TribOS™

articulating science newsletter

07 Sept: Issue 1

Welcome to the first issue of the Tribos™ Newsletter. This will be a quarterly publication covering tribological topics and events, and is part of a new global educational initiative from Stryker. The newsletter aims to bring you the latest information and updates in tribology and bearing-surface technology for orthopaedic surgeons.

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Features

Prof. Rudolph Geesink

Prof. Ian Hutchings

CALL FOR LETTERS

Readers are invited to correspond on issues in orthopaedic tribology and on articles in this newsletter

Address all letters to:
Tribos Newsletter, Xeno Medical, 6 Bramley Business Park,
Surrey, GU5 0AZ, UK

Email: tribos@stryker.com **Fax:** +44 (0) 560 1120835

Letters must be 200 words or fewer and contain the writer's full name and contact details

What is Tribos™?

The word ‘tribology’ is derived from the Greek word ‘tribos’ meaning ‘rubbing’. Tribology is the science of friction, lubrication, and wear of interacting surfaces that are in relative motion.

Tribos™ is the name of an educational programme from Stryker, focused on providing expert education and the latest research in tribology for orthopaedic surgeons. The primary aim of Tribos™ is to bring together distinguished experts in the field of clinical tribology to discuss, debate, and educate.

An international Tribos™ Advisory Board will be formed to provide focus and direction to the newsletter, meetings, and educational materials.

MEETING REPORT

2007 Tribos Congress Prof. Christina Doyle

10–11 May
Palazzo Capponi, Florence, Italy

Chair: Professor Christina Doyle
Xeno Medical Ltd., UK

The Tribos™ programme presents current concepts in bearing surface research and development rather than taking the viewpoint of any one company or academic institution. I was pleased to chair the first Tribos™ educational event, held earlier this year. The meeting was focused on the technical background and clinical implications of tribology. This meeting was the first of three international Tribos™ Congresses to be held each year in Europe, the USA, and the Pacific. These congresses form the basis of many other future educational initiatives focused on the importance of the total bearing surface of the joint. An excellent opening keynote presentation by Professor Ian Hutchings, Fellow of the Royal Academy of Engineering, defined the objectives of the Florence meeting and introduced all the important inter-related topics in tribology, drawing attention to their relevance in total joint replacement. Sixteen internationally renowned academics and clinicians then spoke on central themes related to form and design, materials, clinical effects, and future technologies. A significant level of audience participation led to debates and votes on controversial topics. In some cases, these results were surprising, and these will guide us to areas of educational focus in the future.

2007 Tribos Congress faculty (from left to right): Prof. Rudolph Geesink, Prof. Jerome Chevalier, Prof. Allan Matthews, Prof. Neil Rushton, Dr John Dumbleton, Dr Jim Nevelos, Dr Steven Kurtz, Prof. Christina Doyle (Chair), Prof. Gordon Blunn, Dr Hans Schmotzer, Dr Bill Walter Jnr, Dr Guy Bellier, Prof. Ian Hutchings
Not shown: Dr Pat Campbell, Dr Christian Kaddick, Prof. Phil Noble

Highlights

I have chosen four reports from the meeting to show some of the themes and issues that were discussed at the Tribos Congress in Florence. The first by Professor Ian Hutchings, a world-renowned expert in the field of tribology from Cambridge, introduces the technical and engineering basis of tribology. Three reports follow of lectures that focused on important clinical topics: lessons to be learnt from the systematic examination of implant retrievals, by Dr Pat Campbell from Los Angeles; wear due to impingement and how this can be minimised, by Professor Noble from Houston; osteolysis and whether today's polyethylene can combat the challenge, by Professor Geesink from Maastricht.

Tribology in Joint Replacement Prof. Ian Hutchings

Professor Ian Hutchings
Institute for Manufacturing, Department of Engineering, University of Cambridge, UK

The application of tribology

Tribology is an interdisciplinary subject. A full understanding of tribological behaviour requires an appreciation of the mechanical, physical, and chemical aspects of the problem, as well as of materials science. In the medical context, biological sciences also enter the picture. Tribology plays a crucial part in the design and functioning of prosthetic joints. Replacement joints in the body can exhibit many types of tribological phenomena, which are also familiar in more conventional mechanical engineering situations and include pure sliding motion, pure rolling, and combinations of rolling and sliding. Under abnormal conditions, replacement joints can also be subjected to abrasive wear due to the presence of extrinsic hard particles.

Tribology of artificial joints

The main function of an articulating joint, whether natural or artificial, is to transmit loads while enabling relative motion within a well-defined range. The friction within the joint is important, and in a healthy natural joint it is maintained at a very low level. Tribologists define the coefficient of friction (denoted with the symbol μ) as the ratio between the tangential force acting between two sliding or rolling bodies and the normal force acting across the joint. In the body, sliding interfaces are usually lubricated, i.e. separated by a thin film of low shear-strength liquid, and the friction is mainly controlled by the properties and behaviour of this film. At high loads, low sliding speeds, or with rough surfaces, however, the film may become insufficient to separate the asperities (high spots) on the surfaces and the friction rises; the friction then depends more on the properties of films molecularly adsorbed onto the surfaces. This behaviour is often plotted on a 'Stribeck curve', as shown in Figure 1. The severity of the interaction between asperities is described by the ratio λ (lambda) between the minimum lubricating film thickness and the combined heights of the roughness of the surfaces. The solid line shows the typical behaviour of well-lubricated engineering components, whereas the shaded area shows the characteristics exhibited by healthy synovial joints. The remarkably low friction seen in this case (typically $\mu = 0.002–0.006$) is due to the presence of a natural boundary lubricant (surface active phospholipid) in the synovial fluid.

Materials for artificial joints

A wide range of materials are used in artificial joints. Current knee prostheses almost exclusively use metallic (usually cobalt-chromium-molybdenum alloy; CoCrMo) femoral components and polymeric (usually ultra-high molecular weight polyethylene; UHMWPE) tibial components, which in some designs also slide against a metallic plate. Conversely, hip replacements can be designed with hard-on-soft bearing surfaces (e.g. a femoral head of CoCrMo alloy, or alumina or zirconia ceramic, fitted into an acetabular cup of UHMWPE) or with a hard-on-hard combination (e.g. an alumina head on an alumina cup, or a CoCrMo head on a CoCrMo cup). The point on the Stribeck curve at which these joints operate depends on their design, the mechanical properties of the materials, the component

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geometry (e.g. dimensional and shape accuracy, and clearances) and surface topography, both when new and after use. Metal-on-polymer joints (in both hips and knees) tend to operate in the boundary or severe mixed-lubrication regime where there is significant asperity contact. However, thicker fluid films can be formed in metal-on-metal and ceramic-on-ceramic total hip replacements (THRs) under certain conditions, leading to less severe asperity contact. It should be noted, however, that the Stribeck curve and its theoretical foundations assume steady sliding in a constant direction at a constant load, whereas the loads and relative motion imposed on human joints are constantly varying—any conclusions based exclusively on the Stribeck curve are bound to be of limited validity.

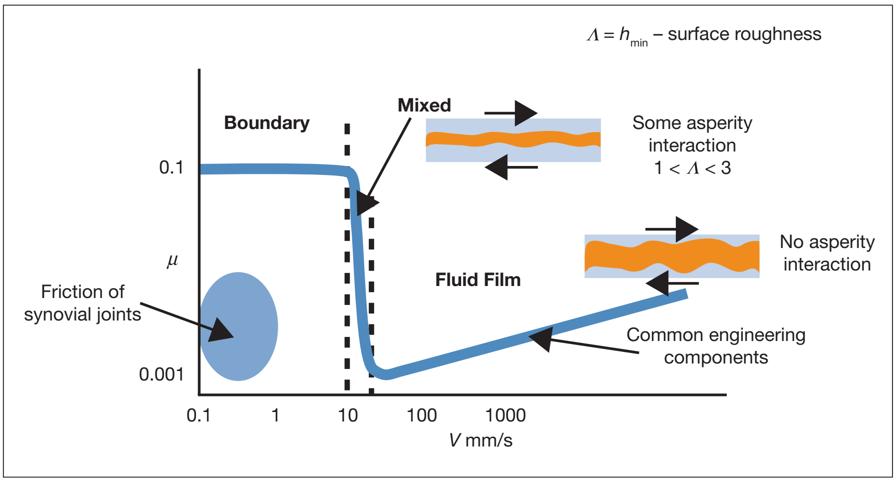

Figure 1. Based on: Hills BA. *Proc Inst Mech Engrs [H]*. 2000;**214**:83–94.

> “We still need research in tribology, although we have made fantastic advances since the early days”
> – I. Hutchings

Wear of artificial joints

Wear is an inevitable consequence of relative motion between sliding surfaces; mechanical damage and removal of material occurs at the points of contact between the asperities. The mechanisms of wear depend on the topography of the surfaces (e.g. their roughness and distribution of asperities), their mechanical properties (e.g. yield stress and elastic modulus) and the presence or absence of surface films (e.g. oxides or hydroxides). Under the conditions encountered in joint replacements, metals form surface oxide films, and ceramics, such as alumina and zirconia, form hydrated surface layers. It is these reaction products that will usually be removed in wear by adhesive forces in asperity interactions. These mechanisms are termed ‘mild wear’ by tribologists, in contrast to ‘severe wear’ in which the wear debris are fragments of unreacted metal or ceramic. Severe wear of metal or ceramic in a prosthetic joint would indicate rapid degradation, leading to surface roughening, high friction, gross changes in joint geometry, and intolerably large amounts of wear debris—a serious joint failure. Mild wear, in contrast, can be accompanied by very low rates of material loss, and even in some metal-on-metal joints by a beneficial reduction in surface roughness (polishing), which leads to improved lubrication. Abrasive wear, which is associated with the presence of extraneous hard particles or sharp protuberances on one or both surfaces, should in principle be rare in joint prostheses, but can occur when fragments of bone or particles of bone cement become trapped or entrained in a joint. Similarly, scratches or abnormal roughness on one or both surfaces can be introduced during handling or use.

Artificial joint design

Designers of artificial joints may aim to reduce wear rates by improvements in materials, mechanical design, and manufacturing methods, but complete elimination of wear is almost certainly unattainable if we are to retain the freedom of motion essential for physiological function. A well-designed joint should be tolerant not only of the broad differences in conditions to which it is exposed in patients with widely ranging lifestyles and expectations, but also of the spectrum of anatomies into which it might be implanted and the accuracy with which this is be performed. The success and lifetime of a joint depend critically on the details of its design, the materials from which it is made, and on the conditions to which it is exposed in the body. Some aspects of these conditions will depend on the patient, but others will also be influenced by the surgeon. In 1961, Sir John Charnley, the great pioneer of hip replacement, made the provocative statement in his seminal *Lancet* paper that we would never be able to develop a hip joint that lasts for thirty years and allows the patient to play football. It remains to be seen whether this prediction will be disproved.

Alternate Bearings: Lessons Learned from Implant Retrievals

Dr Pat Campbell

Dr Pat Campbell
Implant Retrieval Lab, Orthopaedic Hospital and University of California in Los Angeles, California, USA

The Implant Retrieval Lab of Orthopaedic Hospital/UCLA has been collecting and analysing failed hip replacement components for nearly two decades. This era saw the introduction of alternative bearings, such as metal-on-metal and ceramic-on-ceramic hip replacements. We conducted a review of the archived cases to address some of the current issues and concerns about these alternative bearings, namely the actual wear occurring in vivo, ceramic fracture, and metal sensitivity as a cause for failure.

The cases in our laboratory come mostly from revision surgeries, although a small number of autopsy-retrieved components are available through donations made as part of the Willed Joint Program. Typically, each case was submitted with removed components, periprosthetic tissues, and the clinical history with radiographs. Routinely, the implants were inspected, photographed and, in selected cases, the wear and clearance were measured by a Coordinate Measuring Machine (BMT 504, Mitotoyo, Aurora, IL). Surface arthroplasty components were sectioned, and peri-prosthetic tissues were processed into paraffin wax for routine histology. The sections were examined for tissue and cell type, and the extent and type of wear debris.

Currently, the archive contains over 1,700 specimens, including 554 metal-on-polyethylene THRs, 367 metal-on-polyethylene surface arthroplasties, 224 total knee replacements (TKRs), 212 metal-on-metal surface arthroplasties and 65 metal-on-metal THRs. Times in situ ranged from 1 week to 36 years (longest median: 74.5 months for metal-on-polyethylene THRs; shortest median: 24 months for metal-on-metal surface arthroplasties). Patients ranged in age from 13 to 99 years. The main reason for failure of metal-on-polyethylene hips and knees was aseptic loosening of one or both components. Most hip bearings were cobalt-chromium alloy against UHMWPE of the gamma-irradiated type. Only two cross-linked polyethylene liners were submitted to the laboratory. Moreover, 84 ceramic-on-UHMWPE bearing hips (including two alumina and one zirconia 28-mm balls that broke, on titanium alloy stems at 30, 64, and 90 months), four ceramic-on-ceramic hips revised for loosening, and 267 metal-on-metal hips are in the collection. The latter includes 180 femoral metal-on-metal surface arthroplasty specimens, which have been sectioned and analysed. Examples of retrieved joints are shown in Figures 2 and 3.

Wear measurement of metal-on-metal hips have confirmed that well-made, well-placed, and well-fixed implants produce only a few microns of wear per year, but that poorly made (such as early-generation McKee THRs), poorly placed (such as steep cups), or poorly fixed implants have much higher wear, often resulting in metallosis and tissue necrosis. Damage due to third-body wear was noted on nearly every retrieved component. Signs of wear and damage to non-bearing surfaces were common (such as impingement against acetabular rims).

Histological features consistent with an immune response were seen in around a third of metal-on-metal retrievals, irrespective of implant type or manufacturer. Such features included perivascular lymphocytes, often with plasma cells, fibrin deposition, and oedema. Extensive necrosis was rare but focal necrosis was common, especially where lymphocytes were abundant. Metal sensitivity was a rare cause for

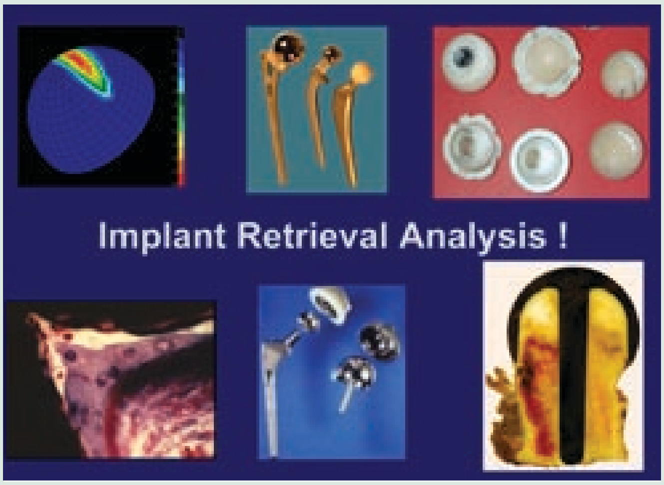

Figure 2. Retrieval analysis includes gross inspection, wear analysis, and histology.

Figure 3. Examples of sectioned hip resurfacings.

revision, but it was observed in well-functioning implants with only low amounts of wear.

We concluded that wear-related failures have been substantially reduced by modern bearings, but this places greater emphasis on surgical technique for long-term durability. Implant retrieval analysis can be an informative way to assess the mode of failure of metal-on-metal surface arthroplasties, especially in cases of unexplained pain. Additionally, with the abundance of different designs of metal-on-metal surface arthroplasty devices, and now with new material combinations being used in total hips, analysis of failed implants can sometimes be the only way to provide information about their clinical performance. Surgeons retrieving these new devices, or with problem cases, are therefore encouraged to send specimens to implant retrieval laboratories for analysis.

Prosthetic and Bony Impingement after THR: Guidelines from Computer Simulations

Prof. Philip C Noble

Professor Philip C. Noble
The Institute of Orthopedic Research &
Education and The Barnhart Department
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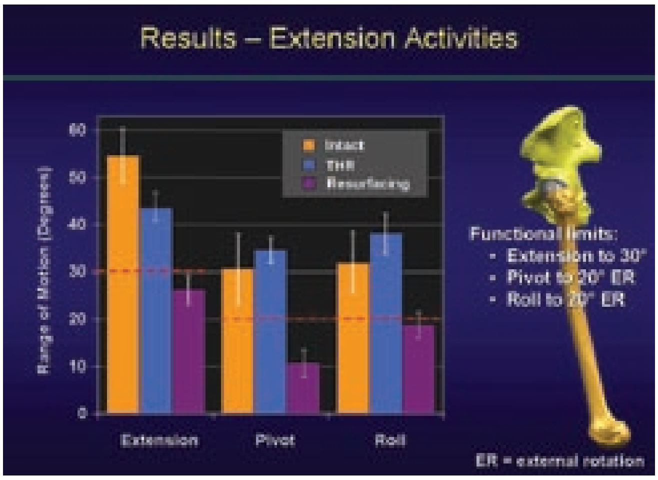
of Medicine, USA

Improving the range of motion (ROM) of the hip after THR is of increasing importance because this procedure is now being performed on younger, more active patients. My colleagues and I have recently assessed the validity of guidelines for positioning of the prosthetic components to avoid both prosthetic and bony impingement, maximising range of motion after THR. In our study, eight hips were reconstructed by use of computer tomography (CT) scans and were virtually implanted with hip prostheses. Anterior cup depth, cup anteversion, head size, medial head offset, neck length, and femoral stem anteversion were varied, and the ROM of nine activities was performed for each variation using standard computer-aided design software. Statistical correlations were examined between ROM values and the parameters describing component position.

We found that as cup anteversion varied from 0° to 30°, hip flexion at impingement increased from an average of 79.5° to 112.0° for activities associated with posterior instability, and decreased from 45.1° to 24.8° for activities causing anterior instability (Figure 4). When considering the aggregate motion (calculated as the sum of the ROM for the flexion, extension, and internal rotation activities) ROM was greatest when the implant anteversion matched that of the intact femur, as compared with the anteverted and retroverted positions (180.9° vs 163.4° and 178.9°, respectively) (Figure 5).

From this interesting study, we concluded that prosthetic impingement within the normal ROM of the hip is minimised if the acetabular cup does not protrude beyond the anterior margin of the acetabulum and if posterior protrusion is less than 5 mm. Optimal function is observed by restoring the original offset of the femur with respect to the pelvis, without alteration of femoral anteversion. Careful attention to each of these details will provide excellent, balanced joint motion without impingement during most functional activities, even with conventional prosthetic components.

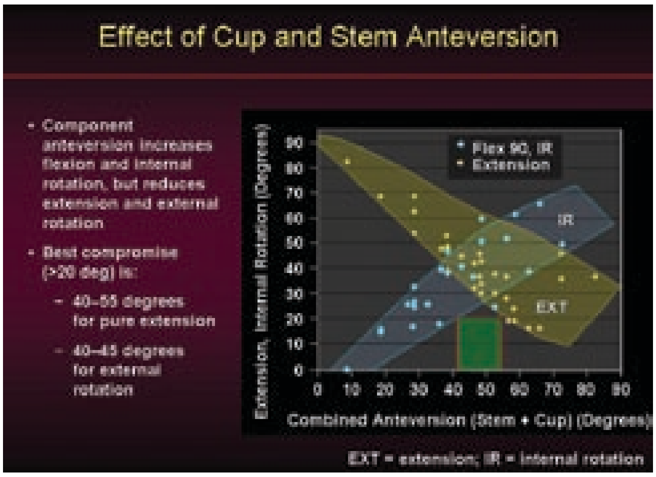


Results – Extension Activities

Functional limits:
- Extension to 30°
- Pivot to 20° ER
- Roll to 20° ER

ER = external rotation

Figure 4. Range of motion in extension.



Effect of Cup and Stem Anteversion

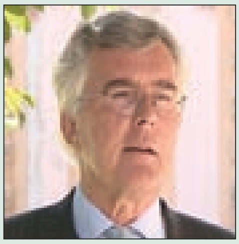
- Component anteversion increases flexion and internal rotation, but reduces extension and external rotation
- Best compromise (>20 deg) is:
  - 40–55 degrees for pure extension
  - 40–45 degrees for external rotation

EXT = extension; IR = internal rotation

Figure 5. Effect of anteversion on extension and internal rotation.

Polyethylene: Are We on the Right Track?

Prof. Rudolph Geesink



Professor Rudolph Geesink
Department of Orthopaedic Surgery,
Maastricht University,
The Netherlands

Osteolysis became a recognised problem in THR during the 1990s. Polyethylene was blamed for poor wear resistance through oxidation by free radicals and has since undergone significant improvements. Sequential radiation and annealing is the latest incarnation to achieve the best compromise between the elimination of free radicals and deterioration of mechanical properties by the cross-linking process. Even though the technical debate is ongoing, one might ask why it took so long before osteolysis was regarded as a clinical problem and whether we are addressing the right problem.

Polyethylene has been used in THR for almost 50 years and early reports on the problem of osteolysis were scarce. Patients have become more active, and indications for THR have been expanded to ever-younger patient groups, but these changes cannot explain all the differences in wear. Every orthopaedic surgeon knows active young patients who have had functional total hips for more than 20 years and who have no evidence of wear or osteolysis. What, then, makes the difference, or in other words, what makes THR fail by wear and osteolysis? This issue is clearly multifactorial, with causes originating from the patient, the implant, and the surgeon. Patients' activity level and gait affect the number and pattern of loading cycles. Implant design influences the joint reaction force, as does the surgical technique of implant positioning and its ability to prevent third-body materials from entering the bearing area. This is to mention only a few factors other than the material properties of polyethylene, which are the sole focus of materials scientists. Even so, the focus has been almost exclusively on the physical structure of the polyethylene (the chain structure). Only recently have the chemical properties of polyethylene come under more scrutiny, such as with the potential use of vitamin E to reduce oxidation.

In clinical practice of revision THR, we have learned that most failures caused by so-called 'polyethylene wear' are in fact compounded by factors other than just wear. Wear, as visible on a radiograph, is just the common final pathway of failure, but is rarely the leading and initiating cause of failure. More recent biomechanical studies point to the same conclusions. Impingement by less optimal implant positioning with regard to the natural ROM is a commonly observed problem, initiating polyethylene damage rather than wear. Also micro-separation and subluxation during gait are functional disturbances that have a major effect on the bearing behaviour, but are difficult to visualise and prove. From a patient-management perspective, not only have biomechanical parameters of gait been recognised, but now differences in genetic profiles for bone formation may be much more important than we previously thought.

Progress in polyethylene cross-linking has provided significantly better wear results from the test laboratory; even for materials with 'negative' wear. The clinical implantation environment, however, is very harsh and laboratory wear studies so far have rarely reflected processes in their test protocols such as third-body wear, micro-separation, subluxation, and impingement. The time has come to reconsider all the relevant influences on damage of the bearing couple and to choose materials in accordance with the required properties, whether it be polyethylene or any other material that is either currently available in the clinic or is under development.

> "In clinical practice of revision THR, we have learned that most failures caused by so-called 'polyethylene wear' are in fact compounded by factors other than just wear"
>
> – R. Geesink

TECHNOLOGY

Polyethylene

Development of polyethylenes
One of the themes explored at the Florence meeting was improvements in bearing materials to enhance longevity in vivo. There was strong audience feedback about the new, second-generation, highly cross-linked UHMWPEs and how they may improve head-size to cup-size ratios, and thus stability, and also how they may eliminate the need for mobile bearings in knee replacement. To be seen as a true advancement, any new material must have demonstrated improved wear resistance, strength, and oxidation resistance. The development of one such material, X3™, is discussed in the article below, which has been sponsored by Stryker.

Evolution of UHMWPE As a Bearing Material Dr Jim Nevelos

Dr Jim Nevelos
Stryker EMEA,
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Newbury, UK

The development of UHMWPEs

UHMWPE has become so ubiquitous as a bearing material that we take it for granted today as being the standard. Actually, metal-on-metal bearings in the hip pre-date UHMWPE by several years, although the results of metal-on-metal were not ideal at that time because of manufacturing and design inadequacies. There are many stories about how UHMWPE came into use by Professor Sir John Charnley. He experimented with Teflon (PTFE or polytetrafluoroethylene, a low friction plastic), which has very poor wear properties. UHMWPE was being used industrially at the time, with one application being gear wheels on the textile looms used in the North West of England (much quieter than metal gears and lower friction). Professor Charnley tried this material in his laboratory, and the rest is history. The material has been used in the same form since – or has it? The evolution of UHMWPE as a bearing material has been continuing for over 40 years, with new developments still coming to the market.

The impact of UHMWPE

There have been very significant improvements in UHMWPE for joint replacement as well as some notable failures. The base material has changed very little in 40 years and there are two grades in common use: GUR1050, with a molecular weight around 5 million (typically used in hips); and GUR 1020, with a molecular weight of around 2.5 million (typically used in knees). Both are formed as powder from the polymerisation of acetylene, C_2H_2 (Fig 6a). The molecular weight of one CH_2 unit is 14, which gives an idea of the relative lengths of these molecules (if the molecule width was scaled up to that of a piece of spaghetti, the spaghetti would be 2 km long). Two major positive changes to the processing were introduced in the mid-1990s by all of the orthopaedic companies. These were:

a) The consolidation of the material by compression moulding (which increased the quality of the material in terms of there being fewer fusion defects)

b) Packaging and sterilisation in an inert environment (such as argon in the case of Arcom [Biomet], which was the first and probably best known of these inert-atmosphere-sterilised materials)

The reason behind the latter change was that the gamma radiation used for sterilisation breaks C–C and C–H bonds, leading to some cross-linking (and hence almost all UHMWPE used today is cross-linked to a certain extent). However, it also leaves some broken molecules, known as free radicals, which are very reactive. Any oxygen present will combine with these free radicals, leading to oxidation of the material and reduction in mechanical properties and wear resistance. This can lead to early failure of the prosthesis. Eliminating oxygen from the packaging virtually eliminates any oxidation occurring on the shelf before implantation, but does not address the issues of free radicals and potential oxidation in vivo. One way to extinguish free radicals present in UHMWPE

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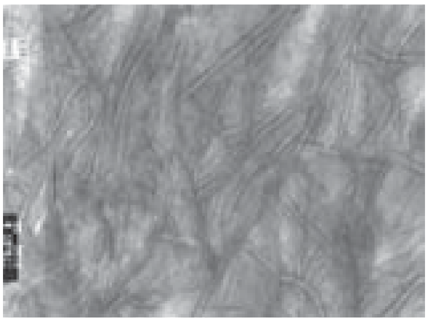


Figure 6a: Microstructure of conventional UHMWPE.

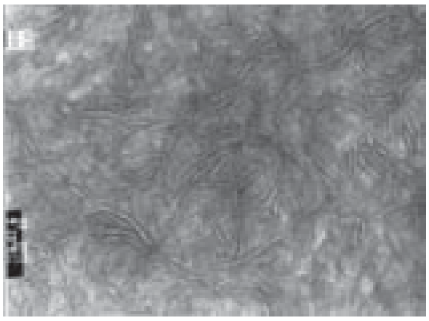


Figure 6b: Microstructure of re-melted, highly cross-linked UHMWPE with reduced crystal size.

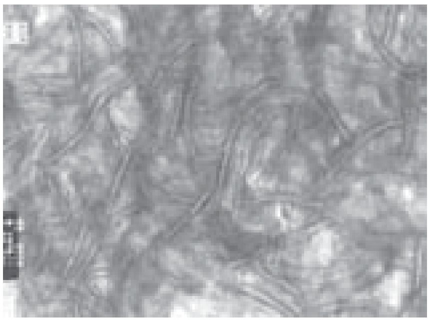


Figure 6c: Microstructure of annealed, highly cross-linked UHMWPE with no change in crystal size.

is to use heat to increase molecular mobility and thus react the free radicals within the material, thereby increasing cross-linking. This finding led to the development of the first medium-cross-linked material, Duration™ (Stryker). This material was produced by taking material sterilised conventionally using gamma radiation and then heating it, in an inert atmosphere, to approximately 50°C for 144 hours (the maximum the packaging could take safely). This has led to a more stable material, which has demonstrated approximately 40%–50% decreases in wear both in vivo and in vitro.[1]

Optimising cross-linking

In the late 1990s, efforts were made to further increase the numbers of cross-links in the UHMWPE to provide greater wear resistance. This process has typically used large doses of radiation (between 5 and 10 Mrads), either using gamma radiation or an electron beam. The numbers of free radicals then also increases, which must be resolved to avoid potential oxidation in vivo. Free radicals can be reduced, using heat (which allows the molecules to move around and cross-link) or by mechanical deformation (which also moves the molecules around). Most highly cross-linked UHMWPEs made in the late 1990s used re-melting to virtually eliminate free radicals. However, their strength was also reduced because the material recrystalised (Fig 6b). This lead to some design compromises and meant the materials were generally unsuitable for knee applications. One type, Crossfire™ (Stryker), was annealed (heated to just below the melting point) after irradiation to 7.5 Mrads. This material retained more strength than the re-melted UHMWPEs, but also had moderate free-radical content and was again deemed unsuitable for knee applications.

> "The evolution of UHMWPE as a bearing material has been continuing for over 40 years…the latest evolution is sequential irradiation and annealing, which gives improved wear and oxidation resistance without compromising strength"
>
> – J. Nevelos

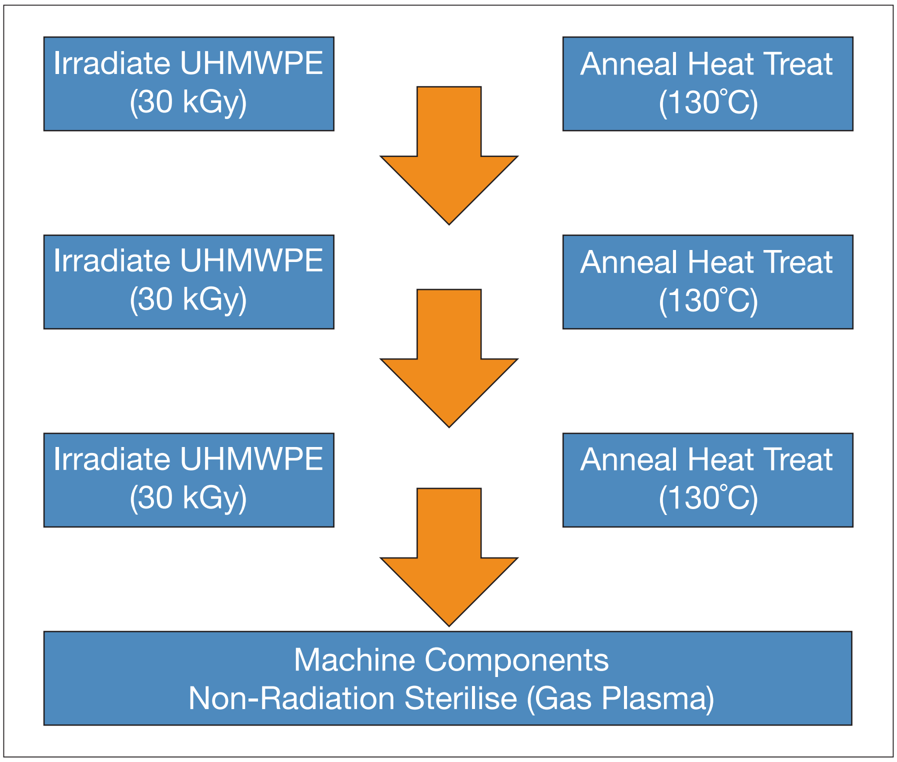


Figure 7: The patented X3™ process for producing a highly cross-linked material with improved resistance to oxidation compared with conventional UHMWPEs as well as vastly improved wear resistance (97% less wear than for conventional UHMWPE)[3] and strength at least as good as conventional UHWMPE.[3]

Further reducing free-radical levels

The past few years have seen some further exciting developments in processing of UHMWPE, with a focus on retaining strength while reducing free-radical content to insignificant levels. One way to achieve this goal is to use a sequential irradiation and annealing process, whereby the UHMWPE is irradiated to 3 Mrads and is then annealed. This process is then repeated three times to give a very high level of cross-linking (equivalent to 12 Mrads in a single dose) (Fig. 7). The relatively low individual doses of radiation mean that the annealing steps can produce enough molecular mobility to virtually eliminate free-radicals after each irradiation step. The result is a highly cross-linked material that has less than 1% of the free-radical levels of conventional UHMWPE, sterilised by gamma-irradiation in an inert-atmosphere (Fig 6c).[2] This means a more wear-resistant and more stable (resistant to oxidation) material with no change in strength compared with conventional UHMWPE. This material, known as X3™ (Stryker), is a major step forward in UHMWPE technology. Given its unique properties, it is suitable for hip, knee, and other joint replacement applications. X3™ represents the first of a new generation of bearing materials for joint replacement.

1. Geerdink CH, et al. *Acta Orthop*. 2006;**77(5)**:719–725.
2. Wang, et al. Transcript of the 5th Combined meeting of the ORS, Banff, Canada, 2004.
3. Essner A, et al. Transcript of 5th Combined meeting of the ORS, Banff, Canada, 2004.

Five facts about...

Highly cross-linked polyethylene

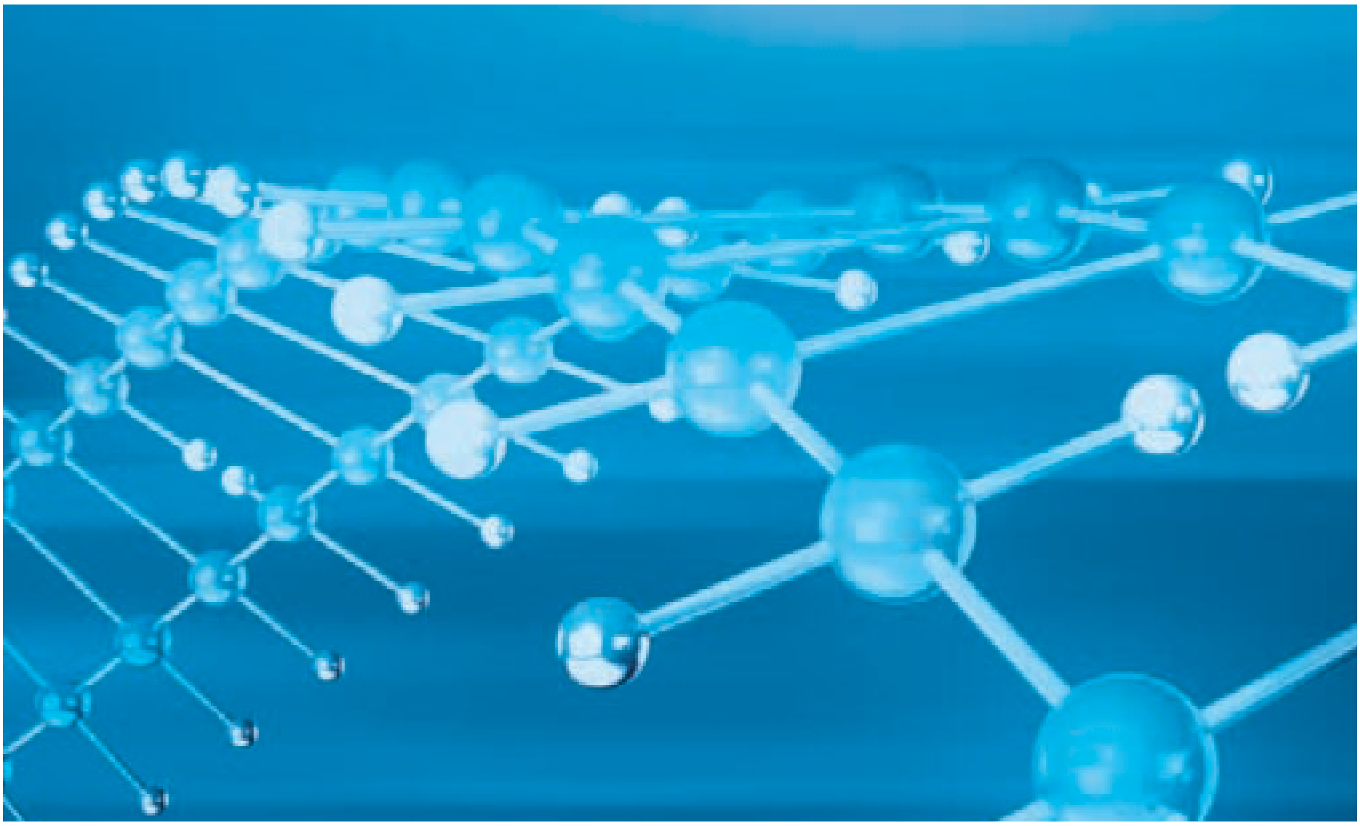
1. The first industrial highly cross-linked UHMWPE material was prepared in the 1930s by irradiating the extruded tube of high-density polyethylene with an electron beam. This process was made more industrially feasible in the 1970s, but was still expensive.

2. Charnley first used chemically sterilised UHMWPE in November 1962. The production of the Charnley socket from 1968 onwards, however, was gamma-sterilised and therefore slightly cross-linked.

3. Highly cross-linked polyethylene was probably first used clinically in orthopaedics in 1970, by Professor Oonishi in Japan. The material had a massive 100-Mrad radiation dose.

4. Chemical cross-linking of UHMWPE was being explored by Grobbelaar in South Africa in the mid-1970s.

5. The first modern highly cross-linked UHMWPEs were introduced in 1998. A second generation of these materials without compromises on strength, wear, and oxidation are available today and the future looks bright for polyethylene as it continues to evolve.



Q & A: METAL-ON-METAL WEAR DEBRIS

Dr Jenny Burke
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Australia

Another key area of discussion and debate within the field of tribology is the effect of wear debris both locally and systemically. Perhaps the area of most controversy is that surrounding the effects of metal-on-metal wear debris. Although every metal implant inevitably leads to some systemic exposure to corrosion products such as metal ions, there is little dispute that metal-on-metal hip bearings raise these levels more than a metal-on-UHMWPE total hip or a trauma plate, for example. Metal-on-metal wear particles are generally very small, of the order 20–80 nm. This leads to a large surface area of wear debris even for small amounts of volumetric wear. This, in turn, leads to the release of corrosion products, such as cobalt and chromium ions that can be detected in the blood. There is little doubt that metal-on-metal bearings produce much less wear than standard UHMWPE; however, many questions remain about the effects of metal-on-metal wear debris in the long term, especially as the average age of patients drops.

In order to gain some insight into the latest thinking on the subject, Andrew Shimmin from Melbourne, Australia, is interviewed by Jenny Burke, both faculty members of the 2007 Pacific Tribos Congress in Australia.

1. One very emotive issue is the question of genetic damage caused by wear particles. In your opinion, is this purely a metal-on-metal phenomenon?

No, this issue is not just related to metal-on-metal bearings; localised genetic damage has been seen with other bearing surfaces with hip arthroplasty, as described by Ladon, et al.[1] There have been no reported cases of birth defects with metal-on-metal bearings, and Ziaee and colleagues[2] have recently shown that the placenta exerts a modulatory effect on the rate of metal-ion transfer.

2. Wear rates and ion levels in blood are remarkably consistent across many types of metal-on-metal prosthesis, although most series do contain some 'outliers' with very high levels. What do you think are the causes, and are these elevated levels cause for concern?

The outliers with elevated metal ion levels may relate to edge loading of the implant,[3] which can be caused by incorrect implant positioning or extreme ranges of motion. In that regard, implant design is important, as some designs have less head coverage and a higher chance of edge loading with slight variations in implant orientation. There are theoretical issues with elevated ions levels, but currently the measurement of these ion levels is still regarded as a research tool only, and no recommendations can be given as to how these ion levels should influence patient management.

3. There is a lot of work going on into the hypersensitivity or Aseptic Lymphocyte-Dominated Vasculitis Associated Lesion (ALVAL) phenomenon. Given your work in this field, how big of an issue do you think this is?

In my mind, local reaction to products of corrosion and wear is one of the biggest concerns with metal-on-metal hips. The patients present with a recurrence of symptoms 1–2 years after initial implantation and often require revision to a non-metal on metal bearing. Willert and colleagues[4] reported that the persistence or early reappearance of symptoms, including a marked joint effusion and possible development of osteolysis after primary implantation, may suggest the possibility of hypersensitivity.

Note: Dr Andrew Shimmin and Dr Pat Campbell have recently written a paper about ALVAL, which has been accepted for publication in the *Journal of Arthroplasty*.

1. Ladon, et al. Transcript of the 51st Annual meeting of the ORS, 2005, Washington DC, USA.
2. Ziaee H, et al. *J Bone Joint Surg Br.* 2007;**89(3)**:301–305.
3. Campbell P, et al. *Clin Orthop Relat Res.* 2006;**453**:35–46.
4. Willert HG, et al. *J Bone Joint Surg Am.* 2005;**87(1)**:28–36.

Send in your tribology questions!

An expert will answer your bearing surface queries. Email questions to tribos@stryker.com

If we select your question for the Q & A section of the newsletter, we will notify you prior to printing.

INTERNATIONAL CALENDAR OF EVENTS

Year	Date		Event	City	Country	Website
2007	SEPT	25–28	British Orthopaedic Association (BOA)	Manchester	UK	www.boa.ac.uk
	OCT	4–6	International Society for Technology in Arthroplasty (ISTA)	Paris	France	www.ista.to
		7–12	Australian Orthopaedic Association (AOA)	Gold Coast	Australia	www.aoa.org.au
		14–17	New Zealand Orthopaedic Association (NZOA)	Auckland	New Zealand	www.nzoa.org.nz
		20–24	Orthopaedic Research Societies (ORS) Combined Meeting	Honolulu	Hawaii	www.ors.org
	NOV	5–8	La Société Française de Chirurgie Orthopédique et Traumatologique (SOFCOT)	Paris	France	www.sofcot.com.fr
	DEC	9–13	2nd International Conference of the Biomechanics of Biomaterials and Tissues (ICMOBT)	Lihue, Kaua’i	Hawaii	www.icmobt.elsevier.com
		12–15	Current Concepts in Joint Replacement (CCJR)	Orlando	USA	www.ccjr.com
2008	JAN	10–11	Annual Congress Dutch Orthopaedic Society	Maastricht	The Netherlands	
		19–20	The Great Debate	London	UK	www.thegreatdebate.uk.com
	MARCH	2–5	Orthopaedic Research Society (ORS)	San Francisco	USA	
		5–9	American Academy of Orthopaedic Surgeons (AAOS)	San Francisco	USA	www.aaos.org
	APRIL	17–18	Stryker Anatomic Hip meeting	Warsaw	Poland	
	MAY	21–24	European Society of Sports traumatology Knee surgery and Arthroscopy (ESSKA)	Porto	Portugal	www.esska.org
		27–28	**Tribos Congress**	**Amsterdam**	**The Netherlands**	**email: tribos@stryker.com**
		28 May to 1 June	World Congress of Biomaterials (WBC)	Amsterdam	The Netherlands	www.wbc2008.com
		9 May to 2 June	Stryker Pacific Hip and Knee Conference	TBC	TBC	
	JUNE	11–14	Sociedad Española de Cirugía de Ortopédica y Traumatólogica (SECCA)	Madrid	Spain	
		11–13	NOF (Nordic Orthopaedic Federation)	Amsterdam	The Netherlands	www.nof2008.org
	SEPT	16–19	British Orthopaedic Association (BOA)	Liverpool	UK	www.boa.ac.uk
		TBC	Stryker Orthopacific Meeting	TBC	Australia	
		TBC	**Tribos Congress**	**TBC**	**Australia**	**email: tribos@stryker.com**
	OCT	8	Sociedad Española de Cirugía de Cadera (SECOT)	Valencia	Spain	www.secot.es
		12–17	Australian Orthopaedic Association (AOA)	Hobart	Australia	www.aoa.org.au
		19–23	New Zealand Orthopaedic Association (NZOA)	Napier	New Zealand	www.nzoa.org.nz
		22–25	Deutsche Gesellschaft für Orthopädie und Orthopädische Chirurgie e. V. (DGOOC)	Berlin	Germany	www.dgooc.de
	NOV	10–13	La Société Française de Chirurgie Orthopédique et Traumatologique (SOFCOT)	Paris	France	www.sofcot.com.fr
		19–22	Medica	Düsseldorf	Germany	www.medica.de
		23–27	La Società Italiana di Ortopedia e Traumatologia (SIOT)	Rome	Italy	www.siot.it