In-vitro wear of fixed and mobile bearing unicompartmental knee replacements

+1Brockett C L; 1Jennings L M; 1Fisher J
+1Institute of Medical and Biological Engineering, University of Leeds, Leeds, UK
J.Fisher@leeds.ac.uk

Introduction

Unicompartmental knee replacement (UKR) is an increasingly popular surgical intervention for the treatment of osteoarthritis, involving the replacement of only one compartment of the natural knee. There is promising clinical literature which shows excellent long term survivorship of both fixed and mobile bearing UKR, with fixed bearings showing more consistent long-term performance [1]. There is limited data examining the in-vitro performance of UKR [2].

The purpose of this study was to investigate the influence of bearing design and kinematics on the in-vitro wear performance of medial and lateral unicompartmental knees.

Materials and Methodology

The wear of the unicompartmental knees was investigated using a physiological six station Prosim knee wear simulator (Simulator Solutions, UK). Two size-matched bearing designs were tested, a fixed bearing (size 3, GCK, DePuy) and a mobile bearing (size large, Oxford, Biomet). The GCK (XLK – cross-linked GUR1020 polyethylene) polyethylene bearing, that had a low conformity, clipped into a polished cobalt chrome (CoCr) tibial tray. The more conforming spherical Oxford polyethylene bearings (ArCom – Argon packaged, compression moulded polyethylene) were guided to slide anteriorly-posteriorly along a polished CoCr tray. The femoral components of the UKR system were polished CoCr. Three sets of medial and lateral bearings were tested for each design, mounted anatomically in each test station. The central axis of the two implants was offset from the aligned axes of applied load and tibial rotation to replicate a right knee.

Two kinematic conditions were used for this study, both under anterior-posterior (AP) displacement control; intermediate kinematics for 5 million cycles (Mc) and high kinematics for 3Mc. Intermediate kinematics were defined as a maximum femoral axial loading of 2600N, flexion-extension of 0 to 58º, an anterior-posterior displacement of 0-5mm, and an internal-external rotation of ±5º. High kinematics used the same profiles for loading, rotation and flexion-extension, but used an increased anterior-posterior displacement of 0-10mm [3].

The lubricant was 25% (v/v) calf serum supplemented with 0.03% (w/v) sodium azide solution in deionised water, as an antibacterial agent, and was changed approximately every 0.33Mc. Wear was assessed gravimetrically at 1, 3 and 5 Mc for intermediate kinematics, and at 1 and 3 Mc for high kinematics, and moisture uptake was assessed using unloaded soak controls of both designs. Volumetric wear was calculated using a density of 0.934mg/mm³, and statistical analysis was performed using one-way ANOVA.

Results

The mean wear rates for the medial and lateral bearings of both designs, under intermediate and high kinematics are shown in Figure 1, with the corresponding wear rates in Table 1. The large 95% confidence limits indicated on the Oxford medial bearings, under intermediate kinematics, were due to edge loading occurring on one insert, resulting in increased wear. The wear rates for all bearings were higher under high kinematics compared with intermediate kinematics, but this increase was not statistically significant (p>0.05). There was no significant difference when comparing the mean wear rates of the medial and lateral bearings within a design, under both high and intermediate kinematics, although the mean wear rates were higher in the medial bearing for both designs (p>0.05).

The wear of each medial and lateral bearing set was combined to give a ‘total knee’ wear rate for each design (n=3). The mean wear rate of the Oxford bearing was significantly higher than the GCK bearing under intermediate kinematics (p=0.03), but the difference was not significant under high kinematics (p>0.05) (Figure 2).

The mean wear scar areas on the superior surface of the Oxford and the GCK bearings were 60.7% and 20.8% of the total bearing surface respectively.

Discussion and Conclusions

This study investigated the in-vitro wear performance of the medial and lateral variations of fixed and mobile bearing UKRs. The lateral bearings for both designs had lower wear rates than the medial bearings under both intermediate and high kinematics, although the difference was reduced under high kinematics. The fixed bearing UKR showed reduced wear rates compared with the mobile bearing UKR for both medial and lateral variations, under high and intermediate kinematics.

The GCK bearing is a fixed bearing, where the contribution of backside wear to the overall wear rate was likely to be low due to the design. The Oxford mobile design is a sliding bearing, which may have increased backside wear on the inserts. The wear scars, expressed as a percentage of overall bearing surfaces, confirmed the higher conformity of the Oxford bearing, compared with the GCK bearing. Low conformity in fixed bearing total knee replacement has previously been shown to be a low wearing implant option [4]. The difference in wear rates of the two designs may also be affected by the materials, as the GCK implant used a cross-linked GUR1020 polyethylene, and the Oxford bearing was a argon-packaged compression moulded polyethylene. The combined ‘total knee’ data under high kinematics, for both designs, showed a lower mean wear rate than a fixed CoCr total knee replacement tested under the same kinematic conditions [4].

This study has demonstrated that under in-vitro wear test conditions, a relatively low conforming fixed UKR shows reduced wear, in both medial and lateral bearings, compared with a more conforming AP sliding mobile bearing.

Acknowledgements

This work is supported by the NIHR (National Institute for Health Research) as part of a collaboration with the LMBRU (Leeds Musculoskeletal Biomedical Research Unit). The study was also supported by DePuy International, Leeds and the EPSRC.

References