas Schmalzried Metal-Metal Bearing Surfaces in Hip Arthroplasty	OrthoSuperSite	Post 2009
	Metal-on-metal Total Hips	Totaljoints.info	Post 2006
No.	**Author & Title**	**Source**	**Date**
F. NOTES			
	NHS data re ODEP View	NHS	2010

No.	Author & Title	Source	Date
G. UK RESEARCH CENTRES			
	Norfolk and Norwich University NHS Foundation Trust	Norfolk and Norwich University NHS Foundation Trust	2010
	Nuffield Orthopaedic Centre NHS Trust	Nuffield Orthopaedic Centre NHS Trust	2010

Metal on metal hip implants

Index to Research Materials

FILE 3			
No.	**Author & Title**	**Source**	**Date**
1. NCCHTA REPORT			
	Vale et al Systematic Review of the effectiveness and cost-effectiveness of metal on metal hip resurfacing Arthroplasty for treatment of hip disease	NCCHTA	28 November 2001
No.	**Author & Title**	**Source**	**Date**
2. National Institute for Clinical Excellence			
	National Institute for Health and Clinical Excellence (NICE) 2002 Technology Appraisal Guidance No. 44 – Guidance on the use of metal on metal hip resurfacing Arthroplasty	NHS	June 2002
	Press Release – NICE recommends the selective use of metal on metal hip resurfacing	NHS	19 June 2002
	Letter from Dr C Longson re Review of NICE Technology Appraisal Guidance No 2, the Selection of prosthesis for total hip replacement and no.44 Metal-on-metal hip resurfacings	NHS	18 July 2005
	Letter from Dr C Longson re Review of NICE Technology Appraisal Guidance No 2, the Selection of prosthesis for total hip replacement and no.44 Metal-on-metal hip resurfacings	NHS	30 August 2005
	Review Proposal (February 2005)	NHS	2008
	Review Proposal Project – Appendix A: Provisional matrix of consultees and commentators	NHS	April 2009
	Review Proposal (May 2009) – Review NICE Technology Appraisal Guidance No's 2 & 4: Replacement prostheses for hip disease and metal on metal hip resurfacing for hip disease	NHS	5 May 2009
	NICE Hip Disease – metal on metal hip resurfacing: the clinical effectiveness of metal on metal hip resurfacing – Background information	NHS	May 2009

	NICE Hip Disease – metal on metal hip resurfacing: the clinical effectiveness and cost effectiveness of metal on metal hip resurfacing – Guidance documents	NHS	May 2009

No.	Author & Title	Source	Date
3. Committee on the Safety of Devices Expert Advisory Group			
	MINUTES – on metal wear debris from hip implants		23 October 2006
	MINUTES – on metal wear debris from hip implants		09 January 2007
No.	**Author & Title**	**Source**	**Date**
4. Miscellaneous			
	List of Articles re Metal on Metal		
	Practical Advice for clinicians and patients on Metal on Metal hip replacements	Finsbury Orthopaedics Bulletin	15 January 2008
	Expert Advisory Group on 'Biological effects of metal wear debris generated from hip implants: genotoxicity' – scientific background	MHRA	3 March 2008
	Environmental Health Criteria 61 – Chromium	World Health Organisation	1988