COMPARISON OF WEAR IN FIXED AND MOBILE BEARING KNEE DESIGNS

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Introduction

Ultra High Molecular Weight Polyethylene (UHMWPE) remains the only bearing surface of choice in total knee replacements (TKR). While excellent medium term results can be found for knee replacements at ten years, there remains concerns about wear debris induced osteolysis in the longer term, particularly in young and more active patients. It has been shown previously that the wear of fixed bearing knees increases markedly with elevated kinematic inputs, as might be expected in more active, high demand patients. While in the knee there is interest in modified polyethylenes to reduce wear and osteolytic potential, little is known about the impact of different design variables. Rotating platform (RP) mobile bearing knee design options are now becoming available in a number of fixed bearing knee designs. The aim of this study was to investigate the wear of a rotating platform mobile bearing component with that of a fixed bearing component of the same design.

Materials and Methods

The wear of six PFC Sigma Rotating Platform (DePuy, Leeds, UK) mobile bearing knees was investigated. These comprised of six 10mm thick 1020 UHMWPE curved PFC Sigma RP inserts, which were sterilised in foil pouches by 2.5-4.0 MRads gamma irradiation in a vacuum (GVF). Each insert rotates around a central stem location in a CoCrMo alloy tibial tray and congruently mates with a corresponding CoCrMo femoral component, independently of the tray placement. This provides maximum conformity for low contact stress. These were compared with twelve fixed bearing PFC Sigma knees. These comprised of PFC Sigma 1020 UHMWPE, 10mm thick GVF sterilised tibial inserts. These snap fit into titanium alloy tibial trays and articulated against CoCrMo alloy femoral components.

Testing was performed in a six station knee simulator (ProSim, Manchester, UK). Samples were rotated around the different stations in the simulator each million cycles to minimise station variability. The six PFC Sigma RP and six PFC Sigma components were tested using ‘high’ kinematics. ‘High’ kinematics inputs were based on natural knee kinematics and subjected the knees to ± 5° internal/external (IE) rotation and 0-10mm anterior-posterior (AP) displacement. For the PFC Sigma RP the AP displacement was force controlled using ISO 14243 (1999) AP force profile (-262N to 110N) as the RP design restricts AP movement. ‘Low’ kinematic inputs were half the ‘high’ kinematics at ± 2.5° IE rotation and 0-5mm AP displacement. The low kinematics were used to test the remaining six PFC Sigma components. Femoral axis loading (maximum 2.6kN) and flexion-extension (0-58°) were adopted from ISO 14243 (1999) and used for both low and high kinematics. Testing was performed at 1Hz using a 25% (v/v) newborn calf serum (Harlan Serlab, Loughborough, UK) with 0.1% (m/v) sodium azide solution in de-ionised water. Knee components subjected to high kinematics were tested to 5 million cycles (PFC Sigma RP and PFC Sigma) whereas the PFC Sigma tested under low kinematic inputs was tested to 3 million cycles.

Gravimetric analysis was performed every million cycles using a Mettler AT201 microbalance (Leicester, UK) with unloaded soak controls to adjust for moisture uptake. Volumetric wear was calculated from the weight loss of the insert using a density of 0.934mg/mm³. Digital images of the wear scars on the upper bearing surface of the tibial inserts were also obtained every million cycles using Image-Pro Plus software (Media Cybernetics, MD, USA). Femoral and tibial tray surface damage was analysed using a Form Talysurf (Taylor Hobson, Leicester, UK) stylus profilometer.

Results

The mean wear rate with 95% confidence limits for the PFC Sigma fixed bearing was 3.9 ± 2.9 mm/million cycles (MC) under low kinematic conditions, and was 22.75 ± 5.95 mm/MC under high kinematic conditions. In contrast, the wear of the PFC RP under high kinematics was 5.1 ± 5 mm/MC (figure 1). The PFC Sigma (low) and PFC Sigma RP had significantly (p<0.05) lower wear rates than the PFC Sigma fixed bearing under high kinematic inputs.

The mean wear scar areas for the PFC Sigma (low), PFC Sigma (high) and PFC Sigma RP were 42 ± 4%, 48 ± 3% and 78 ± 3% respectively. The more conforming PFC Sigma RP design gave rise to larger contact areas and reduced contact stress.

Figure 1: Mean Wear Rates with 95% Confidence limits

Discussion

The wear rate for the PFC Sigma rotating platform was significantly lower than that for the fixed bearing PFC Sigma under the same kinematic conditions. The larger wear scars seen on the PFC Sigma RP indicate the greater conformity of the rotating platform, however this did not increase the wear. In the fixed bearing knees an increase in the IE rotation increased the wear rate by a factor of five. Under the high kinematic conditions, additional cross shear of the polyethylene orients it in the flexion-extension and AP axes, markedly accelerating the wear rate. In the rotating platform design the IE rotation is decoupled to the inferior tibial surface which provides a linear rotational motion. The resulting motion at the femoral surface is primarily (flexion-extension and AP translation) linear with very little cross shear, which results in low wear rates.

The rotating platform design significantly reduced wear compared to the fixed bearing knee, under high kinematic conditions. Rotating platform designs are likely to benefit young, active and high demand patients.

References


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