CROSSLINKED UHMWPE IN TOTAL KNEES: CLEAN VERSUS ABRASIVE CONDITIONS

INTRODUCTION
Crosslinked ultra high molecular weight polyethylene (XPE) of various formulations is currently being used clinically to help reduce wear in acetabular liners of total hip arthroplasty (THA). Based on the success of XPE materials in hip applications, the use of these materials in the knee is being explored. Clean (non-abrasive) knee simulator wear tests for XPE materials have already demonstrated significant wear reductions [1]. Nonetheless, XPE has not found widespread clinical use in total knee arthroplasty (TKA) primarily because the crosslinking process inevitably leads to reductions in critical mechanical properties such as toughness and fatigue strength [2]. This is particularly important because it has previously been common to find delamination and cracking, both of which are fatigue phenomena, in some embrittled TKA tibial inserts [3]. Contemporary XPE materials, however, are stabilized against oxidative aging [4]. Therefore, the risk of mechanical breakdown in XPE tibial inserts may be reduced sufficiently to warrant use in TKA clinically [5]. An additional factor to be considered prior to the clinical use of XPE in tibial bearings is resistance to abrasive wear. Clinically retrieved CoCr femoral components typically show surface scratching from third body abrasion [6], which can lead to accelerated wear of the tibial components. To-date there are no reports in the literature addressing the effect of scratched femoral components on the knee simulator wear behavior of XPE materials.

This study was undertaken to investigate the knee simulator wear performance of a 10 Mrad crosslinked UHMWPE under (1) clean conditions, and (2) simulated abrasive conditions, with scratched femoral components.

MATERIALS AND METHODS
Knee simulator (AMTI, Watertown, MA) testing to 5 million cycles was conducted on conventional, non-crosslinked (C-PE) and 10 Mrad crosslinked (10-XPE) UHMWPE under clean and simulated abrasive conditions (n=3). Ram extruded GUR 1050 bar stock (PolyHi Solidur, Ft. Wayne, IN) was used to manufacture C-PE and 10-XPE (10 Mrad γ-irradiation, melt anneal) tibial inserts. The inserts were terminally sterilized with EtO. The femoral components (ASTM F-75 CoCr) were used out of sterile packaging and left clean, or tumbled in a centrifugal mass finisher which contained 25 μm alumina and abrasive-embedded plastic cones. This protocol has been reported to produce scratches similar to those observed on retrieved femoral components [6].

Roughness measurements of the femoral components were taken using a Surfcom 575A Profilometer (Tokyo Seimitsu, Japan) with a 2 μm radius stylus tip and a cut-off length of 0.8 mm. Ten roughness measurements were made at pre-selected locations from 0° to 45° of flexion on each condyle of each femoral component. Measurements were made before and after tumbling. Statistical significance (p=0.05) was determined using ANOVA assuming unequal variances.

Knee simulation was carried out in 50% Alpha calf bovine serum at 1 Hz, with a load/motion simulating walking gait and stair climbing at a ratio of 10:1. Walking gait inputs were 16.2 kg to 256 kg axial load, 2.3° to 50° flexion, 2.5° external to 7.5° internal rotation, 4.9 mm anterior to 7.3 mm posterior translation. Stair climbing inputs were 30 kg to 259 kg axial load, 10° to 95° flexion, 0.5° to 5.2° internal rotation, 0.1 mm to 10.8 mm posterior translation. Gravimetric measurements were made every 500,000 cycles.

RESULTS
The tumbling protocol employed in this study increased the roughness of CoCr femoral components to values which were within the range reported for clinically scratched components [7]. Rz increased from 0.06 ± 0.01 to 0.12 ± 0.02 μm (p<0.05), Ra increased from 0.22 ± 0.04 to 0.83 ± 0.28 μm (p<0.05), and Rpk increased from 0.09 ± 0.03 to 0.24 ± 0.09 μm (p<0.05).

Clean Conditions. The gravimetric wear rates are shown in Figure 1. C-PE wore measurably greater than 10-XPE (11.2 ± 1.04 mm/Mc vs. -0.51 ± 0.20 mm/Mc, p<0.05).

Simulated Abrasive Conditions. The gravimetric wear rate of 10-XPE increased dramatically compared to clean conditions (70.4 ± 2.85 mm/Mc vs. -0.51 ± 0.20 mm/Mc, p<0.05). The wear rate of C-PE increased by approximately 245% compared to clean conditions (11.2 ± 1.04 mm/Mc clean vs. 38.8 ± 2.58 mm/Mc abrasive, p<0.05). The wear rate of 10-XPE was 84% greater than C-PE under abrasive conditions.

DISCUSSION/CONCLUSION
In this knee simulator study, the 10-XPE material showed virtually zero gravimetric wear under clean conditions. Under simulated abrasive conditions, however, the gravimetric wear rate of the 10-XPE material was dramatically increased to a level 84% greater than the wear rate of non-crosslinked material.

This knee simulator study confirmed previous findings that under clean, ideal conditions thermally stabilized crosslinked UHMWPE demonstrates a considerably reduced gravimetric wear. However, the clinical conditions are unlikely to remain pristine, leading to scratching of femoral components. Under simulation of such abrasive conditions, the gravimetric wear rate of crosslinked UHMWPE increases dramatically. Furthermore, the wear rate of crosslinked UHMWPE under these abrasive conditions were greater than for non-crosslinked UHMWPE. This abrasive knee simulator finding is in contrast to abrasive hip simulator results, which show crosslinked UHMWPE maintaining an advantage over non-crosslinked UHMWPE [8]. Further investigation of the use of crosslinked UHMWPE for tibial bearing components is therefore warranted to determine if the benefit of reduced wear under clean conditions is outweighed by the risk of accelerated abrasive wear. A cautionary approach to clinical use of crosslinked UHMWPE in TKA is advocated based on these findings.

REFERENCES
5. Laurent et al., Trans ORS, p. 158, 2002.

Figure 1: Gravimetric wear rates for non-crosslinked and 10 Mrad crosslinked UHMWPE under clean and simulated abrasive conditions.