Friction couples in total hip replacement

N. Passuti*, JM. Philippeau, F. Gouin

Orthopedic and Traumatic Surgery Department, pôle ostéoarticulaire, Nantes Teaching Hospital, Hôtel-Dieu, 1, place Alexis-Ricordeau, 44093 Nantes cedex, France

Summary  The problem of friction couples remains unresolved to this day. Improvements in femoral and acetabulum implant anchorage over the last 20 years have significantly extended total hip replacement (THR) implant lifespan; the formation of wear debris, however, leads to resorption and osteolysis, considerably shortening implant lifespan in active patients. Alumina—alumina friction couples provide an excellent friction coefficient, with wear particles that do not cause any osteolysis. There is, however, a problem of acetabulum anchorage of solid alumina, and the risk of fracture persists with ceramic implants despite improvements in their mechanical properties. Metal—metal couples also display very good tribological behavior, but at the cost of the formation of Co and Cr ions impacting surrounding bone tissue and accumulating in remote organs. The behavior of such “hard—hard” couples greatly depends on implant component positioning and on the consequences of repeated neck-insert contact. Very highly crosslinked polyethylene (PE) shows very significant improvement in terms of wear at five years’ follow-up compared to conventional PE, but the behavior of this new concept will need to be monitored in the clinical situation if the disappointments experienced with previous hyalamer-type improved PE are to be avoided. All these friction couples need to be validated by prospective clinical studies conducted over more than five years, to provide orthopedic surgeons with an eclectic choice of friction couples adapted to the patient’s activity.

© 2009 Elsevier Masson SAS. All rights reserved.

Introduction

For more than 15 years, acetabular and femoral component anchorage has very significantly improved, thanks to the validation of fixations using bioactive coatings and to improvements in cementing techniques. These undeniable advances in the implant—bone interface have enabled orthopedic surgeons to perform total hip replacement (THR) in young active patients, with considerable functional benefit. Over the same period of time, however, the problems of friction couple wear have become more acute, thanks to the very satisfactory quality of life enjoyed by THR beneficiaries and the consequently increased wear of polyethylene (PE) components, causing the formation of significant quantities of microparticles, in turn a source of periprosthetic osteolysis.

There is as yet no consensus as to the choice of friction couple, wide differences existing between current practices in different countries. In the USA, 62% of THRs use very highly crosslinked PE, associated in 87% of cases to a metal head. In France, 65% of THRs use conventional PE,
associated in 52% of cases to a ceramic head. And in Korea, 72% of THRs involve a ceramic–ceramic couple.

**Conventional polyethylene**

Conventional PE is a high (2m to 6m) molecular weight material associating crystals and long polymer chains, with mechanical properties deriving directly from the crystallinity and spatial cohesion of the macromolecules. The problem lies in the presence of free radicals, causing zones of oxidation and thus of aging, especially in biological environments. Three types of wear have been described:

- adherence, related to friction;
- fatigue, due to high stress;
- abrasion, relating to the condition of the implant head.

Retrospective series with 20 years’ FU have revealed a mean wear rate of 0.1 mm/yr and 22.2 mm diameter. This is an essential parameter. There is a direct correlation between wear rate and THR implant lifespan. Sochart and Porter [1] reported a direct relation between degree of wear and implant lifespan: for a wear rate of 0.1 mm/yr, 25-year survivorship is around 70%, whereas wear rates in excess of 0.25 mm/yr reduce 20-year survivorship to less than 20%.

All the theoretical data on conventional PE are found in Langlais’ 1997 teaching presentation [2].

Many parameters impact conventional PE wear. Head diameter is an important factor: a 1 mm increase in diameter increases annual wear volume by 8%, in direct relation to PE thickness.

Metal-back cup fixation is associated with high surface stress and hence wear, requiring a minimum PE thickness of 10 mm.

This "wear" factor is essential. There is a direct correlation between degree of osteolysis and rate of wear. Dumbleton et al. [3] reported a mean wear rate of 0.15 mm/yr and a volume of 185 mm$^3$/yr in a group of implants showing osteolysis on X-ray.

Table 1 (derived from Devane and Horne [4]) presents the factors influencing PE wear.

<table>
<thead>
<tr>
<th>Factor</th>
<th>Increased wear</th>
<th>Reduced wear</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>Young (&lt; 50 yrs)</td>
<td>Older</td>
</tr>
<tr>
<td>Activity level</td>
<td>High (2 m cycles/yr)</td>
<td>Low</td>
</tr>
<tr>
<td>Head diameter</td>
<td>32 mm</td>
<td>26 or 28 mm</td>
</tr>
<tr>
<td>Fixation</td>
<td>Macroporosity</td>
<td>Cement</td>
</tr>
<tr>
<td>PE thickness</td>
<td>&lt; 8 mm</td>
<td>&gt; 8 mm</td>
</tr>
<tr>
<td>Offset</td>
<td>Non-restored</td>
<td>Restored</td>
</tr>
</tbody>
</table>

One important parameter was long overlooked: recovery of good implant offset. Lateralization optimizes offset, reducing impingement and improving centering by the abductor muscles.

Annual wear rate directly impacts implant lifespan. PE fixation in a metal cup entails wear in the convex part of the PE against the metal surface ("backside wear"), with a correlation to acetabular osteolysis. Wasielewski et al. [5] revealed this phenomenon in a study of 55 explanted components, showing micromobility due to defective anchorage of the PE in the metal cup.

Obviously, larger head diameters have often been tried, to enhance implant stability while enabling increased movement amplitude (Table 2).

This, however, entails increased wear and the formation of wear debris. Kabo et al. [6] reported this relation between Table 2 Correlation between head diameter and range of movement.

<table>
<thead>
<tr>
<th>Head diameter</th>
<th>ROM 112°</th>
<th>ROM 127°</th>
<th>ROM 128°</th>
<th>ROM 132°</th>
<th>ROM 133°</th>
</tr>
</thead>
<tbody>
<tr>
<td>22 mm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>28 mm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>32 mm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>36 mm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>40 mm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 1 Relation between diameter and wear [6].
head diameter and quantity of PE particles in six explanted components (Fig. 1).

To sum up, the significant parameters in conventional PE wear are:

- PE thickness;
- head diameter;
- the patient’s activity and age (> 3m cycles per year in an active subject);
- metal-back and acetabulum modularity;
- head area: 28 mm and especially 32 mm Co-Cr/PE couples display twice as much wear as 22.2 mm steel/PE couples, and 32 mm alumina heads cause half as much PE as do Co-Cr heads (at 28 mm, there is no significant difference in young active subjects).

There is a direct and constant relation between wear volume and degree of osteolysis.

More recently, another factor has appeared to impact wear: cup orientation. If the cup is at 45°, wear is 17.2 mg/million cycles; but if it is too vertical (55°), the rate is 21.7 mg/million cycles. The mean PE wear rate increases to 40% if the cup is at 55°.

All these data are confirmed by retrospective clinical series. For a 22.2 mm metal–PE couple, survival falls by 1% per year in young active subjects. The 1997 SOFCOT symposium reported 86% 15-year survival in patients under 50 years of age, and 13% revision at 20 years in subjects under 40 years of age [7]. For the year 2000, the Swedish THR registry reported 80% 10-year survival in patients under the age of 55 [8].

The concept of double mobility: associating low friction and high amplitude

This concept was developed by Bousquet around 1975, the idea being to associate low 22.2 mm-interface friction and high stability by means of mobility between a head in stainless steel and PE and a PE and metal back. Stability is significantly improved: for a 53 mm acetabulum with an 11 mm neck, flexion-extension amplitude is 186°, comparable to that obtained with a large-diameter metal–metal interface.

Obviously, such a double interface can lead to double wear sites, raising the question of the consequences of this concept in terms of the formation of wear debris.

Analysis of explanted components provides more interesting information. Adam and Farizon [9] analyzed 40 inserts explanted after a mean eight years' use, revision being for acetabular loosening and intra-implant dislocation.

In 16 inserts there was neck-PE conflict; internal (head-PE) wear was 73 microns/year and convex wear 9 microns/year: i.e., 82 microns in all, or 0.08 mm/year and 54 mm²/year in terms of volume.

This study confirmed good tribological behavior and linear wear half that reported by Kusaba [10] for intermediate implants (170 microns/year).

Clinical findings should confirm these tribological data. In a retrospective study of 438 cups revised at a mean 17 years, Philipot et al. [11] reported 89.2% overall survival for the two implants, and 96.3% for the cup.

Detailed analysis found 25 cases lost to follow-up, 99 deaths and 23 intra-implant dislocations.

In terms of age, there was a 12% failure rate in patients under the age of 65 and no failure in the over-70s. This study highlights two problems: acetabular loosening (fixation defect) and intra-implant dislocation, either by wear or, especially, by PE blockage.

In a prospective study of 194 patients with a mean age of 70 years (range: 32 to 91) and a mean six years’ FU, Leclerc et al. [12] found 100% acetabular component survival.

In all, this is an interesting solution, significantly improving implant stability; laboratory studies and clinical series reveal no particular wear with normal use. It is important that the acetabular anchorage have a bioactive coating such as hydroxyapatite, to reduce the risk of loosening.

Alumina and zirconia ceramics

General data indicate that alumina–alumina couples are the most effective, with a wear rate of 0.005 mm/million cycles and linear wear of 5 microns/year.

The mechanical properties have been improving constantly over 20 years. Alumina is resistant (550 M pascals) and rigid, with good thermal conductivity [13] (Table 3).

Even so, certain problems arise. Al–Al couples show poor piston tolerance, with decoaptation phases during the step, as described by Nevelos et al. [14], which increases wear. If the cup is too vertical, local stress is excessive, with wear concentrated in the superior area.

One of the major problems with first-generation Al–Al couples was capsule loosening (5 to 35.7%), due to the great difference in rigidity between the solid alumina ceramic and the bone tissue.

Another inherent problem, especially in alumina heads, is fracture, with a rate of 0.1% to 13.4%. The first data, published by Fritsh and Gleitz [15] in 1996, for a cohort of 4,430 alumina heads, gave a fracture rate of 0.21% in Al–Al couples, versus 0.07% for Al–PE.

The two essential parameters observed were the manufacturing procedure and, more especially, the grain size: the fracture rate fell from 0.026% for a grain size of 7.2 microns to 0.004% for 1.8 microns [16].

Fracture is currently rated at two or three per 10,000; the major factors are impingement (a little known and underestimated factor), excessive stress on too vertical a cup, and cyclic decoaptation of 1.2 to 3 mm during walking, as described by Lombardi et al. [17].

Other problems have also been reported. The rate of squeaking is currently put at 0.6 to 1%, whether in flexion, or extension (according to cup anteversion); Walker et al. [18] found two groups of patients with squeaking-risk factors, cup positioning appearing to be significant in this regard (Table 4).

<table>
<thead>
<tr>
<th>Table 3 Mechanical properties of alumina ceramics.</th>
</tr>
</thead>
<tbody>
<tr>
<td>-----------------</td>
</tr>
<tr>
<td>Resistance (Pa)</td>
</tr>
<tr>
<td>Harness (HV)</td>
</tr>
<tr>
<td>Grain size (Hm)</td>
</tr>
</tbody>
</table>
Table 4  Walker et al. [18].

<table>
<thead>
<tr>
<th></th>
<th>Squeakers</th>
<th>Non-squeakers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>56</td>
<td>65</td>
</tr>
<tr>
<td>Size</td>
<td>179 cm</td>
<td>169 cm</td>
</tr>
<tr>
<td>Weight</td>
<td>90 kg</td>
<td>76 kg</td>
</tr>
<tr>
<td>Ideal cup orientation</td>
<td>35%</td>
<td>94%</td>
</tr>
</tbody>
</table>

Alumina sandwich ceramics

The principle here is to associate the tribological properties of Al—Al couples with PE cushioning of the bone tissue, to reduce the risk of loosening; the PE lip should reduce the risk of repeated neck/ceramic contact.

The problem is the increased fracture risk in the Al ceramic insert. For 2003, 23 insert fractures were declared to the French health product safety agency, AFSSAPS, of which 20 concerned a single manufacturer (13 fractures for 3,800 fittings). Analysis revealed a thickness defect. There have since been many reports of fracture: e.g., Hasegawa et al. [19] reported three fractures in 36 implants and Park et al. [20] six fractures in 357 (1.7%). The current trend is to analyze the causes of fracture in greater detail and to inventory all declarations and publications concerning this kind of implant.

Zirconia ceramics

Zirconia has excellent mechanical properties (four times those of alumina). Shaping requires the addition of stabilizers, such as yttrium, to sustain grain binding. Delaunay [7] reviewed all the mechanical and tribological properties of zirconia. The first trials, in 1985, showed good wear resistance, but two problems emerged: head fracture, and abnormal wear beyond a certain in vivo use-time. The theoretical interest lay in the possibility of reducing diameter from 28 to 22 mm without increasing the fracture risk.

The initial fracture risk was assessed as 1/10,000. Ten years ago, a change in production conditions led to an increase in fracture risk to between 9 and 15% in certain batches. AFSSAPS therefore suspended all batches concerned by the new procedure, with selective assessment of follow-up of implanted zirconia heads.

The first five-year retrospective clinical studies reported no major problems of wear in zirconia—PE couples. Seven-year FU studies, however, found increased wear and a high rate of loosening [21—22]. This highlighted the issue of accelerated aging of zirconia in biological environments, and the concept of thermal elevation at the zirconia—PE interface was raised. In vitro [23] and in vivo [24] studies showed a rise in temperature from 43 to 90°C; subsequently, the study of components explanted at six years showed a clear increase in the monoclinic phase, with increased roughness and accelerated wear.

The last 10 publications, since 2003, report over 0.2 mm/yr wear at seven years’ FU, associated with 30 to 40% osteolysis and loosening. Clarke’s excellent article [25] analyzes 40 explanted components; most of the zirconia heads showed over 20% phase transformation, with surface irregularities.

Surgical revision for ceramic head fracture requires excision of surrounding tissue, synovectomy and fitting an Al—Al couple. If the Morse cone is damaged, the femoral component has to be replaced. Refitting a metal head and PE cup accelerates wear, as shown by Allain et al. [26] in a series of 105 revisions, with 21% femoral loosening and 63% implant survivorship at five years.

In all, alumina—alumina couples have the lowest wear rates, with only moderate formation of debris. Two problems remain: head and insert fracture, although improvements in mechanical properties have reduced this risk in recent years; and poor acetabular behavior with respect to the very rigid ceramic.

Metal—metal couples

Cobalt—chromium alloy couples have excellent tribological properties, with wear estimated at 5 to 7 microns/million cycles (0.4 to 1 micron for alumina—alumina couples); study of explanted components confirmed a 3 to 5 micron annual linear wear rate.

There is an inevitable grinding phase during the first two years of use (initial wear, 25 microns; wear volume, 1 mm³), stabilizing at 0.2 mm² (60 to 100-fold less than for metal—PE couples) [27] (Table 5).

Table 5  Five-year clinical results [27].

<table>
<thead>
<tr>
<th>Author</th>
<th>Implant type</th>
<th>Patients (n)</th>
<th>Mean age (yrs)</th>
<th>FU (yrs)</th>
<th>Survivorship %</th>
<th>Revision (loosening)</th>
<th>Other cases</th>
<th>Osteolysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Doerig</td>
<td>Metasul</td>
<td>218</td>
<td>60</td>
<td>2—6</td>
<td>96</td>
<td>2</td>
<td>3</td>
<td>Not described</td>
</tr>
<tr>
<td>Doerig</td>
<td>Metasul</td>
<td>138</td>
<td>59</td>
<td>5</td>
<td>93.3</td>
<td>1</td>
<td>2</td>
<td>Not described</td>
</tr>
<tr>
<td>Wagner</td>
<td>Metasul</td>
<td>80</td>
<td>49</td>
<td>6</td>
<td>NA</td>
<td>0</td>
<td>3</td>
<td>Not described</td>
</tr>
<tr>
<td>Delaunay</td>
<td>Metasul</td>
<td>64</td>
<td>64</td>
<td>6</td>
<td>NA</td>
<td>0</td>
<td>2</td>
<td>Not described</td>
</tr>
<tr>
<td>Delaunay</td>
<td>Metasul</td>
<td>100</td>
<td>59</td>
<td>3</td>
<td>NA</td>
<td>0</td>
<td>2</td>
<td>Dislocation revision</td>
</tr>
<tr>
<td>Dorr</td>
<td>Metasul</td>
<td>55</td>
<td>52</td>
<td>3.1</td>
<td>NA</td>
<td>0</td>
<td>1</td>
<td>No</td>
</tr>
<tr>
<td>Dorr</td>
<td>Metasul</td>
<td>70</td>
<td>70</td>
<td>5.2</td>
<td>95%</td>
<td>0</td>
<td>3</td>
<td>Not described</td>
</tr>
<tr>
<td>Lombordi</td>
<td>M—H</td>
<td>97</td>
<td>49</td>
<td>3.2</td>
<td>NA</td>
<td>0</td>
<td>0</td>
<td>Not described</td>
</tr>
<tr>
<td>Korooessis</td>
<td>Sahomet</td>
<td>350</td>
<td>55</td>
<td>4.3</td>
<td>97%</td>
<td>0</td>
<td>6</td>
<td>Not described</td>
</tr>
</tbody>
</table>

© 2018 Elsevier Masson SAS. Tous droits réservés. - Document téléchargé le 06/12/2018 Il est interdit et illégal de diffuser ce document.
Delaunay [7] presents the fundamental metallurgic and tribological facts about metal–metal couples.

Retrospective clinical studies of first-generation metal–metal couples (MacKee-Farrar implants), with 25 years' FU, found unexplained loosening. August et al. [28], with 28 years' FU, reported 67% 17-year survivorship and a 55% loosening rate; this was confirmed from the Swedish registry, where the revision rate was 10% [8].

The second generation cups developed by Weber in 1988 were in forged Co–Cr alloy (protasul), with smaller carbide content and increased wear resistance.

At the same time, some clinical studies reported less satisfactory findings: Korovessis [29] and Park [20] found a 6 to 7% loosening rate, with osteolysis around the implants and some cases of lymphocyte infiltration with metal particles. The problem was the formation of Co and Cr ions. This couple is very subject to impingement (often underestimated). Augereau et al. [30] confirmed failure with metasul Muller cups (metal cup set in PE cemented in the acetabular bone), with 143 revisions at 42 months (114 cases of radiolucency, 10% complete and 22% evolutive).

**Consequences of Co and Cr ion formation**

Serous Co and Cr are significantly elevated after walking, with a correlation to head diameter.

Co is eliminated in urine, but Cr undergoes a tissue storage phase, and assays can monitor the metal–metal couple’s functional status (instability, cup inclination). In case of renal insufficiency, serous levels rise significantly and rapidly; the particles are small (0.6 to 1 micron), and thus numerous (6.7 × 10^{12} to 2.5 × 10^{14} per year), and can accumulate in certain tissues (ganglia, liver, spleen).

Accumulation can cause chromosome anomalies; according to Laddon et al. [31], there are chromosome anomalies (translocation) and direct DNA effects (apoptosis, in proportion to tissue ion levels).

Meta-analyses have, however, found no link to cancer [32-33].

The other problem is delayed hypersensitivity: 10 to 15% of the population show skin allergy to heavy metals. Davies and Willert [34] studied surrounding tissue in 25 explanted metal–metal prostheses and found systematic lymphocyte infiltration, as confirmed by Willert [35] (Fig. 2).

**Genotoxicity and general risks**

Regular Co and Cr ion formation raises questions. The UK Medical Device Agency expert group analyzed 14 publications and confirmed genotoxicity, but with a low risk of genetic mutation (DNA repair inhibition). Some authors (e.g., McMinn, in prospective study [36]) have reported Co and Cr infiltration of the placenta, but variations in blood assay techniques hinder comparison.

The contra-indication is absolute in case of renal insufficiency, and the greatest reserves are expressed for metal–metal couples in women of child-bearing age. What will happen over aging to a patient fitted with metal–metal couple in case of secondary kidney disease?

A registry of metal–metal couple implants would be useful for prospective studies.

One interest of metal–metal couples lies in the possibility of using large diameters to reduce the rates of displacement and eliminate impingement mechanisms. Cuckler et al. [37] reported 2.5% displacement with a diameter of 28 and 0% at 38; but the larger diameter was
associated with greater Co and Cr release in the grinding phase.

Kham et al. [38] reported levels six to nine times as high with large diameters compared to 28 mm in a forced walking exercise. There is thus a correlation between large diameter, degree of activity and Co and Cr ion formation.

Overall analysis of metal—metal couples

Second-generation metal—metal couples have excellent tribological properties and clinical studies at more than 10 years’ FU report satisfactory actuarial curves, with around 90% implant survivorship.

The problem remains of the long-term implications of metal ion formation. Some authors claim a risk of periprosthetic osteolysis. Lazennec et al. [39] described significant degradation in metal—metal couples at seven years, with considerable radiolucency and metallosis; but these were Weber cups. Comparison must be between the same kind of alloys, specifying the carbide content and type of anchorage to assess the 10-year metallosis and loosening risk.

The use of large diameters and implant surface replacement calls for cohorts with 10 years’ FU. The UK National Institute of Clinical Excellence targets 90% 10-year survivorship. McMinn et al. [40], in a pilot study run from 1991 to 1994, found a high loosening rate associated with surface replacement. In 1996, 11.6% failure was reported in a cohort. Since 1997, the more recent publications, concerning 446 cases of patients under the age of 55 years, report a failure rate of 0.2%, but with just a mean three-years’ FU.

The new very highly crosslinked PE

The principle is to enhance chain crosslinkage between crystals by radiation and avoid free radical oxidation by secondary heat treatment. This change in structure should significantly improve wear resistance and reduce PE wear debris release. Radiation doses vary from 5 to 10M rads and manufacturers claim 42 to 100% less wear than with conventional PE; for an excellent review, see Gordon [41].

This treatment significantly improves wear, and alters the mechanical properties of PE, proportionally to the radiation dose. Even so, in vitro simulator studies show a very low wear rate of 0.02 mm and a volume of 17 mm³ after five million cycles, unaffected by the use of large head diameters.

Extreme study conditions, in particular with addition of a third body (cement particles), still find low wear rates of around 0.7 mg/million cycles versus 29 for conventional PE [42].

These new PEs, on the other hand, show reduced resistance to cracking (lower plasticity). Holley et al. [43] studied an impingement model on a simulator and found greater wear under these conditions.

Overall, there is less tolerance than with conventional PE, and the disadvantages resemble those of hard—hard couples.

At a mean 30 months’ FU, clinical findings confirm the good trend, with mean wear of 0.07 mm/yr. More recently, Glyn-Jones et al. [44], in a prospective randomized study using RSA analysis, found 40% wear at two years, which was less for highly crosslinked than conventional PE (0.06 mm versus 0.1 mm). Leung et al. [45], using scanner assessment, found 28% acetabular osteolysis with conventional PE and 8% with crosslinked PE.

There are at present certain contradictory findings: experimental studies have indicated the negative impact of impingement. A study of 113 THR revisions found 159 mm³/yr wear in case of impingement, versus 70 mm³/yr otherwise.

Bradford et al. [46] performed surface analysis on 24 acetabular components explanted at a mean 11 months, and found signs of abrasion and erosion in all.

The first mechanical incidents were reported in PE that was thin or too vertically positioned. Bradford et al. [46] confirmed reduced resistance to cracking with large diameter acetabula and thin PE, especially where positioning was too vertical.

In the 1970s, “poly-two”, associating conventional PE and carbon fiber, encountered failure at the junction between the two.

In the 1990, hylamer PE, which had high crystallinity and good in vitro resistance on traction and fatigue tests, proved disappointing in clinical use. Numerous studies [47–50] found wear at less than five years’ FU ranging from 0.15 to 0.37 mm/yr and failure rates (revision for osteolysis) of between 4 and 15%.

Attempts at titanium alloy surface treatment were resounding failures. Titanium should in fact never be used as a friction surface. Innovative friction couples should be treated with caution. The first trend is to improve the mechanical properties of ceramics by associating alumina and zirconia grains in so-called alumina matrix composite (AMC) ceramics. Apart from mechanical properties, the interest lies in possible applications in revision when the Morse cone is damaged, using a titanium mantle to enable the ceramic head to be reused without replacing the femoral component.

Other current trends

Ceramic—metal friction couples (ceramic delta head and Co—Cr cup) have very good friction coefficients of around 0.23 mm²/million cycles. There is 100 times as little metal ion release as with metal—metal couples.

More recently, an original material, oxinium, has been introduced. This is an oxidized zirconium—niobium alloy, used in 5 microns’ surface thickness. The mechanical properties are excellent, it is nearly as wettable as alumina, and 5,000 times as resistant to abrasion as Co—Cr.

Studies at two years report no detectable wear between a 32 mm oxinium head and very highly crosslinked PE. Kop et al. [51] found surface abrasion in three heads explanted due to displacement. This new material will therefore need clinical studies with more than five years’ FU to determine oxinium’s in vivo behavior.

Basic data on osteolysis

Wear debris acts on macrophage-type cells. Under the influence of certain biochemical factors such as interleukin 6, TNF alpha and RANKL factor, these stimulate the osteoclastic differentiation underlying osteolysis. Loosened implant
membrane samples reveal such cellular and biochemical items. See Holt et al. [52] for a very full review of osteolysis mechanisms.

Early osteolysis screening by specific biological methods is possible. Also Wilkinson et al. [53] confirmed a genetic predisposition to wear debris (TNF alpha promoter marker), offering hopes for medical management for patients with early stage osteolysis mechanisms.

**Practical recommendations**

In patients over 65/70 years of age (taking account of the patient’s real activity level), a highly crosslinked PE couple with 28 mm head (PE thickness: 8—10 mm) can be used.

Between the ages of 40 and 65, alumina—alumina couples can be used in patients with moderate sports activity and in those weighing less than 90 kg (fracture risk factor).

Metal–metal couples are possible in very active males doing intense sport, while informing the patient of the known drawback of metal ion formation; moreover; component positioning has to be perfect.

The new highly crosslinked PEs have given good clinical results at five years, but the debris particles are very small and reactive, so that large diameter (> 44 mm) heads are to be avoided to conserve minimal thickness.

Langlais’s [54] table usefully defines suitable couples according to acetabulum diameter (Table 6).

**General conclusion**

Friction couples pose as yet unsolved problems, and the optimal choice depends upon the patient’s age, level of activity and functional requirements: risk—benefit information for each material must be clear. Innovation in techniques is needed, but only given prospective studies of more than five years’ FU. Biology enables very early screening for osteolysis liable to respond to specific medical treatments.

Orthopedic surgeons need to be ecletic in their choice, adapting the friction couple indication to the age and activity level of the patient.

**Conflicts of interest**

None.

---

**Table 6** Acetabular diameter [54].

<table>
<thead>
<tr>
<th>Acetabular diameter</th>
<th>Possible couple Ø thickness insert + fixation (metal-back or cement)</th>
<th>Couple not advised</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 52 mm</td>
<td>Metal or Al Ø 28 metal-back</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>Large Ø M—M</td>
<td></td>
</tr>
<tr>
<td>46 — 50 mm</td>
<td>Al—Al</td>
<td>Metal—PE</td>
</tr>
<tr>
<td></td>
<td>Metal or Al—PE cement Ø 28 mm</td>
<td>Metal-back</td>
</tr>
<tr>
<td></td>
<td>M or Al with VHCL—PE (Ø &lt; 44 mm)</td>
<td></td>
</tr>
<tr>
<td>40 — 44 mm</td>
<td>M or Al—PE cement Ø 22 mm (age)</td>
<td>Al—Al</td>
</tr>
<tr>
<td></td>
<td>M—M 28 or large Ø (stability)</td>
<td>M or Al—PE with metal-back</td>
</tr>
<tr>
<td>&lt; 40 mm</td>
<td>M—M</td>
<td>Al—Al</td>
</tr>
<tr>
<td></td>
<td>VHCL—PE</td>
<td>M or Al Ø 28 and PE</td>
</tr>
</tbody>
</table>

**References**


