Surface Modification of PEEK to Aid Primary Human Osteoblast Attachment and Functionality

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Introduction: Polyetheretherketone (PEEK) has due to its high strength, good wear and radiolucent properties come into the spotlight as a replacement for metals in devices such as spine cages and craniomaxillofacial (CMF) implants[1]. X-ray and MRI evaluation of soft and hard tissue integration to implants can be obscured or distorted by the presence of the metal devices. Several implants have therefore been re-designed in PEEK to allow ease of visualisation. However, cellular attachment to polymers such as PEEK is restricted due to its low surface energy, which can lead to implant loosening, as a result of fibrous encapsulation. To aid cell attachment the surface energy can be increased by plasma surface treatment. The importance of surface oxygen for cell attachment is well established[4], though the effect of the specific oxygen functional groups such as alcohol/ether(C-OR), carbonyl (C=O) and carboxyl (O-C=O) is less understood and has been shown to vary depending on cell type[2,3]. The present study aims to investigate the effect of these functional groups on the attachment and functionality of primary human osteoblast-like cells (HOB).

Materials and Methods: Injection moulded PEEK Optima™ discs (Invibio) with a 13mm diameter were modified by radio frequency (RF) plasma treatment, Thermanox (Nunc) and Ti ISO 5832/2 (Synthes) were used as the control surfaces. Using an EMITECH RF plasma treater, the samples were exposed to varying treatment times. Surface chemical compositions of treated and untreated surfaces were characterised by XPS, wettability by contact angle; topographic changes by AFM and SEM. HOB cells isolated from femoral heads removed during total joint replacement operations were grown to 70-80% confluence in DMEM (10% FCS in 5% CO_2 at 37°C), and plated at 10000 cells/cm^2. Alpha-MEM (0.1µM dexamethasone and 10mM beta-glycerophosphate) was used as mineralisation media over 21 days. Cell functionality was assessed by alkaline phosphatase expression (ALP), mineralisation by Alizarin red S staining of calcium, cell attachment by SEM and cell density through alamarBlue™ assay.

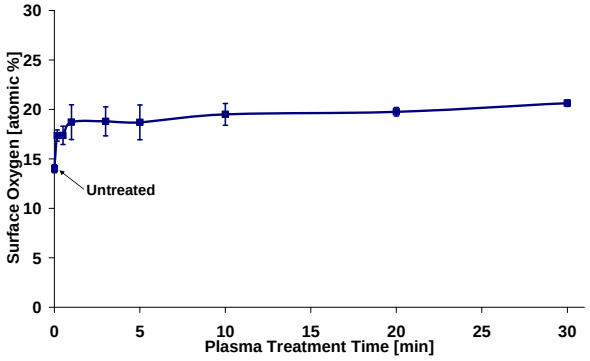

Figure 1: *Surface oxygen concentration of PEEK surfaces with increasing plasma treatment time.*

Results: XPS analysis of the untreated PEEK showed the presence of 14 atomic% surface oxygen, indicating that these surfaces are relatively hydrophobic in character. The treated PEEK surfaces showed the surface oxygen concentrations to increase with increasing treatment time up to ~20 atomic%, figure 1. High resolution C1s spectra showed a greater increase in C-OR type functional groups than C=O and O-C=O with increasing treatment time. To study the effects of the surface treatment on cell attachment and functionality, the cells were observed after plating on the treated and untreated PEEK, THX and Ti discs. Within 24hrs, the treated surfaces were shown to have higher cell densities than the untreated surfaces. By day 21 the treated surfaces were shown to have similar cell densities to Ti. Initial findings indicate that surfaces with higher C-OR and lower C=O and O-C=O functional group concentrations have higher initial HOB cell attachment and this trend continues to day 21, in contrast to the surfaces with lower C-OR and higher C=O and O-C=O concentrations.

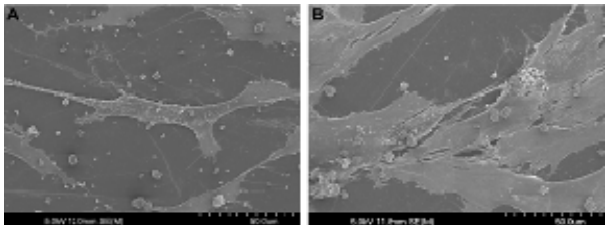

Figure 2: *SE micrographs of cellular attachment after 3 days culture, a) untreated PEEK and b) treated PEEK.*

Cells were also observed by SEM to attach more readily to the surfaces with higher concentrations of C-OR functional groups, figure 2, where a) shows the typical attachment to the untreated surfaces and b) shows the typical more flattened attachment on the surfaces with higher CO-R concentrations. ARS staining and ALP expression were observed to be more characteristic on the surfaces with higher concentrations of C-OR functional groups.

Discussion/Conclusions: This study shows that the incorporation of oxygen with plasma treatment can be used to increase the surface energy and thereby aid the adhesion of cells. These findings indicate that the overall influence may be an optimal concentration of C-OR, and the C=O and O-C=O type functional groups are less influential on HOB cell attachment and functionality. Over the 21 day period the HOB cells were shown to behave characteristically on the treated surfaces and by day 21 the ALP expression was higher than on the untreated surfaces and similar to the levels observed on Ti.

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