THE INFLUENCE OF FEMORAL CONDYLAR LIFT OFF ON THE WEAR OF ARTIFICIAL KNEE JOINTS

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Introduction

Although current designs of total knee replacements (TKR) exhibit good results at ten years, there remain concerns that in the longer term accumulation of polyethylene wear particles will cause osteolysis and loosening. Recent in vitro knee simulator studies have shown that surface wear and generation of wear particles are highly dependent on the kinematic input conditions, with increases in anterior/posterior translation and internal/external rotation producing a five fold increase in wear rate [1]. The effect of knee prosthesis design has been shown to be equally important, with a mobile bearing rotating platform TKR design producing a four-fold reduction in wear compared to a fixed bearing TKR [2]. In vivo fluoroscopic studies of patients with knee prostheses have shown considerable differences in kinematics between different designs and compared to the natural knee. Notably, lift off of the femoral condyles from the tibial insert has been observed in many patients [3, 4, 5]. The aim of this study was to investigate the influence of femoral condylar lift off on the wear of fixed bearing and mobile bearing TKRs using a physiological knee joint simulator.

Materials and Methods

The wear of fixed bearing (FB) and mobile bearing (MB) Rotating Platform (RP) design TKRs was investigated using the commercially available PFC Sigma TKR (DePuy, Leeds, UK). In the fixed bearing design, 10 mm thick curved UHMWPE inserts were assembled by snap fit into titanium alloy tibial trays. In the mobile bearing design, rotation of the UHMWPE tibial insert relative to the polished cobalt chrome alloy tibial trays was permitted. Both designs articulated against Co-Cr-Mo alloy cruciate retaining femoral components, and the tibial inserts were GUR 1020 UHMWPE which had been sterilized in foil pouches by gamma irradiation in a vacuum (GVF).

The testing was performed on six station knee simulators (Prosim, Manchester, UK) using femoral axial loading (max. 2600N) and flexion-extension (0 - 58°) profiles taken from ISO 14243 (1999). Intermediate kinematic input conditions, which consisted of internal-external (IE) rotation ±5° and anterior-posterior (AP) displacement 0-5 mm, were used for the FB knees [2]. For the MB knees standard kinematic input conditions were used. These consisted of IE rotation ±5° and an AP force profile adopted from ISO 14243 (1999). -262 to 110 N) [2]. Each design of knee was tested under these kinematic conditions with and without lateral femoral condylar lift off for up to 5 million cycles, and six knees of each design were tested under each condition. The femoral condylar lift off was achieved by introducing an abduction addition rotation torque. This increased the contact moment to the tibial carriage to produce between 1 and 1.5 mm of lateral femoral condylar lift off during the swing phase of the gait cycle, returning to full contact when the peak load was applied at the start of the stance phase. The simulator was run at 1 Hz and the lubricant used was 25% (v/v) newborn calf serum with 0.1% (m/v) sodium azide solution in deionised water. Wear of the tibial inserts was determined gravimetrically, using unloaded soak controls to compensate for moisture uptake. Volumetric wear was calculated from the weight loss of the inserts using a density of 0.934 mg/mm³. Statistical analysis was performed using Students t-test.

Results

The mean wear rates with 95% confidence limits for each design of TKR, with and without lift off, are shown in Figure 1. In the absence of lift off the PFC Sigma RP MB knees exhibited a lower wear rate at 5.2 ± 3.8 mm³ per million cycles (mm³/MC) compared to 9.8 ± 3.7 mm³/MC for the PFC Sigma FB knee. This difference was statistically significant at the 90% level. Both designs of TKR saw statistically significantly increased wear rates when femoral condylar lift off was simulated (p < 0.01 for both the FB and MB designs). For the FB knees the wear rate increased to 16.4 ± 2.9 mm³/MC, and the MB knees saw a three-fold increase to 16.9 ± 2.9 mm³/MC. The wear rates of the FB and MB TKRs were very similar (p < 0.76) under lift off conditions.

The femoral articulating surface of all of the inserts showed more burnishing wear on the medial condyle. However, under lift off conditions the medial condyle was more aggressively worn showing evidence of adhesion and surface imperfections. In contrast, the lateral side of the inserts were only lightly burnished.

Discussion

The presence of femoral condylar lift off accelerated the wear of the PFC Sigma FB and RP MB knees. For the MB knees the acceleration in wear rate was more marked, resulting in a similar wear rate for both designs of knee under lift off conditions. In both cases the medial condyle displayed more wear damage. This could be due to elevated contact stresses as the lateral lift off produce uneven loading of the bearing and the dynamic loading conditions observed at the start of the stance phase. Furthermore, it was likely that cross shearing of the polyethylene was extremely important on two counts. Firstly, in terms of increasing the wear of both designs due to additional medial/lateral sliding of the medial condyle whilst it remained in contact. The medial/lateral direction is weakened when the polyethylene is preferentially molecularly orientated by sliding in the flexion-extension axis. Secondly, the benefit of the reduced wear rate for the MB knee observed under standard kinematic conditions is due to the design being able to decouple motions to simple linear motions at the femoral and tibial countereface [2]. This benefit was reduced under lift off conditions due to the increase in multidirectional motion and resulting cross shears of the polyethylene on the medial condyle. In the simulator test lift off was simulated on every cycle. The amount of wear and effect of lift off clinically would depend on the frequency of occurrence of lift off in vivo.

Conclusion

Lateral femoral condylar lift off has resulted in higher wear rates on the medial compartment for the PFC Sigma fixed bearing and rotating platform mobile bearing total knee replacements.

Figure 1: Mean Wear Rates with 95% Confidence Limits

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References


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