Journal of Advanced Clinical & Research Insights (2019), 6, 24–26

REVIEW ARTICLE

Polyetheretherketone in prosthodontics – A review

Sushant A. Pai, Shubhangi Kumari, B. Umamaheswari, Mangala Jyothi, C. B. Shanthana Lakshmi

Department of Prosthodontics Including Crown and Bridge, Sri Rajiv Gandhi College of Dental Sciences and Hospital, Bengaluru, Karnataka, India

Keywords:
Fixed partial dentures, implant, polyetheretherketone, polymer, prosthodontics, removable prostheses

Correspondence:
Dr. Shubhangi Kumari, Department of Prosthodontics Including Crown and Bridge, Sri Rajiv Gandhi College of Dental Sciences and Hospital, Bengaluru, Karnataka, India.
E-mail: shubhangikumari27@gmail.com

Received: 20 January 2019;
Accepted: 22 February 2019

doi: 10.15713/ins.jcri.252

Abstract

Materials used in different fields of prosthodontics have evolved over the years. In recent years, patient more preferably demands a metal-free, lightweight, tooth-colored prosthesis. Polyetheretherketone (PEEK) can be used in various ways in prosthodontics. The aim of this article is to encapsulate the precedence of PEEK, compared to other restorative materials that have been used currently, based on various studies conducted on this material.

Introduction

Polyetheretherketone (PEEK) is a man-made, white-colored polymer. This has been used in various medical fields such as orthopedic, trauma, and spine implants as an active biomaterial for many years.[1,2] PEEK is a semi-crystalline material. It consists of two phases, namely amorphous and crystalline.[2] Injection molded PEEK in implants typically contains 30–50% of crystal. However, it may differ (0–40%) depending on its manufacturing process.[2] It is produced by the reaction between 4,4'-diflurobenzophenone and the disodium salt of hydroquinone in the presence of solvent like diphenyl sulfone at 300°C.[3] Since April 1998, PEEK has been used as implant material. Having an elastic modulus, similar to human cortical bone (3–4 GPa) makes it an excellent alternative of titanium (Ti) and other conventionally used metal in orthopedics and traumatology field. Table 1 shows the mechanical properties of PEEK.

PEEK can be modified by various surface treatments such as carbon reinforced and glass fiber reinforced. Carbon-reinforced PEEK has an elastic modulus up to 18 GPa comparable to dentine.[4,5] Thermal properties of PEEK are well suitable to be used in the oral environment. PEEK is a bioinert material. After the completion of polymerization reaction, it becomes extremely unreactive to any chemical, thermal, and post-irradiation changes.[2] Chemical solvents (except concentrated H_2SO_4) do not have any degrading effect on this polymer.[6] Considering the mechanical properties of PEEK, it can be used as a dental implant, in fixed partial dentures (FPD) and removable prostheses.

PEEK as an implant material

For spinal implants, PEEK has been used since 1996. Numerous studies also have been conducted to check the reliability of PEEK as a spinal implant material. However, for dental application, much more researches still required. Stress shielding is an important property for any implant material. It is a phenomenon of a decrease in bone density as a result of the removal of typical stress from the bone by an implant. To being an ideal implant material, stress shielding should be low to prevent further bone loss.

Benefits of PEEK over Ti as an implant material:

1. PEEK may exhibit less stress shielding than Ti.
2. It exhibits fewer hypersensitive and allergic reactions in compare to Ti.
3. It does not have a metallic color as Ti, so esthetically more pleasing.
4. It can be used as a core material by adding the bulk and modifying the surface properties.
5. It has better wear and abrasion resistance.
6. The friction coefficient of PEEK is low.
7. It has shock absorption effect.

Victrex (now known as Invibio) is a leading manufacturer for medical grade PEEK. In 1999, they launched PEEK-OPTIMA for an implant.

PEEK Reinforcement

The pure PEEK has a very low elastic modulus compared to Ti, ceramics, and bone. To increase its elastic modulus, to make it

more suitable for dentistry, several reinforcements have been done. Several experiments have been done to obtain PEEK composites, after reinforcing PEEK with other materials. These composites have improved mechanical properties than pure PEEK.

Table 2 shows the elastic modulus of these composites along with commercially used dental alloy for an implant.[7]

Surface modification of PEEK for osseointegration

Since PEEK is a bioinert compound, several customizations have been tried in an attempt to make it more osteoconductive. The surface of the pure PEEK can be modified by various processes such as plasma spraying, spin coating, acid etching, chemical modification, and ultraviolet irradiation. Several nanoparticles can be coated on the surface of PEEK to make it more bioactive for integration with bone. The primarily used particles are titanium oxide, hydroxyfluoroapatite, and hydroxyapatite. The tensile properties of these composites are superior to pure PEEK.

Table 3 shows different surface modifications of PEEK.[7]

PEEK in fixed prostheses

PEEK can be used to make the framework of fixed denture prostheses. It can also be used for the dental crown preparation with a facial coating of veneering composites. Hence, many procedures have been illustrated to facilitate the bonding of PEEK with resin composite crown. Bonding agent application increases the tensile bond strength to composite resin. Etching with various acids such as sulfuric acid and piranha acid also increases the bond strength to the resin.

Advantages of PEEK as an FPD material:

1. Highly polished surface.
2. Less plaque accumulation.
3. Gum irritation is absent.
4. Bond strength is sufficient to be veneered with any composite material.
5. High fracture resistance.
6. No discoloration, due to the absence of exchange of ions in the mouth.

Table 1: Mechanical properties of PEEK

Elastic modulus	3–4 GPa
Glass transition temperature	143°C (approximately)
Melting temperature	343°C

PEEK: Polyetheretherketone

Table 2: Elastic modulus of pure PEEK, PEEK composites, and different dental alloy

Material	Elastic modulus (GPa)
Ti	110
Cr-Co	180–210
Zirconia	210
Porcelain	68.9
PMMA	3–5
PEEK	3–4
CFR-PEEK	18
Continuous CFR-PEEK	150
GFR-PEEK	12
Cortical bone	14
Enamel	40–83
Dentin	15–30

PEEK: Polyetheretherketone, Ti: Titanium, Cr-Co: Cobalt-chromium

PEEK as a removable prosthesis material

Conventionally, metals (mainly cobalt-chromium [Cr-Co]) are used as the framework material, for a removable dental prosthesis. These are still in use due to its cheaper price. However, there are certain drawbacks with these metal prostheses such as esthetical unacceptability by the patient, the heaviness of prosthesis, and metallic taste that lead to the search for newer material to overcome these drawbacks.

Initially, nylon and acetal resin were used as an alternative to the metal framework. Several studies have been done on that. After these studies, they concluded that nylon is esthetically better, but it cannot be relined. Contrarily, acetal resin has adequate mechanical strength, but it lacks liveliness of the natural teeth.[8-11]

Panagiotis Zoidis did a clinical study on a 70-year female patient having a conventional Cr-Co mandibular distal extension removable denture. The patient complained of the metallic taste, the weight, and the unpleasant display of the metal clasps of her existing Cr-Co prosthesis and demanded an alternative material for the fabrication of a new prosthesis. He treated the patient with modified PEEK material (Bio-HPP) distal extension framework with acrylic teeth and conventional heat cure resin denture base. Zoidis did 1 year of follow-up after completion of treatment. In his follow-up, he founded that there is no breakage of denture framework, good clasp retention, and color stability of Bio-HPP.[12]

PEEK can be used to make the complete denture. For complete denture fabrication, computer-aided design/computer-aided manufacturing system is required. It is also used in the construction of a removable obturator. Costa-Palau *et al.* used PEEK to make maxillary obturator in a patient with partial maxillary and mandibular edentulism. After 6 months of follow-up, they found that strength and appearance of the bond were satisfactory. There was no marginal leakage from the prosthesis.[13]

Advantages

1. Esthetically more pleasing.
2. Less density, so lighter in weight.
3. Non-metallic.
4. Less irritation and allergic reactions.
5. Patient acceptance is more.
6. The processing procedure is easy and less time consuming.

Table 3: Surface modifications of PEEK

Surface modifications	Procedure	Material
Coating	Plasma spraying	HA, Ti
	Spin coating	Nanosized HA crystals containing surfactants, organic solvents, an aqueous solution of Ca $(NO_3)_2$ and H_3PO_4
	EBE	Ti; Silicate
	PIII	Titanium dioxide; calcium; H_2O; argon
Surface topographical modifications	Acid etching	Sulfuric acid
	Sandblasting	TiO_2, alumina (AL_2O_3)
Chemical modifications	Sulfonation	Sulfonate groups (-SO_3-)
	Amination	Amine functions
	Nitration	Nitrate functions
Incorporating with bioactive properties	Bioactive inorganic materials	Nano-TiO_2; nanofluorohydroxyapatite
Improving hydrophilicity	UV irradiation	UV-A light, UV-C light
	Plasma gas treatment	Oxygen plasma

PEEK: Polyetheretherketone, UV: Ultraviolet, TiO_2: Titanium oxide, HA: Hydroxyapatite, Ti: Titanium, PIII: Plasma immersion ion implantation, EBE: Electron-beam evaporation

Disadvantages

1. High cost.
2. Chemical processing is tough, due to its low surface energy.
3. Specific machines (e.g., 5 axial milling machines) required for processing.

Conclusion

This article reviewed the applications of PEEK in different fields of dentistry. Although PEEK has various benefits overcurrent restoratives, due to its higher cost and limitation in certain physical properties, it is still under research. It can be a good alternative to various dental restoratives, but sufficient studies and clinical trials still required.

References

1. Toth JM, Wang M, Estes BT, Scifert JL, Seim HB 3rd, Turner AS, *et al.* Polyetheretherketone as a biomaterial for spinal applications. Biomaterials 2006;27:324-34.
2. Kurtz SM, Devine JN. PEEK biomaterials in trauma, orthopedic, and spinal implants. Biomaterials 2007;28:4845-69.
3. Najeeb S, Zafar MS, Khurshid Z, Siddiqui F. Applications of polyetheretherketone (PEEK) in oral implantology and prosthodontics. J Prosthodont Res 2016;60:12-9.
4. Rees JS, Jacobsen PH. The elastic moduli of enamel and dentine. Clin Mater 1993;14:35-9.
5. Skinner HB. Composite technology for total hip arthroplasty. Clin Orthop Relat Res 1988;235:224-36.
6. Ha SW, Kirch M, Birchler F, Eckert KL, Mayer J, Wintermantel E, *et al.* Surface activation of polyetheretherketone (PEEK) and formation of calcium phosphate coating by precipitation. J Mater Sci Mater Med 1997;8:683-90.
7. Rahmitasari F, Ishida Y, Kurahashi K, Matsuda T, Watanabe M, Ichikawa T. PEEK with reinforced materials and modifications for dental implant applications. Dent J 2017;5:35.
8. Donovan TE, Cho GC. Esthetic considerations with removable partial dentures. J Calif Dent Assoc 2003;31:551-7.
9. Ito M, Wee AG, Miyamoto T, Kawai Y. The combination of a nylon and traditional partial removable dental prosthesis for improved esthetics: A clinical report. J Prosthet Dent 2013;109:5-8.
10. Fueki K, Ohkubo C, Yatabe M, Arakawa I, Arita M, Ino S, *et al.* Clinical application of removable partial dentures using thermoplastic resin-part I: Definition and indication of non-metal clasp dentures. J Prosthodont Res 2014;58:3-10.
11. Arda T, Arikan A. An *in vitro* comparison of retentive force and deformation of acetal resin and cobalt-chromium clasps. J Prosthet Dent 2005;94:267-74.
12. 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 Prosthodont 2016;25:580-4.
13. Costa-Palau S, Torrents-Nicolas J, Brufau-de Barberà M, Cabratosa-Termes J. Use of polyetheretherketone in the fabrication of a maxillary obturator prosthesis: A clinical report. J Prosthet Dent 2014;112:680-2.

How to cite this article: Pai SA, Kumari S, Umamaheswari B, Jyothi M, Lakshmi CBS. Polyetheretherketone in prosthodontics – A review. J Adv Clin Res Insights 2019;6: 24-26.