# Novel strategies in joint replacement

**As the need for hip and knee replacement continues to increase, technical and material changes have allowed a dramatic evolution in the way that degenerative, inflammatory and traumatic arthritis are managed. Advances include new bearing surfaces which should have greater longevity, minimal incision joint replacement, computer guidance and partial joint resurfacing for younger patients. These advances and their implications are discussed.**

Joint replacement surgery has been around for some time. It has been a constantly evolving field as new technologies and materials have been developed, and patient and surgeon expectations have risen. This article looks at current areas of interest in joint replacement.

## Minimal bone resection

This concept relates mainly to bone stock preservation in hip resurfacing. To a lesser extent it can also be applied to unicompartmental knee replacement and patello-femoral resurfacing.

*Figure. 1. Birmingham hip resurfacing prosthesis in situ.*

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## Hip resurfacing

This is classic example of new technology being applied to an old concept. Previous models have been used, but they failed as a result of fixation and wear issues. Hip resurfacing has enjoyed a recent revival because of better technology and improved wearing surfaces (*Figure 1*).

There are several potential benefits that hip resurfacing holds over conventional hip replacement (*Figure 2*). Femoral neck resection is avoided. This results in no stress shielding, better biomechanics and proprioception. The preservation of bone stock means that hip resurfacing can easily be converted to a total hip replacement (i.e. the next operation is easy). Hip resurfacing retains a large femoral head which improves joint stability and reduces the risk of dislocation. The modern metal-on-metal bearings provide very smooth surfaces, excellent sphericity and very good radial clearances. A study looking at 446 hip resurfacing with a mean follow-up of 3.3 years (1.1–8.2 years) showed six unrelated deaths and one revision out of 440 cases, which equates to a 99.8% survivorship (Daniel et al, 2004).

*Figure 2. Radiograph of conventional total hip replacement.*





There are some concerns related to hip resurfacing. This is a more complex procedure than a total hip replacement, which means that there is a natural learning curve. Femoral jigs can sometimes be difficult to use especially in obese or muscular patients. Alignment is not always correct and this gets worse with smaller incisions. Femoral neck fractures are increasingly recognized, particularly in patients with osteonecrosis.

There are concerns with the acetabular bone stock. There is a danger of over-reaming the acetabulum to match the femoral head. The socket is often larger than the diameter accepted for standard hip replacements. Some have found that the cup can be more difficult to seat with occasional fixation failure.

The final concern is with the metal-on-metal bearing surface; it is known that this leads to increased metal ion levels in the blood, however, it is not known if it has any carcinogenic or toxic effects on patients especially if they are of child-bearing age.

At present, the first few medium-term results and functional outcomes are very exciting, but the jury is out and continued surveillance and vigilance is required.

*Figure 3. Radiograph of unicompartmental knee replacement.*

## Unicompartmental knee replacement

Unicondylar knee arthroplasty was introduced in the early 1970s. In the 1980s enthusiasm for the procedure began to increase (Scott and Santore, 1981). The concept behind the unicompartmental knee arthroplasty is to replace only the damaged part of the knee (medial or lateral compartment) while preserving as much normal tissue and bone as possible in order to allow the restoration of the normal kinematics. It is estimated that up to 30% of arthritic knees are suitable for unicompartmental knee arthroplasty. The number of surgeons now offering the procedure is increasing.

There are several unicompartmental knee replacements available. The Oxford prosthesis is used most widely. This has a metal femur and tibia with a polyethylene spacer which provides a mobile bearing (*Figure 3*).

Careful patient selection is critical for unicompartmental knee arthroplasty if reliable results are to be achieved. No significant degenerative changes in the other (medial, lateral, or patellofemoral) compartment should be present (Tabour and Tabour, 1998), and both cruciate ligaments should be intact. Malalignment of the limb should be passively correctable to neutral and not beyond. This is usually possible in patients with a varus deformity of less than 15° or a valgus deformity of less than 20°. The deformity of the knee should be only mild; therefore, a flexion contracture should be less than 15°. Unicompartmental knee arthroplasty with excision of osteophytes in the notch cannot correct moderately severe flexion contractures. Ideally, the knee can be flexed to 110°. This is important for the preparation of the femoral condyle during the operation.

The advantages of unicompartmental knee replacement include preservation of uninvolved tissue and bone, smaller incision, less blood loss, close approximation of normal kinematics, reduced operative time, rapid recovery, better range of motion, improved gait and increased patient satisfaction. When they fail, these knees can be revised to a total replacement with good results. Thus, they can be considered for younger patients in the 40–60 year age group.

With appropriate patient selection, careful surgical technique and proper implant design, unicompartmental knee arthroplasty can now be viewed as a procedure with reliable medium- to long-term success.

## Patellofemoral resurfacing

Patellofemoral arthroplasty is now receiving enthusiastic consideration as there have been improvements in design and materials, and the orthopaedic community embraces the concept of minimally invasive surgical options for the knee. It offers a more conservative alternative to total knee arthroplasty or patellectomy in younger more active patients with arthritis localized to the anterior compartment of the knee. McAlindon et al (1992) found that as many as 24% of women and 11%

of men older than 55 years of age with symptomatic knee arthritis had isolated degeneration of the patellofemoral joint.

The success of patellofemoral arthroplasty is, in part, contingent on appropriate patient selection. It should be limited to patients with isolated patellofemoral osteoarthritis or posttraumatic arthrosis, only after non-operative measures have been exhausted. Additionally, this option is best reserved for patients with severe functional limitations. The procedure should not be performed in patients with inflammatory arthritis (Lonner, 2003) or in patients with patellar maltracking or malalignment. Sparing of the tibiofemoral compartments, menisci and cruciate ligaments allows preservation of a more kinematically sound knee joint than total knee arthroplasty (TKA). It is a particularly attractive option for young active patients and can easily be converted to TKA if necessary.

Lonner (2003) has advocated patellofemoral arthroplasty rather than TKA or patellectomy for patients younger than 55 years of age. Elderly patients may be better suited to TKA because of its remarkable track record and proven survivorship.

## Minimally invasive surgery

Minimally invasive surgery (MIS) is the latest trend in surgery. MIS refers to a growing number of surgical procedures that achieve the same surgical results as traditional operations, but are performed with a much smaller incision. This is done with the help of specially designed instruments and retractors. MIS does require extensive training to become accomplished in its use.

MIS typically result in less pain and blood loss, minimal scarring, a quicker recovery time, as well as a reduction in health-care costs. This has led to daycase joint replacements in some centres. This sounds very attractive to the patient, however, there are concerns. The potential complications are similar to standard surgery but may prove to be more common. There is also the concern that MIS (especially the two incision hip) has a longer operating time. One should remember that these are developing techniques, and there are potential risks primarily as a result of a lack of visualization. Joint replacement is for life and the longevity of the joint is highly dependent upon the technical skill of the surgeon. The short-term gains may not be worth the long-term risks if the joint replacement does not last as long. To date there are few peer reviewed published results on long-term outcomes.

It is clear that MIS is here to stay, however, currently needs further refining. Image guidance or navigation systems should help with 'visualization' problems. Several basic MIS procedures are examined below.

### Single incision hip

The one incision 'mini hip' involves a traditional approach to the hip (anterior or posterior) using special instruments. This has enabled surgeons to insert tried and trusted hip replacements through smaller incisions (approximately 4 inches). The actual length of the incision depends on the size and obesity of the patient. This has the same deep dissection as the standard hip but has a better cosmetic outcome.

### Two incision hip

This has required the development of new surgical approaches to the hip. The approach involves a small incision in the groin, through which the acetabular cup is inserted and a second small incision, over the side of the hip, through which the femoral component is implanted. This technique allows the surgeon to navigate between and around the muscles, tendons and other soft tissues, rather than cutting through them.

Unfortunately, the well-established joint replacements cannot be used in this technique and there are no medium-term results for the new implants that have been developed for this purpose. Many surgeons have tried this technique and abandoned it because of a higher complication rate (Pagnano et al, 2005).

### Minimally invasive total knee replacement

The attention towards MIS to joint replacement has resulted in interest by some surgeons in applying minimally invasive techniques to TKA (Globe and Justin, 2004). It requires a larger approach than for the unicompartmental knee replacement, simply because the implants are larger and the bone preparation is more extensive. The principle is still the same, however, by limiting dissection into the quadriceps muscle a more rapid recovery may ensue.

These new techniques must be evaluated thoroughly and changes approached with caution. Medial and lateral techniques that minimize interruption and dissection of neurovascular tissues, muscles, tendons and ligaments have been described. Patients who have undergone these procedures have benefited short-term from quicker recovery time and less pain and have benefited long-term from the use of conventional prosthesis.

## Computer-assisted navigation systems

Computer-assisted technology is the latest advancement to ensure accuracy and excellence in joint replacement surgery. It provides a degree of accuracy not possible with the naked eye or conventional instruments. It informs the surgeon exactly where to position instruments, what part of the joint to remove, and where to properly align bones and the new joint. This helps reduce incorrect positioning or orientation of an implant which will reduce implant wear and loosening. Computer-assisted navigation involves the three steps described below.

### Data acquisition

Data can be acquired in three different ways: fluoroscopic, computed tomography (CT) or magnetic resonance imaging (MRI) guided, or via imageless systems. The data are then used for registration and tracking,





described below. Image-guided systems are self explanatory. The imageless systems rely on other information such as centres of rotation of the hip or knee, or visual information like anatomical landmarks.

### Registration

This refers to relating images (e.g. X-rays, CTs or MRIs) to the anatomical position in the surgical field. Early registration techniques require the placement of pins or 'fiducial markers' in the target bone. This required an additional surgical procedure. More recently, a surface matching technique is used in which the shape of the bone surface model generated from preoperative images are matched to surface data points collected during surgery.

### Tracking

This refers to the sensors and measurement devices that can provide feedback during surgery regarding the orientation and relative position of tools to bony anatomy.

## Surgical robotic systems

In contrast to planning and navigation, in which the surgeon is performing the operation with guidance or assistance from a computer, in robotic surgery a computer-controlled tool performs the surgery with some degree of human oversight. The first active robot to be used in medical applications was the ROBODOC in 1992 (Paul et al, 1992). The system consists of a preoperative planning computer and a five-axis robotic arm with a high-speed end milling device that prepares the femoral canal for the selected implant in the position chosen preoperatively on the computer workstation. Disadvantages with this system are that it is expensive, it is bulky and takes a lot of theatre space, and takes longer than conventional joint replacement.

## The bearing surface

Over the past 2 decades it has become clear that the major stumbling block to prolonged survival of hip replacements is the wear of the bearing surfaces. Wear is defined as the progressive shedding of minute amounts of material from the implant. Wear particles cause bone resorption and granuloma tissue production. They may cause pain and, ultimately, loosening of the prosthesis. The success of joint replacement depends on the materials that are used.

The traditional bearing surfaces used in hip replacement surgery were metal-on-plastic. A polished metal ball and high molecular weight polyethylene cup became the standard for the first 3 decades that this surgery has been offered. Metal (cobalt-chrome) on ultra-high molecular weight polyethylene (UHMWPE) remains the standard bearing surface of choice.

Biomaterial advances have allowed experimentation with new bearing surfaces, and there are now several options when hip replacement surgery is considered. The exact 'best' option is unknown. The main reason for this uncertainty is that the results of laboratory testing of the various surfaces do not always translate to similar findings when the materials are used in people. The goal of selecting materials for coupling construction is to select materials that have low production of wear particles and low friction resistance.

During the last decade several modifications of bearing materials for artificial joints were introduced.

### Crosslinked UHMWPE

Crosslinking is a process in which polyethylene molecules are bonded together to result in a stronger material, substantially improving the material's wear resistance. It has been reported that the amount of crosslinking of polyethylene is directly related to its wear performance, and significant reductions in polyethylene wear have been shown in joint simulation studies with highly crosslinked polyethelyne components.

Such a material should lead to much better resistance to wear, fewer polyethylene particles, less osteolysis and less frequent implant loosening.

### Metal-on-metal

These bearings were recently reintroduced with improved alloys, design and manufacturing. Currently metal-on-metal bearings are used for hip resurfacing and for total hip replacement. They have clinically proven wear resistance higher than that of metal-on-polyethylene bearings. These surfaces couple to polish away scratches on the surfaces, the so-called self-polishing capability. Despite a lower volume of wear, the particles that are produced are very small. This may be of some concern as the full biological response to metal particles or ions is currently unknown. A major issue is the question of potential metal toxicity and carcinogenesis.

### Ceramic-on-ceramic

These are the most expensive bearing option. They produce the lowest quantity of wear particles and there is no toxicity of wear particles. Ceramic-on-ceramic is brittle and although rare, fracture of the component is a catastrophic complication (*Figure 4*). The wear rate of

***Figure 4. Fracture of brittle ceramic component.***

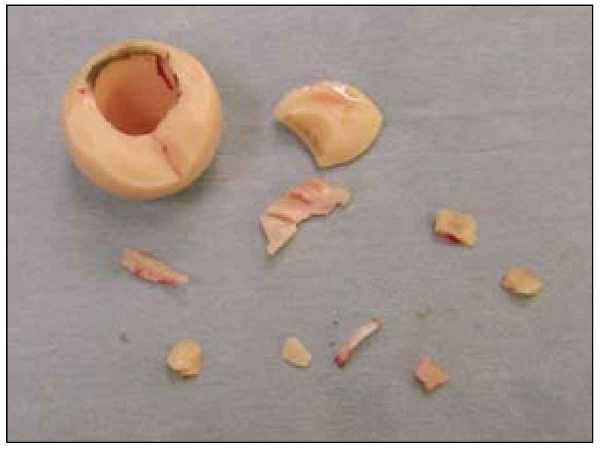

*Figure 5. Oxinium head for total hip replacement.*

ceramic-on-ceramic is more sensitive to precise positioning of the components. The contact between the two ceramic bearing surfaces must be on large areas, when the contact occurs on small areas large local stresses arise with considerable wear (so-called stripe wear).

### Oxinium-on-polyethylene

Metal heads made of zirconium have their surface oxidized to create a ceramic-like surface (*Figure 5*). This affords all the advantages of ceramics without the fracture risk and lack of versatility. The early results are very promising.

## Conclusions

This is an exciting time in joint replacement surgery. The rapid advance in technology means that old solutions to problems can be revisited with encouraging results (e.g. hip resurfacing) and that new solutions can be applied to revolutionize joint arthroplasty surgery (e.g. computer-assisted navigation systems). BJHM

## KEY POINTS

- Bone stock preservation is the key principle in hip resurfacing, patello-femoral resurfacing and unicompartmental knee replacement.
- Minimally invasive surgery advantages include reduced pain and blood loss, minimal scar, quicker recovery times and reduction in health-care costs.
- Minimlly invasive surgery concerns include lack of visualization which may result in mal-positioning and short-term benefits may be outweighed by long-term risks.
- New technologies (computer-assisted navigation systems) are being used to improve accuracy of joint replacement.
- Advances in biomaterials have lead to improved life-span of the components.

*Conflict of interest: none.*


Daniel J, Pynsent PB, McMinn DJW (2004) Metal-on-metal resurfacing of the hip in patients under the age of 55 years with osteoarthritis. *JBJS B* **86:** 177–84

Globe EM, Justin DF (2004) Minimally invasive total knee replacement: principles and technique. *Orthop Clin N Am* **35**(2): 234–45

Lonner JH (2003) Patellofemoral arthroplasty. In: Lotke PA, Lonner JH, eds. *Master Techniques in orthopaedic surgery: Knee arthroplasty.* 2nd edn. Lippincott Williams and Wilkins, Philadelphia: 261–73

McAlindon RE, Snow S, Cooper C, Dieppe PA (1992) Radiographic patterns of OA of the knee joint in the community: The importance of the patellofemoral joint. *Ann Rheum Dis* **51:** 844–9

Pagnano MW, Leone J, Lewallen PG, Hanssen AD (2005) Two-incision THA had modest outcomes and some substantial complications. *Clin Orthop Related Res* **441**: 86–90

Paul HA, Barger WL, Mittlestadt B et al (1992) Development of a surgical robot for cementless total hip arthroplasty. *Clin Orthop* **285:** 57–66

Scott RD, Santore RF (1981) Unicondylar unicompartmental replacement for osteoarthritis of the knee. *J Bone Joint Surg* **63A:** 536–44

Tabour Jr OB, Tabour OB (1998) Unicompartmental arthroplasty: A long term follow-up study. *J Arthroplasty* **13:** 373–9