Reduction of ultra high molecular weight polyethylene (UHMWPE) surface wear in total knee replacement (TKR) bearings may delay the onset of osteolysis and subsequent loosening of components. Crosslinking has been shown to increase the wear resistance of UHMWPE bearings in multidirectional total hip replacement applications when articulating against smooth counterparts [1]. The aim of this study was to compare the wear of crosslinked UHMWPE bearings with a standard UHMWPE material in a moderate constraint fixed bearing TKR using a physiological knee simulator.

Materials and Methods
Twelve (n = 12) PFC Sigma cruciate-retaining fixed bearing TKR (DePuy) were investigated. Curved, 10 mm thick UHMWPE inserts snap fit into titanium alloy tibial trays and articulated with Co-Cr-Mo alloy femoral components. Six commercially standard bearings were tested (1020 GVF). These were machined from GUR1020 UHMWPE before sterilisation with a nominal dose of 4.0 MRad gamma irradiation under vacuum. The standard bearings were compared with six custom inserts manufactured from Marathon*, which involved 5 MRad gamma irradiation of GUR1050 UHMWPE under vacuum followed by quenching in an inert atmosphere for 24 h at 155 °C and annealing. Three of the Marathon inserts were machined while three components were compression molded. All Marathon inserts were sterilised using gas plasma.

Testing was completed using a six-station knee simulator (ProSim, Manchester, UK). Femoral axial loading (max. 2600 N) and extension-flexion (0 – 58 °) input profiles were adopted from ISO 14243 (1999). Internal-external rotation (± 5 °) and anterior-posterior displacement (0 – 10 mm) inputs were based on natural knee kinematics [2]. The simulator was cycled at 1 Hz and the lubricant used for testing was 25 % (v/v) newborn calf serum with 0.1 % (m/v) sodium azide solution in deionised water. Each set of knee components was tested in the simulator under these standard conditions for five million cycles. A scratched femoral model was then introduced for a further million cycles. For this model, one scratch (R_p = 1 to 2 μm; R_v = 2 to 3 μm) was inscribed in the centre of each femoral component, parallel to flexion-extension to replicate in vivo TKR damage [3].

Gravimetric measurements of the inserts were obtained prior to testing and after every million cycles with unloaded soak controls used to ascertain moisture uptake. Volumetric wear was calculated from the weight loss of the inserts and using densities of 0.934 mg/mm³ and 0.932 mg/mm³ for the 1020 GVF and Marathon bearings, respectively.

Results
The 1020 GVF inserts exhibited a mean wear rate with 95 % confidence limits of 22.75 ± 5.95 mm³ per million cycles. This reduced to 13.36 ± 3.98 mm³ per million cycles with crosslinked Marathon bearings (Fig. 1) and the difference was highly significant (p < 0.01). No significant difference in UHMWPE wear rate was observed between the machined and molded Marathon inserts (p > 0.05). Surface damage on the tibial trays and femorals was similar for both sets of TKR components and the bearings of different material exhibited similar wear modes.

Under scratched femoral counterpart conditions, no significant change in wear rate was observed for either bearing material (p > 0.05) with mean wear rates of 23.21 ± 8.77 and 16.09 ± 9.22 mm³ per million cycles for the 1020 GVF and Marathon bearings, respectively.

Discussion
Molecular orientation of UHMWPE induces anisotropy and weakens the inter-fibre strength in the transverse direction (strain softening), reducing wear resistance when subjected to cross-shear on the articulating surface. Crosslinking retards molecular mobility and therefore reduces the extent of molecular orientation. The use of crosslinked acetabular cups in hip simulator studies articulating against smooth counterparts significantly decreases the wear rate in comparison to uncrosslinked bearings [1]. In fixed bearing knees, a degree of multidirectional motion occurs at the femoral-insert articulating surface, although this is less than that experienced in a total hip joint. Previous studies have shown that increased tibial rotation kinematics in PFC Sigma fixed bearing TKR resulted in increased polymer wear due to greater cross shear on the surface of the UHMWPE [4]. Therefore, for high kinematic patients it is appropriate to consider some level of crosslinking in total knee bearings.

The PFC Sigma Marathon crosslinked inserts provided a significant 40 % reduction in volumetric wear rate compared with the standard 1020 GVF moderately crosslinked material. Therefore, use of an UHMWPE bearing with greater levels of crosslinking, such as Marathon, reduces polymer wear in fixed bearing total knee replacements under high rotation kinematic conditions by preventing molecular orientation and strain hardening. This phenomenon was independent of the manufacturing method used for the tibial inserts, that is whether molding or machining processes were utilised, similar to previously reported data [5].

The damage model employed in this testing revealed that scratching parallel to flexion-extension did not significantly accelerate wear of the medium crosslinked Marathon material or the moderately crosslinked 1020 GVF bearings.

A deterioration of mechanical properties by crosslinking of UHMWPE is of great concern in TKR applications. Therefore, use of a medium level of crosslinking such as Marathon is beneficial as it allows maintenance of mechanical properties while providing a significant reduction in UHMWPE surface wear.

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![Figure 1: Mean wear rates with 95 % confidence limits](image-url)

**References**


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