Institute of Medical & Biological Engineering

Friction of PEEK and Carbon Fibre Reinforced PEEK Bearing Couples under Contact Conditions Typical of the Cervical Spine

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Introduction and Aim

- Cervical total disc replacements (C-TDR) [Figure 1] are often made utilising ultra high molecular weight polyethylene (PE) and cobalt chromium (CoCr) bearing surfaces
- However, PEEK (polyetheretherketone) has begun to be implanted as a C-TDR bearing [1] and there is growing interest in other combinations of PEEK and carbon fibre reinforced PEEK (CFRP) [2]

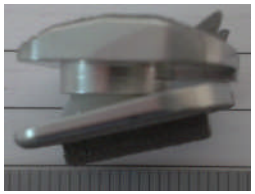

Figure 1 Example of a C-TDR (1 mm scale)

- **The aim** of this experiment was to assess the frictional response of PEEK and CFRP bearing material combinations under contact stress and sliding velocities approximating conditions in the cervical disc.

Materials & Methods

- A pin-on-plate rig used a pin loaded and displaced against a counterface plate, submerged in diluted bovine serum [Figure 2]
- Frictional force (F_R) was converted to a friction coefficient using $\mu = F_R/F_N$, where F_N= Normal reaction force to the load applied
- Results of PEEK and CFRP combinations were compared to a baseline control (PE on CoCr)

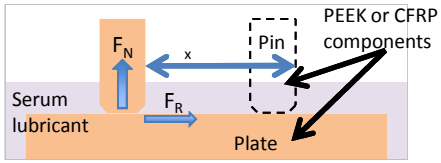

Figure 2 Pin-on-plate experimental set-up

- Experimental methods and materials are listed in Table 1
- Light microscopy (10x) and 3d profilometry were employed

Table 1 Materials and methods

Test Parameters	
Lubricant	25% bovine serum
Contact pressure	1 MPa
Sliding velocity	4 mms^{-1}
Sliding displacement (x)	20 mm
Friction Experiments	
Control test	PE pin on CoCr plate
PEEK and CFRP tests	PEEK pin on PEEK plate
	PEEK pin on CFRP plate
	CFRP pin on PEEK plate
	CFRP pin on CFRP plate

Results

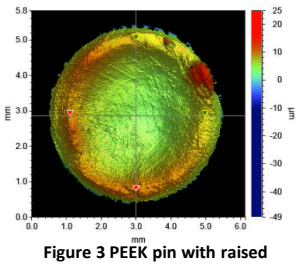

Figure 3 PEEK pin with raised debris (top right)

Figure 4 PEEK plate scar

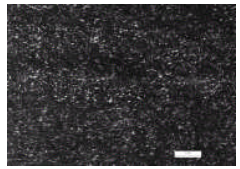

Figure 5 CFRP plate (showing carbon fibres)

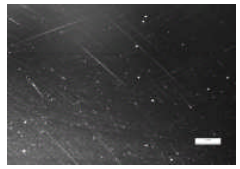

Figure 6 CoCr control plate

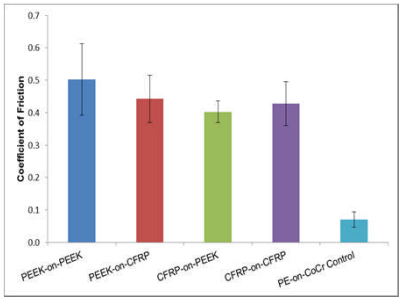

Fig 7 Pin-on-plate friction results for all four combinations of PEEK and CFRP bearings

- PEEK pins showed signs of debris re-attachment [Figure 3]; PEEK plates had deep groves [Figure 4]; CFRP plates were resilient to wear scar formation [Figure 5]; control CoCr plate showed no wear scar [Figure 6]
- No significant difference in friction between PEEK and CFRP combinations (1-way ANOVA, α=0.05), however, **all were significantly and substantially higher** than the PE-on-CoCr control [Figure 7]
- Squeaking and/or low-pitched humming were present on all tests except the PE-on-CoCr control
- Friction was generally much lower at the start of the experiments and reached steady state by approximately two minutes; some transient changes in friction were observed

Discussion

- High friction of all-polymer PEEK and reinforced PEEK bearing couples are important considerations for implant performance. Small transient changes in friction may have been due to attachment and subsequent loss of polymer material to the pin bearing face [Figure 3]
- Friction factor of ceramic-on-reinforced-PEEK total hip replacement has been shown to be 0.23 [3] which is ~2x lower than PEEK on PEEK in this study. Bearing combinations using different materials typically produce lower friction coefficients

References
1 Brown, T., et al., Spine (Phila Pa 1976), 2010. 35(16): p. E774-81.
2 Grupp, T.M., et al., Biomaterials, 2009. 31(3): p. 523-531.
3 Brockett, C.L., et al., Journal of Biomedical Materials Research Part B: Applied Biomaterials, 2012

Injection moulded PEEK and CFRP pins and plates were supplied by Invibio Biomaterial Solutions, UK

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