MINI-SYMPOSIUM: HIP REPLACEMENT

(iii) Resurfacing arthroplasty of the hip

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Summary

Hip resurfacing is an attractive concept as it preserves proximal femoral bone stock, optimises stress transfer to the proximal femur and offers inherent stability and optimal range of movement. The results of hip resurfacing in the 1970s and 1980s were disappointing and the procedure was largely abandoned by the mid-1980s. The expectation that these prostheses would be easy to revise was not often fulfilled. The large diameter of the articulation combined with thin polyethylene cups or liners, led to accelerated wear and the production of large volumes of biologically active particulate debris, leading to osteolysis and implant loosening.

The renaissance of modern metal-on-metal articulations for total hip arthroplasty enabled the introduction of a new generation of hip resurfacings and the majority of the main implant manufacturers have already introduced such systems. Early results are encouraging and complications commonly seen in the 1970s and 1980s, such as early implant loosening and femoral neck fracture, now appear to be rare.

Introduction

Total hip replacement in its current form has proven very effective in late middle aged and elderly patients, with implant survival rates in excess of 90% at 10 years.\textsuperscript{1} However, when younger patients are reviewed, especially males under 55 years of age, this survival figure drops to 80% at 10 years. By 16 years postoperatively reported survival figures are as low as 33%. Hip resurfacing is being advocated as an alternative treatment for young and active patients with hip arthritis. Resurfacing is an attractive concept, as it preserves proximal femoral bone stock, optimises stress transfer to the proximal femur and, due to the large diameter of the articulation, offers inherent stability and optimal range of movement.
History

The concept of hip resurfacing is not new. Contemporary designs have evolved directly from the original mould arthroplasty introduced by Smith Petersen in 1948.² Despite this being a hemiarthroplasty with no means of stable fixation to the femoral head, some survived for many years, although the outcomes were unpredictable. The first total resurfacing arthroplasty was developed by Charnley in the early 1950s utilising a Teflon-on-Teflon bearing.³,⁴ This implant was associated with early failure, which Charnley ascribed to avascular necrosis of the femoral head. He subsequently recognised the poor wear characteristics of Teflon when he used it as the bearing material in total hip replacement.

In 1967, Maurice Muller designed a metal-on-metal articulation. He implanted 18 surface replacements in young patients, in addition to 35 stemmed prostheses (Fig. 1). Despite excellent early clinical results, Muller abandoned the use of the metal-on-metal articulation in favour of metal-on-polyethylene. Six of these all metal articulations were revised after functioning for up to 25 years.⁵,⁶

Cemented hip resurfacings utilising polyethylene (PE) acetabular components and metal femoral components were implanted in 1971 by Paltrinieri and Trentani in Italy⁷ and in 1974 by Freeman in the UK.⁸,⁹ Freeman had earlier used a PE femoral component and a metal acetabular component, but this was associated with rapid wear of the convex surface. In the same year, Wagner in Germany introduced a hip resurfacing (Fig. 2) which became widely used in Europe.¹⁰ The PE acetabular components had a thickness of only 4 mm. Both Co–Cr and ceramic femoral components were available, but the technique of femoral head preparation was crude. From 1976 a cementless alumina ceramic-on-ceramic resurfacing was used by Salzer in Vienna, but it was soon abandoned because of high rates of early loosening.¹¹

In 1975, Amstutz introduced the total hip articular replacement using internal eccentric shells (THARIES) at UCLA.¹²,¹³ The original prosthesis was cemented and consisted of a Co–Cr femoral component and an all-PE acetabular

Figure 1 Metal-on-metal hip prostheses introduced by M. Mueller and A. Huggler in 1967. On the right, a cementless hip resurfacing.

Figure 2 Cemented metal-on-polyethylene resurfacing system, introduced by H. Wagner in 1974.
component. Subsequently, an uncemented system was introduced.

In 1989, Buechel and Pappas introduced a cementless resurfacing system with a modular PE acetabular component and a titanium-nitride-coated titanium alloy femoral component.14

Modes of failure of first generation resurfacings

The results of hip resurfacing in the 1970s and 1980s were disappointing and the procedure was largely abandoned by the mid-1980s except in a small number of centres. The expectation that these prostheses would be easy to revise was not often fulfilled. Although proximal femoral bone stock was well maintained, there was frequently extensive destruction of the acetabulum. This was partly a consequence of excessive removal of bone to accommodate the acetabular component and its cement mantle, but was mainly due to periprosthetic osteolysis.

With our present knowledge, the first generation of metal-on-polyethylene resurfacings represented an excellent model of a high wear producing bearing. The large diameter of the articulation combined with thin PE cups or liners led to accelerated wear and the production of large volumes of biologically active particulate debris, leading to osteolysis and implant loosening (Fig. 3). However, as the implications of wear debris induced osteolysis were not fully appreciated at the time, failure was attributed to other factors, including avascular necrosis of the femoral head and acetabular component loosening due to high frictional torque. The high incidence of femoral neck fracture was also an issue.

The concern that resurfacing of the femoral head leads to avascular necrosis has not been confirmed by retrieval studies. Howie et al.15 examined 72 failed Wagner resurfacings. They concluded that there was viable bone in the femoral head and neck in the majority of cases. The bone destruction was consistent with wear particle induced osteolysis, not avascular necrosis. Similar findings have been reported by other investigators.16

Freeman has argued that the major blood supply to the arthritic femoral head is through intrasosseous vessels, not through the subsynovial anastomoses.17 Such intrasosseous vessels would not be disrupted during the exposure and preparation of the femoral head. This may explain why avascular necrosis has not been proven to be a significant complication following hip resurfacing. However, the debate concerning the effect that resurfacing has on the blood supply of the femoral head continues.

The influence of the increased frictional torque, which is a consequence of the large diameter of the articulation, has been addressed by Mai et al.18 A relatively homogeneous group of 170 osteoarthritic patients who underwent a cemented THARIES resurfacing arthroplasty was studied. Hips were divided into three groups according to the diameter of the articulation. The authors showed that the larger-diameter prostheses survived significantly longer than the smaller ones, indicating that frictional torque was not the main factor causing acetabular component loosening.

The experience of surface hemiarthroplasty for AVN of the femoral head using cemented components articulating against the host acetabulum, has clarified further the role of PE wear debris in the failure of hip resurfacing.19,20 In the absence of a PE bearing, no loosening or osteolysis was observed and the hips that required reoperation were revised for groin pain related to wear of the acetabular articular cartilage. Histological examination of the retrieved femoral head remnants showed a thin soft-tissue membrane interposed between the bone and the cement. The cement mantle was intact and the adjacent bone was viable. Contact radiographs of the slab sections showed the normal appearance of trabecular bone and no osteolytic lesions.

The femoral neck fractures seen in the first generation of hip resurfacings were, with the benefit of hindsight, due to a combination of osteolysis of the femoral neck and the surgical technique advocated at the time. Intraoperative

Figure 3 Extensive osteolysis around a Porous Surface Replacement system introduced by H. Amstutz in 1983. The modular acetabular cup consisted of a chamfered Titanium alloy shell and a thin polyethylene liner.
neck notching was often a consequence of extreme valgus positioning of the implant, which was recommended to reduce the tension and shear stresses across the head–neck junction. Under-sizing of the implants in order to minimise frictional torque also resulted in notching. Trochanteric osteotomy, which was commonly used, could also compromise the femoral neck if it was too extensive.

**The renaissance of hip resurfacing**

The reintroduction of metal-on-metal articulations for total hip arthroplasty (THR) began in 1988. Bernard Weber in collaboration with Sulzer developed the Metasul bearing; a precisely engineered, high-carbon-containing wrought-forged cobalt–chrome alloy with excellent wear characteristics. Large numbers of these bearings were used in Europe with good early results.

The availability of a durable, low wear bearing which could be used in a large-diameter articulation enabled Heinz Wagner in Germany to introduce a second-generation hip resurfacing in 1991. This was a cementless system (Fig. 4). The acetabular component was a titanium alloy shell with a Metasul inlay. The thickness of the construct and the extensive macro-features on its external surface made it difficult to implant. There were only four sizes available and the instruments for the preparation of the femoral head were crude. Only small numbers of the Wagner metal-on-metal resurfacings were used and no long-term results are available.

In the same year, in the UK, Derek McMinn in collaboration with Corin introduced a hip resurfacing based on a cast Co–Cr alloy. The initial design was smooth surfaced, press-fit on both sides (Fig. 5). The acetabular component was a modification of the Freeman finned cup. This design was associated with a high incidence of early failure due to aseptic loosening of both components. The following year the components were coated with hydroxyapatite (HA), but only a small number of these implants were inserted. In the same year, McMinn introduced a system in which both components were cemented. The original acetabular component was modified by removing the central peg and peripheral fins. The femoral component was not modified for cementing. This system had a high incidence of early acetabular loosening due to cement-cup debonding. This led to the introduction of a hybrid system in 1994, with a cementless HA-coated acetabulum. This implant was withdrawn in 1996, apparently because of problems with the manufacturing of the bearing. Subsequently, two different resurfacing systems evolved,
<table>
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<tr>
<th>Bearing</th>
<th>Introduced</th>
<th>Process</th>
<th>Heat treatment</th>
<th>Acetabulum</th>
<th>Femur</th>
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<tr>
<td>Conserve plus</td>
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<td>Cast</td>
<td>HIP* and SHT†</td>
<td>2</td>
<td>Truncated hemisphere</td>
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<td>Wright Medical</td>
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<td>Cormet Corin Durom</td>
<td>1997</td>
<td>Cast</td>
<td>HIP and SHT</td>
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<td>Equatorial expansion Truncated hemisphere</td>
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<td></td>
<td>2001</td>
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<td>Not applicable</td>
<td>2</td>
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<tr>
<td>Zimmer ReCap</td>
<td>2004</td>
<td>Cast</td>
<td>None</td>
<td>2</td>
<td>Hemisphere</td>
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<td>Biomet ASR</td>
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*HIP hot isostatically pressed. †SHT solution heat treated. ‡HA hydroxyapatite. §Ti-VPS Titanium vacuum plasma spray.
one developed by Corin and the other by Midland Medical Technologies.

Contemporary hip resurfacing

By the end of 2004, the majority of the main implant manufacturers had introduced metal-on-metal hip resurfacing systems (Table 1). All these systems have a number of features in common including:

(i) a bearing made from high carbon containing Co–Cr alloy,
(ii) cementless fixation of the acetabular component,
(iii) cemented fixation of the femoral component.

However, there are important differences between these implants, particularly relating to the metallurgy and geometry of the bearing and to aspects of the fixation of the acetabular and femoral components.

The bearing

The factors that influence the tribological behaviour of metal-on-metal bearings include:

- the type of alloy,
- the manufacturing process,
- the clearance of the articulation (diametrical mismatch),
- the sphericity of the components,
- the roughness of the articulating surfaces,
- the diameter of the articulation.

Metallurgy

Perhaps the most controversial issue in contemporary metal-on-metal hip resurfacing is the metallurgy of the bearing. Whilst all manufacturers now use high carbon containing Co–Cr alloy, the processing of the alloy differs. The alloy can either be wrought-forged or cast. If cast, the components may undergo post-casting heat treatments such as hot isostatic pressing and/or solution heat treatment.

Wrought Co–Cr alloy offers theoretical advantages over cast Co–Cr alloy as a bearing surface. Wrought Co–Cr is harder than cast Co–Cr (~430 HV vs. ~365 HV), enhancing wear resistance. The wrought alloy can also be highly polished, reducing surface roughness and enhancing lubrication. However, the results of hip simulator studies are conflicting: St. John et al. reported that cast alloys had greater wear resistance than wrought alloys. In contrast, Streicher et al. showed that wrought Co–Cr alloy had better wear characteristics than cast.

The importance of heat treatments on cast Co–Cr alloy has been particularly hotly debated over the last 6 years. The annealing process results in depletion of the surface carbides, but the results from hip simulator studies demonstrate no significant difference in the wear behaviour between cast and heat-treated alloys.

Until long-term clinical outcomes and/or reliable retrieval studies become available, it will not be possible to determine the relevance of the differences in the metallurgy of the currently available hip resurfacings.

Bearing geometry

Whilst metallurgical differences may be important, the control of bearing geometry is critical in determining the behaviour of large-diameter metal-on-metal bearings. In particular, the clearance, sphericity and surface roughness, all of which are dependant on the quality of the manufacturing process, greatly influence both the initial running-in wear and the steady state wear of the bearing.

If other factors are equal, a low clearance increases the potential for fluid film lubrication, with full separation of the bearing surfaces. This lubrication regimen is associated with very low wear and very low friction (theoretically nil). However, a clearance that is too low could result in clamping of the articulation if there is deformation of the acetabular component under load, a significant risk with thin-walled, large-diameter cups. In contrast, an excessively large clearance will not generate full fluid film lubrication and will result in a low contact area and therefore high contact stresses, with associated high wear. A clearance of 100–150 µm appears to be the optimal compromise for large-diameter metal-on-metal articulations.

Surface roughness is also an important factor in influencing the lubrication of metal-on-metal bearings. The lambda coefficient (film thickness ratio) indicates the lubrication mode occurring in total hip prostheses, with lambda values greater than 3 indicating full fluid film lubrication, and values less than 3 indicating mixed film lubrication. The value of lambda is inversely related to the mean roughness of the articulating surfaces. A 50% reduction in the average roughness would lead to doubling of the lambda coefficient, and thereby enhanced lubrication. Wrought Co–Cr alloy can now be polished to achieve a surface roughness of only ~5 nm, greatly improving the potential for full fluid
film lubrication compared to alloys with higher surface roughness.

For hard-on-soft articulations in general, the greater the diameter of the articulation the higher the volumetric wear, primarily because of the increased sliding distance. This relationship does not hold true for large-diameter metal-on-metal articulations. Smith et al. reported significantly lower steady-state wear rates for 36 mm diameter metal-on-metal bearings compared to 28 mm bearings under the same test conditions. Our own hip simulator studies of the bearing of the Durom™ hip resurfacing have confirmed this observation. It appears that for metal-on-metal bearings a large diameter is an advantage, probably because of the greater propensity for generating continuous fluid film lubrication.

Acetabular fixation

The main difference between the various contemporary resurfacing acetabular components is the surface used for bone in-growth. Titanium vacuum plasma sprays and Co–Cr beads are currently in use, with or without HA. Both surfaces have been shown to have satisfactory performance when used for conventional total hip replacements, although Titanium is considered to be more biocompatible than Co–Cr. However, concern has been raised that the extreme temperature involved in the sintering process of Co–Cr beads may alter the metallurgy of the monobloc component, which could in turn have a deleterious effect on the bearing surface.

Femoral fixation

The major issue relates to the optimal cement mantle thickness and the degree of cement pressurisation. The thickness of the cement mantle is determined by the diametrical difference between the implant and the corresponding reamer. Systems which produce very thin or incomplete cement mantles, and which do not allow escape of cement during femoral component insertion, can result in excessive penetration of cement into the cancellous bone of the femoral head, jeopardising bone viability. In addition, the force required to fully seat such implants can result in fracture of the femoral neck.

Our finite element studies have demonstrated that a cement mantle less than 1 mm is prone to fatigue fracture under cyclical loading. A thicker mantle reduces the risk of cement fracture but would result in increased removal of femoral head bone and could be associated with neck notching. The optimal compromise is a cement mantle of approximately 1 mm.

The role of the short stem of these implants can be for alignment alone, or alignment and force transmission. Force can be transmitted by cementation of the stem, by bony in-growth or by friction-fit. Whether it is advantageous for the stem to transmit force remains controversial. A stem which transmits force may protect a deficient femoral head, but could result in stress shielding, leading to loss of bony support in the long term.

Indications and contra-indications

Before defining the indications and contra-indications for hip resurfacing, it is appropriate to consider the theoretical advantages and disadvantages of the procedure compared to conventional THR (Table 2).

To date, the follow-up is too short to confirm all the potential advantages of metal-on-metal hip

<table>
<thead>
<tr>
<th>Table 2</th>
<th>Potential advantages and disadvantages of hip resurfacing.</th>
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<tr>
<td><strong>Advantages</strong></td>
<td><strong>Disadvantages</strong></td>
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<tr>
<td>Initial preservation of proximal femoral bone stock</td>
<td>No long-term outcome data</td>
</tr>
<tr>
<td>More normal loading of femur eliminating proximal femoral stress shielding</td>
<td>No published controlled studies</td>
</tr>
<tr>
<td>Easier and more durable revision of femoral component if required</td>
<td>Technically more demanding</td>
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<tr>
<td>Reduced risk of leg lengthening/shortening</td>
<td>New modes of failure—femoral head collapse, femoral neck fracture</td>
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<tr>
<td>Reduced risk of dislocation</td>
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<tr>
<td>Improved range of movement</td>
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<tr>
<td>Improved function/activity level</td>
<td></td>
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<tr>
<td>Low wear bearing reducing risk of peri-prosthetic osteolysis</td>
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resurfacing. The procedure is self-evidently conservative of proximal femoral bone stock at the time of surgery and Kishida et al.34 have reported better preservation of periprosthetic bone mineral density 2 years after surgery in a group of patients who had undergone resurfacing arthroplasty of the hip compared to a similar group who had undergone a conventional uncemented THR (case control study). There is however no published report documenting better outcomes for revision of hip resurfacings compared to revision of stemmed hip replacements, although such a study would take many years to complete. The results from the first generation of hip resurfacings indicate that there is a reduced rate of dislocation, though controlled trials will be required to determine if hip resurfacing offers a reduced risk of leg length discrepancy, an improved range of movement and improved activity level compared to conventional THR. Such studies are currently ongoing (Personal Communication, M Lavigne, P Venditelli, Hopital Maisonneuve-Rosemont, Montreal).

Indications

The general indications for surface arthroplasty of the hip are essentially the same as for conventional THR. Based on current evidence it appears reasonable to offer hip resurfacing to fit and active patients who wish to regain an active lifestyle after surgery and who would most probably outlive a conventional hip replacement and therefore face the possibility of multiple revision procedures during their lifetime. In the UK, the National Institute for Clinical Excellence (NICE) have documented the lack of long-term outcome data on hip resurfacing and the lack of randomised controlled trials comparing metal-on-metal resurfacing arthroplasty of the hip with conventional THR. Nevertheless, they concluded that: "patients who are likely to outlive conventional primary hip replacements should have the choice of receiving metal-on-metal hip resurfacing arthroplasty". They also stated that: "the suitability of hip resurfacing should be based on patient’s activity levels rather than age alone". A further review is due this year.

The NICE guidelines could be reasonably extended for patients with deformity of the proximal femur which would make stemmed conventional THR difficult or impossible (Fig. 6). Hip resurfacing, or some other form of hip reconstruction using a large-diameter articulation, may also be appropriate for patients with a high risk of dislocation, such as those with neuromuscular conditions.

General contra-indications

The contra-indications for hip resurfacing relate primarily to the bone stock and bone quality of the femoral head and femoral neck (Table 3) (Fig. 7). The most common reported modes of failure of contemporary hip resurfacing are aseptic loosening of the femoral component and fracture of the femoral neck. Whilst early femoral neck fracture is usually related to a technical problem at the time of surgery, such as neck notching or forceful impaction of the femoral component, the causes of femoral component loosening and late femoral neck fracture are more complex, but the bone stock and bone quality of the femoral head appear to be critical.

The problem is determining what extent of femoral head deficiency or what degree of femoral head/neck osteoporosis is incompatible with the long-term survival of a cemented resurfacing femoral component. Beaule et al.36 have developed a "Surface Arthroplasty Risk Index" (SARI) in an attempt to identify preoperatively patients unsuitable for surface arthroplasty (Table 4). They studied 119 patients under the age of 40 undergoing metal-on-metal surface arthroplasty of the hip. In patients with a SARI score of greater than 3, the relative risk of early problems was 12 times greater than if the SARI score was equal to or less than 3. However, the SARI score does not take into account the position of the cysts within the femoral head, particularly cysts extending across the head–neck junction. Although a potentially useful tool, the validity of the SARI score needs to be verified with long-term outcome data.

The relevance of osteoporosis of the femoral head and neck to loss of femoral component fixation is yet to be defined. This is of particular importance if hip resurfacing is carried out on postmenopausal women and young patients with inflammatory arthritis.

Specific contra-indications

Renal failure

Blood, serum and urine levels of cobalt and chromium ions are higher in all patients with metal-on-metal bearings in situ, compared to the "normal" population. The levels continue to increase during the initial running in period of the bearing and then stabilise at around 18–24 months. Both chromium and cobalt ions are excreted in the kidney by glomerular filtration. There is no active excretory pathway. The blood and serum levels are consequently dependent on the rate of production/
ingestion and the glomerular filtration rate. The serum level will therefore mirror the serum creatinine level and will be particularly elevated in patients with renal failure. Until the effects (if any) of the long-term elevation of chromium and cobalt ions are understood, it is prudent to avoid the use of metal-on-metal bearings in patients with renal disease.

**Metal allergy**

The relevance of cutaneous metal sensitivity to implant failure remains controversial. Helab et al. reported that preoperative skin testing in patients undergoing joint replacements is unreliable for predicting the response to the metallic components. Doubt remains as to whether non-cutaneous metal allergy is a clinically relevant problem. The issue of aseptic lymphocytic vasculitic

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**Table 3** Contra-indications for hip resurfacing.

<table>
<thead>
<tr>
<th>Bone stock</th>
<th>Femoral cysts</th>
<th>AVN</th>
<th>Acetabular rim deficiencies</th>
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<tr>
<td>Bone quality</td>
<td>Osteoporosis</td>
<td></td>
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<tr>
<td>Systemic</td>
<td>Renal failure</td>
<td></td>
<td>Metal allergy</td>
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**Figure 6** (a,b) Osteoarthritic hip above a deformed femoral shaft. The deformity can be ignored by using a surface replacement.
Figure 7 Contra-indications to hip resurfacing. (a(i)–a(iii)) large cyst crossing head-neck junction; (b) extensive avascular necrosis; (c) superior rim deficiency.
associated lesions (ALVAL) will be discussed later in this article.

**Developmental dysplasia of the hip (DDH)**

Patients with osteoarthritis secondary to minor DDH (Crowe type I) can be treated satisfactorily with hip resurfacing (Fig. 8). However, the deformities associated with more severe forms of DDH (Crowe types II, III and IV) are difficult to address with surface arthroplasty. In particular, it is not possible to correct the often-marked anteversion of the proximal femur or address the issues relating to leg length (Fig. 9). Although combined hip resurfacing and subtrochanteric de-rotational osteotomy has been advocated in such cases, the senior authors (PR and PG) consider conventional THR to be more appropriate in patients with osteoarthritis secondary to severe DDH.

The problem of addressing leg length inequality also applies to the post-Perthes’ hip, with a coxa magna and a short femoral neck.

**Women of childbearing age**

The issue of the use of metal-on-metal bearings in women of childbearing age has been addressed by Brodner et al. They investigated pregnant women who had metal-on-metal bearings in situ. They measured the metal ion concentrations in the maternal blood and the cord blood. They found, as expected, that the concentrations of chromium and cobalt in the maternal blood were elevated. However, there was no elevation of metal ion concentrations in the cord blood, indicating that

<table>
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<th>Surface Arthroplasty Risk Index.</th>
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<tr>
<td>Femoral cysts &gt; 1 cm</td>
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<tr>
<td>Weight &gt; 82 kg</td>
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<tr>
<td>Activity level UCLA activity score &gt; 6</td>
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<td>Previous surgery to hip</td>
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**Figure 8** (a,b) Secondary osteoarthritis in Crowe type I DDH treated by hip resurfacing.
metal ions do not cross the placental barrier. Based on this work, it appears that there will be no deleterious effects on the foetus if a pregnant woman has a metal-on-metal bearing in situ.

Operative technique

There are significant differences between the operative technique for hip resurfacing compared to conventional THR. The differences relate particularly to the exposure, the implantation of the acetabular component and the preparation of the femoral head. Many surgeons have reported a significant learning curve, with an increased incidence of complications in the early cases. It is therefore highly recommended that appropriate training is undertaken before embarking on hip resurfacing. NICE have stated: “metal-on-metal hip resurfacing arthroplasty should be performed only by surgeons who have received training specifically in this technique”.

The essential objectives during a hip resurfacing procedure are to maintain or restore the anatomy of the femoral head and neck (head height, orientation, and neck offset) and to preserve the acetabular bone stock. Should revision of a resurfacing be required, it is the acetabular bone stock rather than the femoral bone stock that will be critical. Because there is a fixed relationship between the diameter of the acetabular and the femoral components, acetabular bone stock can be compromised if the femoral component is oversized in an attempt to avoid neck notching. Preservation of acetabular bone stock is therefore dependent on accurate preparation of the femoral head.

Exposure

Hip resurfacing can be carried out through a posterior or a direct lateral approach, although the posterior approach is currently favoured by most surgeons. The Ganz approach to the hip has also been advocated as a way of preserving the deep branch of the medial femoral circumflex artery, which may be important in supplying the anterior-superior quadrant of the femoral head.

The direct lateral approach has been less favoured than the posterior approach because of the risk of abductor dysfunction if the abductor repair fails, particularly as the surgery is generally carried out in young patients who wish to regain an active lifestyle. Our own in-vitro strain gauge studies have also demonstrated that if the abductors are dysfunctioned after a hip resurfacing, the stress across the femoral neck is doubled compared to the state when the abductors are functioning normally. This may explain the historical observation that fractures of the femoral neck following hip resurfacing most commonly occur in patients with an abductor lurch. The senior authors (PR, PG) therefore recommend the posterior approach.

Because the head and neck of the femur are preserved, exposure of the acetabulum can be difficult. The exposure can be facilitated by carrying out a circumferential capsulotomy and releasing the tendon of gluteus maximus from the linea aspera. When using a posterior approach, the femoral head should be translated superior to the acetabulum, under the gluteus minimus, so that it comes to lie on the wing of the ilium close to the lateral side of the anterior inferior iliac spine. Forceful retraction of the femoral head and neck should be avoided as this can result in femoral nerve palsy and/or fracture of the anterior wall of the acetabulum.

In particularly difficult cases (muscular male, large femoral head, ankylosed hip), it can be advantageous to partially prepare the femoral head prior to acetabular exposure. The debulked femoral head is then a lesser obstacle to the exposure of the acetabulum.
In muscular males the bulk of the thigh muscles, together with the femoral head and neck, tend to push the acetabular reamer shaft and acetabular impactor shaft into excessive abduction and retroversion, resulting in malpositioning of the acetabular implant, which can be associated with instability. In such cases, the use of offset (dog leg) reamers and cup impactors can be beneficial.

Hip resurfacing is inherently a form of "minimally invasive surgery", as the femoral head and neck are preserved and the femoral canal is not violated. However, it is a difficult procedure to carry out through a "mini incision" because of the problems associated with exposure of the acetabulum and the necessity for access to the femoral head and neck for precise femoral head preparation. There have been anecdotal reports of increased intraoperative complications, including nerve palsies and femoral neck notching, when mini incisions are used for hip resurfacing. The value of mini incision surgery for hip resurfacing remains to be defined.

Acetabular cup insertion

The insertion of the uncemented acetabular component can be more difficult than in conventional THR because:

(i) Primary stability must be achieved without the use of screws (unless a "dysplasia system" is being used).
(ii) The lack of holes in the cup can make it difficult to determine when full seating has been achieved.
(iii) The cup insertor fixes to the rim of the acetabular component. The cup insertor is therefore more bulky than a conventional insertor which fixes to the acetabular shell through a polar hole.
(iv) The femoral head and neck and the bulk of the thigh muscles can push the cup impactor shaft into excessive abduction and retroversion (from a posterior approach).

The keys to acetabular preparation and insertion are the recognition of the factors which can lead to component malpositioning and gaining adequate exposure to the whole of the acetabular rim.

Femoral head preparation

Preparation of the femoral head is challenging. The head must be prepared to accept a femoral component without oversizing (which would lead to oversizing of the acetabulum and thereby unnecessary sacrifice of acetabular bone stock) and without notching the femoral neck, which is recognised to be a potent cause of femoral neck fracture. Femoral component positioning is complicated by two factors:

(i) In general the femoral head is not centered on the femoral neck. The osteoarthritic process leads to the bulk of the head being more posterior and more inferior than the neck (Fig. 10). There is often little femoral head bone superior and anterior to the neck. This deformity can be extreme in cases of previous slipped upper femoral epiphysis. In order to avoid notching of the femoral neck, the preparation of the femoral head must be based on the anatomy of the femoral neck rather than the anatomy of femoral head. Consequently, the preparation of the femoral head invariably appears to be eccentric, with the bulk of the bone being removed from the posterior and inferior parts of the head.

(ii) Osteophytes can distort the normal anatomy of the femoral neck and head–neck junction. Preservation of such osteophytes can lead to oversizing of the femoral component and/or reduction in the range of movement due to impingement. However, if the osteophytes are removed, particularly "mature" corticated neck osteophytes, then large areas of soft cancellous bone may be exposed, which is thought to be a risk factor for subsequent neck fracture.

In general, soft osteophytes can be removed, but mature corticated osteophytes should be removed only if they will result in femoral component oversizing or significant impingement. Even in this situation, corticated osteophytes should only be partially debulked in order to avoid exposing cancellous bone of the neck (Fig. 11). Accurate, reliable and reproducible preparation of the femoral head can be facilitated by the use of sophisticated jigs which allow angular alignment and component positioning to be set independently. Computer guidance may be of value in femoral head preparation, but to date, there is no evidence that this technique is any more accurate or reproducible.

Results of contemporary hip resurfacing

No randomised controlled trial comparing the outcome of hip resurfacing with conventional THR has
been published. Likewise, there are no long-term (greater than 10 years) observational data on outcomes. However, short- and medium-term results of hip resurfacing are now becoming available.

Daniel, Pinsent and McMinn reported on 446 patients under the age of 55 at the time of surgery, who had undergone hip resurfacing using either the McMinn resurfacing hip arthroplasty or the Birmingham Hip Resurfacing prosthesis. The minimum follow-up was 1.1 years, the maximum 8.2 years and the mean 3.3 years. Follow-up was by postal or telephone questionnaire. The results of radiological follow-up were not documented. There was only one failure; a case of avascular necrosis occurring at 8 months. The Kaplan–Meier cumulative survival rate was 99.78% at 8 years. Excellent Oxford hip scores and UCLA activity-level scores (modified) were achieved. However, 186 patients operated on by the senior author (D.J.W. McMinn) in 1996 were excluded from this study, apparently because a unique pattern of failure of the implants was observed (metal wear, metallosis and osteolysis), which the authors ascribed to problems with the manufacturing of the bearing.

Amstutz et al.43 have reported on 400 Conserve Plus hip resurfacings carried out on patients with a mean age of 48.2 years. The minimum follow-up was 2.2 years, the maximum 6.2 years and the mean 3.5 years. The vast majority of patients were assessed both clinically and radiologically. The Kaplan–Meier survival rate of the component at 4 years was 94.4%. There were 14 clinical failures requiring revision surgery: seven for femoral component loosening, three for femoral neck fracture, one for acute cup migration, one for recurrent subluxation, one for deep infection and one for component mismatch. In addition, in 16 cases there was extensive radiolucency around the short femoral stem. This was considered to be probably indicative of early femoral loosening, although only one such patient was symptomatic. The dislocation rate was 0.75% (three of 400 cases). Excellent functional results were achieved.

Our early results of the first 200 consecutive hip resurfacings using the Durom system have also been encouraging. The patients average age was 48. At a mean follow-up of 2.2 years (minimum = 1.1, maximum = 4.6), there have been no failures and no cases of dislocation or deep infection. Similar good early results were reported by De Smet et al.45 for the Birmingham Hip Resurfacing, with

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**Figure 10** (a,b) Eccentricity of the femoral head on the femoral neck. The remodelling commonly seen in osteoarthritis results in there being little femoral head bone superior or anterior to the neck.
only one failure (a femoral neck fracture) in 200 patients at a mean of 1.1 years after surgery.

In summary, the above papers and other papers in the literature indicate that contemporary hip resurfacing is associated with good early–mid-term results. The primary modes of failure are aseptic loosening of the femoral component and femoral neck fracture. Further work will be required to determine whether these complications are technique related, or whether they relate to biological problems of the femoral head inherent to the procedure of hip resurfacing. Long-term observational studies and controlled trials will be required to determine if the potential advantages of hip resurfacing compared to conventional THR are realised.

Continuing concerns

Cancer risk

Concern has been raised about the biological effect of the elevated levels of metal ions and metal particles found in the blood, periprosthetic tissues and lympho-reticular system in patients with metal-on-metal bearings. However, it is not known at what levels chromium and cobalt ions released from implants are likely to be toxic.

The latency period for the development of haemopoetic or musculo-skeletal malignancies is likely to be prolonged. However, to date, there is no evidence that patients with metal-on-metal bearings in situ are more likely to develop such malignancies when compared with the general population. Visuri analysed a large cohort of patients in Finland with McKee-Farrar metal-on-metal THR’s in situ. At 15 years, the total cancer risk in this study group did not deviate from that of the general population.

Metal sensitivity

Recent reports have documented the presence of a marked perivascular infiltration of lymphocytes and plasma cells in the periprosthetic tissues around some metal-on-metal articulations (ALVAL). The pattern of inflammation is different to that seen in the tissues around metal-on-polyethylene implants. It has been postulated that the lymphocyte-rich infiltrate could represent some form of immunological response to the metal wear debris. The clinical relevance of this finding is as yet unclear, but the possibility exists that it might represent a novel mode of failure for some metal-on-metal joint replacements.

Conclusion

The failure of previous generations of hip resurfacing was essentially a consequence of the use of inappropriate materials, poor implant design and inadequate instrumentation. It was not an inherent problem with the procedure itself. The early results of contemporary hip resurfacing are encouraging. The complications commonly seen in the 1970s and 1980s, such as early implant loosening and femoral neck fracture, now appear to be rare. Whilst early results should be regarded with caution, the present generation of metal-on-metal surface replacements potentially offer the ultimate bone
preservation and restoration of function in appropriately selected young patients.

Resurfacing implants demand high manufacturing standards to produce consistently low wear bearings. Rigorous quality control by the implant manufactures is therefore essential. The background research and better understanding of implant failure suggests that hip resurfacing has now developed beyond that of an experimental procedure. Concerns remain with the long-term biological effects of the elevated metal ion levels found in all patients with metal-on-metal bearings in situ, although to date there is no evidence of any adverse clinical effect. Only long-term results and experience with this technology in the wider Orthopaedic community will give the answer as to whether the results will be durable, or if hip resurfacing will simply become a bone conserving intervention prior to conventional total hip replacement.

References


