Introduction: Wear of polyethylene continues to be a significant factor in the clinical longevity of total knee replacement (TKR). To improve longevity and reduce wear, alternative materials have been investigated. Carbon-fibre reinforced poly-ether-ether ketone (CFR-PEEK) has shown promising results in experimental wear studies of hip and knee replacement [1-3]. The aim of this study was to explore the wear behaviour of PEEK and CFR-PEEK materials through simple configuration pin-on-plate studies, and examine the wear performance of these materials through experimental knee wear simulation.

Methods: PEEK (OPTIMA®) and CFR-PEEK (MOTIS®) pins, plates and custom knee inserts were injection moulded (Invibio Inc, UK). Two pin-on-plate studies were conducted to explore the effect of cross-shear on the wear of the materials, and the effect of counterface configuration. The cross-shear studies were conducted with flat-faced pins articulating with polished high carbon CoCrMo plates. Tests were conducted under an applied load of 80N, and the rotation/sliding distance adjusted to create several cross shear conditions (0, 0.039, 0.087, 0.18, 0.254; n≥3 for all conditions). High carbon CoCrMo pins, with curved counterfaces (35mm or 100mm radii) were paired with PEEK, CFR-PEEK or GUR1020 UHMWPE flat plates, and tested with an applied load of 80N and a cross shear ratio of 0.18. All studies were lubricated with 25% bovine serum. All studies were run for a period of one million cycles (Mc), with wear assessed gravimetrically every 1/3Mc. Six right Sigma CR fixed bearing TKRs (DePuy Synthes, UK) were paired with either PEEK or CFR-PEEK custom inserts (Invibio, UK) in a Prosim knee simulator (Simulator Solutions, UK). A flat geometry was selected as this has previously been shown to yield low wear in polyethylene bearings [4]. The tests were conducted under High Kinematics, with anterior-posterior and internal-external displacement control [4]. Tests were conducted for three million cycles, lubricated with 25% bovine serum, with wear assessed gravimetrically at 1 and 3Mc.

Results: The wear factor of the PEEK material was significantly higher than the CFR-PEEK material for all pin-on-plate test conditions (ANOVA, p<0.05). The PEEK material appeared to show increasing wear factor with increasing cross shear ratio. However, the cross-shear ratio appeared to have little effect on the wear factor of the CFR-PEEK material (Figure 1A). When the counterface configuration was reversed, it was apparent that PEEK still showed the highest wear factors (Figure 1B). However, the CFR-PEEK wear factors were also significantly higher than conventional UHMWPE (ANOVA, p<0.05). The effect of pin geometry appeared to have a significant effect on the wear factor of the CFR-PEEK material, but a less apparent effect on PEEK and UHMWPE. Extensive material loss and wear was observed in the total knee replacement study for both the PEEK and CFR-PEEK custom inserts at 3Mc (Figure 2). Large, deep wear scars were observed with evidence of some material failure and cracking.

Discussion: Previous literature has highlighted the influence of cross-shear ratio on the wear of polyethylene bearings [5]. Whilst there appeared to be a direct correlation between wear factor and
cross shear for the PEEK material, this relationship was not present for the CFR-PEEK material. In this
dpolymer pin/metal plate configuration, the wear factors for the CFR-PEEK were of a similar magnitude to
moderately cross-linked UHMWPE, and lower than conventional UHMWPE [5]. A change of
configuration to metal pin/polymer plate resulted in increased wear factors for both PEEK and CFR-PEEK,
and both PEEK and CFR-PEEK had significantly higher wear factors than conventional UHMWPE. Total
knee replacement wear simulation demonstrated very high wear rates for both materials, with evidence
of material failure. Wear rates for conventional UHMWPE under comparable conditions have been much
lower (<4mm³/Mc [4]). Previous studies of CFR-PEEK have examined highly conforming geometries of
hip and knee replacement, which would yield lower contact pressures than the present study.

**Significance:** This study highlights the importance of design and conformity when considering new
materials for total knee replacement. Whilst highly conforming designs such as total hip replacement
and conforming uni-compartmental knee replacements have shown CFR-PEEK to be a low-wear
material, this study demonstrates that in low conformity bearings, where higher stresses may be
generated, CFR-PEEK may be less suitable.

![Figure 1](image1.png)

Figure 1 (A) Effect of cross shear on wear factor (mean ± 1SD); (B) Effect of counterface configuration on
wear factors (mean ± 1SD)

![Figure 2](image2.png)

Figure 2: Mean wear rates for PEEK and CFR-PEEK (±95% CI)