EFFECT OF MULTIPLE ACTIVITIES ON WEAR OF UHMWPE IN CRUCIATE-RETAINING (CR) KNEES

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Introduction: A vast majority of the simulator wear studies to date were performed using walking gait motion. However, typical activities of daily living (ADL) such as stair climbing, chair rise and double leg squatting rise impose more severe conditions on the knee joint. For example squatting involves flexion angles over 150°, internal tibia rotation above 25° and peak load of 5-6 times body weight. The purpose of this study was to simulate the effect of ADL on wear of a prosthetic knee implant.

Materials and methods: Six NexGen® Cruciate-Retaining (CR) and six high flexion (CR-Flex) knee implants (Zimmer Inc., Warsaw, IN) were tested for 5.5 million cycles (Mc). All the knees were articulated against aged conventional (CPE) and crosslinked (HXPE) ultra high molecular weight polyethylene (UHMWPE) inserts. The CPE inserts were gamma sterilized at a dose of 37 KGy while the HXPE ones were electron beam irradiated with a dose of 65 kGy melt annealed and gas plasma sterilized. A displacement controlled knee simulator (AMTI Boston, MA) was used and the implants were tested in undiluted bovine calf serum lubricant (JRH Biosciences, Lenexa, Kansas,) containing 8g/L disodium EDTA and 3g/L sodium azide bactericide. Wear of the tibial inserts was determined gravimetrically.

The test protocol [1], divided in three phases, was designed to reproduce the ADL as quantified by Morlock et al [2]. Phase I consisted of 3 million cycles (Mc) of walking gait to account for run-in wear and establish a common baseline for both types of knees. In Phase II, the implants were subjected to a multigait sequence composed of 97% trigait (chair rise, stair climb and walk) and 3% low squat (walk + 125° flexion).

Table 1. Distribution and testing frequency for ADL

	Phase I 1.0 to 3.0 Mc	Phase II 3.0 to 5.0 Mc						Phase III 5.0 to 5.5 Mc	
Activity	Walk	Walk	Chair	Walk	Stair	Walk	125° Squat	Walk	152° Squat
Freq (Hz)	1.1	1.1	0.5	1.1	0.8	1.1	0.33	1.1	0.33
ADL (%)	100	43.7	4.5	43.7	5.4	1.8	0.9	67	33

Phase III, applied to CR-Flex knees only for 0.5Mc was composed of walking and deep squatting (152° flexion). The sequence consisted of 2500 loops of 150 cycles of walking and 50 cycles of deep squatting. This phase simulated extremely severe deep squat activity and was intended to test the ability of the inserts to sustain severe conditions for a relatively high frequency of occurrence. The overall load/motion testing conditions have previously been published [1].

Results and Discussion: Fig. 1 shows the time dependent load soak-corrected average weight loss of the articulating surfaces. Table 3 shows the wear rates corresponding to various ADL activities. During the walking gait, HXPE showed a 72% wear improvement over CPE, in agreement with previous results. [3]. The introduction of multigait activities did not significantly increase the wear rate of both HXPE and CPE inserts. This may be due to the very small amount of overall ADL (10.8%) cycles. High flexion activity has a dramatic effect on the wear rates of both types of inserts as clearly shown in Table 3. The wear rate of HXPE doubled (when compared to that during walking) while that of CPE was increased by approximately an order of magnitude. At greater flexion angles (152° deep squat), the radius of curvature in the sagittal plane of the femoral component is reduced resulting in a smaller contact area and the potential for higher contact stresses. While no delamination or cracking was observed on the HXPE inserts, most of the aged CPE samples delaminated and fractured during this severe high flexion activity.

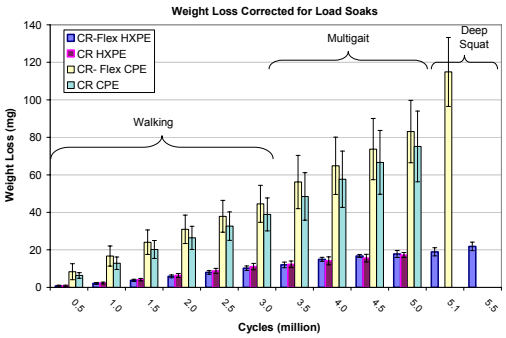

Figure 1: Weight loss of NexGen CR and CR-Flex polyethylene inserts as a function of number of test cycles

Table 3: Wear rates of CPE and HXPE during various ADL activities

	Material	CR		CR-Flex	
		Wear Rate (mg/Mc)	P Value (Relative to walking)	Wear Rate (mg/Mc)	P Value (Relative to walking)
Walking (0 to 3 Mc)	CPE	12.97 ± 2.94	-	14.85 ± 3.29	-
	HXPE	3.69 ± 0.57	-	3.41 ± 0.39	-
Multigait (3 to 5 Mc)	CPE	18.12 ± 5.50	0.07	19.28 ± 4.89	0.13
	HXPE	3.09 ± 0.54	0.094	3.8 ± 0.67	0.25
High Flexion (5 to 5.5 Mc)	CPE	-	-	273.80 ± 23.25*	0.002
	HXPE	-	-	8.6 ± 2.16	0.006

* CR-Flex CPE at 5.1 Mc

Conclusion: Within the limits studied, the presence of ADL did not significantly increase the wear rate of crosslinked and conventional UHMWPE inserts. CR and CR-Flex knees produced similar wear rates during walking and multigait motions. Testing under high flexion and high load dramatically increased the wear rates of both type of inserts. The wear of HXPE doubled while that of CPE increased by more than an order of magnitude. Wear reduction and delamination resistance of HXPE was more pronounced for high flexion accommodating implants and activities. CPE inserts underwent delamination and fracture while the HXPE inserts remained intact with only minor surface changes.

References: 1) Johnson et al, ORS 2004; 2) Morlock et al, J. Biomech., 2001, 34, 873-881; 3) McKellop et al., Proc. ORS, 1998, 98-17