SEM WEAR-MODE OF EXTENSIVELY CROSS-LINKED POLYETHYLENE CUP SURFACE AND WEAR DEBRIS

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(Introduction) Polyethylene (PE) wear debris can cause severe osteolytic changes within the space of only a few years of clinical use in active patients. This process appears to be the major long-term limitation of total hip arthroplasty (THA). Our experimental studies demonstrated that wear was minimal for PE cups treated with 50-1000 Mrad of radiation, due to the extensive cross-linking. Our radiological evidence showed a 5 to 6 fold reduction in wear compared to non-irradiated PE cups. At present, the far lower dose of 2.5 Mrad is universally used. The objective of this study was to compare the wear mode of retrieved 100 Mrad PE cups to simular cups run in a hip simulator and to investigate the effect of gamma irradiation on the morphology of UHMWPE wear debris.

(Materials and Methods) 3 each 0, 2.5, 50, 100 and 150 Mrad PE cups were run in 9 channel simulator (6.2 million cycle duration, Paul, 2kN maximum load at 1Hz using 30% bovine serum). Retrieved cups (N=5) included 0 Mrad @ 8yr (N=1, SOM), 2.5Mrad @ 13-18yr (N=2, T28) and 100Mrad @ 15yr (N=2, SOM). The cups were examined using a SEM (Philip XL30 FEG) for wear scar locations and PE wear-topography. Two sections were cut and coated for SEM analysis of the bearing surface. PE wear debris was collected from the simulator studies for SEM analysis and subjected to image-analysis to quantify the size and shape of PE surface fibrils lying on the cup surfaces.

(Results) Original machine marks were observed in the weight-bearing areas of the highly cross-linked PE in-vitro. No machine marks were observed for the 0 and 2.5 Mrad cups in-vitro and none were seen in any of the retrieved cups. The formation of more nodules and fibrils in the 0 Mrad cups compared to the extensively cross-linked cups (in-vitro and retrieved) was striking (Fig. 1,2). The frequency of occurrence and length of fibrils and nodules was dependent on the dose of gamma irradiation as demonstrated by log-log plots of fibre length versus radiation dose (Fig.3). More ripples were formed in the 2.5 Mrad and higher-dose cups compared to the non-irradiated cups both in-vitro and retrieved (Fig.4). The in-vitro cups formed more ripples than the retrieved cups. Scratches were found in the 0 and 2.5 Mrad retrieved cups probably due to abrasive or third body wear. Very few scratches were found in the in-vitro cups. In general, the SEM features for simulator Mrad cups appeared similar to those of the retrieved Mrad cups.

(Discussion) (1) The simulator Mrad cups accurately reflected the conditions of the PE cups in the living body. Therefore, comparison of retrieved PE cups with simulator PE cups appeared to be a very powerful research tool.
(2) After original machine marks worn away by intial shearing, a fine array of ripples formed perpendicular to predominant motion, accompanied occasionally with short fibrils originating from the top of the ripples. Further severe wear on PE surface induced, the disruption of such ripples, forming numerous PE nodules with long fibrils.
(3)The extensively cross-linked PE cups appeared to be a significant improvement over conventional PE cups in terms of wear resistance. These data support our previous radiographic findings of 5 to 6 times less wear.


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