REVIEW

Hip resurfacing: a technology reborn

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In recent years there has been a resurgence of interest in the concept of hip resurfacing. Much of this interest has stemmed from the work of McMinn in the West Midlands. Hip resurfacing is now emerging as a viable alternative to conventional hip replacement. In this article, we discuss the conceptual advantages offered by hip resurfacing and review the early clinical results and the ongoing clinical concerns regarding this technology.

In recent years, hip resurfacing has been regarded as a viable alternative to conventional hip replacement.

The operation for conventional hip replacement requires the surgeon to completely remove the femoral head by cutting through the neck of the femur using a power saw. Later, a metal hip replacement is secured by pushing a stemmed prosthesis into the upper part of the femoral shaft. In contrast, hip resurfacing attempts to preserve most of the femoral head and only replaces the surface of the joint. This technique preserves a virgin femoral canal, making eventual revision surgery much easier.

Also, hip resurfacing has a lower dislocation rate and allows a greater range of active movement than conventional hip replacement. For this and other reasons, hip resurfacing represents a particularly attractive proposition for the younger, high-demand patient.¹ In this review, we discuss the philosophy behind hip resurfacing, its proposed advantages over conventional hip replacement and the emerging literature on this technique.

History of resurfacing

The actual concept of hip resurfacing arose quite early in the history of modern hip surgery.

Sir John Charnley² experimented with Teflon hip resurfacing during the 1960s, but eventually abandoned the technique owing to rapid wear.

During the 1980s, many units experimented with Wagner resurfacing,³ which required a metal head to articulate against a thin (3 mm) plastic socket.

In 1981, Lapp and Schatzker⁴ reported good early results using Wagner resurfacing and expressed their optimism for this approach. Later, in 1990, Howie *et al*⁵ published a follow-up paper from Adelaide, describing good initial results with Wagner resurfacing followed by a series of early failures, with 30% of cases requiring revision at 5 years and 60% requiring revision at 8 years. In an independent publication, Head⁶ reported similar conclusions. These disappointing results fed the conviction that

conventional, stemmed hip replacement was the way forward.

However, a young and active patient population were beginning to make demands of the orthopaedic community that could not be satisfied with conventional total hip replacements.

Metal on plastic hip replacements exhibit a higher rate of plastic wear in this younger, high-demanding patient group.⁷⁻⁹ Wear of this kind leads to the generation of microscopic (1 µm diameter) debris particles that are believed to be associated with the process of aseptic joint loosening.

Despite the early set backs, the conceptual attractions of hip resurfacing remained.¹ In the early 1990s, a new generation of prosthesis designers attempted to overcome previous disappointments by careful attention to materials and instrumentation.

Modern hip resurfacing

British leadership in this speciality owes much to the work of Derrick McMinn, an orthopaedic surgeon based in the West Midlands with a long track record of technical innovation. Corin (Cirencester, UK) manufactured his first hip resurfacing system, and the Birmingham Hip Resurfacing (BHR)¹⁰ (his second-generation prosthesis) was introduced by Midlands Medical Technology in 1997.

Both these designs use a metal on metal, cobalt chrome articulation (cobalt chrome molybdenum alloy). After an initial period of experimentation, McMinn settled on a hydroxy apatite-coated press fit acetabular component and a cemented femoral component.

DISCUSSION: THE KEY ISSUES IN HIP RESURFACING

By 2005, both laboratory-based analysis and medium-term clinical results had emerged in the literature.¹¹⁻¹⁵ Despite this, debate continues on the true merits of hip resurfacing in comparison to conventional total hip replacement. There are several key issues to consider in this matter.

Prosthesis survival

Studies using Roentgen Stereophotogrammetric Analysis have shown that the femoral component of the BHR is stable over a 2-year follow-up period.^{11 12} Previous studies have shown that any implant that loosens quickly is probably associated with early migration.¹³ These results would suggest that the BHR ought to do well in the long term.

Abbreviations: AVN, avascular necrosis; BHR, Birmingham Hip Resurfacing

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However, it is difficult to extrapolate from studies of this kind and accurately predict the long-term behaviour of an individual implant. Only peer-reviewed published follow-up studies provide true insight into the reliability of a design.

Recently, the first such clinical papers have emerged on the medium-term results of hip resurfacing. In 2004, McMinn's own paper¹⁴ looked at a series of 446 hips (384 patients) with a maximum follow-up of 8 years (mean follow-up 3.3 years), in which only one patient required a revision procedure (for avascular necrosis of the femoral head).

The encouraging figures shown in McMinn's 2004 paper were criticised for excluding a subgroup of patients with unsatisfactory results from his series. The explanation put forward in the paper was that a batch of prostheses of inadequate quality had been produced, and that with this group excluded, the results were excellent.

Treacy *et al*¹⁵ published their first 5-year follow-up results in 2005. In a series of 144 consecutive joints, three femoral components failed during the first two years. Two of these were infected and one fractured. The mean age of patients was 52.1 years at the time of implantation. Survival at 5 years was 98% overall and 99% for aseptic loosening alone.

Infection

There is little reason to suppose that hip resurfacing infection rates will differ from those associated with total hip replacement. Treacy's infection figures¹⁵ are similar to infection rates for total hip replacements already described in the literature.^{16 17}

Dislocation

It seems intuitively obvious that a large femoral head will be associated with a lower risk of dislocation, and evidence has emerged in the literature to support this view.^{10 14 15} However, the relationship between head size and the risk of hip dislocation is far from linear. For example, it has long been recognised that the Charnley hip replacement has a very low risk of dislocation. This is despite the fact that Charnley chose to use a remarkably small 22-mm femoral head.¹⁷ In fact a variety of factors may probably determine the risk of dislocation. For example, in older patients, deteriorating abductor muscle function probably has a role. It may be that the data on hip dislocation associated with the typical (ie, elderly) patient is not applicable for a younger more active population and that in this age group, hip resurfacing will confer a greater advantage.

Pulmonary embolism

A conventional hip replacement involves the penetration of the proximal femoral canal by large reamers and in most cases by pressurised, liquid cement. Studies have shown the presence of fat embolus in the inferior vena cava, with subsequent embolism in the lung.¹⁸ Although usually asymptomatic, fatalities have been reported from fat embolism.¹⁹ The operation for hip resurfacing does not damage the medullary canal of the femur, and it has been suggested that this will reduce the already very low risk of symptomatic pulmonary embolism. At the time of writing, the experimental data on this issue remain unpublished.

Fractured neck of femur

Fractured neck of femur is a recognised complication of hip resurfacing that has no obvious parallel in modern conventional stemmed hip replacements. This issue has been investigated at length.

Watanabe *et al*²⁰ performed a finite element analysis of the BHR and found considerable stress concentration around the base of the femoral component, suggesting that a fracture of the femoral neck was likely.

Shimmin and Black,²¹ in a large Australian retrospective study, reviewed 3497 BHR and identified 50 cases of fractured neck of femur. This was twice as likely in women as in men and the mean time to fracture was 15.4 weeks (men 13.5 v women 18.5 weeks), suggesting that when fractured neck of femur occurs in hip resurfacing it tends to occur early. The occurrence of fracture in this study did not seem to correlate with the experience of the surgeon.

Additional isolated reports of neck fracture have appeared in the literature. Sharma *et al*²² reported two fractures at 8 and 15 months after operation in 2005.

Cossey *et al*²³ reported a series of seven undisplaced fractures occurring within 4 months of surgery that were treated conservatively (by non-weight bearing) with no functional deficit. Similarly, Cumming and Fordyce have reported an isolated case of successful conservative management.²⁴ However, in clinical practice, many fractures would require revision surgery.^{25 26}

Stress shielding

One matter of concern in conventional hip replacement is loss of femoral bone stock owing to stress shielding.

Forces are transferred away from the bone of the proximal femur and into the metal femoral component owing to the much greater stiffness of the metal. This leads to wasting of the local bone stock, which in turn increases the risk of fracture around the hip replacement. Stress shielding also exacerbates the challenge of reconstituting bone mass at the time of revision surgery.

Harty *et al*²⁷ performed a study of bone mineral density in the femoral neck after BHR and showed that bone mineral density around the femoral neck did not seem to be reduced. Working in Japan, Kishida *et al*²⁸ made similar observations regarding the proximal femur. These studies appeared to alleviate previously voiced concerns that stress shielding around the prosthesis would lead to a fracture.^{20 29}

Tribology and plasma ion levels

Tribology is a branch of engineering that deals with wear and friction between moving surfaces. An improved understanding of tribology has a central role in the improved performance of modern joint replacements.

For an equivalent arc rotation, a large femoral head requires a far higher speed of movement at the articulating surfaces than the smaller total hip replacement. The formation of a fluid film between rapidly moving surfaces might serve to completely separate the surfaces, reducing the wear to zero. This so-called "hydrodynamic lubrication" is similar to water skiing and is influenced by both the space between the articulating surface³⁰ and the speed of motion.

The success of hydrodynamic lubrication in resurfacing is heavily dependent on the precision of the manufacturing process.³¹

In vivo articulation appears to be a combination of hydrodynamic lubrication with episodes of more conventional friction, and the suggestion that hip resurfacing is associated with zero wear is probably fanciful.

When wear does occur, it generates many fine particles of metal known as debris.

In comparison to metal on plastic hip replacements, metal on metal hip resurfacing produces a much lower volume of debris. It does, however, produce a very fine cobalt chrome debris. Some studies suggest that over a million such particles are generated with every step.

As in metal on plastic total hip replacements, metal particles generated at the hip have been found as far away as the liver and spleen in postmortem studies.³² Their long-term systemic effect remains uncertain.

The large surface areas generating this fine metallic powder increase the level of cobalt chrome ions in the blood.

Table 1 Hip resurfacing versus hip replacement

Resurfacing advantages	Conventional total hip replacement
Good Preserves a femoral head remnant Technical ease of revision on the femoral side of the joint More physiological femoral load bearing avoids stress shielding Large head size may reduce dislocation risk—especially in patients at risk Hard bearing surface does not generate 1 µm-sized debris particles believed to cause aseptic loosening Large head size may facilitate hydrodynamic lubrication Reduced risk of leg length changes Bad Not conservative on the acetabular side Generation of very small particles of debris with increase in cobalt chrome ion levels New modes of failure, eg, fractured neck of femur Limited long-term follow-up	Good Follow-up data available for 20 years on several prostheses and for 30 years on a more limited number of designs Metal on plastic joints not associated with an increase in plasma metal ion levels Dislocation rate considered to be approx 1% in best published series Problem of fractured neck of femur does not apply Bad Technically difficult and protracted revisions, especially to reconstruct the femoral side of the joint Generation of 1 µm-sized plastic debris particles believed to cause aseptic loosening Dislocation rate may be higher in younger, active patients Known to have inferior performance in the younger patient

Dunstan *et al*³³ recently reported considerably raised levels of whole blood Ti, Va and urinary Cr in a review of several designs of metal on metal articulating joints 30 years after surgery.

Back *et al*³⁴ looked at serum cobalt and chromium levels after modern hip resurfacing and their effect on renal function. In this study, serum cobalt peaked at 6 months and then declined over the next 15 months. A similar pattern was observed with chromium, which peaked at 9 months. There was no adverse effect on renal function.

The initial rise in metal ion levels has been attributed to the wearing in effect of the prosthesis, which tends to self-polish in the first few months of use.

Teratogenicity

Given the age group that might be treated with hip resurfacing, it has been suggested that circulating cobalt chrome ions may represent a teratogenic risk to younger women.

Brodner *et al*³⁵ analysed the ion levels in blood taken from the placenta of three pregnant women who had previously

been treated with metal on metal hip replacements. These were then compared with the maternal serum levels. This study shows that at term, cobalt chrome ions do not cross the placental barrier.

It is important to remember that at the time of writing there have been no reports of a clear-cut association between teratogenicity and metal ion levels. However, the theoretical risks to the unborn child should be mentioned at the time of consent to women of child-bearing age.

Carcinogenesis

Less than 30 cases of peri-prosthetic malignancy have been reported since prosthetic joints were first introduced, and most of these were associated with metal on plastic articulation. The tumours that have been identified may simply represent randomly located neoplasms that have occurred adjacent to a prosthesis.³⁶ We are unaware of a soft tissue sarcoma occurring adjacent to a metal on metal hip resurfacing.

Avascular necrosis

The femoral head remnant may undergo avascular necrosis (AVN) after hip resurfacing. If this does occur, then AVN might have a role in subsequent failure of the prosthesis.

In a large retrieval study in 1993, Howie *et al*³⁷ looked at 72 femoral heads that had been treated initially by resurfacing and found only limited evidence of AVN. A correlation between component loosening and histological evidence of AVN could not be found in this study.

Similar results were reported by Bradley *et al* in 1987.³⁸

More recently, Little *et al*²⁵ reviewed a series of 377 hip resurfacings that required 13 revision procedures. Histological examination of the retrieved femoral remnant showed evidence of osteonecrosis in all but one specimen. None of these cases had shown histological evidence of osteonecrosis in the femoral bone at the time of the initial implantation.

CONCLUSIONS

The conceptual advantages of hip resurfacing are now well recognised and by the end of 2004 most prosthesis manufacturers had introduced their own metal on metal hip resurfacing.

Figure 1 Plain x ray of the right sided hip resurfacing.

This debate also touches on the conservative instincts of the British orthopaedic community and forces us to confront one of the fundamental dilemmas of all medical research. If we deliberately confine ourselves to those treatments in which there is an existing collective confidence, we will effectively freeze our technology at its current level. Conversely, if we experiment with new technologies in orthopaedics which are subsequently found to have failed, we may expose patients to unnecessary revision surgery.

Hip resurfacing is a technically different procedure from conventional hip replacement. A patient requesting a resurfacing should be referred to a surgeon with an established interest in hip resurfacing.

In a cost-conscious age, it should be remembered that the Charnley hip replacement is available for about £500 and that a BHR costs £1500. The British National Health Service is now tending towards a policy of fixed price arthroplasty and this policy may create pressure to use cheaper hip implants.

But these are difficult figures to interpret. The true total cost of any hip replacement is hard to establish. For example, small variations in likely revision rates will lead to dramatic changes in long-term costs.

In Britain, the National Institute for Clinical Excellence recommends that hip resurfacing be regarded as a separate technology from ordinary hip replacements. The National Institute for Clinical Excellence also recommends that resurfacing be contraindicated in anyone deemed to be at risk of osteoporotic fracture.

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