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Hip Resurfacing Arthroplasty: The Liverpool Experience

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HIP RESURFACING ARTHROPLASTY: THE LIVERPOOL EXPERIENCE

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Total hip arthroplasty has proved to be one of the most successful operations in terms of pain relieve and improving patients' quality of life [1]. The published data from specialised centres have shown a high level of patient satisfaction and very low revision rate in 15-20 years follow up [2]. These excellent results in elderly population and even in young patients with systemic illness or health problems [3], which limit their activities, does not reflect the picture on the young active patients [4] especially with osteoarthritis OA as a primary diagnosis [5].

The unsatisfactory results in the younger population have renewed the interest in hip resurfacing with a new design and metal on metal bearing surface. This new design carries the theoretical advantage of less critical size wear of the metal on metal bearing surfaces [6], bone preserving and easier revision surgery if needed. It may also decrease the risk of dislocation with a better range of hip motion. These theoretical advantages, however, have not been supported by long-term clinical results yet although the early results presented by the designers are encouraging [7]. We are presenting our early results from Liverpool as an independent reviewer.

Material and Methods

Between June 1998 and September 2001 we have performed 137 Birmingham hip resurfacing in 129 patients. We are reporting the results of the first 100 hips in 93 patients, 55 males and 38 females. The mean age of these 93 patients was 51.5 years (range 18 to 73 years). The mean follow up period is 17 months (range 6 to 42 months). Those who completed a follow up period of 12 months were 73, and 24 months were 22 hips. The primary aetiology for hip arthritis varied in this group of patients between hip dysplasia 7 hips, inflammatory arthritis 2 hips, avascular necrosis (AVN) 3 hips, Haemophilia 1 hip and primary osteoarthritis (OA) 87 hips.

All cases were done by or under direct supervision of the senior author (SFJ) through the posterior approach with the patient in the lateral position. Hybrid resurfacing with Hydroxyapatite coated press fit cups and cemented femoral heads were implanted according to the technique provided by the manufacturer Birmingham Medical Technologies MMT, Birmingham, UK. We have used dysplasia cups with fixation bolts in 10% of cases because of deficient acetabulum that led to incomplete cover of the cup or inadequate primary stability by press fit alone.

All patients were assessed prospectively using the WOMAC osteoarthritis index [8] plus pelvis x-rays post-operatively at 6 months, 1 year and then annually afterwards.

Post-operatively patients were subjected to a physiotherapy protocol developed in this unit with the aim to restore normal range of movement, restore dynamic stability of the lumbar Spine, pelvis and hip region and regain normal functional activity of the individual patients.

Results:

The results of the WOMAC score are summarised in figure 1 and shows statistically significant reduction in the 3 different parameters of the score index P<0.00001 as recorded at 1 year (73 hips), and 2 years (22 hips). There was high degree of variability in the preoperative score with coefficient of variation CV% for pain 28.8 1%, joint stiffness 32.54% and difficulty 25.5 1%. Additionally high degree of variability in the postoperative results was noted as many patients have scored 0 in many of the score's parameters reflecting a symptom free function.

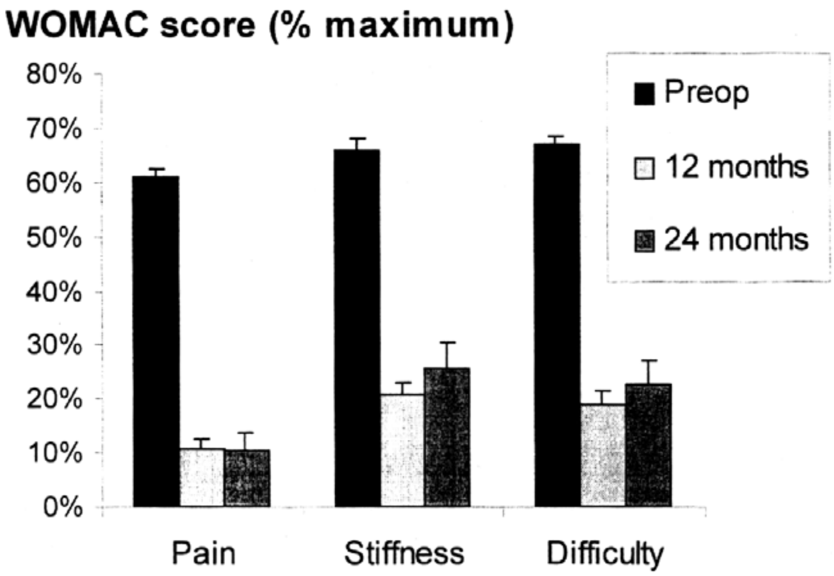

Figure 1. Mean pre and post operative WOMAC score and SE.

On the latest x-ray review of these patients all cases except 1 did not show any radiolucent lines, which can be considered as loosening in any of the zones around the acetabulum. All cases have shown good osteointegration of the cups, even cups which did not achieve direct contact to the floor of the acetabulum but firm press firm in the immediate post operative x-ray have shown filling up of these lucent lines with bone osteointegration.

There were variability in the femoral prosthesis orientation with different degrees of head neck angles, but these did not seem to affect the outcome at this stage of analysis. No notching of the neck was noted in any of our cases.

Considering revision as the endpoint for follow up, only one case was revised because of cup failure. There is another case, which can be considered at risk for revision, because of radiological loosening of the head. This patient has not been revised, as he is symptom free.

Complications:

One case of dislocation has been reported in our series that happened in extreme hip flexion and adduction. Closed reduction was possible with no further instability recorded afterwards. There was another case re-explored within an hour of surgery when postoperative x-ray showed distraction of the joint surfaces. Exploration showed soft tissue interposition.

There was a case of femoral nerve palsy that recovered fully in a course of six weeks, and a case of DVT, which needed further anticoagulation therapy.

About 10% of the patients reported transient squeaking from their hips in the extremes of hip movements about 6 months post-operatively but this has spontaneously disappeared in all cases.

Discussion:

Hip resurfacing is an interesting idea that attracted many orthopaedic surgeons over the years [9-1 1]. The Birmingham design with metal on metal bearing surfaces has many theoretical advantages that are still to be proven in the long term.

Our early results with this resurfacing design are encouraging as a quick post-operative recovery and return to a high level of activity were demonstrated by the WOMAC data. The average age of our patients was 18 years younger than patients for THR in this unit, and this may have helped in achieving good postoperative recovery.

The only reported case of cup revision was a case of difficult dysplasia. Technical error can be the reason for early failure as the cup was supported by one bolt only with probable inadequate primary stability. This case was revised to another dysplasia cup and continued to perform well afterwards. No loosening of the prosthesis could be found apart from one case of femoral loosening.

This system with the big head (38-58 mm) may have a less incidence of dislocation [12]. The only case of dislocation was a fitness instructor with generalised ligament laxity. Closed reduction was possible and this might have happened because of her generalised laxity. No further dislocation occurred following a rehabilitation and re- education physiotherapy course.

We have extended the indication for use of dysplasia cups to another group of patients in whom we could not achieve a tight press fit, or were found with deficient acetabulum that needed bone graft at time of surgery e.g. protrosio sockets. Modification of the physiotherapy with partial weight bearing for 6 weeks was followed in this group of patients.

Patients who reported transient squeaking from their hips have had no further problems and Continue to function well. We cannot explain this problem but it may represent a transient failure of bearing surfaces lubrication.

Indicating the learning curve our mean operative time has dropped from 2 hours and 5 minutes in the first 10 cases to 1 hour and 40 minutes in the last 10 cases excluding dysplasia cases.

Conclusion:

Birmingham hip resurfacing has given early encouraging results in our hands that justify its continued use. Further follow up will need to continue to record the mid and long term results from other centres outside Birmingham.

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Surgical Aspects of Hip Resurfacing

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Surgical Aspects of Hip Resurfacing

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Hip resurfacing with replacement of the diseased acetabular and femoral articular surfaces is the most conservative hip arthroplasty available.

Hip resurfacing was first performed by Professor Sir John Charnley in the early 1950's with numerous designs from other centres following. All of these designs over the subsequent forty years met with universal failure. Surgeons generally have ascribed this failure to ischaemic necrosis of the femoral head. Charnley[1] reported his polytetrafluoroethylene (PTFE) resurfacing failures as due to ischaemic necrosis of the femoral head and made no mention of the wear of the PTFE surfaces, mentioned no tissue reaction to the PTFE particles and made no mention that some PTFE components wore completely through.

Engineers have often ascribed the failures of historical hip resurfacing to loss of bone substance from the femoral head due to stress shielding caused by the femoral resurfacing cap. Both the ischaemic necrosis theory and the stress shielding theory have been shown to be incorrect with the passage of years. The major cause of failure of historical hip resurfacings has been shown to be due to osteolysis, both in the acetabulum and in the femoral head caused by particulate polymer debris [2,3]

Historical metal on metal THR bearings have been remarkably free from metal particle induced osteolysis.

The author has performed 1,997 metal on metal hip resurfacings between Feb 1991 and Feb 2002. Two cases of failure due to ischaemic necrosis of the femoral head have occurred. There have been no cases of failure due to stress shielding of the femoral head. In the first three years several methods of fixation of the metal on metal bearings were tried and optimum fixation proved to be uncemented hydroxyapatite cups and cemented femoral components. Two dislocations have occurred in these 1,997 metal on metal hip resurfacings.

Failures due to wear of the metal on metal bearings have only occurred from implants inserted during 1996. During 1996 double heat treatment of the bearings (hot isostatic pressing & solution heat treatment) was performed. Revision of patients resurfacings performed during 1996, have shown metallosis and osteolysis. Analysis of retrieved components has shown that the double heat treatments have caused a variable amount of carbide depletion of the metal microstructure and the wear of the retrieved components is proportional to the amount of carbide depletion of the metal microstructure, with dramatic wear in totally carbide depleted components. Failures from 1996 have been and will continue to be reported to the Medical Device Authority, UK and to Corin Medical Ltd, the manufacturers of this double heat-treated metal resurfacing.

The Swedish National Hip Arthroplasty Register has identified young and active patients as the most challenging group for conventional total hip replacement. In patients under the age of 55yrs and with a diagnosis of osteoarthritis the failure rate of THR from the Swedish Register is 19% at 10yrs and 67% at 16yrs [4].

Hip resurfacing has its main applicability therefore in this younger and more active patient population. During 1994, 1995, 1997, 1998, 1999, 2000 and 2001 the senior author has performed 509 metal on metal hip resurfacings in patients under the age of 55yrs with a diagnosis of osteoarthritis. Patients in this category from 1996 have been excluded due to the unique failure pattern with high wear of the metal on metal bearings, metallosis and osteolysis caused by double heat treatment of the metal.

Kaplan-Meier survival analyses have been performed on the THR's from the Swedish Register and the senior authors resurfacing patients. A comparison of the under 55yr patients with osteoarthritis in both groups shows a significantly improved survival of the metal on metal resurfacings compared to the THR's at seven years post-op (fig.1).

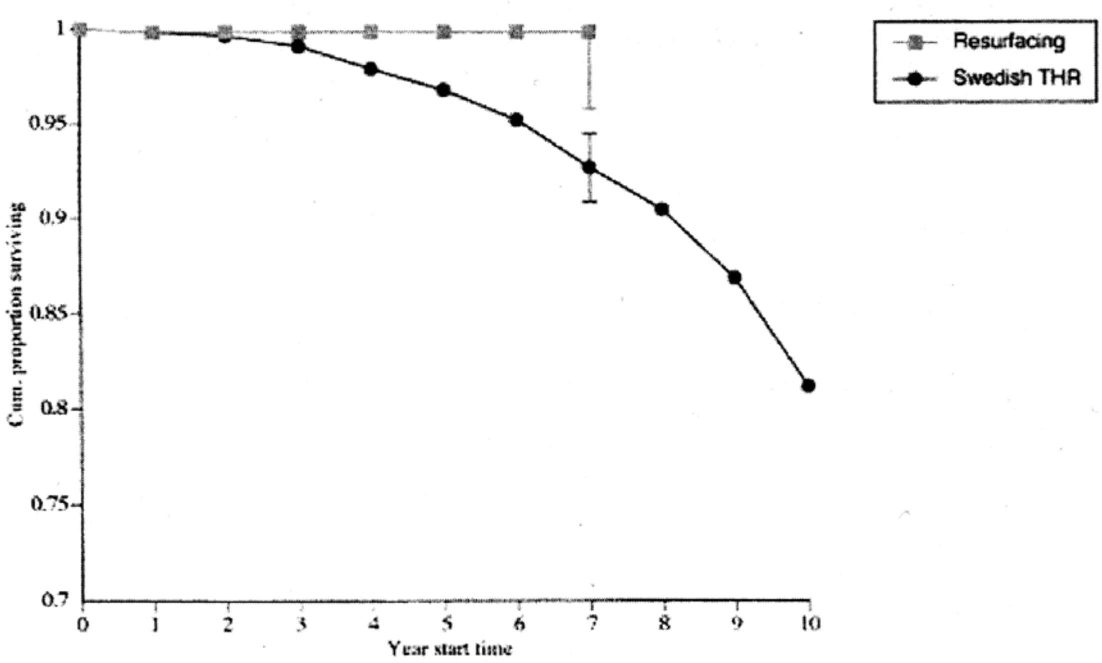

Fig 1. Comparison of survival of metal on metal hip resurfacing and the Swedish hip registry data for patients < 55 years with O.A.

An RSA study has been performed on 19 Birmingham Hip Resurfacing patients (20 hips) with Dr Lars Nistor and Dr Arne Lundberg (Sweden) and migration measurements have been made up to 2-year's. Very low migration has been observed up to the 1-year stage (fig.2). The two-year migration data will soon be available.

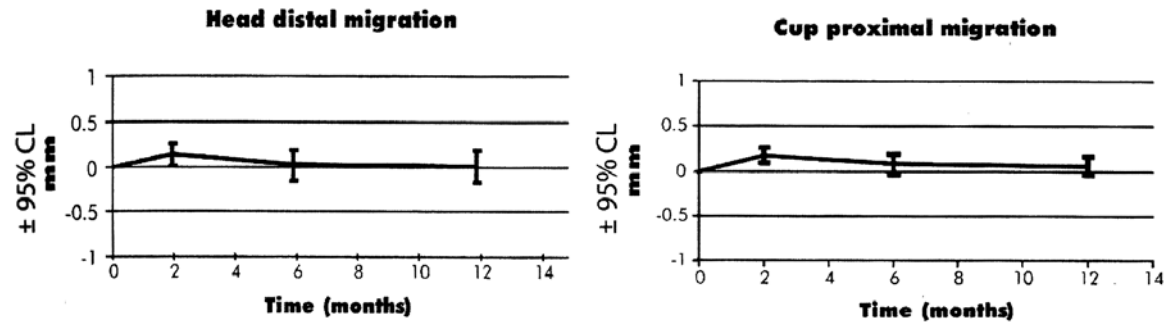

Fig. 2a- RSA migration on BHR femoral component. Up to 1-year. **Fig. 2b**- RSA migration on BHR acetabular component. Up to 1-year.

Hip Resurfacing using metal on metal bearings with historically proven metallurgy, combined with hybrid fixation offers a viable treatment alternative for the young and more active patient with hip arthritis.

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Biological Aspects of Hip Resurfacing

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Biological Aspects of Hip Resurfacing.

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The effects of hip resurfacing are local and general; and early and late. The most profound early, local difference between resurfacing and conventional THR is the absence of femoral medullary canal instrumentation and cementing in the hip resurfacing procedure. Transoesophageal echocardiography has revealed very considerable fat and marrow embolisation following conventional cemented THR whereas the embolisation following hip resurfacing is minimal (fig.1).

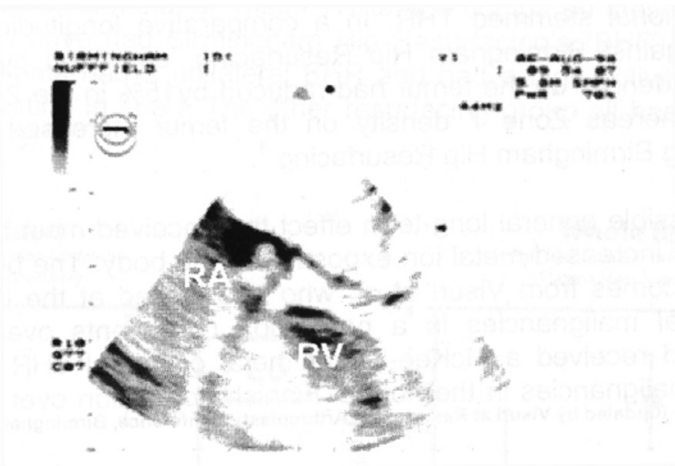


Fig.1a - Severe fat and marrow embolisation into right heart following conventional THR.

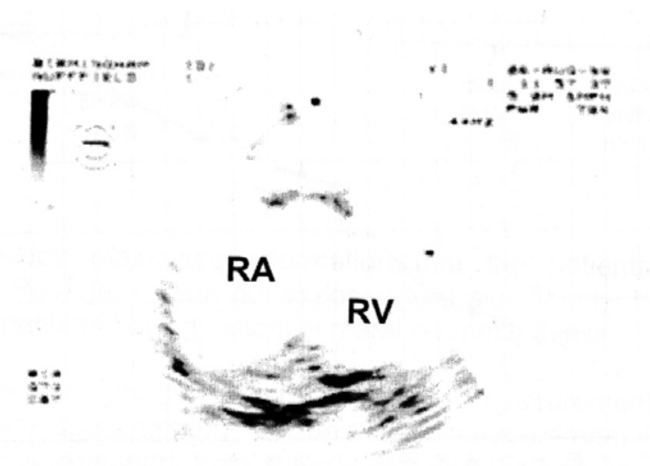


Fig.1b - Virtually no embolisation into right heart following Birmingham Hip Resurfacing.

This fat and marrow displacement from the femur into the general circulation has been shown to be highly thrombogenic [1, 2]. The relatively high incidence of thromboembolic complications following conventional THR may be due in major part to this fat and marrow embolisation. The relative paucity of thromboembolic problems following hip resurfacing may be due in part to the relative absence of fat and marrow embolisation following this procedure. The author has had three thromboembolic complications, all non-fatal in 1,570 consecutive Birmingham Hip Resurfacing's.

Osteolysis has hitherto not been a problem in metal on metal hip resurfacings except with implants inserted during 1996, a period during which the wear resistance of the material was reduced by double heat treatment.

Loading of the upper femur is quite different in hip resurfacing compared to conventional stemmed THR. In a comparative longitudinal study of stemmed THR against Birmingham Hip Resurfacing, assessed by serial DEXA Scans, Zone 7 density on the femur had reduced by 15% in the 2yrs following stemmed THR whereas Zone 7 density on the femur increased by 12% in the 2yrs following Birmingham Hip Resurfacing[3].

The possible general long-term effect that received most attention relates to the effect of increased metal ion exposure on the body. The best information on this aspect comes from Visuri et al, who has looked at the incidence of individual and total malignancies in a population of patients over a thirty-year period who had received a McKee-Farrar metal on metal THR and compared these to the malignancies in the normal Finnish population over the same time period (fig.2) [4] (updated by Visuri at Resurfacing Arthroplasty Conference, Birmingham, Sept 11th 2001)

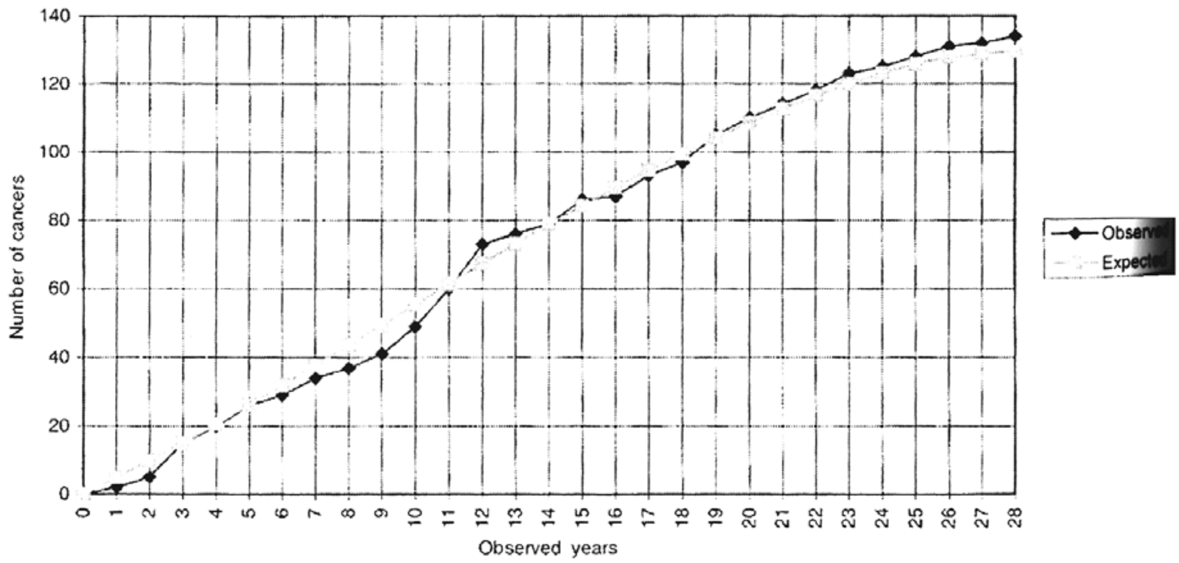


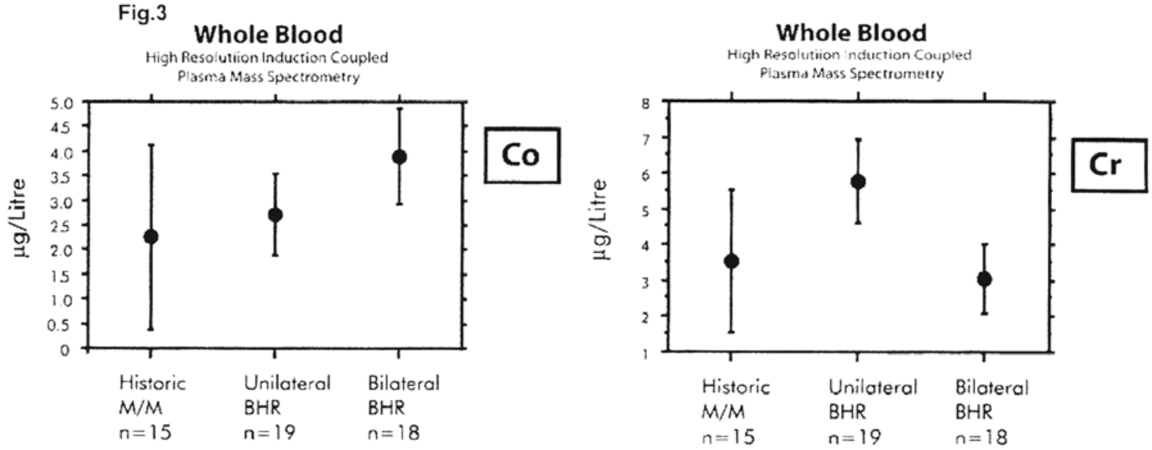
Fig.2- Cumulative number of observed and expected cancer cases among patients with metal on metal total hip arthroplasty, by time since THA.

This study indicates that there was no increase in the individual or total malignancies in the metal on metal patients compared to the normal population.

This information provides the strongest available evidence that metal on metal hip arthroplasty devices are safe over a thirty-year period. However it is not possible to say at this stage if they are safe for longer exposure times. In addition for any new metal on metal device it needs to be demonstrated that the metal ion exposure is no higher than that of the historical metal on metal THR devices, if the safety information on these historic metal on metal devices is to be relied upon.

We have performed a comparative study on whole blood metal ion levels in patients with historical metal on metal THR's and compared these to two groups of patients who have had Birmingham Hip Resurfacing's (BHR). One group of resurfacing patients had a unilateral BHR and had a high activity level with all patients participating in sport. The other resurfacing group all had bilateral BHR procedures (fig.3).

Fig.3



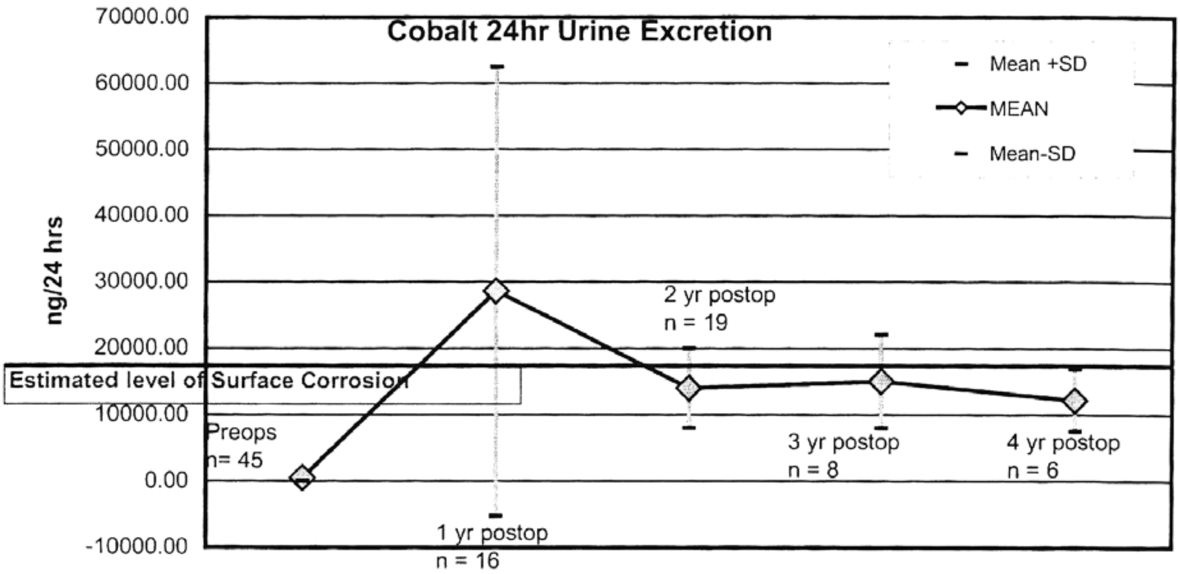
This study provides reassuring information that the patients fitted with a Birmingham Hip Resurfacing are not exposed to a significantly higher metal ion level than those patients having historical metal on metal THR's.

It is now understood that the least satisfactory measurement of metal ion exposure is serum concentration, the next best measurement is either whole blood or red cell assessment of metal ion levels, but the best in vivo assessment of metal ion production both from corrosion and wear of any implanted device is 24hr urine metal ion output measured by high resolution induction coupled plasma mass spectrometry.

The only such in vivo assessment published as far as the authors are aware, is a study on low carbon metal on metal THR [5].

We have performed a four-year cross-sectional study on patients who had unilateral BHR's. In order to standardize this study as much as possible we chose only men, Charnley grade A with size 50mm or 54mm femoral components. Fig.4 shows the 24hr cobalt output at different time periods following operation.

Fig.4



We calculated the baseline production of metal ions from surface corrosion, expected from these implants according to the method of Willert based on implant surface area [6].

One interpretation of these results is that the BHR metal on metal bearings undergo a 'running-in' period giving higher urinary output of cobalt at the one-year post-operative stage. The cobalt output then stabilizes at the two, three and four year post-operative periods. It can be seen that the two-year, three-year and four-year levels of cobalt output could be explained by surface corrosion from the implant only, with no contribution from wear. However this analysis may be proven incorrect with the passage of time if the calculated level of corrosion is excessive. If, however, the first interpretation proves to be correct and following a running in period these large diameter metal on metal bearings are only producing metal ions by corrosion, then further attempts to reduce metal ion exposure to patients fitted with the Birmingham Hip Resurfacing may not be achieved by attention directed at reducing wear. Measures directed at reducing surface corrosion may instead have a more beneficial effect.

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The lubrication regime in a metal-on-metal total hip replacement.

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The lubrication regime in a metal-on-metal total hip replacement.

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1. INTRODUCTION

Wear debris produced by the articulation of the femoral head against the polyethylene cup of a total hip replacement has been implicated as one of the major causes of failure in these artificial joints (1, 2, 3). Hard bearing surfaces such as metal-on-metal or ceramic-on-ceramic have been introduced in an attempt to try and reduce wear debris generation and subsequent failure of total hip replacements. The amount of wear debris generated is lowest in joints with a fluid film lubrication regime as no contacting of the surfaces occurs (4, 5). The aim of this study was to show which type of lubrication took place in a particular metal on metal surface replacement joint.

2. MATERIALS AND METHODS

The lubrication regime of nine different metal on metal Birmingham Hip Replacements was examined with different lubricants. All of the joints were supplied by Finsbury Instruments, Surrey, UK. The two components of each joint were mounted in specially designed holders and friction measurements were carried out on the Durham Hip Function Simulator. A low friction carriage held the acetabular cup while the femoral head was fixed in a moving frame. A dynamic loading cycle comparable with that of flexion extension loading in a walking subject in vivo was applied with a hydraulic system controlled by a microprocessor via a PC (6). The loading cycle had a maximum load of 2000N and a minimum load of l00N and was applied in an oscillatory fashion in the flexion extension plane with an amplitude of 24° for a period of 1.2 seconds. Throughout each cycle the angular displacement, the load and the frictional torque were measured 128 times. In order to obtain accurate measurements, all joints were tested in a similar way with the rotational axes aligned. The frictional torque found for each joint was then used to calculate the friction factor (f) as follows:

$$f = \frac{T}{RL}$$

In this equation T is the frictional torque generated between the bearing surfaces, R is the radius of the femoral head and L is the load applied.

Five joints were examined with solutions of non-biological carboxy methyl cellulose (CMC), each with a different viscosity (0.183, 0.128, 0.102, 0.031, 0.009, and 0.003 Pa s). To prevent damage to the joint, the highest three viscosities were tested first, after which they were also tested with solutions of 50% bovine serum with the same viscosities as mentioned above. The measurements with the lower range of CMC viscosities were then completed. The remaining four joints had similar diametral clearances but were manufactured with a different surface finishing technique. These were examined with solutions of 50% bovine serum only. The joints were tested with each viscosity three times each and the joints were cleaned thoroughly between every test.

The surface roughness of each femoral head was measured with a non-contacting profilometer (Zygo NewView 100) before and after testing each range of viscosities.
The mode of lubrication was determined through Stribeck analysis (Fig.1) in which the friction factor found in the measurements was plotted against Sommerfeld number *(z),* defined as:

$$z = \frac{nuR}{L}$$

Here *n* is the viscosity of the lubricant, *u* is the entraining velocity of the bearing surfaces, *R* is the radius of the femoral head and *L* represents the applied load. A decrease in friction factor with an increase in Sommerfeld number indicates mixed lubrication with the load partly carried by the asperities of the joint surfaces and partly by the pressure in the lubricant. A full fluid film regime is indicated by a rising trend in the friction factor, which means that the bearing surfaces are kept entirely apart by the layers of lubricant. In this case the shear within the lubricant generates the frictional resistance (4).

For each joint the theoretical prediction of the lubrication regime for the physiological viscosity (0.009 Pa s) was calculated and compared with the experimental results.

3. RESULTS

The theoretical calculations for the joints with the smaller radial clearances showed that the ratio of the minimum film thickness to the combined surface roughness was larger than three (Table 1), which meant that these joints should be operating in a full fluid film lubrication regime (8)

Table 1: The theoretically predicted lubrication regime for each joint.

Joint	Diametral clearance *(um)*	λ value	Predicted regime
A	190	1.05	Mixed
B	60	3.06	Fluid film
C	120	1.44	Mixed
D	160	1.22	Mixed
E	*35*	3.34	Fluid film
F	120	3.31	Fluid film
G	*35*	*5.53*	Fluid film
H	190	1.28	Mixed
I	20	8.81	Fluid film

Contrary to the theoretical findings, the experimental results showed that with the CMC as well as with the bovine serum lubricant at a viscosity close to physiological, all joints were operating within the mixed lubrication regime. However, at higher viscosities some joints showed a rising trend in friction factor as shown in Figure 1 where the results of the 60 *um* radial clearance joint (tested with bovine serum) are displayed.

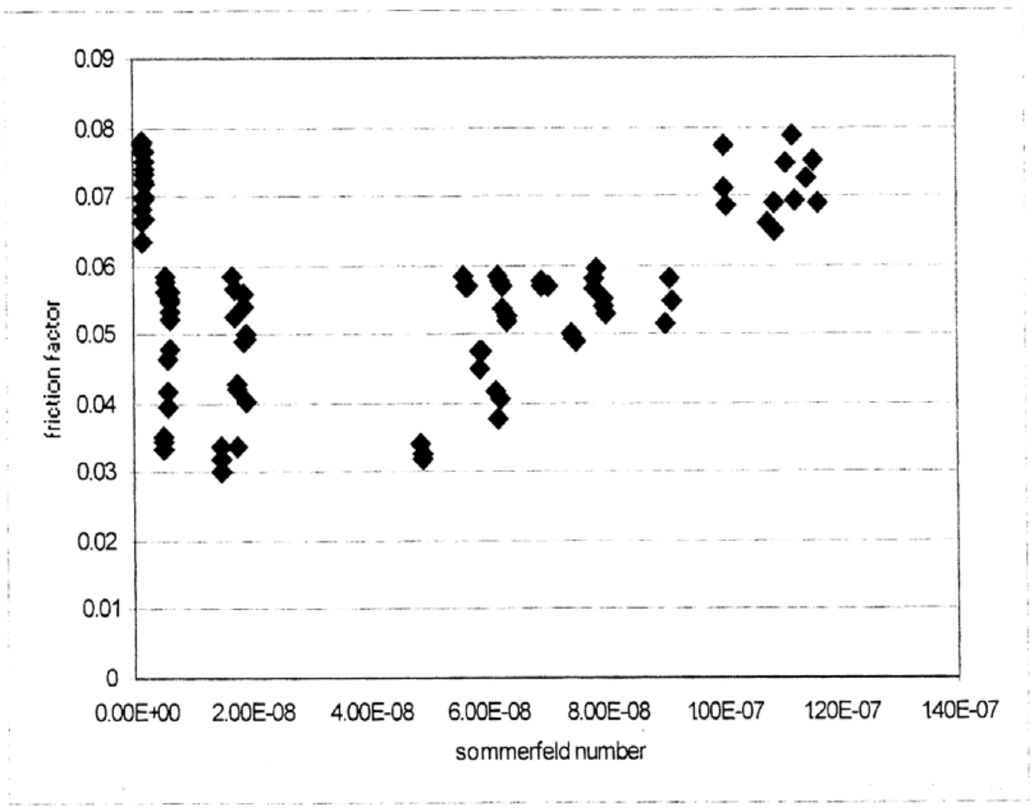

Figure 1: Stribeck plot showing a rising trend in the friction factor with an increase in Sommerfeld number.

All results for the friction factors measured at physiological viscosity are displayed in Figure 2 in which each point represents the average of three measurements for each joint tested with CMC or bovine serum lubricant. The joints manufactured with a different surface finishing technique are represented by triangles (s-serum), the polished joints by squares (n-serum).

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Histopathological Findings and Metal Ion Concentrations in MetaSUL® and Birmingham Hip Resurfacing® Metal on Metal Bearings

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„Histopathological findings and metal ion concentrations in MetaSUL® and Birmingham Hip Resurfacing® metal on metal bearings“

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1. INTRODUCTION:

Polyethylene wear particles from the bearing surfaces have been identified as one of the main causes of periprosthetic osteolysis and aseptic loosening of THR. Especially in young and active patients this problem is immanent and causes unsatisfactory long term results of conventional THR. Because of the greater bearing surface area in historic metal on polyethylene hip resurfacings this problem increased because of a 4-10 times higher wear rate with the larger diameter and combined with too thinner polyethylene cup, lead to significant bad long term results (6). Metal on metal bearings may solve this problem because of their potential for improved wear performance (10) and capability of manufacture as a thin component to avoid excessive bone resection in the young patients in case of hip resurfacing. After the renaissance of these bearings in conventional THR between 1986 and 1988 by Weber (11) in the early 90ies Derek McMinn, Heinz Wagner and Harlan Amstutz developed modern resurfacings, which were based on that tribology (9,11,12). Early and mid-term results of modern metal on metal bearings have been reported to be satisfying in many studies and they confirm the expectation of significantly reduced wear (5). Considering the long time experience of the historic metal on metal joints like McKee-Farrar, Huggler, Müller, Stanmore and Ring which partly showed extremely low wear and usually only mild- if any- metal wear caused foreign body reactions in the periprosthetic tissue (4) the long clinical background of metal on metal bearings has to be pointed out. With modern metal on metal hip resurfacings only short term experiences exists to date. But because the capsule tissue shows histopathological alterations caused by wear debris very early histological examinations may help to predict the long term results.
In opposition to the low local reactions metal on metal bearings are responsible for increased metal ion serum levels of their components (2). The consequences of this significant increased rate are not yet well identified. Otherwise detectable metal ion serum concentrations make a comparison of different metal on metal articulations possible.

2. MATERIALS AND METHODS:

An assessment of early clinical and radiological results of 163 McMinn Birmingham Hip Resurfacings® (BHR) implanted in 154 patients (72 female, 92 male; average age: 50 years) between 1998 and 2001 is presented. We obtained capsule tissue specimens during 5 BHR® and 4 MetaSUL® revision operations. Early and late infection, femoral neck fracture, impingement

of the iliopsoas tendon and ectopic ossification were the reasons for revision in the BHR® cases which were performed 8 months on average (1-14 months) after primary implantation. In the MetaSUL® cases aseptic loosening in 2 cases, dislocation and ectopic ossification caused revision in average 28 months (12-49 months). The tissue probes were formalin fixated (4% buffered formaldehyde), paraffin embedded and in HE and Berlin blue reaction stained. Every tissue probe was examined in more than 3 areas intensively in different magnifications (38x – 400x) and under polarisated light. Berlin blue reaction was done to distinguish foreign body macrophage reactions from bleeding residuals (haemosiderophages).
Cobalt and Chromium ion concentrations were measured in the serum of 67 Patients after implantation of a BHR® and 32 Patients implanted with a cementless all titanium alloy THR and a MetaSUL®- bearing. Patients that bore another metallic implant were excluded. Serum probes were drawn at the time of clinical and radiological assessment in average 6 months (1-26 months) after the primary implantation in the BHR® cases and in average 14 months (2-44 months) postoperatively in the MetaSUL® cases. The specimens were introduced into metal free plastic tubes and frozen by –20°C until the analysis by atomic absorption spectrophotometry.

3. RESULTS

Secondary arthritis predominates the presenting pathologies in our BHR® series. The biggest part had CDH because it is very common in our territory. 75 patients had a CDH Eftekhar grade A. 24 patients had a higher grade CDH (Fig. 1). We altogether carried out acetabular graftings in 32 cases. The uncomplicated and opposite stemmed THR faster rehabilitation of our patients was striking despite the surgically more expensive southern approach. The Harris Hip Score rose from 51 preoperatively to 84 after 12 weeks and 90-96 between 6 months and 3 years (Fig. 2).

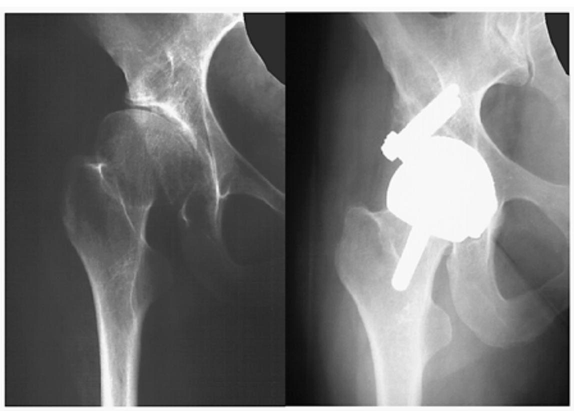

Fig. 1: CDH caused arthritis of a 37 year old woman; one year after implantation of a BHR and acetabular grafting

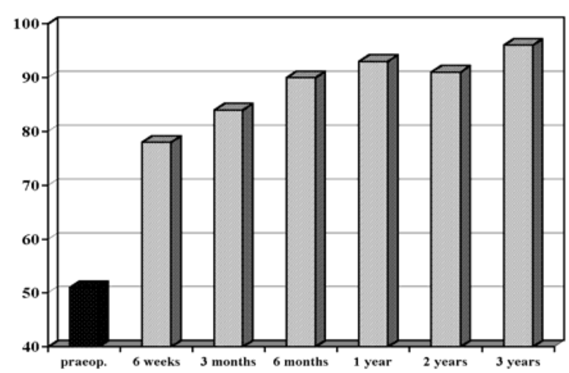

Fig. 2: Clinical outcome of our BHR patients (Harris Hip Score)

We did not find any migration or osteolysis radiologically except one case of a septic cup loosening. All acetabular bone graftings healed in. Altogether we had to revise 7 hips due to different complications: early infection; late infection with septic cup loosening; nerve palsy; missing implantation; femoral neck fracture; impingement of the iliopsoas tendon and ectopic ossification's. 4 times the device had to be revised, which results in a revision rate of 2.4%.

As described in other studies too we found in the capsule tissues of the 28 mm MetaSUL® bearings not high amounts but regularly metallic debris (3,14). In opposition to that the capsule tissues of the BHR® showed wear particles in only two of our five cases, and then, only small amounts in the stroma but not in the synovial layer, which could be classified as operation residuals. The most interesting cases, in our opinion, were the two revised in the case of ectopic ossification's because in these cases no other intraarticular influences, such as infection or loosening were present beside the articulation itself. To our surprise the capsule tissue of a 59 year old man revised 7 months after implantation of a BHR® showed only a minimal fibrosis but no inflammatory changes, no foreign body reaction and no metallic debris (Fig. 3 and 4).

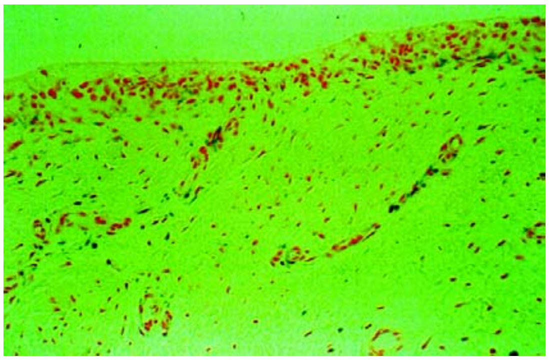

Fig. 3: Section of capsule tissue of a 59 year old man 7 months after implantation of a BHR®; magnification 50x; no metallic debris, no inflammatory changes

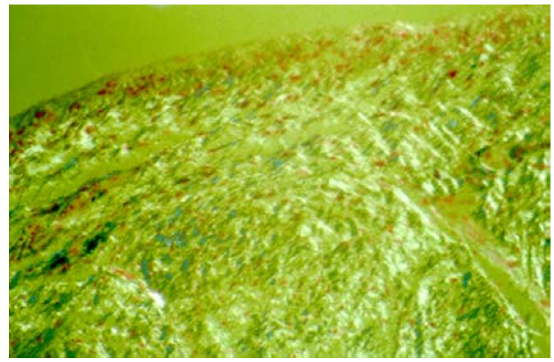

Fig. 4: Same case as Fig. 3; polarisated light, magnification 50x; only the collagen fibres are double refractive, no metallic debris

In opposition to that the capsule tissue of a male patient of the same age whom we had to revise also because of ectopic ossification's, 18 months after implantation of a MetaSUL® THR showed a moderate chronic inflammation with exsudative synovialitis and a capsular fibrosis. We found metallic debris in the fibrinous exsudates on the synovial membrane and in the stroma (Fig. 5 and 6)

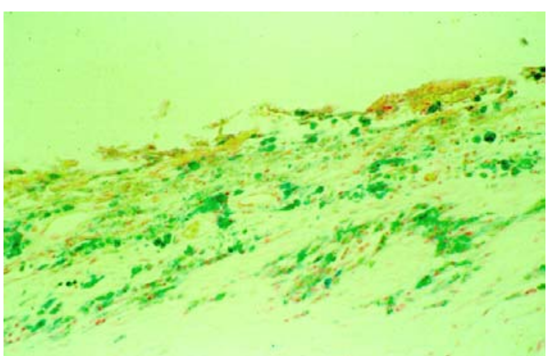

Fig. 5: Section of capsule tissue of a 59 year old man 18 months after implantation of a MetaSUL® THR; magnification 100x; moderate synovialitis, capsular fibrosis, few black metallic particles

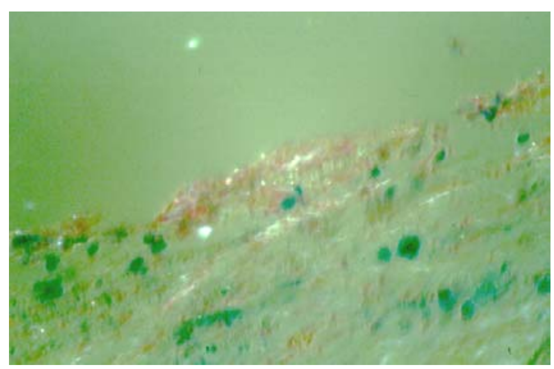

Fig. 6: Same case as Fig. 5; polarisated light, magnification 100x; few double refractive metallic debris in the fibrinous exudates, synovialis and stroma

Both devices produced detectable serum chromium and cobalt levels. These levels didn't change either after implantation of a BHR® nor after implantation of a MetaSUL® THR during one to 44 months after the operation and the increasing activity of the patients during the first months. A running in known from hip simulator studies was not detectable. After implantation of a BHR® the patients had slightly but not statistical significantly higher metal ion serum levels than our MetaSUL® patients (chromium: t=0,347; cobalt: t=0,429) (Fig. 7 and 8).

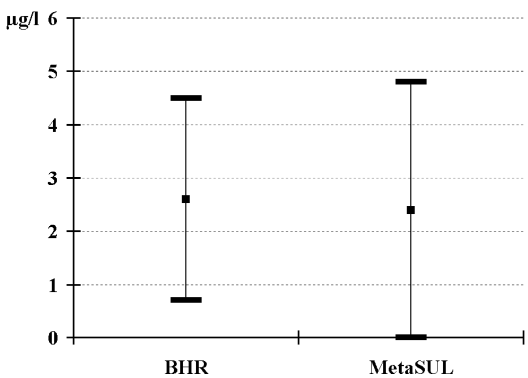

Fig. 7: Serum chromium concentrations (mean, standard deviation) after BHR® and MetaSUL® THR implantation

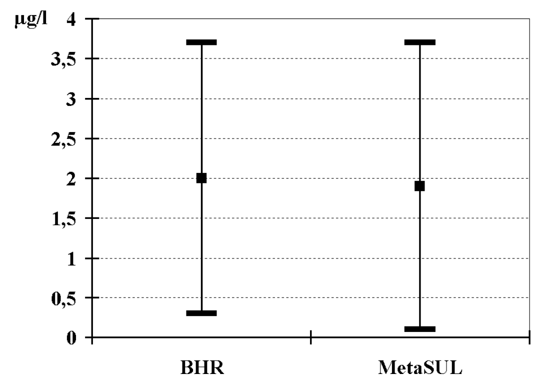

Fig. 8: Serum cobalt concentrations (mean, standard deviation) after BHR® and MetaSUL® THR implantation

4. CONCLUSIONS

The main problems of the historical hip resurfacings lay for certain in the too thin-walled and thus too elastic polyethylene cups and the metal or ceramic on polyethylene bearing. Our comparison of histological findings between BHR® and MetaSUL® THR, which in our opinion could be stated as the "golden standard" of modern metal on metal bearings shows equal perhaps even better results for the BHR®. Of course the short follow-up time must be pointed to.

Also the not statistical significant different metal ion concentrations of the two examined bearings state a better case for the BHR®: Because of that the corrosion rate depends only on the surface of the metal the daily ion delivery of a 28 mm bearing (MetaSUL®) and a 50 mm bearing what is the common size in resurfacing can be calculated (BHR® ca. 21 µg/d, MetaSUL® ca. 4.6 µg/d) (1). The much greater surface area of a 50 mm BHR® bearing delivers ca. 20 µg more metal ions per day than a 28 mm MetaSUL® bearing. The daily wear rate of the MetaSUL® bearings determined from previous simulator studies fits this "gap" surprisingly exact. However, using this model leaves no "gap" for the wear of the BHR® bearing.

In our opinion our short term experiences and the histological and serological results shown above leads to the conclusion, that the disadvantages of historic hip resurfacings are overcome or at least fundamentally improved with the BHR® because of the cementless press fit cup, the low wear metal on metal bearing and the safer implantation technique. So we would advise this procedure young and active patients despite the missing long term experiences, and also because of the poor long term results of conventional THR in this patient population (7,8).

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Hip Resurfacing: How Metal on Metal Articulations Have Come Full Circle

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Hip Resurfacing: How Metal on Metal Articulations Have Come Full Circle

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Since 1960 high carbon, cast cobalt chrome has been used as the articulation for metal on metal total hip replacements. McKee, Ring, Stanmore and Muller are examples of THR's employing this material. Most of these implants used the cobalt chrome in its as-cast state although some McKee implants were solution heat-treated. With the early success of high-density polyethylene all of these metal on metal articulations were subsequently abandoned. With the recognition that polyethylene particles were mainly responsible for pen-prosthetic osteolysis metal on metal articulations have been reintroduced over the past 13 years. None of the currently available metal on metal THR's has the same metallic microstructure as the historical metal on metal devices. Only one of the currently available metal on metal resurfacing's has the same microstructure as the historic metal on metal devices, It remains to be seen whether the new crop of metal on metal devices have bearing durability comparable to that of their predecessors or whether the bearings will be better or worse than the historical devices. Evidence on this matter is conflicting.

Hip simulators have been advocated for pre-clinical testing of new materials, but with metal/metal bearings it is known that different simulators produce very different wear rates in the same bearings[1]. Results from different hip simulators must therefore be interpreted with extreme caution. Hip simulator results from different laboratories have already caused confusion in relation to the wear of different material combinations for metal/metal bearings. One study comparing low carbon cobalt chrome to high carbon cobalt chrome showed no difference in the wear of the two different materials[2]. Another hip simulator study however showed fourteen times higher steady state wear in the low carbon compared to the high carbon cobalt chrome[3]. In the event hip simulators were not required to settle this simple matter of the superiority of high carbon chrome cobalt as a pin on plate study[4] and a pin on disc study[5] showed unacceptably high wear of the carbide free, low carbon cobalt chrome material. One clinical study utilizing low carbon forged cobalt chrome metal on metal THR's has shown dramatically high blood and urine metal ion levels.[6]

What has not been clearly understood until recently is that even when using the historically proven high carbon cast cobalt chrome material certain manufacturing processes dramatically alter the metal microstructure and also alter the material wear resistance. It is known that solution heat treatment whilst improving the mechanical properties of as-cast cobalt chrome, when used as a metal on metal articulation decrease the wear resistance of the material. [7,8,9]

The senior author has experience of using single heat-treated cobalt chrome, double heat-treated cobalt chrome and as-cast cobalt chrome as the bearing material in hip resurfacing components. No adverse bearing wear incidents have occurred with the as-cast or single heat treated materials to date, but unfortunately high bearing wear, metallosis and osteolysis have been seen with some components inserted during 1996, a period during which the manufacturer hot isostatically pressed and solution heat treated the implants without reference to the inventor surgeon.

Laboratory Studies

An extensive programme of investigation has been undertaken at the Materials Research Institute at Sheffield Hallam University, UK into the effect of different heat processes on cast cobalt chrome 10 Following investment casting, high carbon cobalt chrome forms a typical microstructure with large blocky carbides precipitating in the metal matrix. These M_{23} C_6 carbides are the same hardness as alumina ceramic and confer wear resistance on the material when used as a metal/metal articulation[5]. Three heat processes and combinations of these have been investigated, hot isostatic pressing, solution heat treatment and sintering. All these processes involve heating the metal to around 1200°C. The effects of these heat processes on the metal are complex but simply put, during heating the carbides are partially dissolved and during cooling the carbides are reprecipitated. Two main effects can be observed on the metal with these heat processes. First the carbides are rarely precipitated in as great a volume fraction after heat processes as in the original metal (fig.1). Different heat processes cause more carbide depletion than others, and as will be seen in the wear retrieval analysis, considerable variation in carbide depletion occurs even with the same heat processes. The second effect of the heat processes is that the original large blocky carbides are disintegrated into numerous smaller carbide particles (fig.2).

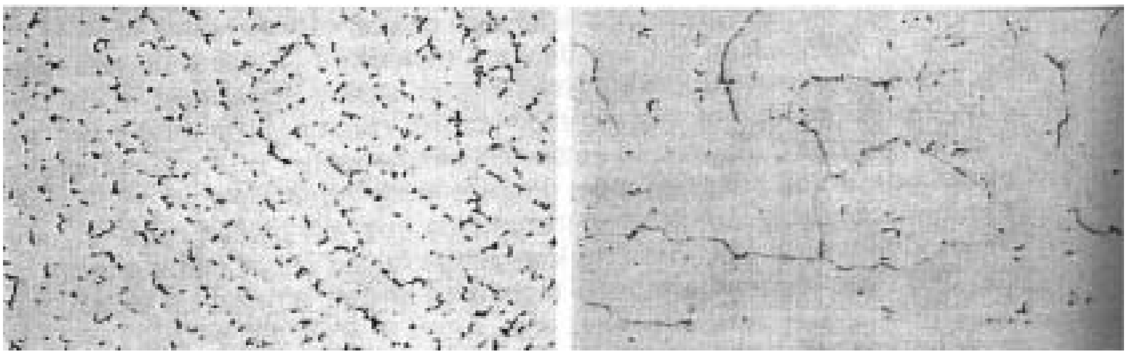

Fig.1a- Typical blocky carbide in as cast high carbon cobalt chrome. Optical xl00. Fig.lb Moderate carbide depletion following hot isostatic pressing & solution heat treatment. Optical xl00.

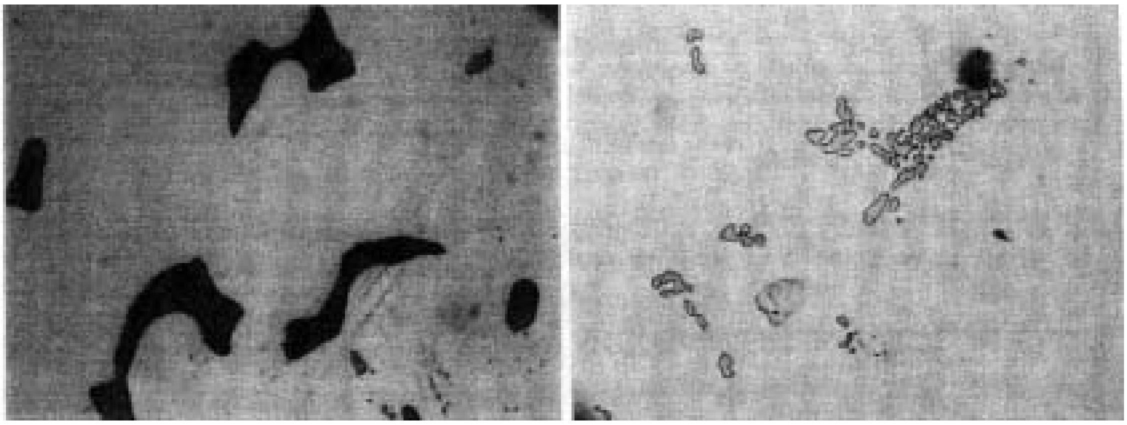

Fig. 2a- Typical blocky carbide in as cast high carbon cobalt chrome. Optical xl000.
Fig 2b-Carbide disintegration following solution heat treatment. Optical x l000.

Different microstructures have been investigated with adhesive wear testing (Pin on disc) and abrasive wear testing (Calowear). Pin on disc tests revealed a difference in the mechanical stability of the carbides in the metal matrix of the as-cast and heat processed cobalt chrome. In the as-cast metal, examination of the disc wear track showed that the large blocky carbides remained stable in the metal matrix whereas with the disintegrated smaller carbides in the heat processed metal there was evidence of instability with some small carbides torn out of the metal matrix (fig.3). This phenomenon is partially explained by the reduction in surface area of the smaller carbides reducing the resistance to extraction forces. Calowear tests on different metal microstructures showed significant differences in the wear factor of metal from the same master melt subjected to differing heat processes (fig.4).

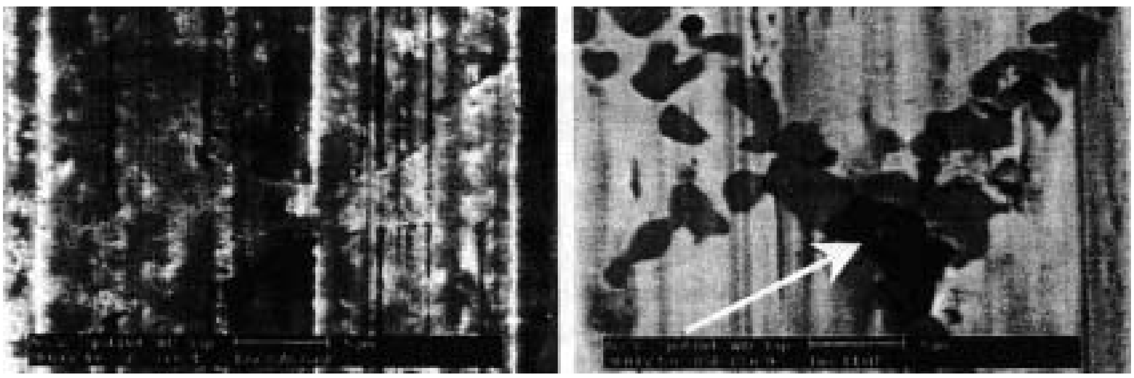

Fig. 3a – Disc wear track following pin on disc test with as-cast metal. Irregular blocky carbide seen stable in metal matrix. Viewed by electron scan microscopy. Fig. 3b – Disc wear track following pin on disc test with solution heat-treated metal. Small carbide (arrow) has been torn from the metal matrix. Viewed by the electron scan microscopy-.

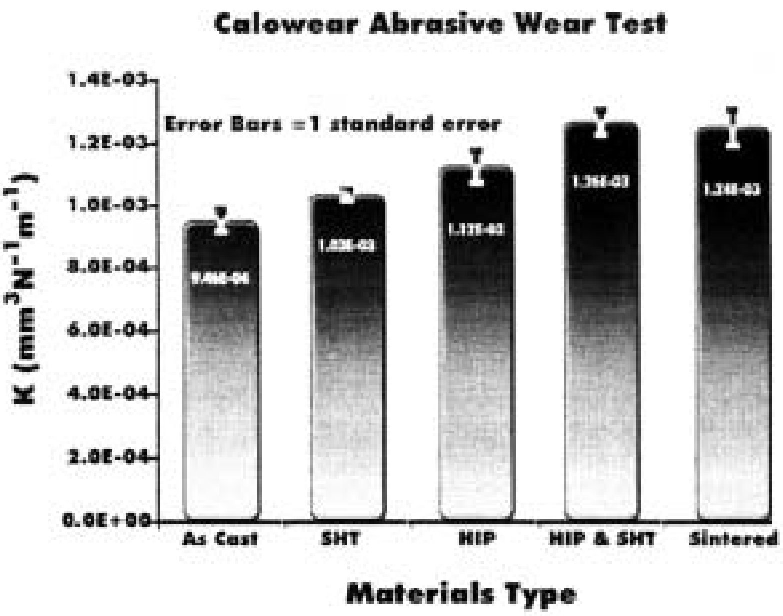

Fig.4 - Wear factor (K) with different materials. All tests repeated five times.
SHT = solution heat-treated.
HIP = hot isostatically pressed.
sintering of test pieces performed by Astromet Inc. Cincinnati USA.

Implant retrieval analysis

Four pairs of McMinn 1996 Hybrid resurfacing implants where metallosis and osteolysis were observed at revision operation have been analysed. Wear was measured on a roundness measurement device (Roundtest RA300- Mitutuyo) by multiple traces which first established the original shape, then by tracing across the wear scar, the exact amount of wear on the articulating surfaces of the cup and head was measured as the linear deviation from the original intact circumference. Wear of components is presented as total linear wear and wear rate per year (assuming a constant wear rate). Metal wear of the non-articular surfaces of the cups by abrasion of a loose component against bone was noted after examination under a magnifying glass. The metal microstructure of the articular surfaces was identified using scanning electron microscopy and further examination of the microstructure of the components was identified by sectioning the components and optical microscopy, of polished stained surfaces. The presence of carbide in the metal of each component was graded on a scale from zero to forty were zero is no carbide in the metal and forty is the normal carbide presence in high carbon as-cast chrome cobalt. Results of implant analysis from these four patients are summarized in Table 1.

Table 1.

Sample Name	Linear wear (Micrometres)	Time in situ (Months)	Wear rate (Micrometres per year)	Polishing of non-articular cup surface	Carbide presence in metal (0-40 Scale)
Cup 1(C1)	8	61	1.6	Present	30
Head I (Hi)	55		10.8		10
Cup 2 (C2)	2	38	0.6	Present	30
Head 2 (H2)	12		3.8		30
Cup 3(C3)	20	42	5.7	Present	20
Head 3(H3)	35		10.0		10
Cup 4 (C4)	50	50	10.8	Absent	0
Head 4 (H4)	150		36.0		0

When wear rate of implants is plotted against carbide volume fraction in each implant it can be seen that the highest wear rate in these implants occurs when the metal is most carbide depleted and the lowest wear rates occur in less carbide-depleted components (fig.5).

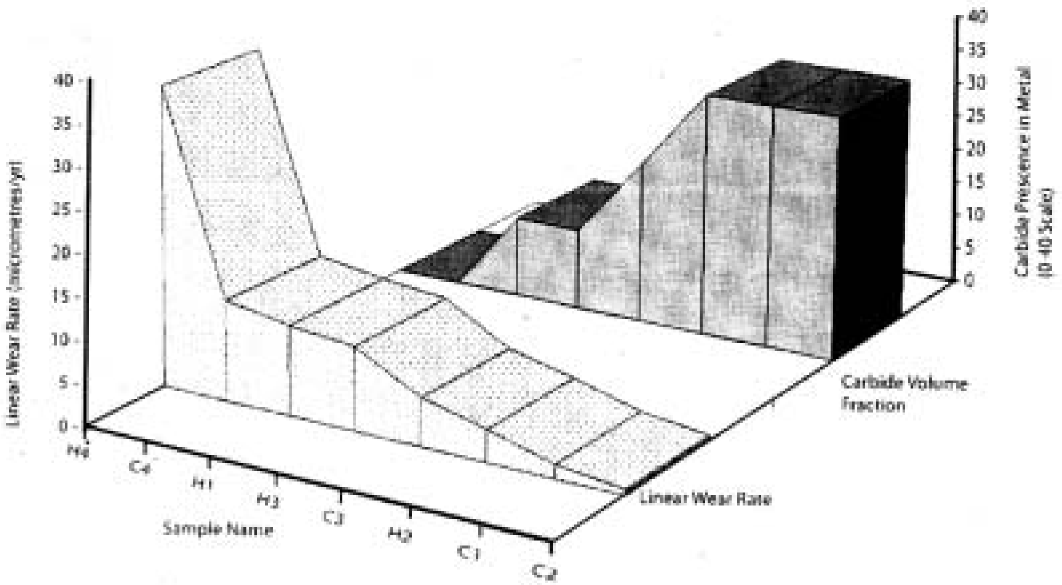

Fig.5 Explant linear wear rate versus carbide volume fraction

From our retrieved resurfacing components the heat processes of hot isostatic pressing and solution heat treatment increase component linear wear rates by up to 20 times compared to the as-cast microstructure components. Volumetric wear measurements are up to 80 times higher in the heat-treated components compared to the as-cast resurfacing components. This is much higher wear than one would expect from the Calowear tests with the double heat treated metal wear factor only 33% higher than the as-cast material. A possible explanation for the worse clinical performance comes from the pin on disc tests where carbide pluck out has been observed in the heat-treated metal. These hard carbides may act as a third body and cause excess wear of the heat-treated metal/metal bearings. This however seems unlikely since as can be seen from the retrieved implants, low wear rates of one component did accompany high wear rates of a matching component. This argues against third body debris as a cause of increased bearing wear in these retrieved components, as any third body debris would be expected to damage and wear both matching bearing surfaces. The more likely explanation is that the double heat treatment of the laboratory test pieces produced only moderate carbide depletion and not the profound carbide depletion seen in some retrieved components with very high wear.

Many of the currently available metal on metal implant systems are relatively new and they all rely on the satisfactory long term bearing performance of historical metal on metal total hip replacements as justification for their use. It seems to the authors fundamentally unsound to implant a metal on metal bearing which has a quite different microstructure from the historical metal on metal bearings and then expect that the new bearing will behave like the bearings of 30 years ago.

The authors wholeheartedly agree that there is no such thing as a small modification.

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