Ultra Smooth Nanocrystalline Diamond Coatings for Dental Implant Applications

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Statement of Purpose: Wear of articulating surfaces is a major problem in dental devices, including the temporo-mandibular joint (TMJ), which resides in very close proximity to the eye, the ear, various nerves, and the brain[1]. The National Institute of Dental and Craniofacial Research (NIDCR) of the National Institutes of Health (NIH) states that over 10 million people in the United States suffer from TMJ problems at any given time. In some cases, TMJ implant devices are needed and their success is greatly influenced by the degree of wear at articulating surfaces. A major goal is to develop ultra smooth and wear resistant coatings on the articulation surfaces in order to reduce the friction and wear in mating total joint replacement components. We developed ultra smooth nanocrystalline diamond coatings (USND) that are hard, ultra smooth, wear resistance and biocompatible.
Methods: Ultra smooth nanocrystalline diamonds (USND) were deposited on medical grade Ti-6Al-4V by plasma assisted chemical vapor deposition (MPCVD) using $He/H_2/CH_4/N_2$ feed gases. Surface wettability of the substrates was determined by the half angle method using a CAM-MICRO model contact angle meter (Tantec Inc., Schaumburg, IL), with deionized water as the probe liquid. We evaluated the biocompatibility of diamond coatings *in vitro* using standardized tests including human gingival fibroblasts and human mesenchymal stem cells (hMSCs). Human gingival fibroblasts were cultured in complete DMEM, supplemented with 10% fetal bovine serum, and 1% antibiotics, in an incubator at 37C, 5% CO_2 and 95% humidity. Cell viability was measured after 24 hours of cell adhesion, with a crystal violet assay using a spectrophotometer at 490 nm wavelength. hMSCs were seeded onto the coatings and allowed to adhere for 1 hour, 24 hours and 7 days. Unattached cells were then removed by washing with phosphor buffered saline (PBS) on a mechanical shaker. The attached cells were then fixed and observed via SEM. Wear tests were performed on the OrthoPOD®, a six station pin-on-disk apparatus with UHMWPE pins articulating on USND disks and a CoCr disk for two million cycles.
Results / Discussion: The diamond coatings with hardness around 70 GPa and the surface roughness as low as 6 nm (RMS, 2 micron square area) were deposited. Biocompatibility study shows that a continued cell proliferation and no signs of toxicity. USND coatings showed the least cell death compared to other materials like titanium, CoCr. Adhesion and spreading of MSCs were found on the deposited coatings after culturing for 1 hours, 1 day and 7 days (Figure 1a). Contact angle measurement on the surfaces of the deposited diamond show that they are hydrophobic in nature. Wear tests shows that the wear of the UHMWPE to be lower for the polyethylene on USND than that of polyethylene on CoCr (Figure 1b).

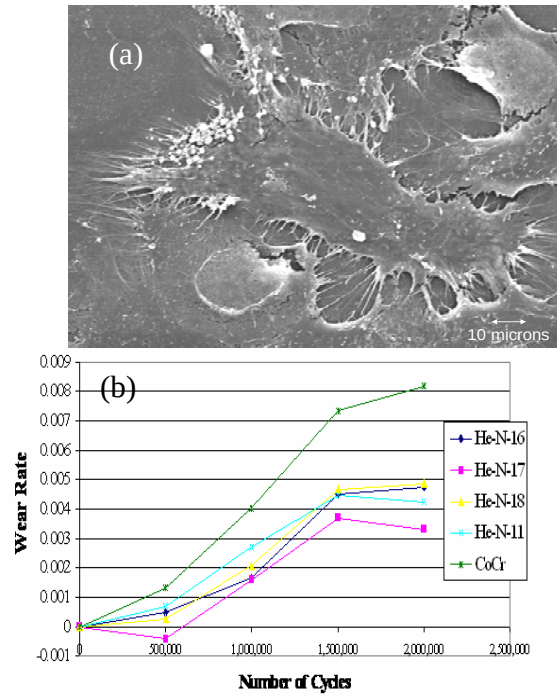

Figure 1: (a) MSCs spreading after culturing for 1 hour on USND coatings (b) The wear rate of four of the USND coatings and the CoCrMo against polyethylene

Conclusions: We have developed ultra smooth nanocrystalline diamond coatings (USND) by MPCVD using $He/H_2/CH_4/N_2$ feed gases for dental implants. The diamond coatings with hardness around 70 GPa and the surface roughness as low as 6 nm were deposited. Biocompatibility studies show continued cell proliferation and no signs of toxicity. USND coatings showed the least cell death compared to other materials like titanium or CoCrMo alloy. Adhesion and spreading of MSCs were found on the deposited coatings after culturing for 1 hours, 1 day and 7 days. Wear of the UHMWPE was found to be lower for the polyethylene on USND than that of polyethylene on CoCrMo alloy.
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References: 1. W.E. Shankland: TMJ: Its Many Faces, 2nd ed. (Anadem Publishing,Columbus, OH, 1998), p. 15.