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Failure analysis of retrieved UHMWPE tibial insert in total knee replacement

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ABSTRACT

This study involves the failure analysis of an ultra high molecular polyethylene (UHMWPE) tibial insert from Apollo® Total Knee System, which was removed after 10 years of service from 70 years old female patient. The tibial insert was investigated by using a stereoscope, scanning electron microscope (SEM), infinite focus microscope (IFM) and energy disperse spectroscopy (EDS) to characterize the morphology and composition of the bearing surface. Differential scanning calorimetry (DSC) and Fourier transform spectroscopy (FTIR) were employed to characterize the degradation and crystallinity of the component. Gel-permeation chromatography (GPC) was used to measure the polyethylene tibial insert molecular weight. Results showed that the failure of total knee replacement (TKR) was associated with high grade wear and oxidation degradation. Surface delamination, scratch marks, pitting, folding, and embedded third body particles were observed on the retrieved UHMWPE tibial surface. Pit depth as large as 60 μm was measured on the surface. The damage features observed on the UHMWPE tibial insert suggested degradation is due to fatigue related wear and is oxidation-induced. Overall results show that the UHMWPE tibial insert which was retrieved from a patient who is active and but not overweight underwent degradation of material properties and high grade wear during 10 years of service.

1. Introduction

Ultra high molecular weight polyethylene (UHMWPE) has been used as a load bearing and articulating counterface in total knee replacement (TKR) for the past 40 years [1]. Polyethylene wear is considered a major limitation of long term success of TKR [2,3]. Analysis of retrieved polyethylene components has been carried out by a number of researchers to reveal the evidence of the TKR failure [4–9]. Their work has helped to characterize and analyse the failure due to wear of polyethylene tibial insert against metal femoral component. Recent studies have dealt with a number of polyethylene tibial inserts from the TKR. The groups of retrieved tibial insert were analyzed by using Hood's grading scale system. The surface of tibial insert was divided in 10 regions and the wear damage on the surface was measured based on the extent and severity of the seven damage modes (pitting, scratching, burnishing, embedded particulate debris, abrasion, permanent deformation and surface delamination). Then, the total damage was achieved by sum the score for all seven modes across all the ten regions. The results then were compared by considering different factors which could cause their failure.

Previous study by Engh et al. [4] compared the wear mode of two different designs of tibial insert, namely mobile and fixed bearing knee inserts. They found that TKR with increased contact areas between metal and polyethylene components can result in reduced contact stresses and decreased wear. Ashraf et al. [10], in their retrieval analysis, determined the wear

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