Institute of Medical & Biological Engineering

THE INFLUENCE OF THIRD BODY DAMAGE WITH PMMA CEMENT ON THE WEAR OF UHMWPE AGAINST PEEK OPTIMA®

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Introduction

Preclinical experimental wear simulation has shown PEEK Optima® to give promise as an alternative bearing material to cobalt chrome in the femoral component of total knee replacement [1]. In this study, the influence of third body damage to PEEK Optima® and cobalt chrome with PMMA particles on the wear of UHMWPE was investigated in a simple geometry pin on plate wear simulator with the results compared to negative controls.

Materials and Methods

Materials: Cobalt chrome plates (initial Ra <0.01µm), PEEK Optima® plates (initial Ra ~0.02µm), GUR 1020 UHMWPE truncated cone pins (not sterilised or crosslinked) with either a 3mm or 8mm flat contact face, 500-1000µm diameter particles of Palacos R & G bone cement

Methods: The study was split into two phases: Phase 1 - Damage simulation; Phase 2 - Wear simulation against the damaged surfaces with comparison to unscratched negative controls. N=3 was carried out for each plate type.

Phase 1: Damage simulation (Figure 1)

- Particles of PMMA cement trapped between a 3mm face UHMWPE pin and PEEK Optima® or cobalt chrome plate
- 120N axial load applied to pin
- Plate pulled beneath pin at 8mm/min to create damage
- Repeated 5 times in each region of damage, 5 damage regions created
- Damage assessed using contacting profilometry

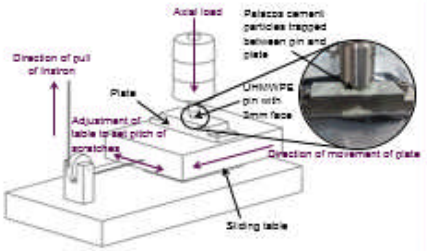

Figure 1: Damage simulation rig

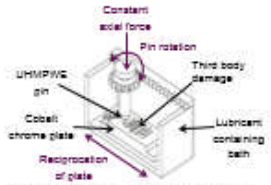

Figure 2: Pin on plate wear test

Phase 2: Wear simulation (Figure 2)

- 1 million cycles (MC) wear simulation carried out perpendicular to the direction of damage simulation
- Wear compared to negative controls (no damage)
- GUR 1020 UHMWPE pins 8mm contact face
- 20mm stroke length, ±20°rotation, 160N constant load (stress 3.2 MPa), 1Hz
- Lubricant 25% bovine serum
- Wear of pins assessed gravimetrically

Statistical analysis was carried out using ANOVA with significance taken at $p<0.05$.

Results

Following damage simulation (Phase 1), a high density of linear scratches were visible of the surface of the PEEK Optima® plates resulting in a 10-fold increase in surface roughness (Ra, Rp and Rv) compared to pre-test values (Table 1). The roughness of the cobalt chrome plates was similar to pre-test values.

After 1MC wear simulation (Phase 2), the wear of the UHMWPE pins was similar ($p>0.05$) for negative control plates and those damaged with third body particles (Figure 3) against both PEEK Optima® and cobalt chrome. In the wear area on the PEEK plates, there was a region where the scratches had been polished out and as a result, the surface roughness significantly decreased (Table 1, Figure 4).

Table 1: Mean surface roughness of plates after damage simulation (Phase 1) and wear testing (Phase 2), n=3.

Parameters	Cobalt chrome			PEEK Optima®		
	Pre-test	Phase 1	Phase 2	Pre-test	Phase 1	Phase 2
Ra (µm)	0.011 ± 0.014	0.012 ± 0.015	0.011 ± 0.009	0.006 ± 0.002	0.054 ± 0.006	0.018 ± 0.008
Rp (µm)	0.058 ± 0.094	0.062 ± 0.088	0.053 ± 0.066	0.030 ± 0.013	0.245 ± 0.037	0.057 ± 0.018
Rv (µm)	0.025 ± 0.021	0.025 ± 0.018	0.023 ± 0.014	0.019 ± 0.003	0.248 ± 0.044	0.057 ± 0.027

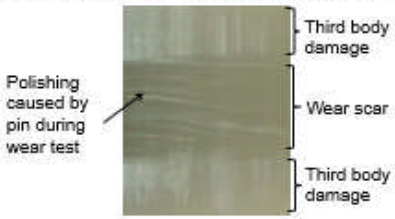

Figure 4: Surface of PEEK Optima® plates following damage simulation and 1MC wear simulation

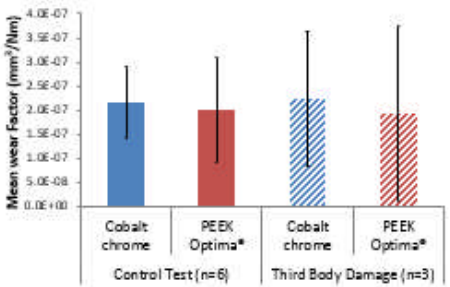

Figure 3: Mean wear factor of UHMWPE against control plates and plates damaged with third body particles

Discussion

- Third body damage to the PEEK Optima® plates did not influence wear of UHMWPE compared to negative (unscratched) controls and there was a polishing effect of the UHMWPE pin against the damaged region of the PEEK plate.
- Damage to metal counterfaces resulting in a lip height (Rp) of similar magnitude to that measured on the PEEK Optima® plates following damage simulation has previously been shown to influence the wear rate of UHMWPE [2].
- Damage simulation with PMMA cement had no influence on surface roughness of cobalt chrome plates or wear of UHMWPE.

Significance

This study showed that when used as an arthroplasty bearing material, PEEK Optima® can be damaged by third body particles of PMMA bone cement. However, the magnitude of damage created had no influence on the wear of UHMWPE and a polishing effect was seen on the surface of the plates in the wear area.

References

[1] Cowie, R.M. et al ISB, Glasgow, UK AS-0340

[2] Minakawa, H. 1998 JBJS(Br) 80-B:894-9

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