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CHARACTERIZATION AND EVALUATION OF ALUMINA NANOPARTICLES DISPERSED ULTRAHIGH MOLECULAR WEIGHT POLYETHYLENE AS HARD TISSUE REPLACEMENTS

by

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Abstract

In order to partially or totally replace defective hard tissues, biomaterial scientists have been looking for synthetic ceramic-polymer composites to match the composition, microstructure, and properties of natural hard tissues. Pure Ultrahigh Molecular Weight Polyethylene (UHMWPE) and its nanofiller composites have a broad range of applications in the biomedical engineering field due to their superior properties. This work aims at studying the use of alumina (Al2O3) nanoparticles as a reinforcing agent for a polymeric matrix based on ultrahigh molecular weight polyethylene (UHMWPE). In spite of the verity that extremely long chains and high molecular weight determines the superior properties of UHMWPE, it simultaneously imposes restrictions on its processing. It has been deep-dyed that the extremely high melt viscosity of UHMWPE originates from the immense entanglements density of the long polymeric chains, which hinder the molecular chain mobility. In that vein, decreasing entanglements density is anticipated as a feasible method to improve the processability of UHMWPE using injection molding, which represents the gold standard among other manufacturing techniques. Hence, the optimum injection molding processing parameters should be obtained before production of UHMWPE/Nanofiller composites. Groups of UHMWPE samples have been prepared at different processing parameters such as barrel temperature, injection pressure, mold temperature, and holding time in both barrel and mold. Using these optimized injection molding parameters, alumina (Al2O3) nanoparticles dispersed UHMWPE samples were fabricated at different nanofiller concentrations. The mechanical, thermal, physical, and chemical properties of the injection molded samples were measured to investigate the impact of processing parameters and Alumina nanoparticles concentration. Different characterization techniques were used. Among these, tensile testing, Thermo-Gravirmetric Analysis (TGA), Differential Scanning Calorimetry (DSC), Scanning Electron Microscopy (SEM), and Fourier Transform Infrared Spectroscopy (FTIR). Moreover, the optimally prepared composites were subjected to in vitro evaluation using mice gastric stem (mGS) cells to evaluate their potential as hard tissues' partial and total replacements. In vitro assessment of injection molded composites intended for biomedical applications is an essential step to confirm the non-toxicity and to ensure that the bio-inertness of the components is maintained. It has been noticed that the characteristics of the produced composites are highly dependent on alumina nanofiller concentration. A prominent improvement of almost 23% and 361% in the yield strength and Young's modulus, respectively, were achieved by the addition of 25 wt.% Al2O3 compared to that of the neat UHMWPE. On the contrary, fracture strength and strain at break values were decreased by around 31% and 89%, respectively. Failure of implanted materials occurs when it yields under service conditions; hence, the increase in the yield stress is more critical than the decrease in fracture stress. The work relevant to optimizing the injection molding processing parameters for UHMWPE in literature is very scanty; therefore, there is an increasing demand to conduct more researches in this area. Based on the results of this study, optimum injection molding processing parameters were specified to produce robust UHMWPE samples. These optimum parameters were used later to produce UHMWPE/Nanofiller composites.

Keywords: Biomedical, Biomaterials, Implants, Composites, Nano-Technology, Polymers, Injection Molding, Ultrahigh Molecular Weight Polyethylene (UHMWPE), Alumina (Al2O3), In VITRO.