Tribology in Joint Replacement

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Tribology 2025- Materials Making the Difference
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Johnson&Johnson MedTech

DePuy Synthes
THE ORTHOPAEDICS COMPANY OF Johnson&Johnson

MedTEST

Tribological systems in medical devices

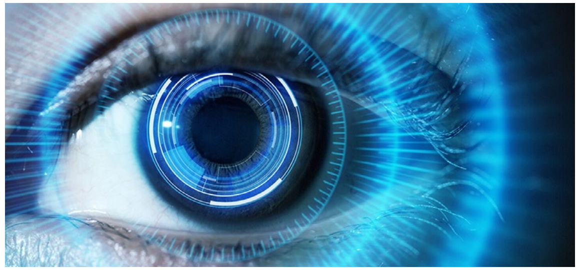
There many Tribological Systems in Medical Devices e.g.

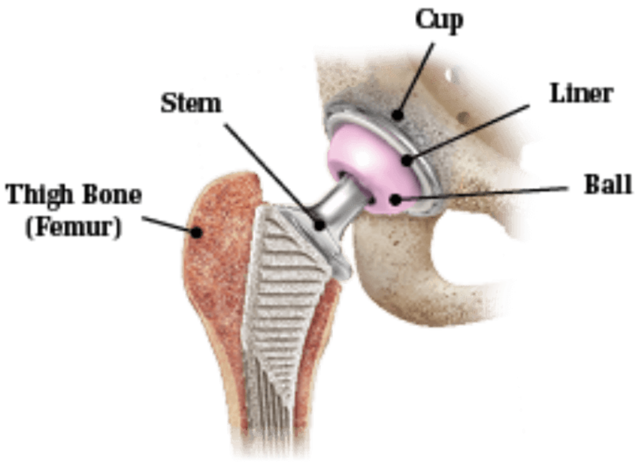
Joint Replacement

Contact lenses

Skin patches

Cardiovascular devices





Hip replacement component

Demands on Materials

Materials challenges in total joint replacement as an example include:

High cyclic stresses

Patient demand / daily living activities

Increasing incidence of high BMI / obesity

Corrosive environment

Biological responses to micrometre and nano size particles

Bone quality / disease and its continued evolution

Variation in implant positioning / surgeon technique

Materials Approaches to Improve Outcomes

Improve Fixation / Reduce Incidences of Loosening -

- Porous coatings
- Porous monolithic structures / scaffolds
- Calcium phosphate coatings

Reduce Incidences of Infection, Pain and Revision -

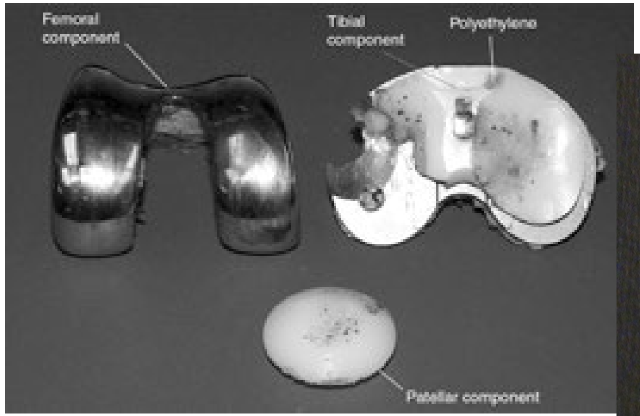
- Coatings
- Surgical process – CAS, patient specific instruments

Reduce Wear, Debris and Ions -

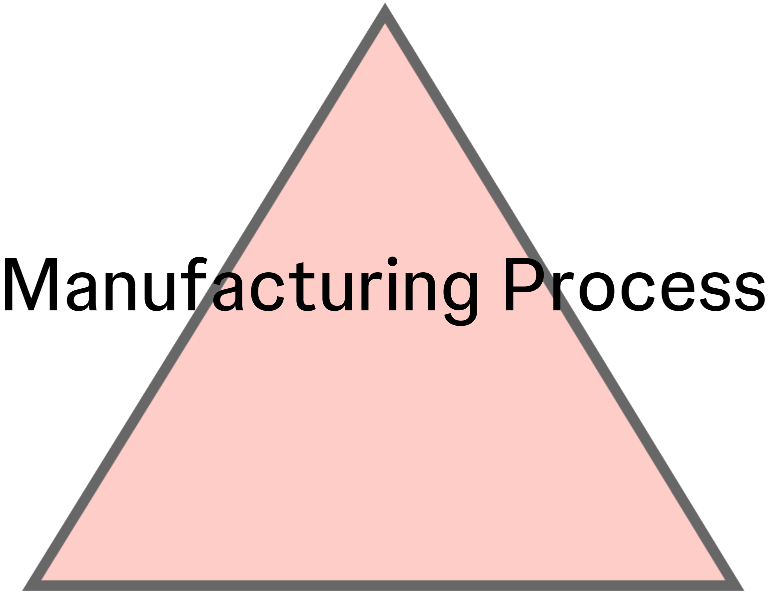
- Improvements in polyethylene materials
- Coatings and surface treatments
- Alternative / new materials

Common Causes of Failure

Wear



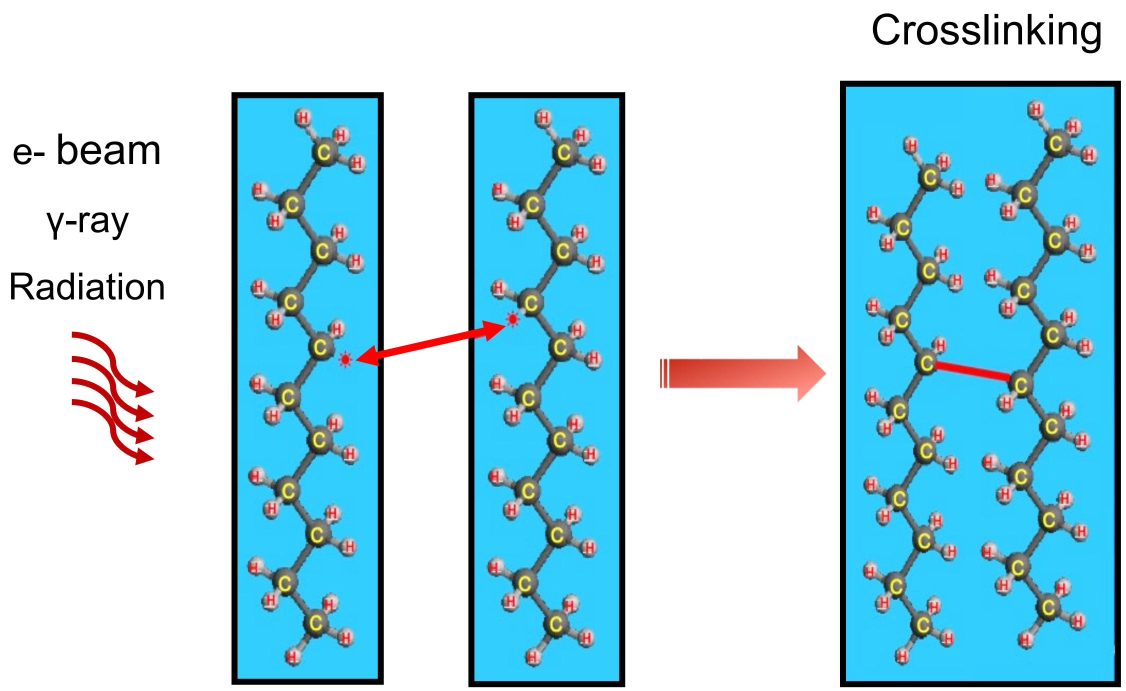
Developments in UHMWPE



1st Generation UHMWPE

Gamma sterilized in air (25- 40 kGy) to increase crosslinking in polymer

Crosslinking reduces adhesive / abrasive wear



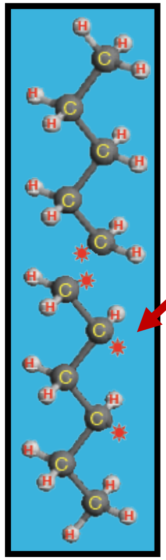
1st Generation UHMWPE

BUT process in air results in increasing oxidation and increased wear

e- beam

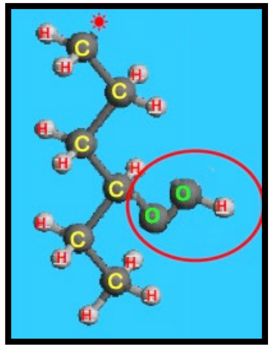
γ-ray

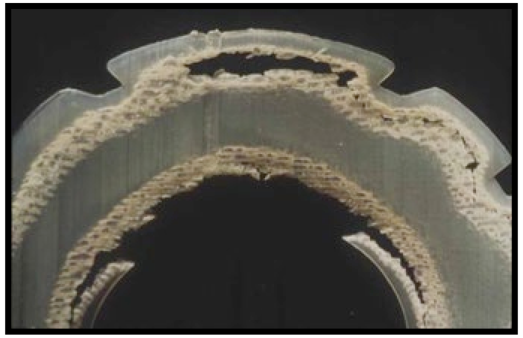
Radiation



1. **Shorten chain length**
2. **Remove hydrogen atoms**

O2+ Free Radicals





2nd Generation UHMWPE

- Gamma sterilization in oxygen free environment utilising barrier packaging
  - Reducing oxidation issue during processing but still creates free radicals material which can lead to long term oxidation

3rd Generation UHMWPE

Eliminates free radicals

Prevent oxidation *after* crosslinking

Remelting	Annealing
↓	↓
Heating above Tm (> 140ºC)	Heating below Tm (<135ºC)

Decreasing wear with higher γ dose

BUT Lower mechanical properties due to high crosslinking and low % crystallinity

4th Generation UHMWPE

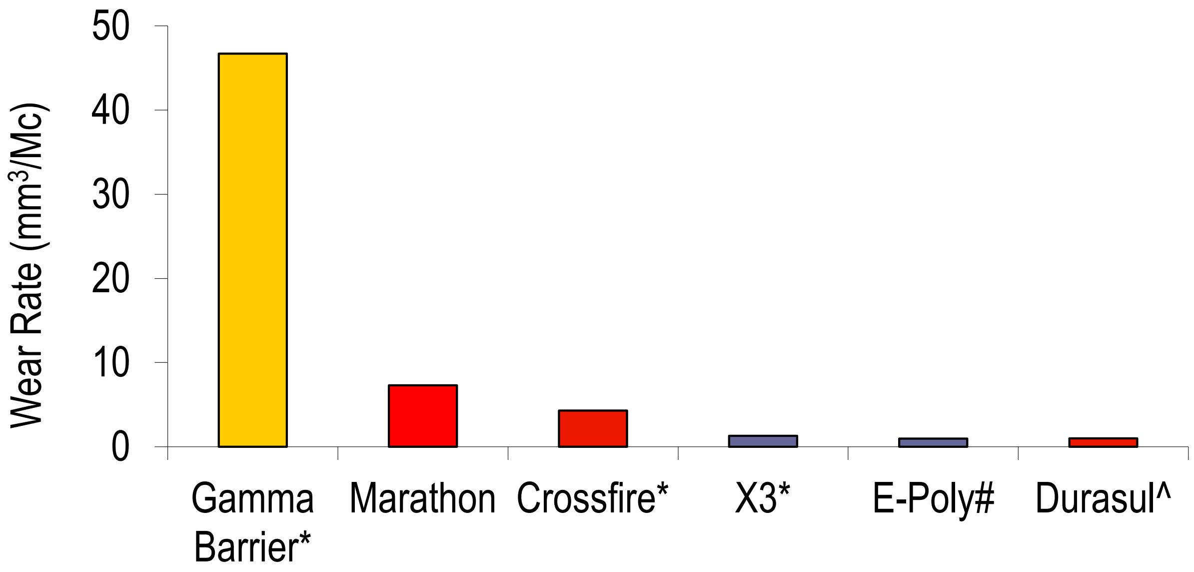
Stabilization of free radicals without thermal treatment

Antioxidants

Addition of antioxidants

before / after irradiation

Decreasing the wear with higher dose but maintaining % crystallinity



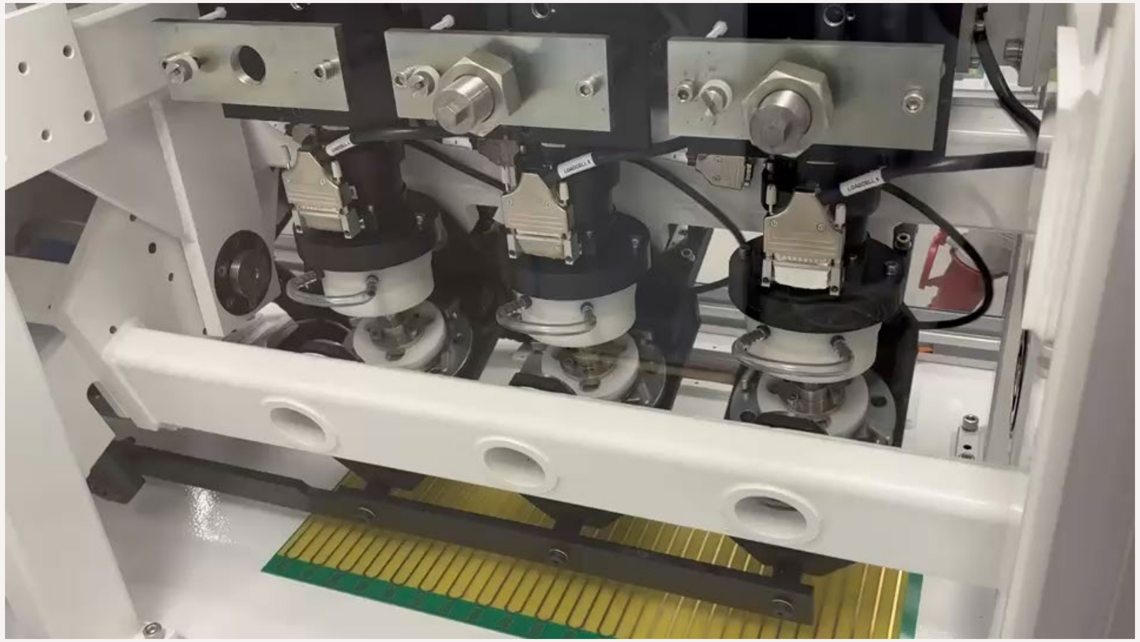
Reduce Wear, Debris and Ions
Developments in Ceramics and Hard Coatings

Potential benefits of ceramics and ceramic coatings:

- Lower adhesive wear of UHMWPE against ceramic
- Hardness
  - Superior surface finish
  - Increased resistance to abrasive wear / scratching

- Reduction / removal of metal ions from wear and / or corrosion products therefore reducing hypersensitivity risk
    - Hypersensitive immune response to Ni is believed to affect as much as 14% of population

Development of Multi-station multi-axis joint simulators



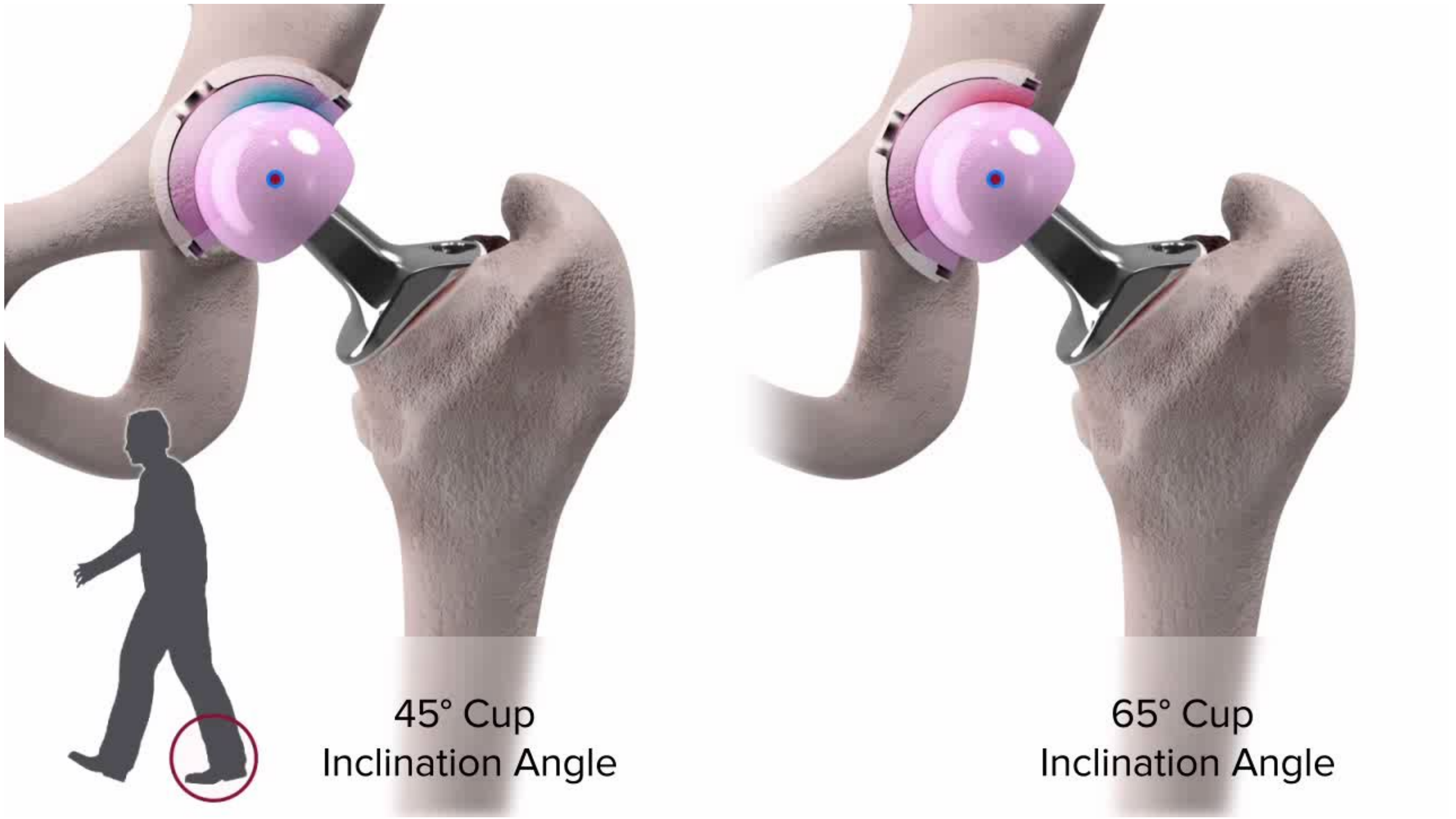
Current Challenges and Opportunities

High demand patients

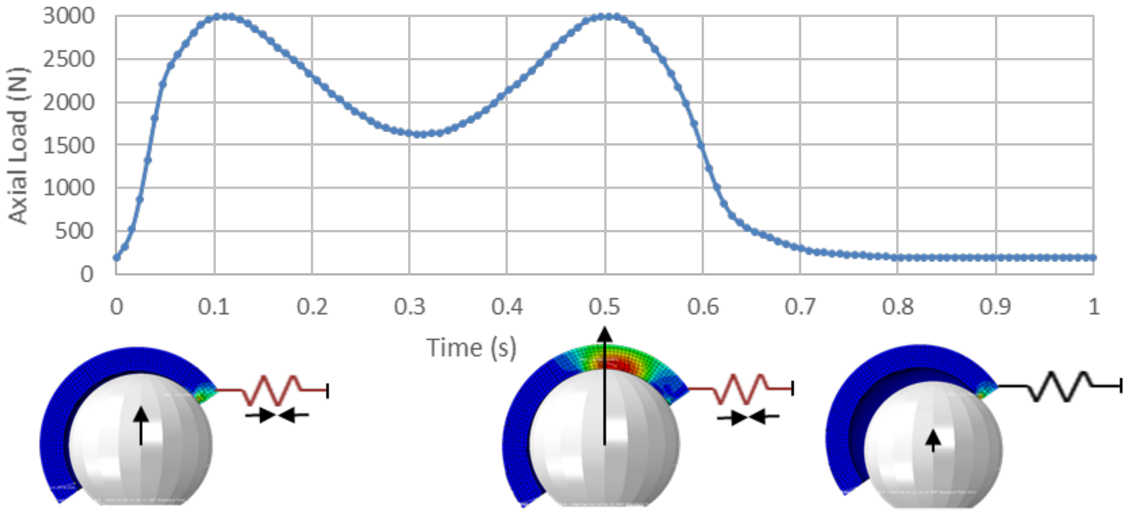
Adverse conditions and cases

Revision surgery

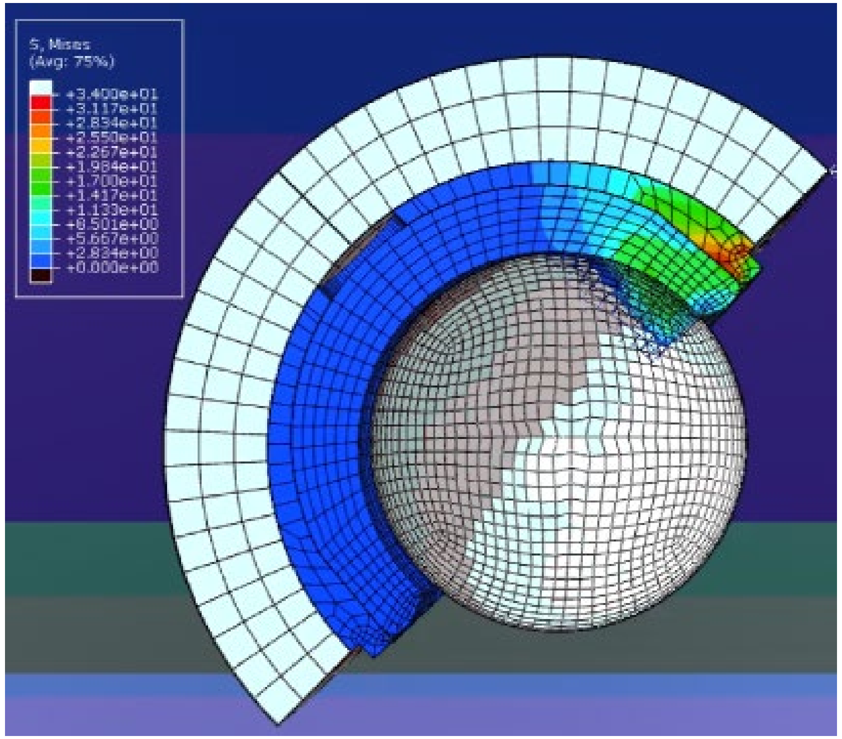
Effect of Implant positioning



Advance simulations



Etchels et al, 2018



Jahani et al, 2018

Mode 3 wear

<u>Particle embedment on VIVO AMTI simulator</u>

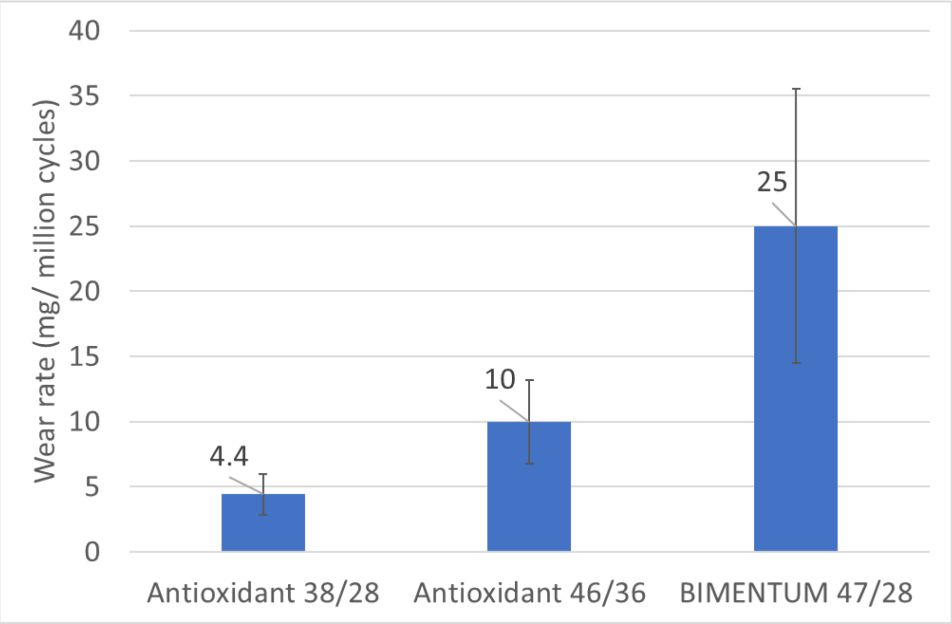
- 2mg of 50/50 weight % mixture of 60 and 80 grit Al_2O_3 media was applied to each of the inner (Figure 2) and outer (Figure 3) polyethylene surfaces.
- 1000N constant axial load and ±30°IE rotation to the intended bearing surface (while keeping the other bearing surface fixed) for 20 cycles at 1Hz.


Figure 2: Particle embedment on the inner surface of the mobile bearing. The axial load went through the pole of the head and mobile bearing.


Figure 3: Particle embedment on the outer surface of the mobile bearing. Acetabular cup positioned at 30° inclination.

Mode 3 wear continued

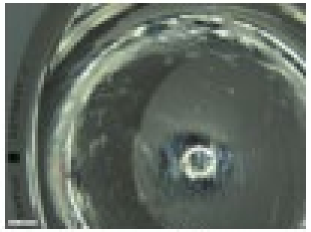
- The wear of antioxidant polyethylene material (for both sizes) was significantly lower ($p=0.001$) than the wear of moderately cross-linked polyethylene material
- The third body particles remained embedded for the duration of the wear test.
- Significant scratching was observed on the metal head and acetabular cups for both DM systems.
- There was no sign of cracking, fracture or delamination of either polyethylene materials after six million cycles of testing.
- The serum lubricant turned dark due to release of significant quantities of metal particles from the metal bearing surfaces.



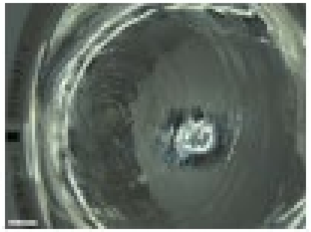
Wear rate after 6 million cycles of testing. Error bars represent 95% CI.

Representative images of samples at the end of the test

CoCr metal head



CoCr metal liner



CoCr metal liner

Stainless steel metal shell

Impingement scenario in joint replacement

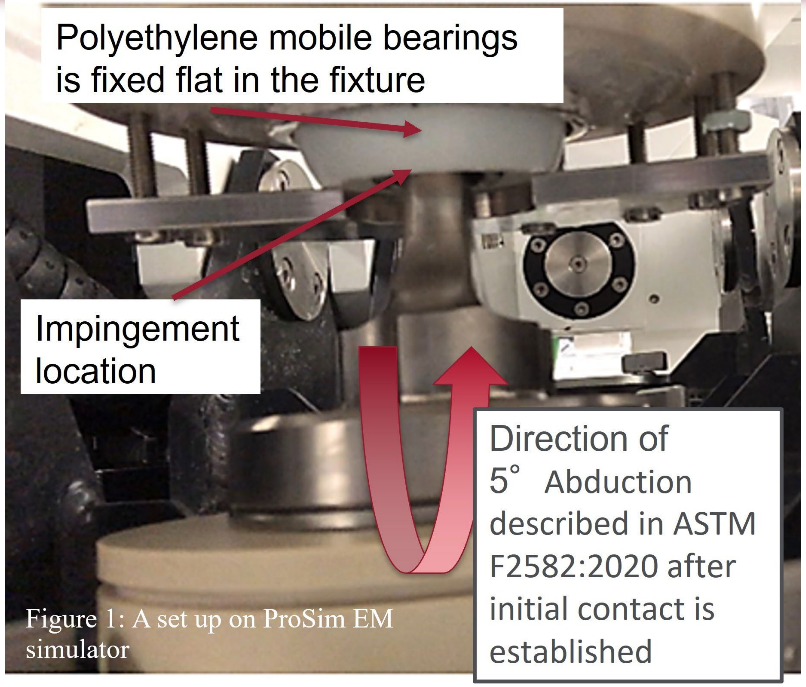
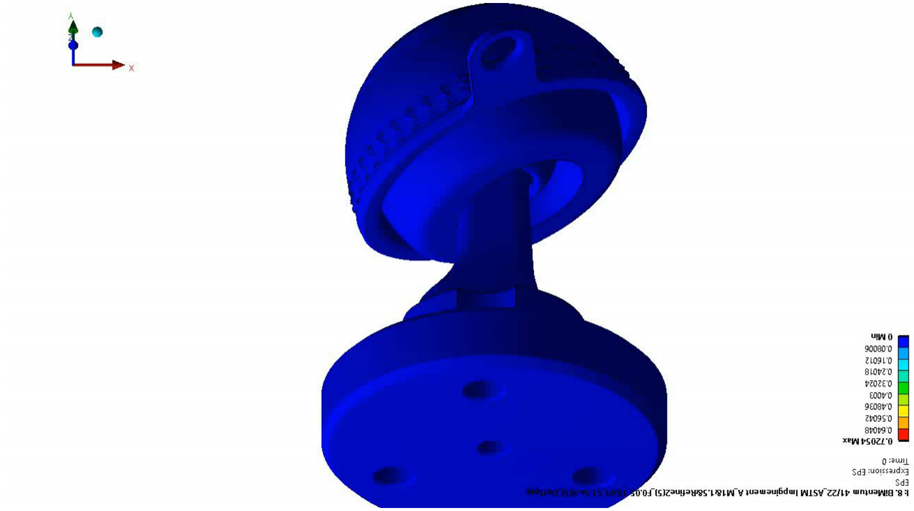


Figure 1: A set up on ProSim EM simulator



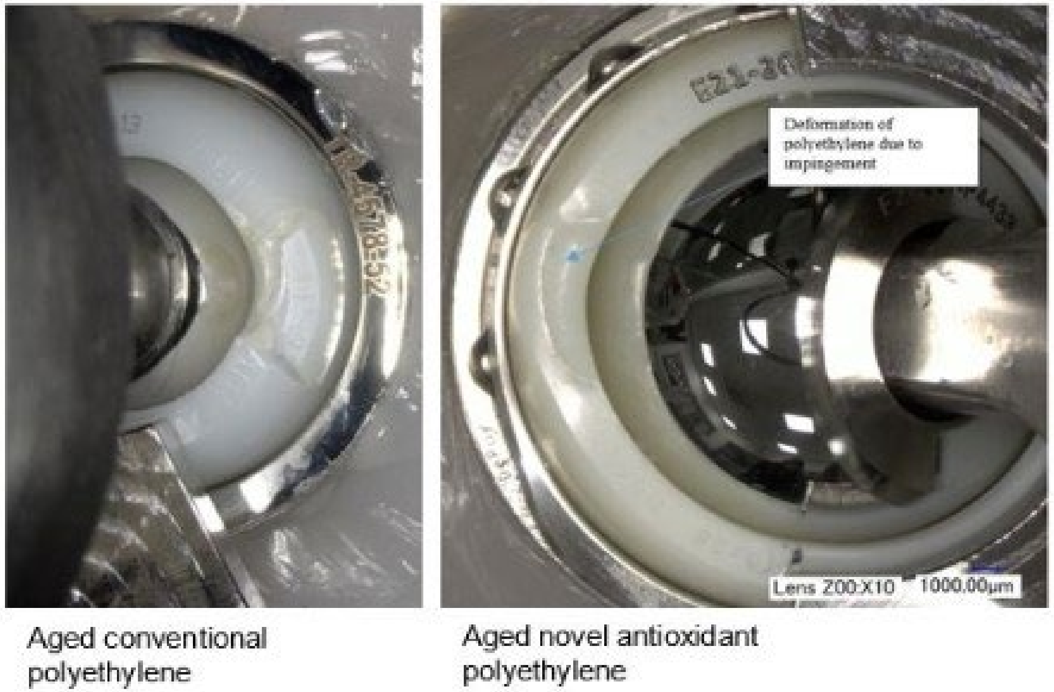


Figure 2: Damage observed on the rim of the restricted aged mobile bearing after one million cycles of impingement. Ageing was completed as per ASTM F2003-02(2015).

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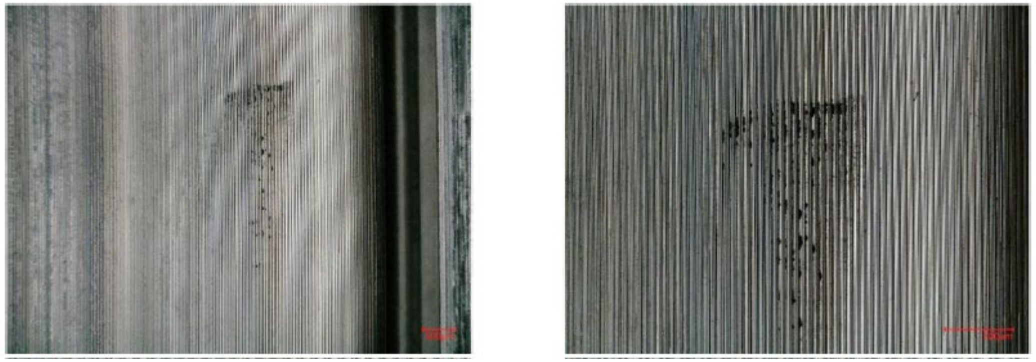
Corrosion considerations



Next steps

Modelling: more predictive;

enhance design;

stratification of design and patients

Helping to achieve net zero carbon

my green lab certification.

- J&J is committed to reducing carbon footprint,
- Tribology laboratory in Leeds, UK achieving Green Level Certification from My Green Lab.
- The scheme is recognized by the United Nations Race to Zero campaign as a key measure of progress towards a zero-carbon future
- My Green Lab Certification is considered the gold standard for laboratory sustainability best practices around the world.

Thank you for listening and the opportunity to present to you today

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