1. Introduction

Unicompartmental Knee Replacement (UKR) is increasing in popularity as a surgical procedure for the treatment of osteoarthritis (OA), particularly with its suitability for utilising minimally invasive (MI) surgical techniques. There is evidence in the literature of promising in vivo survivorship with 98% and 84% at 10 and 22 years respectively [1, 2] but currently there is limited data regarding the in vitro wear performance of UKRs.

Historically, ultra high molecular weight polyethylene (UHMWPE) oxidation and fatigue failure was of significant concern for the in vivo wear performance of joint replacements (JR), but as sterilisation procedures and material properties improve, wear debris generation and osteolysis induced implant loosening are developing prominent roles in JR long term clinical performance [3].

The aim of this study was to investigate the in vitro wear and wear performance of various kinematic inputs and lateral variations of the Preservation MI UKR system (DePuy, UK) using a knee simulator, focusing on the effect of variations in kinematic inputs and femoral condylar lift-off.

2. Methodology

The influence of kinematic inputs and femoral condylar lift-off on the in vitro wear of six medial and six lateral mobile bearing Preservation UKRs (DePuy, UK) was investigated using a physiological six-station ProSim knee simulator (Simulator Solutions, UK). All UKRs were size 3 systems with Co-Cr-Mo alloy femoral and tibial components interposed by a mobile 9.5mm thick GUR 1020 GVF UHMWPE insert.

One medial and one lateral UKR system was mounted anatomically within each station of the knee simulator. The central axis of the two systems was offset by 5mm from the aligned axes of the femoral load and tibial rotation to replicate a right knee. As the UKR design relies upon the constraints provided by soft tissue in vitro, testing was carried out using displacement control. Three variations of kinematic conditions were used for this investigation: High kinematic inputs without lift-off for 5 million cycles (Mc), intermediate kinematics without lift-off (2Mc) and intermediate kinematics with lift-off (2Mc).

High kinematic inputs were defined as: maximum femoral axial loading of 2600N; flexion-extension (F-E) range of 0º to 58º; anterior-posterior (A-P) displacement of -10mm; internal-external (I-E) rotation of ±5º. Intermediate kinematics made use of the same profiles for axial load, F-E and I-E rotation, but used a reduced A-P displacement range of 0 to -5mm [3]. Femoral condylar lift-off was simulated during the swing phase of the gait cycle by introducing an adduction moment to the tibial carriage. Between 1 and 1.5mm of lateral femoral condylar lift-off was achieved each cycle before returning to full contact at the beginning of the stance phase [4].

The test lubricant used was 25% (v/v) newborn bovine serum supplemented with 0.1% (w/v) sodium azide as an antibacterial agent. The simulator operated at a frequency of 1Hz and the test lubricant was supplemented with 0.1% (w/v) sodium azide as an antibacterial agent.

Volumetric wear rates of inserts were determined gravimetrically and moisture uptake was monitored using unloaded soak controls. Insert wear rates were calculated as an average volume loss per million cycles on completion of the three individual studies.

3. Results & Discussion

The mean in vitro wear rates for both medial and lateral variations of the mobile bearing Preservation UKR are shown in Figure 1.

On completion of the 5Mc high kinematic input study, the mean wear rates for the medial and lateral UKR systems with 95% confidence limits were 7.1±1.5mm/Mc (n=6) and 9.9±3.1mm/Mc (n=6) respectively. Although the lateral system wear rate was elevated when compared to that of the medial, this difference was not statistically significant. The increased lateral wear rate is however consistent with previous in vivo studies demonstrating inferior lateral UKR long-term survivorship when compared to medial UKR systems [5].

Reduced A-P displacement (intermediate kinematic inputs) resulted in a reduction in both medial and lateral system mean rates of wear. An overall reduction of 5mm in A-P displacement reduced both medial and lateral wear by 3mm/Mc to 3.8±0.7mm/Mc (n=6) and 6.9±2.4mm/Mc (n=6). Consistent with the high kinematic input study, lateral wear was greater than that of the medial system, but this difference was not statistically significant. Reducing A-P displacement reduces both sliding distance and UHMWPE surface wear area, which in other in vitro studies has been shown to significantly reduce UHMWPE wear [3].

The introduction of 1-1.5mm of femoral condylar lift-off increased medial wear to 5.6±1.7mm/Mc (n=6), but resulted in a further reduction in lateral wear to 4.8±2.2mm/Mc (n=6). Under lift-off, the superior surfaces of the medial UHMWPE inserts showed evidence of light pitting, moderate plastic deformation and adhesive wear, whereas the lateral inserts showed only light adhesion, polishing and minimal deformation. This more aggressive medial wear is consistent with other in vitro studies and can be explained by the elevated contact stresses at the medial UKR interfaces and in some part the resulting cross-shear from the induced medial lateral motion during lift-off [4]. For this in vitro study femoral condylar lift-off was simulated every cycle of gait. However, in vivo frequency would determine the clinical significance of femoral condylar lift-off on the long term wear performance of UKRs.

4. Conclusion

This study investigated the in vitro wear of both medial and lateral variations of the mobile bearing Preservation UKR (DePuy, UK). Anatomical mounting, including offset, allowed for the parallel testing of medial and lateral UKRs. UKR wear was highly dependent upon A-P displacement and the introduction of lateral femoral condylar lift-off resulted in more aggressive medial wear, but a reduction in wear of the lateral UKR system.

There is current uncertainty regarding the clinical benefits of UKR. This study has shown that without lift-off, UKRs can achieve significantly lower in vitro wear rates than fixed bearing total knee replacements (TKRs) and similar wear rates to mobile bearing TKRs [3]. This study has also shown that UKRs may be more robust to variations in kinematics, demonstrating that following the introduction of lift-off, a three-fold reduction in UKR mean in vitro wear rate can be achieved when compared to fixed and mobile bearing TKRs [4].

References

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