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Augmenting the bioactivity of polyetheretherketone using a novel accelerated neutral atom beam technique

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Abstract: **Summary**: Polyetheretherketone (PEEK) is an alternative to metallic implants in orthopedic applications; however, PEEK is bioinert and does not osteointegrate. In this study, an accelerated neutral atom beam technique (ANAB) was employed to improve the bioactivity of PEEK. The aim was to investigate the growth of human mesenchymal stem cells (hMSCs), human osteoblasts (hOB), and skin fibroblasts (BR3G) on PEEK and ANAB PEEK.

Methods: The surface roughness and contact angle of PEEK and ANAB PEEK was measured. Cell metabolic activity, proliferation and alkaline phosphatase (ALP) was measured and cell attachment was determined by quantifying adhesion plaques with cells.

Results: ANAB treatment increased the surface hydrophilicity [91.74 $\pm$ 4.80° (PEEK) vs. 74.82 $\pm$ 2.70° (ANAB PEEK), $p < 0.001$] but did not alter the surface roughness. Metabolic activity and proliferation for all cell types significantly increased on ANAB PEEK compared to PEEK ($p < 0.05$). Significantly increased cell attachment was measured on ANAB PEEK surfaces. MSCs seeded on ANAB PEEK in the presence of osteogenic media, expressed increased levels of ALP compared to untreated PEEK ($p < 0.05$)

Conclusion: Our results demonstrated that ANAB treatment increased the cell attachment, metabolic activity, and proliferation on PEEK. ANAB treatment may improve the osteointegration of PEEK implants. J Biomed Mater Res Part B: Appl Biomater 00B: 000–000, 2016.

Key Words: PEEK, accelerated neutral atom beam technology, bioactivity, cell proliferation

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INTRODUCTION

During the past two decades, polyetheretherketone (PEEK) has been increasingly used as an alternative to metal implants in orthopedic surgery because of its mechanical and biological properties as well as being non-magnetic, translucent to X-rays. Using PEEK in place of metal alloys eliminates concerns over metal allergy.[1,2] PEEK implants have been used successfully in clinical applications such as spinal fusion cages,[3] interspinous spacers,[4], PEEK rods in spinal instrumentation,[5] and for pedicle screw based lumbar fusion systems. Due to its semicrystalline character and the molecular rigidity of its repeating units, PEEK offers excellent mechanical characteristics with a Young's modulus similar to bone.[6] The stable chemical structure of PEEK means that it is unreactive and inherently resistant to chemical and thermal degradation. The inertness of the polymer also explains its high biocompatibility, which has been reported both *in vitro*[7,8] and *in vivo* studies.[9] Although bone has been observed adjacent to the implant surface, direct bone–implant contact has been reported to be minimal and PEEK does not induce osteointegration or osteoconduction which is essential for the stability and success of uncemented implants.[10] Given that PEEK is bioinert, many studies have investigated methods that modify the surface of PEEK, in an attempt to augment direct bone–implant contact. These methods include physical (plasma treatment),[11,12] chemical treatment,[13] calcium phosphate or titanium surface coating (using cold spray,[14] vacuum plasma spraying,[15] aerosol deposition,[16] and magnetron sputtering[17]), and the use of composites with hydroxyapatite (HA).[6,18,19] However, the clinical success of these treatments may be limited because of their potential instability, reduced strength and delamination in physiological environments due to the mismatch in modulus between the coating and the underlying PEEK.

In this study, we have used a novel Accelerated Neutral Atom Beam technology (ANAB, NanoAccel^{TM}) to modify the surface of PEEK to a shallow depth of more than 2-3 nm. The ANAB technique, described in detail,[20] uses an intense directed beam of neutral gas atoms, which have average energies that can be controlled over a range from a few electron volts (eV) to over 100 eV per atom. These neutral atom beams are produced by dissociating energetic gas cluster ions produced by the gas cluster ion beam technique.[21] Immediately following clustering, ionization, and

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