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REVIEW ARTICLE

Current thoughts on total hip replacement

I. D. LEARMONTH, A. SPIRAKIS

Charnley low-friction arthroplasty remains the gold standard by which the outcome of all total hip replacements must be judged. Wroblewski[1] and Older and Butorac[2] have reported excellent results in more than 80% of patients at a mean follow-up of almost 20 years.

The concern generated by reports from several authors[3-5] of poor results with cemented hip replacement in younger patients led to the development of a plethora of cementless prostheses approximately a decade ago. The results of these first-generation cementless prostheses have not matched the early results of cemented hip replacement. Anterior thigh pain is common, and there is a significant incidence of early loosening as a result of undersizing and poor fixation. Cementless arthroplasty was introduced as a bone stock-preserving option, but Santavirta *et al.*,[6] Maloney *et al.*[7] and Learmonth *et al.*[8] have all reported bone stock loss, with cancellisation and rounding off of the calcar and aggressive focal granulomatous lesions.

With regard to the principles of total hip replacement, the original concepts of McKee[9] still pertain: (*i*) use of inert (biocompatible) materials; (*ii*) satisfactory design (that provides adequate mechanical strength); (*iii*) correct operative technique; and (*iv*) fixation of the components to bone. Further criteria include high corrosion resistance of the materials, a low coefficient of friction at the articulating interface and good wear resistance of the materials forming this interface.

Materials

Metals

The introduction of the superalloys improved fatigue resistance and virtually eliminated the incidence of mechanical failure of the stem. Metal may be affected by chemical corrosion or released in the form of small particles as a result of wear.[10]

Metal hypersensitivity may occasionally occur, and it has been shown that some constituents of the chrome-cobalt alloy may be cytotoxic and even carcinogenic. The increased surface area produced by porous coating will result in increased leaching of metal ions.

The use of titanium as an articulating surface is clearly contraindicated. Black *et al.*[11] and Lombardi *et al.*[12] have reported metallosis, osteolysis and loosening induced by wear debris from titanium alloy femoral heads. McKellop *et al.*[13] have noted that titanium alloy is particularly susceptible to abrasive wear by particles of acrylic cement; in addition, normally acid-passivated titanium alloy surfaces tend to cause more wear of polyethylene than do stainless steel and cobalt chrome.[14] Ion implantation reportedly improves the resistance to wear and the fatigue properties, while enhancing the resistance to corrosion.[15] However, the performance as a bearing surface needs to be carefully evaluated in a few selected centres before widespread use in clinical practice.

Departments of Orthopaedic Surgery and Biomedical Engineering, University of Cape Town
I. D. LEARMONTH, F.R.C.S., F.C.S. (S.A.) (ORTH.)
A. SPIRAKIS, B.SC. (ENG.), POSTGRAD. DIP. (ENG.), M.SC. (MED.)

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The favourable characteristics of titanium alloy — high tensile and fatigue strength, a relatively low modulus of elasticity and superior biocompatibility — make it an attractive option for cementless hip replacement, but its poor resistance to wear, and especially its susceptibility to abrasive wear by particulate cement, represent a relative contraindication to its use in cemented implants.

High-density polyethylene (HDP)

Wear of HDP remains a significant problem in long-term follow-up. However, studies have shown that HDP wears at a very low rate, and that radiographic findings previously ascribed to wear were in fact due to plastic deformation. Santavirta *et al.*[16] have, however, implicated HDP debris in the formation of aggressive granulomatous lesions, and have described the biochemical and enzymatic responses which culminate in these lesions.

It is therefore necessary to produce a plastic with improved wear properties. Ultra-high molecular weight polyethylene is being developed further to produce a third generation of more durable, wear-resistant plastics.

Methylmethacrylate

Charnley's[17] landmark publication represented a turning point in total hip replacement. Cement is used as a grout, not a glue, and is well tolerated in bulk. However, in particulate form it may excite an aggressive granulomatous response, so-called 'cement disease'.[8] Mulroy and Harris,[19] in an 11-year radiographic review, report that improved cementing techniques have brought about a marked reduction in the incidence of aseptic loosening of the femoral component. These techniques include meticulous preparation of the bone bed by means of pulsatile lavage and drying with adrenalin-soaked sponges or hydrogen peroxide. Fixation is further enhanced by the use of a distal plug in the femur, the use of a cement gun, with or without venting, and effective pressurisation of the cement.[20] The mechanical properties of cement — which is intrinsically brittle and susceptible to crack propagation — can further be enhanced by reduction of the porosity either through centrifuging[21] or by vacuum mixing.[22] Despite its physical limitations, cement can therefore produce excellent clinical results if used carefully and correctly.

New bio-active materials are being used to provide immediate fixation to the bone. The glass ionomer cement[23] provokes ionic exchange at the interface, with excellent bonding. However, it is brittle and stiffer than methylmethacrylate and requires further mechanical evaluation and clinical trials.

Ceramics

The ceramics such as alumina, zirconia and the titanium oxides demonstrate excellent biocompatibility and wear characteristics. They exhibit good chemical stability in hostile environments, and are hard and durable, but their brittleness and weakness in certain configurations remain cause for concern. The use of modular ceramic heads to articulate with HDP seems a reasonable choice for the younger, more active patient. However, it is possible that ion-bombarded cobalt-chrome will give similar scratch resistance and wear properties, without the vulnerability to brittleness and fracture.

Composite materials

Biological and biomechanical compatibility are both important attributes of a successful implant. Flexural matching can only be obtained in a component which exhibits an appropriate stiffness gradient. Composites with poly-acetal,[24] polyethylene,[25] carbon[26] and acrylic have all been used in an attempt to reduce the stiffness of the femoral stem, so that they can more closely match the structural characteristics of the recipient host bone.

Femoral component

Femoral head

The femoral head/neck complex should provide an adequate offset to permit a good range of movement without impingement. This is more easily achieved with a 32 mm than a 22 mm head, but at the expense of increased friction and torque.

Livermore *et al.*[27] reviewed the effect of head size on wear of the poly-ethylene component. The least amount and rate of linear wear were associated with a 28 mm femoral head, while the 22 mm head exhibited the greatest amount. The greatest volumetric wear and mean rate of volumetric wear were seen with the 32 mm components. In a review of 6 128 total hip arthroplasties, Morrey and Ilstrup[28] reported the highest rate of acetabular revision in those components with 32 mm femoral heads.

Twenty-eight millimetres seems therefore to be the optimal head size at present. Modularity is essential to permit fine tuning of length and offset, and to allow only the head of a well-fixed femoral component to be exchanged at the time of acetabular revision.

Femoral stem

Cemented

Crowninshield *et al.*[29,30] have defined the desirable features of a cemented femoral component. The cross-section should be rounded-trapezoidal or wedge-shaped, with a broad lateral surface to reduce the lateral cement tensile stresses. The neck-shaft angle should be anatomical with 10° anteversion and a rounded (± 132°) calcar region to reduce stress risers in the cement. It is doubtful whether a calcar-bearing collar realises any of its theoretical advantages. A small cement collar probably enhances pressurisation and provides a defined end-point for component insertion in the surgical technique.

The neck should have a Morse taper to accept modular heads of variable sizes and provide different lengths. This introduces flexibility into the system and permits fine tuning of length and offset at reduction. The stem should be approximately 14 cm long with a smooth surface to allow settling in the visco-elastic cement mantle.

We believe that an anatomical asymmetrical stem — incorporating a gentle proximal posterior bow — is essential to provide an adequate, even cement mantle. Spirakis *et al.*[31] have shown that this reduces system stresses and, together with the more uniform thickness, will protect against cement fragmentation and failure. A cement centralisation plug may not only enhance pressurisation, but also position the stem centrally to promote an integral cement sheath. Harris *et al.*[32] recently reported that none of the first-generation cementless femoral components has produced results to equal those of second- and third-generation cementing. However, the practice is still in its infancy.

Cementless

Cementless fixation has been common in Europe for years. However, cementless prostheses only became popular in North America in the early 1980s.

Many studies have demonstrated the clinical importance of matching the cortical dimensions of the femur with those of the implanted prosthesis.[33,34] However, the geometric shape of the proximal femur is variable, and most designs rely on a double taper or wedge to engage proximal cortical bone.

The lateral profile may have a posterior bow in the metaphyseal region to provide an 'anatomical' shape, or it may have a straight stem to promote three-point fixation. We prefer the former, as we believe the latter may cause significant thigh pain and subsequent bone resorption at the contact points.

In North America, biological fixation has been achieved by the application of multi-layered micro-porous bead and mesh coatings. Pilliar *et al.*[35] demonstrated that a pore size ranging from 100 μm to 500 μm was optimal for bone ingrowth.

Implant materials are called bio-active when they are capable of bonding with the adjacent bone. Geesink *et al.*[36] suggest that hydroxylapatite is the most suitable of the bio-active calcium-phosphate ceramics for use in cases of permanent implantation.

It would therefore seem reasonable to use a hydroxyl-apatite-coated porous coating in the metaphyseal region to enhance the predictability and durability of osseo-integration. The optimal extent of porous coating on the component remains contentious, but it should almost certainly be limited to the proximal third or less to avoid stress protection and bone resorption.

A 132° neck shaft angle combined with 10 - 15° of anteversion reduces the load across the hip joint and the rotational stress on the implant, while optimising the joint kinematics.

Acetabular component

Cemented

Stauffer[37] reported a disproportionate increase in the incidence of aseptic loosening of the acetabular compared with the femoral component after long-term follow-up.

The flexibility of high-density polyethylene results in the generation of high stresses in the subjacent cement, particularly when a large (i.e. 32 mm) head is used and the HDP is thin.[38] This has been implicated in the development of late, aseptic loosening of the cup.

Sockets should consist of pure HDP,[39] and should be flanged to enhance pressurisation of the acetabular cement. The flange — which is sculpted to fit the acetabular ostium — retains particulate cement debris, however, which may be a significant cause of third-body wear of the HDP.

Cementless

Wilson-MacDonald *et al.*[40] reported on 545 consecutive hip replacements with a cementless non-coated HDP acetabular component. They noted a high incidence of radiological and clinical loosening at 8 years. They ascribed this to giant-cell foreign body erosions caused by polyethylene debris. They suggest that direct contact between bone and polyethylene be avoided. Acetabular components inserted without cement should therefore be metal-backed.

A wide diversity of these implants is available, which offers the additional advantage of allowing change of the HDP liner. There are essentially three different designs:

Hemispherical cups with porous coated surfaces are the most popular. Fixation is enhanced with screws or pegs, which must be carefully placed to avoid the complications of their protrusion into the pelvic cavity. Bone ingrowth is patchy at best, but Maloney and Harris[41] have reported good results with cementless cups in a hybrid system.

Chamfered cylindrical components achieve fixation with the host bone through an interference fit; while screws and pegs are unnecessary, the procedure is technically demanding.

Lastly, **components may have external threads,** which provide secure fixation at the time of surgery. Although these cups incorporate many variables — surface shape, thread depth, thread width, etc. — and have gained considerable popularity in Europe, their use has not been vindicated by clinical experience. Apel *et al.*,[42] among others,[43] have reported inferior results, with a time-related increased incidence of radiolucencies and migration.

We recommend the use of a hemispherical press-fit prosthesis, with pegs or sharp spikes to provide additional fixation. The use of screws should be avoided in the primary arthroplasty: they not only produce increases in stress as they pass through the shell, but may also impinge on the HDP if the cup settles. The outer surface should have a porous coating to provide biological fixation.

Summary and conclusion

Opinion leaders in the field of total hip arthroplasty express antipodal views with bewildering frequency. New trends notwithstanding, Charnley low-friction arthroplasty has a record of outstanding success, and we should attempt to identify specific problems, and address these accordingly. Biological and biomechanical matching remain important and increased attention to meticulous cement technique should favourably improve the long-term performance of cemented implants. The concept of cementless replacement should not, however, be summarily discarded, particularly for the younger patient. The discovery of existing design limitations should lead to further development based on sound scientific research. In an era of exploding technology, cost-containment must remain a pragmatic reality in the provision of a health-care service to the community.

At this stage we would recommend a cementless hip replacement for the very young, hybrid replacement (cemented stem, uncemented cup) for the middle-aged and a fully cemented replacement for the elderly.

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