Review Article

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Polyether-Ether-Ketone (Peek) with Reinforced Materials and its Applications in Prosthodontics: A Review

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ABSTRACT

Background: Polyether Ether Ketone (PEEK) meets all the demands and has proven its versatility in a very short span of time in recent prosthetic advancements. PEEK is used widely in CAD –CAM manufacturing for dental implants, provisional abutments, implant-supported bars, clamps for removable prostheses, and fixed dental prosthesis. Additionally, it is also non-allergic and has low plaque affinity. This article reviews one of the new dental material PEEK, its characteristics and uses in prosthodontics.

Keywords: PEEK, modification of peek, Bio-HPP.

INTRODUCTION

PEEK is a member of the poly-aryl-ether-ketone family (PAEK).Poly-ether-ether-ketone (PEEK) is a high- temperature thermoplastic material. PEEK is produced in three viscosity grades (high, medium and low) based on the same basic formula (-C6 H4 -OC6 H4 -O-C6 H4 -CO-) n. PEEK has very high mechanical strength due to its aromatic chain of ring structure, it is highly inert, hence very resistive to chemical erosion. PEEK withstands high temperature[1]. It can be sterilized by radiation and heat [2-5].PEEK is widely accepted as an attractive biomaterial and as an excellent substitute of bone.PEEK can be used as a biomaterial in medical science in artificial cranial plates, components of finger and knee joints, and spine implants. It has been used in the field of orthopaedic surgery [3]. A common synthesis route for PEEK is the reaction between 4, 4- difluoro-benzo-phenone and the disodium salt of hydroquinone in a polar solvent such as diphenyl-sulphone at 300°C[6]

PEEK HISTORY[7]

\In 1978, a group of English scientists developed PEEK, a semi-crystalline linear polycyclic aromatic polymer.It was first commercialized in the 1980s for industrial applications in the manufacture of aircraft, turbine blades, piston parts, cable insulation, and compressor plate valves. PEEK was introduced to dental applications in 1992.

PEEK PROPERTIES

1. Semi-crystalline with melting point - around 335 °C.[8]
2. Elastic modulus (3-4 GPa) close to human cortical bone.[10]
3. Thermal stability up to 335.8° C9,[3]
4. Radiolucent[3]
5. Resistant to radiation damage.[3]
6. Wear-resistant[10,11]
7. Biocompatible & Non-toxic.[10,11]
8. Compatible with many reinforcing agents such as glass and carbon fibers.[11]

MODIFICATION OF PEEK DENTAL IMPLANTS

1. **NANO STRUCTURED SURFACES**[13]

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- Spin Coating with Nano-HAP
- Plasma- gas treatment(o2/ Ar/Nh4)
- Plasma electron beam deposition
- Plasma ion immersion implantation

2. BIO-ACTIVE NANO-COMPOSITES[13]

- TIO2/PEEK
- HAF/PEEK**USES OF PEEK**[9,10,11]

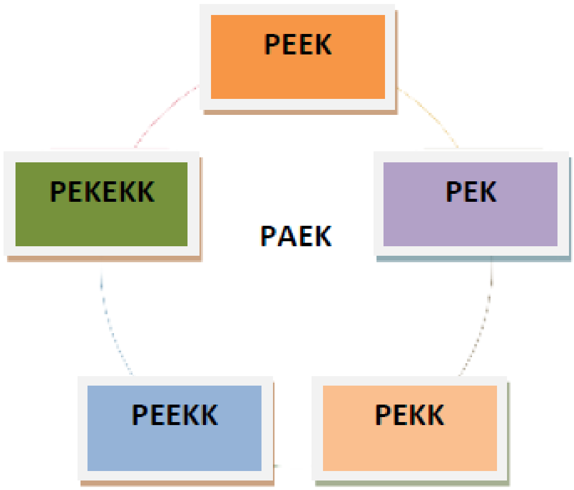

Fig 1: Family Structure of Poly-ether-ether-ketone.

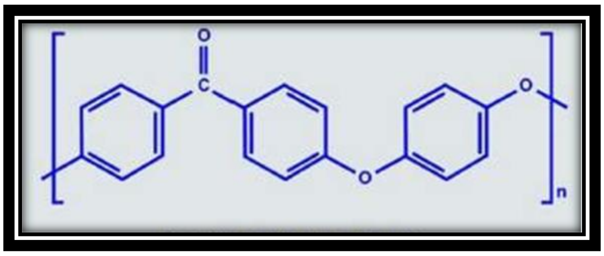

Fig 2: Chemical Structure of Poly-ether-ether-ketone.

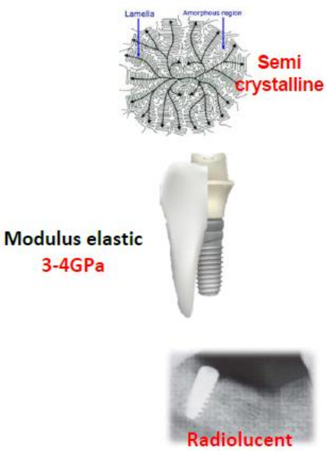

Fig 3: Properties of Poly-ether-ether-ketone.

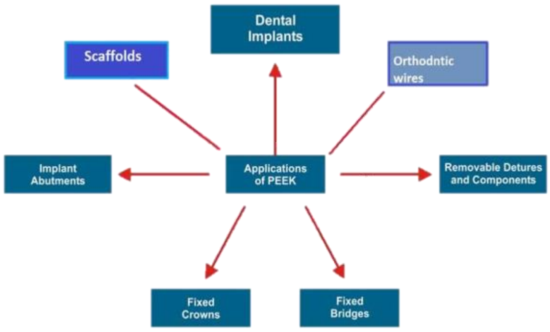

Fig 4: Uses of Poly-ether-ether-ketone.

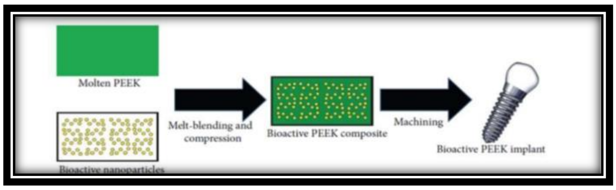

Fig 5: Bio-active PEEK implant.

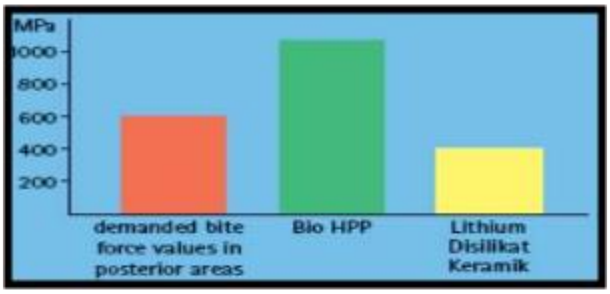

Fig 6: Bio-HPP's fracture resistance(1000 MPa) is more than double in comparison to Lithium Di-silicate Ceramics (400 MPa). Generally discussed minimum requirements range at about (600MPa)[27]

PEEK AS AN IMPLANT MATERIAL

PEEK was introduced to dental applications in 1992, first in the form of aesthetic abutments and later as implants[15]The major beneficial property for PEEK as a dental implant material remains its low Young's (elastic) modulus (3–4 GPa) being close to human bone(14 GPa) while titanium's elastic modulus is about (102- 110 GPa).[10,1]In contrast to titanium, PEEK has very limited inherent osteo-conductive properties. Hence, a considerable amount of research has been conducted to improve the bioactivity of PEEK implants.[16]

BIOACTIVE PEEK NANOCOMPOSITES AS DENTAL IMPLANTS

In order to increase the bioactivity, bioactive inorganic particles have been incorporated to PEEK using melt-blending and compression molding techniques.Nano-hydroxyapatite,Nano-hydroxyfluorapatiteandNano-titaniumoxide particles can be used.[18,19]

PEEK AS DENTAL IMPLANT ABUTMENTS

Unmodified PEEK is used as a provisional abutment, because this material has been demonstrated to reduce stress shielding around the implant.[1]Unmodified PEEK is not used as a definitive abutment materialbecause its fracture resistance is lower than that of titanium.[18]However, the introduction of ceramic reinforced PEEK (Bio-HPP) made its use as a permanent abutment an advantage.[20]

PEEK AS REMOVABLE PARTIAL DENTURE

The mechanical and physical properties of recently developed polymers, such as the aryl-ketone polymers, are similar to those of bone and dentin.[9]

Advantages of PEEK RPD:

1. High biocompatibility, Good mechanical properties, High temperature resistance, Chemical stability[3,8,9]

2. Due to a 4 GPa modulus of elasticity, it is as elastic as bone and can reduce stresses transferred to the abutment teeth.[10]

3. The retentive force of Bio-HPP clasps could be a matter of concern. PEEK clasps offer a lower retentive force than metal clasps. However, properly designed PEEK clasps with an undercut of 0.5 mm could provide adequate retention for clinical use.[23]

Bio-HPP clasps are gentler to the enamel and porcelain restorative materials than conventional Cr-Co clasps are.[23,24]Clasps made of Bio-HPP result in healthy periodontium, especially in cases of tissue proximity, due to the material's low plaque affinity properties.[24]

PEEK AS CROWNS AND FIXED PARTIAL DENTURES (FPD) FRAMEWORKS

There are two ways of processing PEEK for Crowns and bridges framework Vacuum pressing & CAD-CAM[25]. PEEK granules by vacuum pressing or CAD-CAM milling are used as a framework for long span FPD which is finally layered with a Nano-composite.[2] It still requires veneering owing to its low translucency and grayish pigmentation.It stillcan't be used in full contour.[26]

METHODS OF PEEK REINFORCEMENT

The elastic modulus of PEEK is very low compared to those of cortical bone, Ti, and ceramic materials. The higher elastic modulus of PEEK is required for dental implant materials, especially those used for abutments and superstructures.[28]

- Carbon-fiber reinforcedPEEK (CFR-PEEK)[29]
- Glass-fiber reinforced PEEK (GFR-PEEK)[28]
- Ceramic reinforced PEEK (Bio-HPP)[27]
- Hydroxyapatite reinforced PEEK[30]
- Nano-TiO2/PEEK(n-TiO2/PEEK)[31]
- Nano-fluroapatite PEEK (n-FA/PEEK)[32]

CONCLUSION

PEEK is a promising polymeric material that could replace metallic and ceramic materials in dental applications.Studies have shown that it performs well as a dental implant after surface modification to render it bioactive and increaseOsseo integration.

It can also be used as dental implant abutments and removable partial denture frameworks. Due to its grayish color it still needs to be veneered by composite resin when used as crowns and bridges. Long term clinical studies are needed to confirm the eligibility of PEEK as dental biomaterial considering that it is still a new material.

Various uses of peek in dental technology include abutments, fixed prosthetic frameworks and removable partial denture frameworks including precision attachments. More researches should be done regarding the versatility.

CONFLICTS OF INTEREST

The authors declare they have no potential conflict of interests regarding this article.

REFERENCES

1. Yang J, Tyberg CS, Gibson HW. Synthesis of aromatic polyketones via soluble precursors

derived from bis (α-amino nitrile) s. Macromolecules 1999; 32:8259-8268.

2. Green S, Schlegel J. A polyarylketone biomaterial for use in medical Implant applications. Retrieved online June 26, 2014

3. Kurtz SM, Devine JN. PEEK biomaterials in trauma, orthopaedic and Spinal implants. Biomaterials 2007;28:4845-4869.

4. Toth JM, Wang M, Estes BT, Scifert JL, Seim HB 3rd, Turner AS. Polyetheretherketone as a biomaterial for spinal applications. Biomaterials 2006; 27:324- 334.

5. Tetelman ED, Babbush CA. A new transitional abutment for immediate aesthetics and function. Implant Dent 2008; 17:51-58.

6. Zoidis P, Papathanasiou I, Polyzois G. The Use of a modified poly ether ether ketone (PEEK) as an alternative framework material for removable dental prostheses. A clinical report. J Prosthet Dent 2015; 25:580-84.

7. Semadeni M., *Process Development and Materials Optimisation of Injection Moulded Anisotropic(CF/PEEK) Hip Joint Endoprosthesis Stems*. PhDThesis, ETH No 13177, submitted to the SwissFederal Institute of Technology, Zurich. 1999.

8. Monich PR, Berti FV, Porto LM, Henriques B, de Oliveira APN, Fredel MC, et al. Physicochemical and biological assessment of PEEK composites embedding natural amorphous silica fi bers for biomedical applications. Mater SciEng C Mater BiolAppl 2017;79:354-62.

9. Najeeb S, Zafar MS, Khurshid Z, Siddiqui F. Applications of polyetheretherketone (PEEK) in oral implantology and prosthodontics. J Prosthod Res 2016; 60:12-9.

10. Xin H, Shepherd D, Dearn K. Strength of poly-etherether- ketone: effects of sterilisation and thermal ageing. Polym Test 2013; 32:1001-5.

11. Kurtz SM. PEEK biomaterials handbook. William Andrew; 2011. 16. Zhou L, Qia Y, Zhu Y, Liu H, Gan K, Guo J. The effect of different surface treatments on the bond strength of PEEK composite materials. Dent Mater 2014; 30:e209-151415

12. Santing HJ, Meijer HJ, Raghoebar GM, Ozcan M. Fracture strength and failure mode of maxillary implant supported provisional single crowns: a comparison of composite resin crowns fabricated directly over PEEK Abutments and solid titanium abutments. Clin Implant Dent Relat Res 2012; 14:882- 889

13. Bonding of the Polymer Polyetheretherketone (PEEK) to Human Dentin: Effect of Surface Treatments Brazilian Dental Journal (2016) 27(6): 693-699

14. Stawarczyk B, Bahr N, Beuer F, Wimmer T, Eichberger M, GernetW,et al.. Influence of plasma pretreatment on shear bond strength ofself-adhesive resin cements to polyetheretherketone. Clin Oral Investig2014;18:163-170.

15. Bayer S, Komor N, Kramer A, Albrecht D, Mericske-Stern R, Enkling N. Retention force of plastic clips on implant bars: a randomized controlled trial. Clin Oral Implants Res 2012; 23:1377-1384.

16. Tannous F, Steiner M, Shahin R, Kern M. Retentive forces and fatigue resistance of thermoplastic resin clasps. Dent Mater 2012; 28:273-278.

17. Uhrenbacher J, Schmidlin PR, Keul C, Eichberger M, Roos M, GernetW,et al.. The effect of surface modification on the retention strength of polyetheretherketone crowns adhesively bonded to dentin abutments.JProsthet Dent 2014; 112:1489- 1497.

18. Stawarczyk B, Beuer F, Wimmer T, Jahn D, Sener B, Roos M, et al..Polyetheretherketone-a suitable material for fixed dental prostheses?J Biomed Mater Res B ApplBiomater 2013;101:1209-1216.

19. Behr et al. 2001, Clinical Oral Implants Research 12:174-178.

20. Stawarczyk B, Jordan P, Schmidlin PR, Roos M, Eichberger M, Gernet W, et al.. PEEK surface treatment effects on tensile bond strength to

veneering resins. J Prosthet Dent 2014; 112:1278-1288.

21. Lapa VMC. Optimizacao da maquinagem do PEEK e seuscompositos PEEK/CF30 e PEEK/GF30. (Tese). Aveiro (BaixoVouga): Universidade de Aveiro. 2008.

22. Mata F, Gaitonde VN, Karnik SR, Davim JP. Influence of cutting conditions on machinability aspects of PEEK, PEEK CF 30 and PEEK GF 30 composites using PCD tools. J Mater Process Technol 2008; 209:1980–1987.

23. HANCU, V., COMANEANU, R.M., COMAN, C., FILIPESCU, A.G.,GHERGIC, D.L., COTRUT, M.C., In vitro Studies Regarding the Corrosion Resistance of NiCr and CoCr Types Dental Alloys, Rev. Chim. (Bucharest), **65**, no. 6, 2014, p. 706

24. ARDELEAN, L., BORTUN, C., MOTOC, M., Metal-free removable partial dentures made of a thermoplastic acetal resin and two polyamide resins, Mat. Plast., **44**, no. 4, 2007, 345-348

25. KOLBECK C, ROSENTRITT M. Munich: Int. Sky-Meeting, 2012

26. VOSSHANS J, SCHELHOVE M, SCHNIEDER F, BioHPP - A metal-free material for prosthetic restorations, Zahntech. Mag., 17, 3, 138– 143 (2013)

27. EDWIN SEVER BECHIR1, ANAMARIA BECHIR2, CHERANA GIOGA2*, ROXANA MANU2, ALEXANDRU BURCEA2,IONELA TEODORA DASCALU3The Advantages of BioHPP Polymer as SuperstructureMaterial in Oral ImplantologyMATERIALE PLASTICE 53No.32016)

28. Lee, W.T.; Koak, J.Y.; Lim, Y.J.; Kim, S.K.; Kwon, H.B.; Kim, M.J. Stress shielding and fatigue limits of poly-ether-ether-ketone dental implants. J. Biomed. Mater. Res. B Appl. Biomater. **2012**, 100, 1044–1052.

29. Schwitalla, A.D.; Emara, M.A.; Spintig, T.; Lackmann, J.; Müller, W.D. Finite element analysis of the biomechanical effects of PEEK dental implants on the peri-implant bone. J. Biomech. **2015**, 48, 1–7.

30. Rust-Dawicki, A.M.; Cook, S.D. Preliminary evaluation of titanium-coated PEEK implants. J. Oral Implantol.**1995**, 21, 75–77.

31. Wu, X.; Liu, X.;Wei, J.; Ma, J.; Deng, F.;Wei, S. Nano-TiO2/PEEK bioactive composite as a bone substitute material: In vitro and in vivo studies. Int. J. Nanomed. **2012**, 7, 1215–1225.

32. Wang, L.; He, S.; Wu, X.; Liang, S.; Mu, Z.; Wei, J.; Deng, F.; Deng, Y.; Wei, S. Polyether ether ketone-nanofluoro hydroxyapatite composite with antimicrobial activity and osseointegration properties. Biomaterials **2014**, 35, 6758–6775.