Wear and Roughening of Knee Replacement Components

INTRODUCTION:

Knee replacements provide a cost effective treatment for the treatment of severe arthritis (Laverman et al. 1997; Liang et al. 1986) and in the USA total knee replacement has overtaken total hip replacement (Klenerman 2002). Many knee replacements fail on the basis of infection, primary malalignment at surgery and aseptic loosening (Ecker et al. 1987) often requiring revision knee arthroplasty operations. The incidence of revision surgery is higher if the patient is less than 65 years old (Drury P et al. 2007).

Tripling the roughness of the femoral surface of the knee replacement can increase the ultra high molecular weight polyethylene (UHMWPE) wear by a factor of 10 (Schmalzried and Callaghan 1999) and a few scratches on a metallic surface can increase the wear rate of UHMWPE by a factor of 70 (DesJardins et al. 2008). It has been shown that roughened femoral components increase the UHMWPE wear rate by more than a factor of 3 (Muratoglu et al. 2004) and that the wear rate of UHMWPE is proportional to Ra1.4 (Weightman and Light 1986).

METHODS:

Retrieval analysis: Implants were retrieved from first and single stage revision arthroplasty procedures at RNOH and RFH, then soaked in Hycolin for 24 hours for decontamination. Average surface roughness (Ra) was measured using a profilometer (Talsurf 10, Taylor Hobson LTD, UK) with Vh and Vy set at 0.08mm and 10000x respectively. Measurements were taken at 6 points across 3 regions of the articulating region on each condyle, giving 18 values which were averaged to give an overall Ra for each condyle. The average surface roughness from a non-articulating region on each component was also measured to serve as a control.

Wear test: 6 spherical radius CoCr pins were hand polished to a mirror finish. 6 discs of UHMWPE were cut from the same cylindrical bar, hand polished and γ-irradiated in vacuum. A six station hydraulic pin-on-plate fatigue testing machine (RDP-Howden LTD, UK) was used and set up to conditions of: 1 Hz cycles at 20° Celsius, an axial load of 1.5kN, 5° internal and external rotation, and 10 mm of A-P sliding, using fluid which was 30% calf serum (Newborn calf serum from bovine calves, sterile filtered, Sigma Aldrich Inc, USA), 1% sodium azide and 5mMol/L 2-[2-(bis(carboxymethyl)amino)ethyl]- (carboxymethyl)aminocetic acid (EDTA). Ra was measured at 0, 10, 100 and 1000 cycles perpendicular to the direction of movement of the pins using the profilometer above.

Statistical analysis was made using Excel 2007 (Microsoft Corporation, USA) and SPSS 16.0.1 (SPSS Inc, USA). Surface roughness measurements were compared using paired samples T-test. Ethical committee permission was granted by the Ethics committee of The Royal National Orthopaedic Hospital.

RESULTS:

Retrieval analysis: 14 CoCr knee replacement components were retrieved. Average duration in situ was 78 months (9-241 months), average patient age was 69 and the implants came from 6 females and 7 males. 1 had no corresponding clinical data. 2 of the components were unicompartmental, and the remaining were all posterior cruciate retaining from 7 different manufacturers. All of the femoral components appeared to have visible signs of wear on inspection. All had parallel scratching in an anterior-posterior direction. No pitting, abrasion or corrosion was seen on any of the femoral components. Parallel lines were seen under scanning electron microscopy indicating scratching of the CoCr surface belonging to a unicondylar femoral knee replacement component which was found to be significantly (p<0.05) roughened.

Wear test: After 10 cycles the disc surfaces lost their mirror finish, after 100 cycles, there were visible scratches along surface of the pin in the same plane as which the pin was moving relative to the UHMWPE disc. After 1000 cycles central regions of the articulating surface of the pin appeared more dull, and had more scratches across its surface. Scanning electron microscopy of the articulating surface of the CoCr pins showed parallel marks consistent with scratching at 100 and 1000 cycles. After 100 and 1000 cycles the average roughness articulating surface of the CoCr pins was significantly greater than the initial average roughness at 0 cycles.

DISCUSSION:

A large proportion – 8 out of 14 retrievals - of knee replacement components roughened significantly in vivo, supporting the hypothesis. Significant roughening of total knee replacement components may begin very soon after implantation, as indicated by the early macro-pitting. However, average surface roughness of those significantly roughened was within acceptable limits for orthopaedic implants (0.05μm). Further work is to be carried out in an attempt to determine the cause of the roughening of the femoral components of the knee replacement prostheses.

REFERENCES


