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In vitro characterization and osteoblast responses to nanostructured photocatalytic TiO_2 coated surfaces

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ABSTRACT

The aims of the study were to characterize a nanostructured photoactive titanium dioxide (TiO_2) coating and to compare the cellular response of human osteoblasts before and after ultraviolet (UV) irradiation of the coating. A specific nanostructured TiO_2 powder (Degussa P-25), which consists of approximately 80% anatase and 20% rutile, was spin-coated onto commercially pure titanium discs, and was heat-treated thereafter. After topographical, chemical and photocatalytic property characterizations, human osteoblasts were cultured on the coated discs before and after UV irradiation. Cell morphology was evaluated by scanning electron microscopy (SEM), and cell viability was analysed by 3-(4,5-dimethylthiazol)-2,5-diphenyltetrazolium bromide (MTT) assay. From the contact angle analysis, the wettability significantly improved after UV irradiation. The cultured cells were flattened with numerous elongated lammellipodia; however, no morphological differences were indicated between –UV and +UV surfaces. The MTT assay analysis showed that –UV surface presented significantly higher viability compared to the +UV surface except for one cell population group at 3 h where there were no differences. The nanostructured photoactive TiO_2 surface improved its hydrophilicity by UV irradiation, however no enhancing effect in cell response was confirmed at the time tested compared to the non-irradiated surface.

1. Introduction

A photocatalyst is a semiconductor with the ability to create relatively stable electron-hole pairs upon adsorption of photons. In the presence of oxygen or water, free hydroxyl radicals may form that are strong oxidation agents with the ability to oxidize and break down organic compounds to CO_2 and water [1]. Fujishima and Honda [2] demonstrated that, upon ultraviolet (UV) irradiation, one of the commonly used photocatalysts, titanium dioxide (TiO_2), decomposed various organic compounds, which functioned as electrochemical photolysis material. Furthermore, the same group reported that surfaces covered with TiO_2 showed a significantly decreased contact angle after UV irradiation [3]. In this regard, all forms of TiO_2 are potential photocatalysts, and most of the titanium implants available on the market possess some form of TiO_2 on its outermost layer due to the oxidation from air. Since it has been well proven and documented that the hydrophilicity of the implant surface is an important factor for osseointegration [4–7], the photocatalytically driven hydrophilicity is expected to enhance osseointegration. Hence, Sawase et al. [8] investigated the biological effect, i.e. the early bone apposition of photocatalytically induced hydrophilicity on commercially available anodic oxidized implants. It was shown that UV irradiation affected these implants and the surface turned hydrophilic from a hydrophobic state; however, its effect on osseointegration could not be confirmed in animal studies. It was concluded that the outermost layer of the oxidized surface was amorphous, and implied that not all forms of TiO_2 respond in a similar manner to UV irradiation. Several studies suggested that, in order to present photocatalytically driven hydrophilicity, a certain crystalline structure of TiO_2 (such as anatase or rutile) much thicker than the native oxide, might be necessary [1,8,9]. Furthermore, it has been reported that the surface area and nanotopography may affect the photocatalytic activities due to the expansion of the area exposed to UV irradiation [10,11].

In this study, we have focused on a specific nanostructured TiO_2 powder (Degussa P25, Degussa GmbH, Germany), consisting of anatase and rutile crystalline structures, which has been reported to present high photoactivity [12–14]. Since this unique form of

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