EFFECTS OF A-P TRANSLATION AND ROTATION ON THE WEAR OF UHMWPE IN A TOTAL KNEE JOINT SIMULATOR

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Introduction: In TKR, UHMWPE wear is strongly affected by the knee kinematics. With flexion, a normal knee shows posterior shift of the femoral condyle, whereas anterior shifts of the femoral condyle with knee flexion have been observed in some TKRs. Several reports have shown that the distance of anteroposterior (A-P) translation of TKR patients is longer than in normal knees. These abnormal A-P translations observed in TKR patients may lead to a ploughing action followed by delamination from subsurface failure of the UHMWPE. The purpose of this study was to examine the effects of A-P translation and rotation on the wear of UHMWPE tibial inserts on TKR, using the displacement-input simulator.

Materials and methods: A servo-hydraulic, computer-controlled three-channel knee simulator and Anatomic Graduated Component (AGC) knees were used. The loaded stance phase (0-20° flexion) was run with the modified Paul knee load-profile at 2.6 kN peak-load with 1.75 Hz frequency. The lightly loaded swing phase was omitted. For Exp. 1, there was no tibial A-P translation or I/E rotation, while for Exp. 2, tibial I/E rotation was added at ±5°. For Exp. 3, the tibial A-P translation was added at +12 mm during flexion, simulating the PCL-retaining TKR. For Exp. 4, the tibial A-P translation was added at +12 mm, now simulating physiological femoral "roll-back" posteriorly (Fig.1). The control-soak test was performed statically in the same kind of serum as that used in the simulator study. The experiment was conducted in 50% bovine serum with 0.2% sodium azide and EDTA added. The lubricant was changed approximately every 500,000 cycles, and the worn tibial inserts and static-soak inserts were weighed. The simulator performed up to 5.5-6.0 million cycles. The gross wear was determined by the weight-loss method, and the linear-regression technique was used to determine the wear rate.

Results: Wear trends appeared to be reasonably linear in all experiments, with the correlation coefficient ($R^2$) ranging from 0.85 to 0.99 (Fig.2). After correcting for the water absorption, the net wear rate for the UHMWPE tibial insert averaged 1.7 ±0.3, 10.6 ±2.1, 15.1 ±2.6 and 18.8 ±2.7 mg/Mc in Exps. 1, 2, 3 and 4, respectively. The statistical analysis (ANOVA) indicated significant differences between all of the experiments except Exp. 3 vs 4. In Exp. 1, rectangular-shaped wear scars with burnished surfaces were observed. In Exp. 2, with I/E rotation added, the wear tracks became broader. In Exp. 3, with femoral anterior shift, the wear track extended anteriorly, while in Exp. 4, with femoral posterior shift, the wear track extended posteriorly. Longitudinal scratches were observed in all specimens. However, neither cracking nor delamination was observed on the surfaces.

Discussion: Some studies have been performed for which knee kinematics and the TKR wear rates were reported. Wang et al. reported that the average wear rate was 14.4 mm³/Mc (15.3 mg/Mc) with I/E rotation at 6/7.5°, dropping to 3.9 mm³/Mc (4.2 mg/Mc) without rotation. In our study, I/E rotation increased the wear rate from 1.7 mg/Mc to 10.6 mg/Mc, also suggesting that I/E instability caused a greater amount of damage to the tibial UHMWPE. Blunn et al., in their study using a combination of cylindrical metal and flat UHMWPE discs, reported dramatically increased polyethylene wear with cyclic sliding compared with compression or rolling motion. Some reports, however, suggest tractive forces during rolling motion as an important factor leading to polyethylene damage in TKR, which is compatible with our results. Both the additional sliding (tibial A-P translation at -12 mm) and rolling (+12 mm) contributed to the higher wear rate. Further investigations are necessary to evaluate the potential of new in-vitro tests and to examine other types of knee prostheses to demonstrate whether different knee geometries produce different wear patterns. We plan to investigate this problem in the near future. However, the present study has shown encouraging results for knee simulators, which might be powerful tools for future TKR investigations.

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