A Study on Surface Topology of Polydioxanone after In Vitro and In Vivo Degradation

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INTRODUCTION

In vitro and in vivo degradations are among the most important properties for bioabsorbable polymeric biomaterials. Despite many publications by other investigators, one underexplored area is the investigation of surface morphology change during degradation, particularly by an advanced surface analysis techniques. In this abstract, atomic force microscopy was used to examine the change of surface topology of polydioxanone films following in vitro and in vivo exposure.

MATERIALS AND METHODS

The materials were experimental PDO film samples with a thickness of 0.5 mm. The film samples were made in-house from extruded dyed PDO films. For the purpose of this study, the film samples were cut with a metal die cutter into specimens with dimension of 50×4 mm. For in vitro conditioning, the samples were placed into phosphate buffer solution (PBS) of pH7.3 at 37°C. For in vivo study, the samples were implanted subcutaneously into the both backs of the rats following a good animal care procedure. At each pre-determined time period, specimens were removed, and dried in a nitrogen box, and then subjected to the analysis. An atomic force microscope (AFM) (Nanoscope V, MulitMode, Veeco Instruments) was used to examine the surface topology of the PDO sample. The instrument was operated in tapping mode using a RTESP tip (Veeco Probes). The image was captured with the scan rate of 0.5 Hz and the resolution of 512 x 512 pixels. Depending on the scan size, integral gain of 2 ~ 5 and proportional gain of 1 ~ 3 were used during the scanning.

RESULTS AND DISCUSSION

A simple indication of hydrolytic degradation can be determined by the progression of surface topography of the sample. Figs 1 and 2 show the change of surface topography after the in vivo and in vitro degradation. Overall, the results indicate that in vivo degradation rate of PDO was relatively faster than the in vitro rate. It is believed that the metabolism and physical activity of the animal would increase the degradation of the PDO. From the surface analysis of AFM images, a two-stage degradation process is proposed. In the first stage, the degradation of PDO causes short-range surface grooving and cracking on a nanometric scale. This surface grooving effect can be observed in the in vitro samples of 6-weeks and 8-weeks (Fig 1). No micrometric crack is observed in the first degradation stage. After reaching a critical degradation time, the long-range degradation initiates and results in micrometer-sized cracks. However, in the regions between large cracks, the surface grooving effect dominating in the first stage still continues as observed in the 10-weeks in vitro sample and the 2-weeks, 4-weeks and 6-weeks in vivo samples. In Fig 3, the roughness changes of the PDO surface based on the AFM topography image as a function of the degradation time is illustrated. Statistical analysis of the data from the first degradation stage showed no significant change in surface roughness from 0 to 2 weeks for the in vivo samples (p=0.147) and from 0 to 8 weeks for the in vitro samples (p=0.678). For the in vivo samples, the surface roughness shows linear regression with the degradation time during the second degradation stage, suggesting a different degradation rate when compared with the rate in the first stage. The roughness analysis also suggests that the onset of long-range degradation occurs approximately in 1 to 2 weeks of in vivo degradation and 8 to 10 weeks of in vitro degradation.

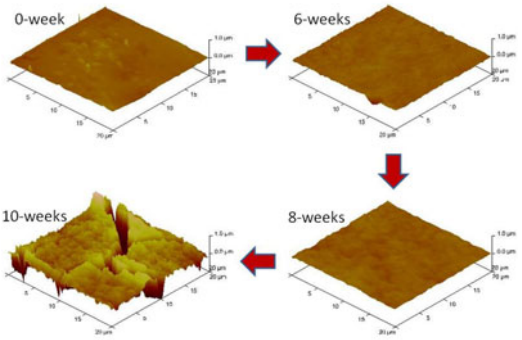

Fig 1. Progression of surface topography after in vitro degradation

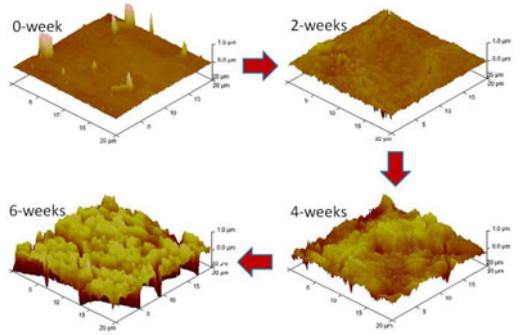

Fig 2. Progression of surface topography after in vivo degradation

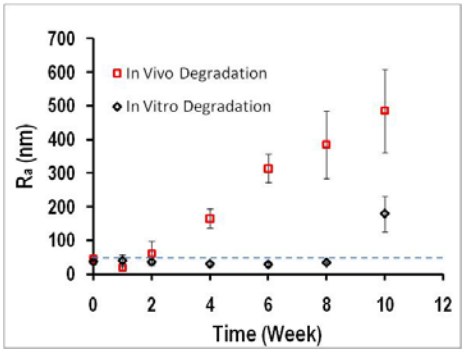

Fig 3. Changes of surface roughness during degradation. The dash line indicates the initial surface roughness before degradation.

CONCLUSIONS

The in vitro and in vivo degradation of a PDO film was studied by AFM analysis. The hydrolytic degradation of PDO is a two-stage degradation process. Two distinct degradation properties (short-range and long-range) were observed. Both topography analysis and roughness analysis were used to determine the transition between the two degradation stages and to further understand the degradation properties of the PDO films.

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