ASSESSMENT OF POLYETHER ETHER KETONE MODIFIED BY ULTRAVIOLET RADIATION'S OSTEOBLASTIC ACTIVITY: AN IN VITRO ANALYSIS

Apoorwa Awasthi[1*], Ratna Priya[2], Nandita Gautam[3]

Article History: Received: 15.04.2023 **Revised:** 01.06.2023 **Accepted:** 15.07.2023

Abstract

Purpose: The goal of the present investigation was to determine how ultraviolet (UV) radiation affected polyether ether ketone's (PEEK) osteoblastic activity.
Materials And Procedures; PEEK disc samples number thirty. The samples were divided into two groups: PEEK with no therapy (group I; n = 15) and PEEK modified by UV radiation (group II; n = 15). Human osteoblastic sarcoma cells were used as the experimental group's seeding material. The specimens were incubated for 48 hours at 37°C with a 1% relative humidity in a humid environment. 2.5% glutaraldehyde was used to attach the seeded cells to the coverslips after 48 hours. SEM images of the discs were taken in order to assess osteoblastic cell adherence and colony development on the PEEK discs.
Results: In contrast to PEEK samples without therapy, UV-treated PEEK samples showed observable osteoblast adherence. The PEEK samples that had not been treated had fewer colonies and less widely dispersed cells. UV-modified PEEK displayed more observable osteoblast cells dispersed throughout the sample. Contrary to group I, the cell adhesion was improved. After using Fisher's exact test to analyze the data, the difference between the test and control groups was statistically significant. In conclusion, UV-modified PEEK had more pronounced osteoblast cells dispersed throughout the sample. When compared to samples that had not been treated with UV, the adherence of the cells was improved.

Keywords: Osteoblastic activity, Polyether ether ketone, Surface treatment, Ultraviolet radiation.

[1*]Department of Prosthodontics and Crown & Bridge, Peoples College of Dental Sciences and Research Centre, Bhopal
[2]Department of Public Health Dentistry, KD Dental College and Hospital, Mathura
[3]Department of Public Health Dentistry, Institute of Dental Sciences, Bareilly

Corresponding Author:
[1*]Apoorwa Awasthi
[1*]Department of Prosthodontics and Crown & Bridge, Peoples College of Dental Sciences and Research Centre, Bhopal

DOI: 10.31838/ecb/2023.12.s3.855

1. Introduction

The synthetic organic polymer polyether ether ketone (PEEK) was developed. It looks like natural tooth, making it a more popular choice for dental implants today.1 It has excellent mechanical and biological qualities and remarkable chemical resistance. PEEK is 1.32 g/cm3 dense, insoluble, and extremely strong. It has a lower elasticity modulus.2,3 Because of all these qualities, it is recommended above titanium as an implant material. Individuals who are hypersensitive to titanium can utilize PEEK. PEEK is radiolucent, making it a superior solution for minimising artefacts in patients who require MRI.PEEK does not have a metallic hue, thus if its qualities can be altered, it may be an advantageous material for dental implants.

In contrast to titanium, PEEK has extremely few intrinsic osteoconductive characteristics. Researchers have suggested a number of ways to boost the bioactivity of PEEK, including covering it with hydroxyapatite, increasing the surface's roughness, applying chemical treatments, adding bioactive particles, and more.[9] The characteristics of the PEEK can be harmed by chemical modification and increased temperature during plasma spraying. As a result of its weak bonding, [12] PEEK can flake.[13]

Substantial research was already performed to increase the bioactivity of PEEK as implant materials.[14,15] UV light can improve the PEEK implant surface's wettability characteristic.16 Investigations have shown that UV irradiation significantly improves the retention, attachment, and functional activity of osteogenic cells taken from humans and animals. Titanium's hydrophobic surface becomes more hydrophilic after being exposed to UV light, which also helps to separate adulterated hydrocarbons. UV-treated titanium surfaces exhibit a specific electrostatic level that immediately draw cells to them. According to the research that is currently available, UV photo-functionalization is a more recent technique.[17] The hydrophilization of PEEK enhanced the osteo-conductivity and demonstrated that the surface characteristic, not the implant substance, determines osteo-conductivity. [18] Hence the purpose of this *in vitro* study was to find the outcome of UV radiation on the osteoblastic activity of PEEK.

2. Materials And Method

A total of 30 samples of milled PEEK discs with dimensions of 15 x 2 mm were created in accordance with ISO standard 15309:2013. The samples were divided into two groups: group I (n = 15) of untreated PEEK and group II (n = 15) of PEEK that had undergone UV radiation modification. In this work, the PEEK surface preparation was carried out below 20°C at a relative humidity of roughly 46%. PEEK samples were subjected to UV treatment using a 15W bactericidal lamp with an intensity of = 360 20 for 48 hours. The samples were subsequently examined using a scanning electron microscope (SEM) to determine the PEEK's surface roughness and topography.

Osteoblast was obtained, the cells were cultured in a cell culture lab, and cell adhesion assays were carried out on PEEK discs for both groups to compare the osteoblastic activities. Human osteoblastic sarcoma cells (1 104 cells/cm2) were implanted into the test discs. The samples were incubated at 37°C with a 5% carbon dioxide humidity level. Glutaraldehyde was used to fix the planted cells to the coverslips after 48 hours.19 SEM images of the discs were taken in order to assess osteoblastic cell adherence and colony development on the PEEK discs. The collected observation was tabulated and statistical analysis was performed (Table 1). Statistical program for the Social Sciences (SPSS) was used to perform statistical analysis on all the information.

3. Results

The PEEK discs in group I that had no surface treatment were photographed using a scanning electron microscope (SEM), which revealed pits and fissures with few parallel lines on the surface. PEEK discs exposed to UV light (group II) exhibited surface fractures. SEM investigation revealed osteoblastic activity in PEEK discs with no surface treatment (group 1), but there were relatively few colonies. SEM analysis revealed the greatest number of colonies with desirable cell shape in PEEK discs exposed to UV radiation (group II). In comparison to group I, osteoblastic cells had stronger adhesion and were more numerous and dispersed across the sample. Under scanning electron microscopy (SEM), UV-treated PEEK revealed polygonal osteoblastic cells with filopodial adhesion and growth (group II).

Table 1: Statistical analysis using Fisher's exact test

	Less spread of osteoblastic cells	***Increased spread ofosteoblastic cells***	***Total***	***Fisher's exact test***
Group II (modified byN	0	15	15	

UV radiation) %	0.0%	100.0%	100.0%	0.001*
Group I (no treatment) N	15	0	15	
%	100.0%	0.0%	100.0%	
Total N	15	15	30	
%	50.0%	50.0%	100.0%	
*$p < 0.05$ is significant				

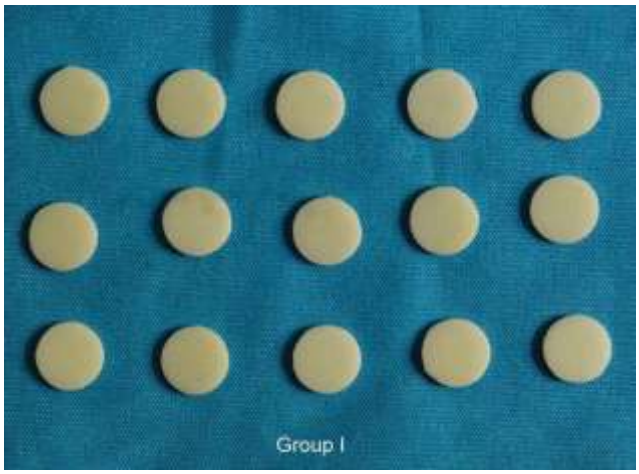

Fig. 1: Group I—PEEK discs without any modification

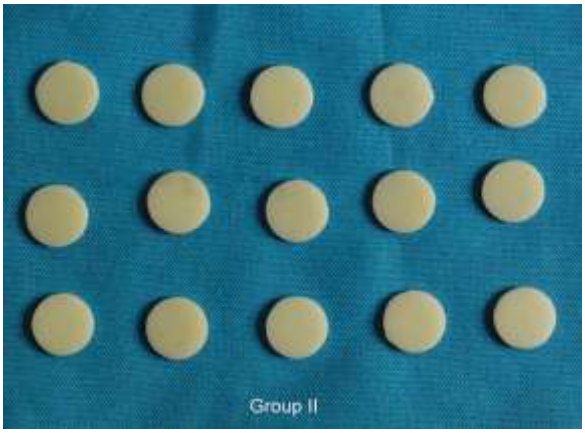

Fig. 2: Group II—PEEK discs modified with UV radiation

4. Discussion

PEEK is a material that is utilized as an implant today for abutments, implants, and superstructures. PEEK possesses mechanical qualities that are similar to those of human bone and is chemically and radiolucent resistant. It has become a viable substitute for a metallic implant.20,21 Due to its bioinert nature and low reactivity with surrounding tissues, PEEK has some disadvantages.

PEEK that has not been changed has a hydrophobic value of 80–90° and a contact angle with water of that size.[16,20,21] approaches have been put forth in an effort to address this problem, including the use of bioactive materials and surface treatment approaches. Hydrophilicity can be improved by surface coating with biomaterials such hydroxyapatite (HA), titanium, nano-modified HA crystals,[23,24,] and modified PEEK. A rise in hydrophilicity influences the interaction amongst the implant material and the surrounding environment by promoting cellular proliferation while improving the wettability of the biomaterials and the implant surface.[11,25]

Plasma spraying creates a thick appetite layer with a rough surface layer that may split into layers and lead to implant loss.4 Because plasma spray is performed at a high temperature, PEEK is additionally coated with HA. Due to PEEK's intentionally low melting point, this temperature might completely damage the material's structure.[13] Whenever there is a coating on the surface of the implant there is a risk of coating being delaminated, which will affect the osseointegration.

Huang et al.,[26] Neiman et al.,[27] and Qahtani et al.[16]

demonstrated that unmodified PEEK is bio inert and shows a contact of 80–90°, which is a hydrophobic value. Matheison and Bradley[28] used UV treatment to modify the energy of the PEEK.

The results presented increased surface wettability of the treated PEEK by UV. In the present study also, increased osteoblastic activity of PEEK after UV treatment was found, which was similar to the study done by AlQahtani et al.[16] who reported that the PEEK surface is hydrophilized after UV radiation. Modification of PEEK increases the hydrophilic property of the PEEK. This causes an increase in the proliferations of the cells with better wettability and thus effects the association between the material and the neighboring environment.[16]

Investigation limitations include the inability of this in vitro investigation to fully translate to in vivo conditions. Instead, the osteoconductive potential of PEEK should be investigated in an in vivo setting by looking at how UV radiation affects cell proliferation and maturation. Alkaline phosphatase can be utilized to focus on the osteogenic potential while also assessing cytotoxicity. Other techniques for assessing osteogenic potential should also be used. Additional animal research may be conducted. The tissue reaction can be further assessed in vivo. The main strategies to improve the bioactivity of PEEK should provide an effective way to obtain both mechanical and biological benefits. Further research and clinical trials are required to explore the surface treatment modification that is required to improve osseointegration.

5. Conclusion

- The cell adhesion in PEEK without treatment showed less spread of osteoblastic cells and had fewer osteoblastic cell colonies.
- PEEK modified by UV radiation showed more prominent osteoblastic cells that were scattered throughout the samples and showed better adhesion of osteoblast compared to group I.

6. References

1. Schwitalla A, Müller WD. PEEK dental implants: a review of the literature. J Oral Implantol 2013;39(6):743–749.
2. Andreiotelli M, Wenz HJ, Kohal RJ. Are ceramic implants a viable alternative to titanium implants? A systematic literature review. Clin Oral Implants Res 2009;20(Suppl 4):32–47.
3. Skinner HB. Composite technology for total hip arthroplasty. Clin Orthop Relat Res 1988;235:224–236.
4. Wheeler SL. Eight-year clinical retrospective study of titanium plasma-sprayed and hydroxyapatite-coated cylinder implants. Int J Oral Maxillofac Implants 1996;11(3):340–350.
5. Lee WT, Koak JY, Lim YJ, et al. Stress shielding and fatigue limits of poly-ether-ether-ketone dental implants. J Biomed Mater Res B Appl Biomater 2012;100(4):1044–1052.
6. Wang H, Xu M, Zhang W, et al. Mechanical and biological characteristics of diamond-like carbon coated poly aryl-ether-ether-ketone. Biomaterials 2010;31(32):8181–8187.
7. Rabiei A, Sandukas S. Processing and evaluation of bioactive coatings on polymeric implants. J Biomed Mater Res A 2013;101(9):2621–2629.
8. Barkarmo S, Wennerberg A, Hoffman M, et al. Nano-hydroxyapatite- coated PEEK implants: a pilot study in rabbit bone. J Biomed Mater Res A 2013;101(2):465–471.
9. Wang L, He S, Wu X, et al. Polyetheretherketone/nano-fluorohydroxyapatite composite with antimicrobial activity and osseointegration properties. Biomaterials 2014;35(25):6758–6775.
10. Schmidlin PR, Stawarczyk B, Wieland M, et al. Effect of different surface pre-treatments and luting materials on shear bond strength to PEEK. Dental Mater 2010;26(6):553–559.
11. Poulsson AH, Eglin D, Zeiter S, et al. Osseointegration of machined, injection moulded and oxygen plasma modified PEEK implants in a sheep model. Biomaterials 2014;35(12):3717–3728.
12. Cook SD, Rust-Dawicki AM. Preliminary evaluation of titanium-coated PEEK dental implants. J Oral Implantol 1995;21(3):176 –181.
13. Ha SW,Mayer J, Koch B, et al. Plasma-sprayed hydroxylapatite coating on carbon fibre reinforced thermoplastic composite materials. J Materials Sci:

Mater Med 1994;5(6):481– 484.

14. Suska F, Omar O, Emanuelsson L, et al. Enhancement of CRF-PEEK osseointegration by plasma-sprayed hydroxyapatite: a rabbit model. J Biomate Appl 2014;29(2):234–242.
15. Abu Bakar MS, Cheng MH, Tang SM, et al. Tensile properties, te nsi on - te nsi on f at i gue and bi o lo gi c a l resp ons e of polyetheretherketone-hydroxyapatite composites for load-bearing orthopedic implants. Biomaterials 2003;24(13):2245–2250.
16. Al Qahtani MS, Wu Y, Spintzyk S, et al. UV-A and UV-C light induced hydrophilization of dental implants. Dent Mater 2015;31(8):e157–e167.
17. Ogawa T. Ultraviolet photofunctionalization of titanium implants. Int J Oral Maxillofac Implants 2014;29(1):e95–e102.
18. Kuroda K, Igarashi K, Kanetaka H, et al. Surface modification of PEEK and its osteoconductivity and anti-inflammatory properties. J Biomaterials Nanobiotech 2018;9(3):233–243.
19. Nayar S, Chakraverty S. A comparative study to evaluate the osteoblastic cell behavior of two nano coated titanium surfaces with NAFION stabilized the membrane. J Indian Prosthodont Soc 2015;15(1):33–38.
20. Wu X, Liu X, Wei J, et al. Nano-TiO2/PEEK bioactive composite as a bone substitute material: in vitro and in vivo studies. Int J Nanomedicine 2012;7:1215–1225.
21. Lai YH, Kuo MC, Huang JC, et al. On the PEEK composites reinforced by surface-modified nano-silica. Mater Sci Eng A 2007;458(1– 2):158–169.
22. M. Rust-Dawicki and S. D. Cook, ”Preliminary evaluation of titanium-coated PEEK implants,” Proceedings of the 1995 Fourteenth Southern Biomedical Engineering Conference, 1995, pp. 75-77.
23. NajeebS,Zafar MS,KhursidZ,etal.Applicationsof polyetheretherketone (PEEK) in oral implantology and prosthodontics. J Prosthodont Res 2016;60(1):12–19.
24. Johansson P, Jimbo R, Kjellin P, et al. Biomechanical evaluation and surface characterization of a nano-modified surface on PEEK implants: a study in the rabbit tibia. Int J Nanomedicine 2014;9:3903–3911.
25. Rupp F, Gittens RA, Scheideler L, et al. A review on the wettability of dental implant surfaces I: theoretical and experimental aspects. Acta Biomater 2014;10(7):2894–2906.
26. Huang RYM, Shao P, Burns CM, et al. Sulfonation of poly(ether ether ketone) (PEEK): kinetic study and characterization. J Appl Polym Sci 2001;82(11):2651–2660.
27. Nieminen T, Kallela I, Wuolijoki E, et al. Amorphous and crystalline polyetheretherketone: mechanical properties and tissue reactions during a 3-year follow-up. J Biomed Mater Res A 2008;84(2):377–383.
28. Mathieson I, Bradley RH. Improved adhesion to polymers by UV/ozone surface oxidation. Int J Adhesion Adhesives 1996;16(1):29–31.