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Peek as a Biomaterial in Dentistry: Why and Why Not?

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Abstract

This paper provides an insight into various aspects of PEEK (Polyetheretherketone) as a biomaterial in prosthodontics and other fields of dentistry. In recent years, many biomaterials like graphene came into existence, PEEK is another material which is gaining importance. In dentistry, PEEK finds its use in many ways, especially in its branch of prosthodontics. This article also reviews various properties of PEEK and its surface modifications. PEEK is a good material for fabricating CAD-CAM fixed and removable prostheses due to its superior properties compared to materials such as acrylic. In addition, this paper also highlights the drawbacks of PEEK.

Keywords: Polyetheretherketone; Dental implants; Dentistry; Evidence-based dentistry; Biocompatible material; Prosthodontics; Dental prosthesis

Abbreviation: BIC: Bone-implant contact; SBF: Simulated body fluid; ICP-MS: Inductively coupled plasma mass spectrometry; SEM: Scanning electron microscopy; EDS: Energy-dispersive X-ray spectrometry; RBFDP: Resin-bonded fixed dental prosthesis

Introduction

Dental implants increase oral health and general health-related quality of life for many patients with teeth loss. Implants based on Titanium and its alloys Ti-6Al-7Nb and Ti-6Al-4V are well evidence-based in all forms of scientific literature and had been recommended for their use in a wide range of clinical situations [1]. Nevertheless, Titanium can cause a wide range of esthetic problems due to its lack of light transmission, especially in the anterior regions [2]. So, alternative ceramic implants were introduced and were made from aluminum oxide [3]. Nowadays, ceramic dental implants made of zirconia are available, which seems to be a better suitable option than Titanium because of its tooth-like color, biocompatibility, and low plaque affinity. The stress contribution of zirconia implants to the surrounding bone could be higher compared to Titanium due to the higher elastic modulus of zirconia of 210 Gpa [4].

About Peek

PEEK, which is a dominant member of the PAEK polymer (Polyaryletherketone) family, came up during the 1990s as the primary substitute for the metallic components for implants, as a high-performance thermoplastic polymer, especially in cases of orthopedics and trauma [5]. The growing interest in polyaromatic polymers is evident in the development of other prostheses and plates for fracture fixation that is similar to the stiffness of bone. This biocompatible material has a wide range of physical, mechanical, and surface properties. It can be made in several shapes, and it provides many possibilities in the development of new implants, mainly due to the biomechanical behavior of this material [6]. In recent years, the most commonly used material as an artificial spinal infusion cage to promote spinal healing is PEEK polymer. It is mainly because of its elastic modulus of 3-4 GPa to that of human cancellous bone of 0.35 GPa, so the stress shield effect is avoided. PEEK materials are also radiolucent to x-rays and do not cause a medical image shielding problem [7]. The monomer unit of ether ether ketone is polymerized via step-growth di-alkylation reaction of bisphenolates to form polyetheretherketone.

PEEK can be modified by the incorporation of certain materials. For example, the incorporation of carbon fibers can increase the elastic modulus upto 18 Gpa. Nano-scaled reinforced PEEK is also available. The modulus of carbon-reinforced PEEK is comparable to cortical bone and dentin. Therefore, this polymer could exhibit lesser stress shielding properties compared to Titanium which is used as an implant material [8]. The various properties of PEEK are as follows:

i. PEEK is hydrophobic.

ii. PEEK is bio-inert.

iii. PEEK is semicrystalline.

iv. PEEK has a melting point of 335 degrees Celsius.

v. PEEK has a young modulus of elasticity around 3-4 GPa.

vi. PEEK is a radiolucent material.

vii. PEEK is chemically and physically stable and resistant to radiation damage.

viii. PEEK is a wear-resistant material.

ix. PEEK is biocompatible invivo, and invitro does not cause toxic and mutagenic effects.

x. PEEK is compatible with other materials like carbon and graphite [9].

Application of Peek in Prosthodontics

In recent times, PEEK had evolved as a material of choice in various medical and dental applications. It is easy to process, non-toxic, natural radiolucency possesses excellent thermal and chemical stability. The multiple applications of PEEK in prosthodontics are as follows:

Peek as a Removable Prosthesis

Tannous et al. [10] had suggested that denture clasp made of PEEK have lower retentive forces compared to cobalt-chromium clasps. However, since the study was conducted in metal crowns in vitro, it is unknown how effective the esthetic PEEK clasps could be in retaining the dentures in the clinical setting. PEEK is also used in the fabrication of a removable obturator. However, more studies are needed to compare the efficacy of PEEK obturators compared to a conventional acrylic prosthesis. Clinical studies or systematic reviews focussing on the use of PEEK dentures have not been published. However, owing to the superior mechanical and biological properties of PEEK, it will not be surprising if dentures constructed from this polymer are routinely built-in near future [11].

Peek Coping Based Crowns

Procedures had been suggested to condition the surface of PEEK and facilitate its bonding with resin composite cement. It has been observed that etching with sulphuric acid for 60-90 seconds can exhibit shear bond strength to composite resin cement as high as 15.3-7.2 MPa after being stored in water for 28 days at 37.8 degrees Celsius [12]. No significant differences were observed in the tensile bond strength of PEEK crowns and dentin abutments using air abrasion and sulphuric acid etching techniques. These studies suggest that PEEK can be used as a resin-coping material. since the mechanical properties of PEEK are closer to those of dentin and enamel, PEEK could have an advantage over alloy and ceramic restorations [13].

Peek as Cad-Cam Milled Fixed Partial Denture

Three-unit fixed partial denture manufactured via CAD-CAM has been suggested to have a higher fracture resistance than pressed granular or pellet-shaped PEEK. The fracture resistance of the CAD-CAM milled PEEK (138.5-111.5) fixed dentures are higher than those of lithium disilicate glass-ceramic (950N), alumina(851N), zirconia. The abrasive properties of PEEK are excellent. Despite significantly low elastic moduli and hardness, the abrasive resistance of PEEK is competitive with metallic alloys [14]. Considering good abrasion resistance, mechanical attributes, and adequate bonding to composites and teeth, a PEEK fixed partial denture would be expected to have a satisfactory survival rate [15]. A PEEK framework veneered with composite resin was used as an alternative material for the fabrication of an interim 3 pontic resin-bonded fixed dental prosthesis (RBFDP) after implant placement. The low modulus (4GPa) of PEEK combined with indirect light polymerized resin as a veneering material used for an RBFDP provided an advantage over metal-ceramic or ceramics in dampening the occlusal forces and reducing debonding rates [16].

Advantages of PEEK as an FPD material includes:

a) Ease of having a polished surface

b) Less plaque accumulation

c) Gum irritation is absent.

d) Bond strength is sufficient to be veneered with any composite material

e) High fracture resistance

f) No discoloration due to the absence of exchange of ions in the mouth [17].

Peek as Modified Post

Modified PEEK material as a prefabricated post for endodontically treated teeth is currently unavailable. In addition, dental research work on PEEK posts is very much lacking. In a research work conducted in my department, to determine to push out bond strength of resin posts and modified PEEK posts, hot-pressed modified PEEK pellets (BioHPP, Bredent, Germany), (Figure 1), from a specialized furnace was utilized to fabricate posts by lost wax technique (Figure 2 & 3) and were sandblasted with Aluminium trioxide 50 microns, at a 10 mm distance at a 2 bar pressure, latter surface treated with a silane coupling agent and bonded to root canal treated mandibular first premolar using resin cement. The results of this study were encouraging. The surface-treated modified PEEK material clinically can be used as an intra-radicular post because there were significant differences in the mean push-out bond strength in all the three regions of the root (coronal, middle, and apical) for PEEK and there was absolutely no cohesive failure (within the PEEK post) seen [18]. However, this material shouldn't be understood as a replacement material for metal or resin posts.

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Figure 1: BioHPP PEEK granules.

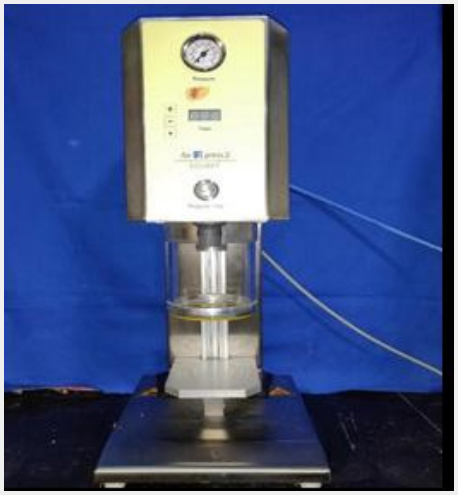

Figure 2: Peek Vaccum press device.

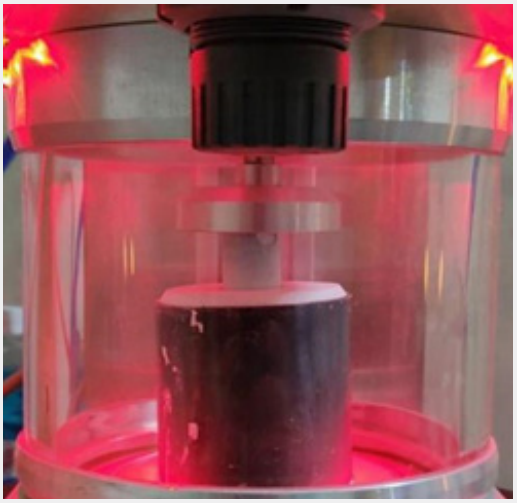

Figure 3: Peek pressed into investment.

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Peek in Maxillofacial Prosthesis

Information on the use of PEEK in the reconstruction of maxillofacial defects has been limited. However, it is believed that PEEK- coupled with a prefabrication process that can produce patient-specific implants (PSIs) may represent an ideal strategy in the reconstruction of challenging maxillofacial defects [19]. The durable yet malleable physical properties of PEEK as a biomaterial provide surgeons with another material with which complex maxillofacial defects can be reconstructed. The material is durable, yet intraoperative modifications can be performed with ease. In addition, the ability to prefabricate an implant based on the patient's anatomy can decrease operative time and a more operative custom fit [20].

Peek as Dental Implants

The adhesion of PEEK implants to bone proceeds slowly because of their relatively low biocompatibility.

It is well known that the quality and quantity of host bone, presence of acceptable primary stability at the time of surgical implant placement, and formation of direct bone-implant contact (BIC) are important parameters that govern the overall success. My department conducted a study to evaluate the Bioactivity of Surface Modified Polyetheretherketone (PEEK) as an implant material (Figure 4) after surface modification by electron beam deposition of Titanium. Twenty-two PEEK samples were water jet sectioned (Figure 5) and divided into two groups of eleven each. Eleven PEEK samples from Group II (To be treated) were coated with Grade II commercially pure Titanium by electron beam deposition technique. One sample from each group was evaluated for surface roughness, topography, and composition using a 3D surface profilometer, scanning electron microscope with energy dispersive X-ray (SEM-EDX) analysis. Simulated body fluid (SBF) was prepared, and calcium (Ca) content in it was quantitatively analyzed using inductively coupled plasma mass spectrometry (ICP-MS) technique. Ten samples from each group were later immersed in SBF for 21 days, and the amount of calcium depletion was analyzed to determine the bioactivity of the two groups. Surface characteristics and elemental composition of immersed samples were later analyzed by SEM-EDX and corroborated with the results of ICP-MS tests. Group II samples showed a significant increase in surface roughness compared to Group I. There were significant differences in Ca depletion of Group I and Group II samples compared to pre immersion Ca content. Group II samples showed higher Ca depletion than Group 1. it was concluded that PEEK dental implants which were surface modified by electron beam deposition of Titanium showed enhanced bioactivity when compared to untreated PEEK of Group1.therefore, they can serve as a valuable alternative to conventional dental implant materials [21].

Figure 4: Medical grade PEEK blank.

Figure 5: Water jet cutting of PEEK sample.

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Peek as Implant Abutments

In another study conducted in my department, wear resistance of two groups of Titanium and PEEK abutments (Figure 6-7) over titanium implants after cyclic loading was analyzed. Abutments were cyclically loaded for 550,000 cycles. Surface profilometry, scanning electron microscopy (SEM), and energy-dispersive X-ray spectrometry (EDS) were performed for all the abutments in both groups before and after cyclic loading. The abutment area at the implant-abutment interface was analyzed for wear. The surface roughness of PEEK abutments was lower than Titanium, which aids in reduced plaque accumulation and decreased marginal bone loss. Within the limitations of this study, and after analyzing the wear resistance results and other associated results, it was encouraging to note that PEEK can be used as definitive abutments [22].

Figure 6: Norris PEEK abutment pack.

Figure 7: Implant PEEK assembly group.

Application in Other Fields of Dentistry

Additive manufacturing can be effectively used to manufacture innovative PEEK for orthodontic uses, used for design and manufacturing of dental appliances, needed for treating tooth irregularity such as in space maintainers in pedodontics and orthodontics. Double crown removal dental prosthesis manufactured by PEEK material provides better retention and support between multiple abutment teeth [23]. PEEK parts can replace metallic and ceramic material due to its greater design freedom, enhanced performance, and lower friction, but to limited applications. This material can perform satisfactorily in the extreme chemical environment [23].

Drawbacks of Peek

a) High cost involved in procuring of blanks for CADCAM milling.

b) Chemical processing is difficult due to its low surface energy.

c) Specific machines (e.g., five axial milling machines) are required for the processing of complex structures.

d) The composite resin veneered PEEK material shows less fracture resistance.

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Conclusion

Since the mechanical and physical properties being close to bone and dentin, surface modified PEEK(Polyetheretherketone) can be used for various applications in dentistry, including manufacturing of dental implants, implant abutments, and post material. This statement had been made based on studies conducted in my department. Increasing the bioactivity of PEEK dental implants without affecting their mechanical properties is a scientific challenge. PEEK is also an essential upcoming bio dental material for fabricating CAD-CAM fixed and removable prostheses due to its superior mechanical properties compared to materials such as heat-cured acrylic. More in-vitro studies with larger sample sizes and clinical studies will enable all research scholars, doctors, and technicians to understand this upcoming promising dental biomaterial better.

References

1. Andreas Schwitalla Wolf -Dieter Muller. (2013) Peek dental implants – A review of literature. J oral implantol 39(6): 743-749. https://meridian.allenpress.com/joi/article/39/6/743/7277/PEEK-Dental-Implants-A-Review-of-the-Literature
2. Murat Yildirim, Horst Fischer Dring, Rudolf Marx, Drrernat, Daniel Edelhoff (2003) In vivo fracture resistance of implant supported all ceramic restorations. J Prosthet Dent 90 (4): 325-331.
3. (2019) Handbook of PEEK BIOMATERIALS, 2nd edition, Steven M. Kurtz, Director, Implant Research Center and Associate Professor, Drexel University, Pennsylvania
4. Ozkurt Z, Kazazoglu E (2010) Clinical success of Zirconia in Dental Applications. J Prosthodont 19(1): 64-68.
5. Sarot JR, Contar CM, Cruz AC, De Souza Magini R (2010) Evaluation of the stress distribution in CFR- PEEK dental implants by three-dimensional finite element method. J Mater Sci: Mater med 21(7): 2079-2085.
6. Katzer A, Marquardt H, Westerndorf J, Weining JV, von Foerster G (2002) Polyetheretherketone-cytotoxicity and mutagenicity in vitro. Biomaterials 23 (8): 1749-1759.
7. Yi ju yang, Hsi Kai Tsou, Ying Hung Chen, Chi Jen Chung, Ju Liang He (2015) Enhancement of bioactivity on medical polymer surface using high power impulse magnetron sputtered titanium dioxide film.Mater Sci Eng 57: 58-66.
8. Najeeb S, Zafar MS, Khurshid Z, Siddiqui F (2016) Applications of polyetheretherketone (PEEK) in oral implantology and prosthodontics. J Prosthodont Res 60(1): 12-19.
9. Weigeng Wang, Luo CL, Jei Huang, Mohan Edirshinghe (2019) Peek surface modification by fast ambient temperature sulphonation for bone implant applications. J R Soc Interface 16(152): 1-10.
10. Tannous F, Steiner M, Shahin R, Kern M (2012) Retentive forces and fatigue resistance of thermoplastic resin clasps. Dental Mater 28(3): 273-278.
11. Costa-Palau S, Torrents-Nicolas J, Brufau-de Barbera M, Cabratosa-Termes J (2014) Use of polyetheretherketone in the fabrication of a maxillary obturator prosthesis: a clinical report. J Prosthet Dent 112(3): 680–682.
12. Stawarczyk B, Beuer F, Wimmer T, Jahn D, Sener B, et al. (2013) Polyetheretherketone—a suitable material for fixed dental prostheses? J Biomed Mater Res Part B 101(7): 1209-1216.
13. Uhrenbacher J, Schmidlin PR, Keul C, Eichberger M, Roos M, et al. (2014) The effect of surface modification on the retention strength of polyetheretherketone crowns adhesively bonded to dentin abutments. J Prosthet Dent 112 (6): 1489-1497.
14. Stawarczyk B, Eichberger M, Uhrenbacher J, Wimmer T, Edelhoff D, et al. (2015) Three-unit reinforced polyetheretherketone composite FDPs: influence of fabrication method on load-bearing capacity and failure types. Dent Mater J 34(1): 7-12.
15. Rzanny A, Gobel F, Fachet M (2013) BioHPP summary of results for material tests.Research Report. Jena, Germany: University of Jena, Department of Materials and Technology 25(7).
16. Zoidis P, Papathanasiou I (2016) Modified PEEK resin-bonded fixed dental prosthesis as an interim restoration after implant placement. J Prosthet Dent 116(5): 637-641.
17. Sushant A Pai, Shubhangi Kumari, Umamaheswari B, Mangala Jyothi, Shanthana Lakshmi CB (2019) Polyetheretherketone in Prosthodontics- A review. Journal of Advanced Clinical & Research Insights 6: 24-26.
18. Badimela A, Hariharan R, Jayakrishnakumar, Azhagarasan NS (2019) Comparative evaluation of the pushout bond strength of fibre reinforced composite resin post and peek (polyetheretherketone) post following surface treatments. Journal of Clinical Prosthodontics and Implantology 1(2) :1-9
19. Scolozzi P, Martinez A, Jaques B (2007) Complex orbito-fronto-temporal reconstruction using computer designed PEEK implants. J Craniofac Surg 18(1): 224-228.
20. Michael M, Kim Kofi DO, Bochene, Patrick J Byrne (2009) Use of Customized Polyetheretherketone (PEEK) Implants in the Reconstruction of Complex Maxillofacial Defects. Arch Facial plast Surg 11(1): 53-57.
21. Asish Martin, Azhagarasan NS, Mahadevan Ravichandran, Hariharan Ramakrishnan, Jayakrishnakumar S, et al. (2020) Evaluation of the bioactivity of the surface modified polyetheretherketone (PEEK) as an implant material. An In Vitro Study. Contemp Clin Dent 11(4): 356-366.
22. Ragupathi M, Mahadevan V, Azhagarasan NS, Ramakrishnan H, Jayakrishnakumar S (2020) Comparative evaluation of the wear resistance of two different implant abutment materials after cyclic loading – An in vitro study. Contemp Clin Dent 11(3): 229-236.
23. Wachtel A, Zimmermann T, Sutel M (2019) Bacterial leakage and bending moments of screw-retained, composite-veneered PEEK implant crowns. J Mech Behav Biomed Mater 91: 32-37.

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