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THIRD BODY WEAR OF AN ALL-POLYMER TOTAL KNEE REPLACEMENT

UNIVERSITY OF LEEDS

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Background

The polymer, PEEK-OPTIMA™, has been considered for use as an alternative arthroplasty bearing material due to its low wear rates, the low biological activity of its wear debris and clearance for clinical use.[1] A PEEK femoral component coupled with an all-polymer UHMWPE tibial component gives potential for a metal-free knee implant. Previous experimental wear simulation of this all-polymer knee shows comparable wear to a conventional cobalt chrome (CoCr)-on-UHMWPE implant of similar initial surface topography and geometry.[2] Wear simulation to date has been carried out under optimal conditions assuming perfect surgical alignment and within a uncontaminated environment. The aim of this study was to investigate the wear performance of this cemented all-polymer bearing couple under third body wear conditions. The third body particles of interest were porcine cortical bone and PMMA cement. The wear and change in surface topography of the PEEK-on-UHMWPE bearing couple was compared to conventional materials CoCr-on-UHMWPE.

Materials and Methods

- 3 injection moulded PEEK-OPTIMA™ femoral components (Invibio Ltd, UK) (Figure 1)
- 3 cobalt chrome femoral components
- All polyethylene GUR1020 UHMWPE tibial components (conventional, ethylene oxide sterilised)
- All components were cruciate retaining, right, mid-size
- Particles were produced by grinding porcine cortical bone and polymerised PMMA cement (Palacos R, Heraeus Medical GmbH, Wehrheim, Germany), before sieving within a size range of 500-1000 µm. The particle size was consistent with previous third body wear simulation by Schroeder et al.[3]

Figure 1: Metal-free knee

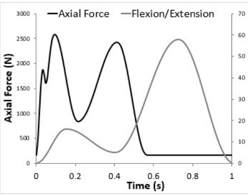

Figure 2: Input Axial Force and Flexion/Extension

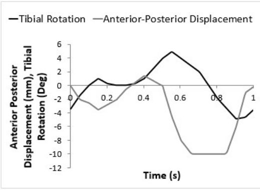

Figure 3: Input Anterior-Posterior displacement and Tibial Rotation[4]

Experimental wear simulation was carried out on an electromechanical 6 station ProSim knee simulator (Simulation Solutions, UK).

Test conditions used:

- 25% bovine serum in 0.03% sodium azide
- Room temperature
- Kinematic conditions (Figures 2 & 3):
  - Axial Force (AF) up to ~2800N, Flexion extension (FE) 0-60°, Tibial Rotation (TR) ±5°, Anterior-Posterior Displacement (AP) 10mm (Leeds high kinematics)[4]
- Three conditions were simulated in series for 1 million cycles (MC) per condition:
  1. Wear simulation in clean lubricant
  2. Wear simulation with porcine cortical bone particles (5 mg/ml)
  3. Wear simulation with PMMA cement particles (5mg/ml)
- Wear of the UHMWPE tibals assessed gravimetrically
- Surface topography of the femoral components measured using contact profilometry
- Statistical analysis carried out using 0ne-way ANOVA to compare PEEK to CoCr with significance taken at $p<0.05$

Results

- In clean lubricant, there was no significant difference in UHMWPE wear against PEEK and CoCr femoral components (Figure 4). Light scratching was visible on the PEEK implants (Figure 5) resulting in a significantly higher Ra compared to CoCr ($p<0.05$) (Figure 6).
- When contaminated with porcine bone particles, there was no significant difference in wear of UHMWPE against PEEK or CoCr femoral components. After 1MC with bone particles, the Ra of the PEEK femoral components was significantly higher ($p<0.05$) than CoCr.
- When contaminated with PMMA cement particles, there was a increase in wear rate of tibial components articulating against both PEEK and CoCr however there was no significant difference between the two femoral component materials. Scratching was evident on both PEEK and CoCr implants, the PEEK implants had a higher Ra however, this was not significant. In this condition, the lubricant in the CoCr-on-UHMWPE became discoloured.

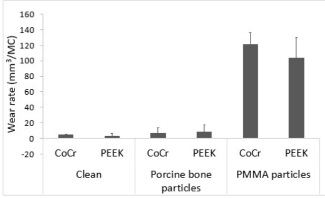

Figure 4: Mean wear rate ± 95% confidence limits of UHMWPE tibials in clean lubricant, with porcine bone particles and with PMMA particles (n=3).

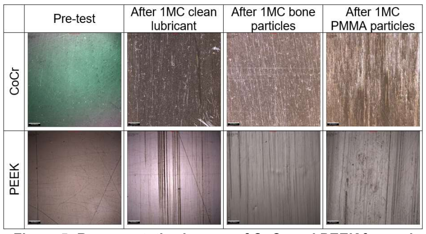

Figure 5: Representative images of CoCr and PEEK femoral components taken with 10X magnification using an Alicona G5 optical microscope (Alicona Imaging GmbH (Graz, Austria), 200µm scale bar.

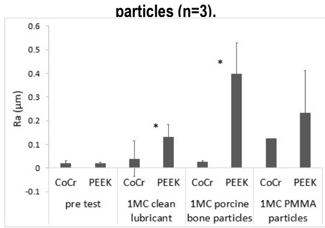

Figure 6: Mean surface roughness (Ra) ± 95% CL of CoCr and PEEK femoral components (N=3). * denotes significant difference between PEEK and CoCr, p<0.05.

Discussion

- For CoCr-on-UHMWPE implants, contaminating the lubricant with bone particles had no influence on the surface topography of the femoral components or the wear rate of the UHMWPE; with PMMA particles, scratching was seen on the femoral components and an increase in wear rate measured. The lubricant discolouration suggests release of metal particles from the implant. The difference in UHMWPE wear with different particles shows that the hardness of the third body particle influences the change in surface topography of the femoral components and subsequent UHMWPE wear.[5]
- For the PEEK-on-UHMWPE bearing couple, scratches were seen on the PEEK in clean lubricant and during third body wear simulation with both bone and PMMA particles demonstrating the lower scratch resistance of PEEK compared to CoCr.[6] The wear rate of the UHMWPE tibial components followed a similar trend against PEEK and CoCr femoral components for both third body particle types over the duration investigated. For the all-polymer bearing couple, no change in the lubricant was visible however, this may be due to the colour of the PEEK and warrants further investigation of the debris. Both bone and PMMA particles led to extensive pitting in the UHMWPE irrespective of the femoral component materials with evidence of embedded particles in the UHMWPE especially when articulating against CoCr, this test artefact may have lowered the wear rate of the tibial components. No embedded particles were visible in the PEEK.

Significance

The study investigated the wear performance of an all-polymer knee implant under third body wear conditions and compared to existing implant materials.

Despite scratching on the surface of the PEEK implants, there was no significant difference in wear rate of UHMWPE articulating against PEEK and CoCr femoral components under third body wear conditions. This demonstrates the potential to use PEEK as the femoral component in a total knee replacement and the importance of pre-clinical assessment of new materials prior to implantation.

References

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Disclosure

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