Improved Osteoblast Response to UV-Irradiated Superhydrophilic PMMA/TiO_2 Nanocomposites

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Introduction: PMMA (poly-methyl-methacrylate) bone cements have been widely used in orthopedic surgery for more than half century. While this material has a good mechanical strength and easy processing feature with low cost, an osteointegration is not sufficient. Weak interface of surrounding bone tissue with PMMA causes the implant doesn't strongly adhere to the bone and thus loosening occurs, which is the main reason of bone implant failures. Additives (e.g., Hydroxyapatite, TiO_2 fibers) are commonly used to enhance the osteoblast cell proliferation resulting in robust adhesion between bone and orthopedic implants.[1] However, complications sometimes occur due to limited mechanical and biological properties of PMMA. One potential way to enhance the osteointegration of PMMA bone cement is to convert the surface to more hydrophilic. It has been demonstrated that increasing hydrophilicity increases the prevalence of osteoblast cell adhesion in the orthopedic applications.[2] In this study, TiO_2 nanoparticles were added in the PMMA resulting in controllable wettability of the composite material simply by UV irradiation.[3] The decreased wettability (i.e., hydrophilic surface) increases the number osteoblast attachment. Osteoblast cell adhesion of the composites of various volume ratios of PMMA and TiO_2 were also prepared and evaluated.

Methods: PMMA powder (Aldrich, MW 15,000, USA) was mixed with 10ml methyl isobutyl ketone (MIBK) and 5ml 2-propanol (IPA). TiO_2 nanoparticles (P25, Evonik Industrie, Germany) were added to the uniform solution in three different volume ratios of PMMA (25:75, 50:50 and 75:25), followed by ball-milling of the mixtures for 12hr. Homogenous pastes were deposited on silica glass by spin coating method (3000rpm for 40sec). Each sample was dried in the air, annealed at 120ºC, and treated with UV light (wave length of 365nm and power density of 1.1mW/cm^2) in different duration (i.e., 0hr, 4hr and 8hr). MC3T3 cells (osteoblasts) were cultured on all samples for 48hrs. The morphology of MC3T3 cells adhered on samples was characterized by scanning electron microscopy (Jeol-JSM 6610 LV, Japan).

Results: The wettability of PMMA/TiO_2 nanocomposites were investigated as functions of UV irradiation time and PMMA:TiO_2 volume ratio. Figure 1 represents the decreased contact angles of three samples with different ratios (25:75, 50:50 and 75:25) depending on UV irradiation time (0hr, 4hr and 8hr). The 50:50 and 25:75 (PMMA: TiO_2) ratio nanocomposite samples showed a significant decrease in the contact angle (i.e., superhydrophilic domain, contact angles < 10°) after 8hr UV irradiation because physical and chemical reaction between PMMA and TiO_2 and orientation of PMMA determines the contact angle of the composite with UV irradiation. By degradation of surface polymer under longer UV irradiation, covered TiO_2 are exposed to the surface resulting in the increased hydrophilicity.[3]

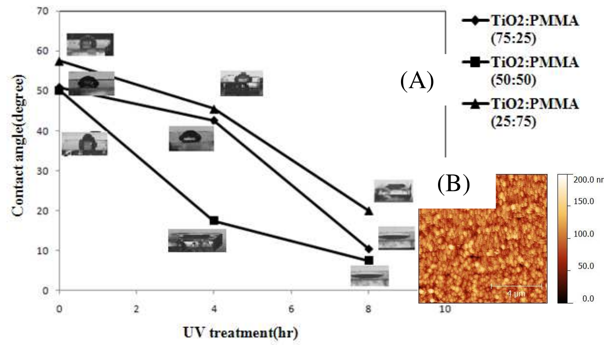

Figure1. Contact angle variation of PMMA/TiO_2 nanocomposite (A) and surface morphology of 25:75 sample before UV irradiation (B).

While no cells were observed in the sample without UV irradiation (Fig. 2A), all superhydrophilic surfaces after UV irradiation showed significantly higher number of cells (e.g., ~1100 cells per mm^2 for 8hr UV irradiated 25:75 PMMA:TiO_2 sample) compared with non-superhydrophilc surfaces. Figure 2 shows representative scanning electron microscopy images of 25:75 PMMA: TiO_2 sample after the cell adhesion test. Therefore, it is demonstrated more than 50% of TiO_2 nanoparticles added PMMA composite created superdhydrophilic surface after 8hr UV irradiation. The optimal ratio of PMMA:TiO_2 was found as 25:75 and the UV irradiation duration was 8hr.

(A)No UV irradiation (B)after 8hr UV irradiation

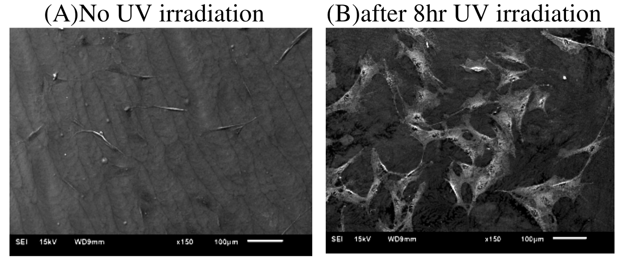

Figure 2. SEM images after MC3T3 cell adhesion test with 25:75 TiO_2:PMMA nanocomposites: (A) no UV and (B) after 8hr UV irradiation

Conclusion: These results demonstrate that superhydrophilic surface created by 8hr UV irradiation of PMMA/TiO_2 (25:75 ratio) nanocomposites significantly enhanced osteoblast cell adhesion compared to non-hydrophilic surface. This surface may confer enhanced cell attachment *in vivo*, suggesting that the PMMA/TiO_2 nanocomposite is a possible superior material for bone cement or coating material of orthopedic materials.

References:

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