Institute of Medical & Biological Engineering

THE INFLUENCE OF ENVIRONMENTAL CONDITIONS ON THE WEAR OF AN ALL-POLYMER KNEE IMPLANT

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Background

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].

This study investigated the potential to use PEEK Optima® as an alternative to cobalt chrome in the femoral component of a total knee replacement to give a metal free implant. The wear performance of all polyethylene tibial components was assessed under different environmental conditions.

Materials and Methods

Figure 1: Metal-free knee

Experimental wear simulation was carried out on 6 station ProSim knee simulators (Simulation Solutions, UK), one run at room temperature and the other at elevated temperature (~33°C).

Test conditions used:

- 25% bovine serum in 0.03% sodium azide
- 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) [3]
- 5 million cycles (MC) at each temperature

Figure 2: Input AF and FE [2]

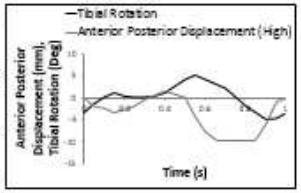

Figure 3: Input AP and TR [3]

- Six injection moulded PEEK Optima® femoral components (Invibio Biomaterial Solutions, UK), initial mean surface roughness (Ra) ~0.02µm (Figure 1)
- Six cobalt chrome femoral components, initial Ra ~0.02µm
- Same design of femoral for both groups
- All polyethylene GUR1020 UHMWPE tibial components (conventional, ethylene oxide sterilised)
- All components were cruciate retaining, right, mid-size
- Wear of the UHMWPE tibials was assessed gravimetrically
- Surface topography of the femoral components was measured using contact profilometry
- Lubricant temperature was measured using a thermocouple
- Statistical analysis carried out using ANOVA with significance taken at $p<0.05$

Results

- After 5MC of wear testing at room temperature, the mean wear rate of the conventional metal-on polyethylene implant was 2.6±1.5 mm³/MC and for the all-polymer knee was 4.2±5.4 mm³/MC, there was no significant difference in wear rate against the different materials p=0.27. At elevated temperature, the wear rates were lower against both materials at 0.2±0.5 and 1.5±2.5 mm³/MC respectively (Figure 4).

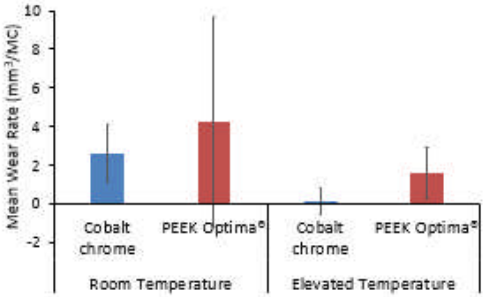

Figure 4: Mean wear rate ± 95% confidence limits of UHMWPE tibials (n=3)

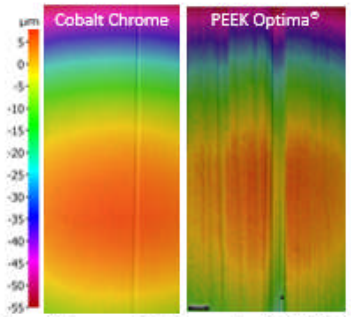

Figure 5: Images of the femorals after 5MC of wear testing at room temperature (x10) taken using an Alicona G5

- At the conclusion of the studies, a high density of linear scratching was visible on the PEEK Optima® implants parallel to the principal direction of sliding (Figure 5). There was a significant increase ($p<0.05$) in the measured Ra of the PEEK femorals for both conditions; for the room temperature study, the post test Ra was 0.32±0.14µm.
- In the room temperature test, the mean bulk lubricant temperature was ~2°C higher in the all-polymer implant than the conventional materials.

Discussion

- Both the conventional metal-on-polyethylene and all-polymer knee replacements produced low wear rates (<5mm³/MC).
- Testing at elevated temperature led to a reduction in wear rate of tibials against both femoral materials, likely due to protein precipitation and deposition on the surface of the implants [4].
- During wear testing, the PEEK Optima femorals became scratched however, this did not influence the wear rate which remained constant over the test duration.

Significance

- **The wear performance of the all-polymer (PEEK-on-UHMWPE) knee was comparable to a conventional metal-on-polyethylene implant**
- **Environmental conditions such as lubricant temperature influence wear and tribology, testing at an elevated temperature introduced a test artefact which would not be seen in room temperature tests or *in vivo*.**

References

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