

In vitro study of improving bioactivity of Polyetheretherketone (PEEK) by Plasma Immersion Ion Implantation

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INTRODUCTION:

Polyetheretherketone (PEEK) recently attracts many applications in orthopaedics such as intervertebral spacer, spinal cage and prosthesis. However, literatures suggest this material is bio-inert in nature. Its inferior bioactivity may lead to poor bone-implant interaction. Some researchers incorporated hydroxyapatite or tri-calcium phosphate in PEEK to enhance its bioactivity [1, 2]. Mechanical properties such as elasticity and fatigue may, however, alter as material micro-structure has been changed. To avoid it, surface modification is therefore an alternative. Among many of the surface modification techniques, plasma immersion ion implantation (PIII) is an advanced technology that is widely utilized in biomaterial studies [3]. This technology may help generate functional groups on the surface for biomolecule interaction. Literature suggested that ammonia plasma creates amino group on treated surface while water plasma can increase the surface energy. Both are believed to enhance biomolecules interaction. This study aims to investigate the feasibility of bioactivity enhancement of PEEK using an advance surface technique named plasma immersion ion implantation (PIII). It is hypothesized that water and ammonia-PIII may improve bone cell attachment and proliferation.

METHODS:

Material used is Ketron LSG PEEK rod (Quadrant EPP Asia Pacific Ltd). Discs made of this material were prepared into 5mm in diameter and 3 mm in thickness. Before plasma implantation, samples were cleaned in acetone and ethanol in an ultrasonic bath and air dried. Untreated PEEK and titanium (Ti-6Al-4V) discs with the same dimension were used as control. Water and ammonia-PIII were applied to PEEK at 50Hz, 30µs at 10KV, 20KV and 30KV for 2 hours.

Surface characterization and in vitro tests were undertaken to investigate the biological effects of PIII treatments to PEEK material. Alteration in surface chemical composition is measured by X-ray photoelectron Spectroscopy (XPS). It helps to identify changes in functionalities on treated surface. Surface energy was found to correlate with biological interaction such as protein absorption and cell adhesion, hence it is studied here by measuring contact angle which is determined by sessile drop method. Five samples of each type of treated material were studied *in vitro* using SAOS-2 osteogenic cell line. Cells were cultured on each of sample with a density of 100,000 cells/ml in 96 well. MTT assay was applied to study cell proliferation and cell number was quantified by absorbance value at day 2, 4 and 7 of culturing.

Statistical analysis was completed by student-t test by SPSS.

RESULTS:

XPS result confirmed that ammonia plasma implantation has established a layer of nitrogen-containing groups, C-O and C=O on the PEEK surface, while water plasma implantation has increased C-O content on PEEK surface. By reading the contact angle measurement, surface energy of both water and ammonia plasma treated samples have been increased significantly with $p < 0.05$. Even in comparison to titanium, all treated samples have higher surface energy. Hence, plasma treated surfaces are more hydrophilic than the others.

According to MTT result, cell proliferation has been significantly increased from day 2 to day 7 in all the samples. Regarding the MTT result, absorbance is an indicator of cell numbers, the higher the absorbance, the larger the number of cells. The difference between various types of samples at day 2 and day 4 are not very obvious. However at day 7, it is shown that all treated samples have significantly higher absorbance than the untreated PEEK or titanium samples which implied surface environment that favor cell adhesion and proliferations.

DISCUSSION:

The increase in surface energy of plasma treated samples implies that the treated surfaces are more hydrophilic and hence they may be more favorable for cell attachment. All plasma treated surface showed a significantly higher absorbance at day 7, implying cell adhere and proliferate better on plasma treated surface. Hydrophilic surfaces probably have better cell attachment and proliferation, which is

compatible to that previously reported in the literature. As a result, both water and ammonia-PIII improved the cell proliferation on PEEK.

According to XPS data, C-O is found on both water and ammonia-treated PEEK, it is possible that C-O may stimulate cell proliferation. However, the result of *in vitro* test and surface characterization among different bias voltage treated PEEK is similar. It appears that bias voltage ranged from 10KV to 30 KV yields similar implantation effect. Perhaps, the variation in voltage (ranged from 10 to 30KV) is not a main factor affecting the implantation quality.

CONCLUSION:

In conclusion, surface modification of PEEK by water and ammonia plasma immersion ion implantation is found to facilitate cell proliferation. *In vitro* data suggested that water and ammonia-treated PEEK performs better than the untreated PEEK or titanium which is also a commonly implant material used in orthopaedics surgery. Our results support the development of a bioactive PEEK by plasma treatment to improve the tissue-implant integration. Further study on cell mineralization on treated PEEK is needed to generate a more comprehensive picture.

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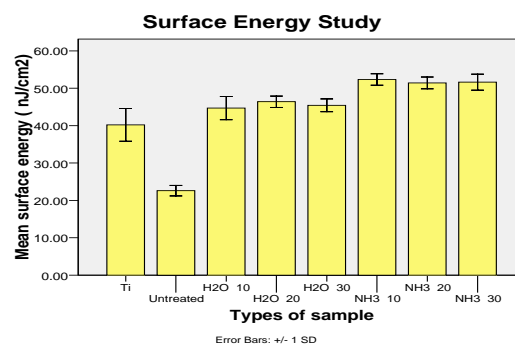


Fig.1 shows the surface energy calculated from corresponding contact angles of various types of treated samples.

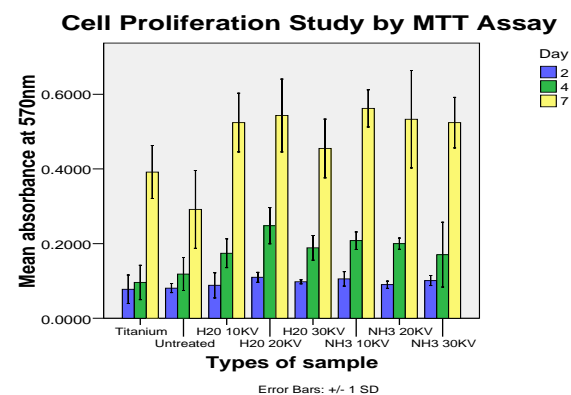


Fig.2 shows the MTT result at day 2, day 4 and day 7

REFERENCES:

- [1] Yu S, Hariram KP, Kumar R, Cheang P, Aik KK. Biomaterials. 2005, 26:2343-2352.
- [2] Abu Bakar MS, Cheang P, Khor KA. Compos Sci Technol 2003, 63:421-425.
- [3] Chu P K, Chen J Y, Wang L P and Huang N. Materials Science and Engineering: R: Reports, 2002, 36:143-206.