The bearing couple of a polyethylene acetabular cup and a polished metal or ceramic femoral head has been a successful combination in hip arthroplasty for over 30 years, but it is now recognised that fine micron and submicron polyethylene wear particles can cause adverse cellular reactions which may lead to osteolysis and loosening. In prostheses showing high wear, the penetration of the femoral head into the acetabular cup often exceeds 2 mm after 10 to 15 years. Although the head does not wear through the cup, which may be over 8 mm thick, there is a significant amount of debris, typically over 600 mm³. Most of these particles are less than a micron, and therefore in the size range for phagocytosis, resulting in inflammatory reactions and osteolysis. Recent studies of failed Charnley prostheses at 10 to 20 years have estimated that well over one thousand billion wear particles (10¹²) are released into the tissue during this period. There is much interest in the wear of polyethylene since it can lead to the failure of hip arthroplasties. 

Wear, unlike elastic modulus or hardness, is not a specific property of a material but is a result of the system and conditions in which the materials articulate. The simplest laws of wear state that the volume produced is proportional to the load and the sliding distance, but many other factors dramatically affect the wear rate. These include:

1) Local damage or roughening of the polished femoral head. 
2) Oxidative degradation after sterilisation by gamma irradiation in the presence of oxygen (p. 340 and Besong et al.)
3) Multidirectional movement. Polyethylene molecules are oriented by the forces of friction in the primary direction
of movement, usually flexion and extension. This strain hardening provides a higher wear resistance in this direction, but other movements such as abduction and rotation apply frictional shear forces in directions perpendicular to this and cause the polyethylene to wear much more rapidly.  

4) Lubricant and lubrication regime. Both the nature of the pseudosynovial fluid (protein and lipid concentration) and the amount of fluid entrained or trapped in the contact can influence wear.

Radiological measurement of the penetration of the femoral head into the acetabular cup involves both creep deformation of the polyethylene cup and wear. Laboratory simulation studies indicate that penetration due to creep is of the order of 0.1 mm in the first million cycles of use, which is equivalent to one year of clinical use. After this initial period, creep makes little further contribution. For cups with low penetration, less than 1 mm in ten years, creep may be significant, but in cups showing over 2 mm of penetration, creep deformation is less important.

In their paper on the direction of penetration in the acetabular cup (p. 197) Murray and O’Connor present a novel and elegant analysis of the variation in the direction of penetration. They discuss penetration due to creep which is mainly superomedial, in the direction of the force vector, and penetration due to wear which is superior and slightly lateral. They point out that the direction of penetration due to wear is at an angle to the axis of rotation, when calculated simply from the pressure distribution and sliding distances. Their analysis is supported by the clinical trend that higher penetration and wear are associated with more superolateral penetration.

In any group of patients and even in hip-joint-simulator studies, there is considerable variation in the direction of penetration. The usual diameter of the area of contact between the head and cup is at least 20 mm and any variation in local tribological conditions such as head damage, degradation of the polymer, the nature of the lubricant and the directional variation of the friction force, will alter the local wear rate and therefore the direction of maximum penetration. Even this list of the variables that can accelerate wear is probably not exhaustive; as research provides a deeper understanding of the complex wear mechanisms of polyethylene in clinical use, other factors are likely to emerge.

Despite this, we are now in a much better position to reduce polyethylene wear than we were five years ago. Important factors are the avoidance of third-body and surgical damage to femoral heads, the use of damage-resistant ceramic and smaller heads (22 to 28 mm). The recent introduction of alternative or improved methods of sterilisation for polyethylene, which avoid the use of gamma irradiation in the presence of oxygen, will also help to reduce polyethylene wear and delay osteolytic changes. These solutions, which have been developed in research laboratories, are now available for clinical use.

References


Editorial

MANAGEMENT OF THE ORTHOPAEDIC COMPLICATIONS OF HAEMOPHILIA

E. Carlos Rodríguez-Merchán

Haemophilia is a hereditary sex-linked disease seen in severe form in 1 in 10 000 men. Haemophilia A, factor-VIII deficiency, is seen in 85% of cases and haemophilia B, factor-IX deficiency, in 15%. Spontaneous mutations cause the disease in a few patients who have totally negative family histories.

The articular problems of haemophilic patients begin in...