

Bioactive PEEK

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Statement of Purpose: Polyetheretherketone (PEEK) is an alternative material to metal alloys in some orthopaedic applications. PEEK has been used for spinal implants, has a low modulus (5GPa), is biocompatible, non-magnetic, translucent to X-rays and eliminates concerns over metal allergy⁽¹⁾. However, PEEK is bioinert and does not integrate with bone. Surface modification of PEEK is required to allow osseointegration. A plasma sprayed coatings were investigated as a way to produce a more osteoconductive PEEK implant. However, high temperature spraying may cause mechanical degradation of PEEK and weak adhesion strength of the coatings⁽²⁾. In this study, we investigated the hypotheses that : 1) plasma sprayed Hydroxyapatite (HA), Titanium (Ti) and Ti-HA coatings on PEEK will be of sufficient interfacial strength for osteointegration in loaded implants (ISO 13779) 2) Mechanical properties of underlying PEEK will not be affected.

Methods: In this study unfilled PEEK samples were assessed. Cylindrical shaped specimens were divided into three groups of the same size. Three coatings were applied to the substrate: (i) Titania based bond coat (TiO₂) + (Ti), (ii) Titania based bond coat+ (HA) and (iii) Titania based bond coat + Ti+HA.

Surface roughness (Ra) was quantified by a profilometer. The adhesion strength of the coatings was measured by pull off tensile test (ASTMF1147-05). Specimens were embedded in resin, and were cut and polished. The coating – substrate interface was investigated using back scattered electron microscopy (BSEM) to detect where coating failure occurred. As a measure of degradation caused by the plasma spraying process, plastic resistance to deformation was determined by microindentation using BioDent. The instrument applied 10 indentation cycles with a maximum force of 10 N at 5 regions. The mechanical properties of PEEK, in particular resistance to fracture and stiffness were quantified by total indentation distance (TID) and average unloading slope (US) obtained from microindentation test. Uncoated PEEK was used as a control. Data were analyzed using SPSS 20. A Mann Whitney-U test used to determine significant differences between coatings. Results were considered significant at the $p < 0.05$ level.

Results: HA coatings presented smoothest topography (Ra- 8.86 μ m), whereas Ti coating showed rougher appearance. The dual coating of Ti-HA had the highest Ra value (21.01 μ m).

The results obtained from pull off test demonstrate that Ti-HA on PEEK had the lowest interfacial strength 11.84 \pm 1.52 MPa. The interfacial strength of Ti was the highest 13.94 \pm 2.95 MPa. The BSEM analysis of samples

at regions of failure after the pull-off test revealed that titanium plasma spray coating failed at the junction between Ti coating and TiO₂ base coat (Adhesion failure). In contrast, failure for HA coated specimens occurred within the coating material (cohesive failure) (Figure 1). The failure for the dual coating occurred between Ti and HA coating. With the dual coating, small bubbles associated with melting the PEEK were seen adjacent to coating. No bubbles were observed in the two other types of coating. HA coated PEEK had the lowest TID (83.9 \pm 1.07 μ m, $p < 0.05$) and highest US (0.53 \pm 0.01 N/ μ m, $p < 0.05$) in comparison to Ti and HA-Ti coating. No significant differences were shown in TID (84.4 \pm 0.89) and US (0.49 \pm 0.01) measurements between control PEEK and three coated samples. Indentation test from coated PEEK taken close to the interface (less than 0.5 mm) showed that the material properties were unchanged.

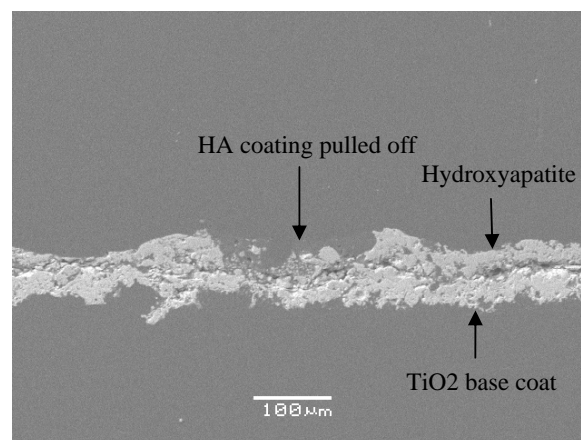


Figure1. SEM images of HA coated PEEK after Pull-off test

Conclusions: The data did not support the first hypothesis. The mean interfacial strength of the coatings obtained from pull-off test was just under 15 MPa for all cases. This suggests the interfacial strength may be suitable for the implants where the load is limited. Microindentation of the coated samples showed no significant differences when results were compared to the control PEEK. Further modification of plasma spray parameters are required in order to improve the properties.

References:

- 1.Kurtz SM, Biomaterials. 2007 Nov;28(32).
- 2.P. Robotti GZ. PEEK Biomaterials Handbook2012. p. 119-43.