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Review Article

Role of PEEK biomaterial in prosthodontics: A literature review

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Abstract

Introduction: Poly-ether-ether-ketone (PEEK) is a synthetic, tooth coloured polymeric material that has been used as a biomaterial in the field of medical sciences especially in orthopaedics for last few years. As PEEK is relatively a new material in dentistry compared to composite, ceramics or zirconia, it is important to explore and summarize its properties.

Aim: The aim of this review is to study the characteristics, properties and clinical significance of recently introduced dental biomaterial in dentistry that is Poly-ether-ether-ketone (PEEK).

Review Results: The PEEK is a recently introduced biomaterial in prosthodontics and due to its excellent properties like stable chemical properties and biocompatibility properties it can be used in fixed and removable prosthodontics and as well as dental implants among others. PEEK is more aesthetic, stable, biocompatible, lighter and has reduced degree of discoloration compared to the various metals used in dentistry hence may be viable option to replace metal used in dentistry.

Clinical Significance: Numerous studies have proven that PEEK is an excellent viable biomaterial which can be successfully used in the field of prosthodontics. Its clinical use varies from an alternative to PMMA, CAD-CAM restorations, copings etc in fixed dental prostheses and also can be used in removable prosthodontics as an alternative to metal braces and hooks among others. It is being explored as viable option for use in various fields of prosthodontics.

Conclusion: PEEK is an attractive modern biomaterial to use in prosthodontics. Due to its favourable chemical, mechanical and physical properties it is used in producing fixed and removable prostheses and also in implant prosthodontics.

Keywords: PEEK (poly-ether-ether-ketone), PAEK (poly-aryl-ether-ketone), BioHPP, PEEK Abutments, Carbon-fiber reinforced PEEK.

Introduction

Advances in field of dental sciences and innovations in technologies has led to introduction of improved materials. Biocompatibility, low affinity towards plaque and debris, improved esthetics and properties close to teeth are some of the properties to modern materials used in dental sciences. These materials help to restore the defects of the teeth and associated structure. [1]

In spite of countless inventions of this topic, still search is going on to find out the material which will be upto the standard requirements.[2] The practice to find most improved material is ongoing and in current literature directed to meet the biocompatible material and aesthetic demands, Polyetheretherketone bio material has been established that can assist the mechanical and aesthetic properties in field of dental sciences.[3]

PEEK is a tooth coloured synthetic material that has been used for many years in the field of orthopaedics.[4-6] As PEEK is new material in dental field compared to other restorative materials, it is important to explore its properties. This article reviews the characteristics, use in prosthodontics for one of the new dental materials that is PEEK.

PEEK (-C6H4-OC6H4-O-C6H4-CO-) n, is a linear polycyclic semi-crystalline polymer. In 1978 PEEK was developed by English scientists and after that PEEK was commercialized for various applications in other fields. During late 1990s, PEEK was considered as an extraordinary enacted thermoplastic substance for substituting metal implant. After introducing carbon fibre reinforced PEEK, this material was exploited for fixation of fracture and femoral prosthesis in hip joints replacement.[7] In 1992, PEEK material was utilized in dental arena, in the form of aesthetic abutments and as implants[8] and in 2013 a study reports that PEEK might be exploited as a better option for FDP.[9]

Discussion

PEEK and its properties

PEEK is a part of PAEK (poly-aryl-ether-ketone) polymer family. It has been considered as substitute for metallic components in orthopaedics and trauma cases. PEEK has an aromatic molecule having combinations of both ketone (–CO–) and ether (–O–) groups between the aryl rings. PEEK has low density (1.32 g/cm^3), low elastic modulus (3–4 GPa), highly stable.[10,11]

PEEK is radiolucent, white and rigid material having great thermal stability up to temperature of 335.8° C.[12] It has low plaque affinity and non-allergic to oral mucosa.[13-15] Flexural modulus is 140-170 MPa, density – 1300 kg/m3 and thermal conductivity 0.29 W/mK.[13,15,16] The mechanical assets of this material do not change while sterilization using steam, gamma and ethylene oxide. The elasticity modulus is in the variance of 3-4 GPa.[17] The elasticity modulus (EM) and tensile strength are close to human bone, enamel and dentin. The material is resistant to hydrolysis

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and non-toxic having best biocompatibility. PEEK exhibits stable chemical properties i.e. resistance to most substances apart from concentrated sulfuric acid. Lieberman[18] compared PEEK, poly methyl methacrylate and composite resin and concluded that PEEK has the lowest solubility and water absorption compared to others.

Other properties of PEEK are:

1. There is no proof of cytotoxicity, mutagenicity, carcinogenicity or immunogenicity in the toxic form during examination of this material.[19]
2. It can be modified in combination with various materials.
3. This substance is having small EM (near to the bone's elasticity modulus)[20] and reflected as its utmost essential stuff for this material. Accumulation of carbon fibers lead to high level of elastic modulus.
4. It allows magnetic resonance imaging (MRI).[21]
5. Simple laboratory stages.
6. It can be easily modified within the oral cavity.

PEEK Reinforcement

The EM of PEEK is less in comparison to that of cortical bone, Titanium (Ti), and ceramic materials. The greater EM of PEEK is required for dental implant materials, especially those used for abutments and superstructures. Numerous armoured PEEK composite has been established, like carbon fiber-reinforced PEEK (CFR-PEEK) and glass fiber-reinforced PEEK (GFR-PEEK) which have shown elastic modulus to be as high as 18 GPa.[22]

Surface Modification of PEEK for Osseo-integration

PEEK can be modified at a micro level to overcome its bioactivity property. Particles such as Titanium dioxide, Hydroxy fluorapatite and Hydroxyapatite can be combined with PEEK by the process of melt-blending to improve its bioactivity. PEEK has lower osteoconductivity than titanium, the surface modification of PEEK with hydroxyapatite, titanium deposition, increasing its surface roughness, chemical modifications like sulfonation, amination, and nitration with addition of TiO_2[23,24] and hydroxy fluorapatite[25] can improve the biocompatibility to achieve good osseointegration. The modified PEEK exhibits significantly higher tensile properties than pure PEEK. PEEK can be also coated with other bioactive materials using plasma spraying, spin-coating, plasma gas etching, electron-beam deposition, and plasma immersion ion implantation[26].

Role in prosthetic dentistry

PEEK was introduced to dental applications in 1992, first in the form of esthetic abutments and later as implants. After this it has been successfully used as a material in a number of applications including dental implants, healing caps, temporary abutments (due to its mechanical strength, aesthetic qualities, soft tissue response and its ability to shape easily), implant supported prosthesis.[9] PEEK is quite new material in prosthodontics. Compared to the various metals used in prosthodontics PEEK is more lighter, biocompatible material and also reduced degree of discoloration.[27-30] The role of PEEK in prosthodontics is described below:

As implant material

According to Wolff's Law, the bone remodels according to the load that has been applied to it. Fixed component exploration of carbon-fiber reinforced PEEK implants recommended that there should be induction of small shielding stress in comparison to titanium. Though, PEEK dental implants consumption is less, still it is not clear whether difference exists among the bone resorption around PEEK and titanium implants in the humans[6]. The iso elasticity of PEEK composites confirms that PEEK exhibits similar properties to bone and therefore lead to similar distribution of stress along the implant bone interface.[31-33]

For achieving positive osteo-integration, research has linked PEEK with conventional implant materials like titanium and zirconium and resolute that there was no noteworthy variance. Toth et al[4] published a study in that PEEK implants were coated with graft or rhBMP-2, and reviewed after 6 months, he found the integration of implant with sheep bone. Cook et al[34] strengthened the PEEK implant with carbon fibre and titanium then implanted to femurs and after 8 weeks evaluation, similar bone-implant contact ratios were reported.

When resent research is examined, there are no long-term in vivo studies for efficacy of this material. Therefore, PEEK implants are not widely used clinically in present days.

PEEK Abutments

Numerous materials like titanium, ceramics and zirconium are used for production of abutments.[35] However, where esthetics is at demand no satisfactory results are obtained. Zirconium abutments also reported to be worn intraorally with time. Results of numerous studies revealed that the use of zirconium abutments with ceramic is restricted for full ceramic prosthesis over a single tooth implant.[36-38]

When the difficulties like screw breakage for implant are reflected, screws prepared from PEEK can be detached comfortably. Numerous researches found that PEEK material is resilient up to 1200N of chewing forces. Due to low EM of the PEEK[39], literature has stated that the stresses happening both in abutment teeth and in the cement, interface are condensed to minimum. Therefore the stress-based problems of PEEK implant can be minimized. Moreover, due to the improved mechanical properties, it has been encouraged that this material may be used both as an abutment and prosthetic material [40].

The semi-crystalline structure of PEEK decreases brittleness and distortion. So, the difficulties happening in upper structures, abutments can be changed and difficulty of removing a broken screw can be evaded. In a study, no damage was found in 40% of prostheses which fabricated over PEEK abutments. Hence, it was concluded that with change of abutment, same prosthesis can be used again[41].

In Fixed Prostheses

Considering good abrasion resistance, mechanical attributes and aforesaid sufficient bonding to composites and teeth, a PEEK fixed partial denture would be anticipated to have a satisfactory survival rate. Those patients who are allergic to metal and PEEK can be used safely as it has a low reactivity with other materials.[42,43] PEEK dental three-unit fixed prosthesis displayed outstanding outcome during in-vitro exploration. No harm happened to the frameworks or conditions equivalent to 5 years intraoral use[44]. PEEK restorations have greatly exceeded the fracture resistance required to withstand masticatory forces assumed for anterior (300N) and posterior regions (500-600N). Therefore, PEEK substructures could be used in clinical applications. Dental PEEK is reinforced by carbon or glass fibres in different percentages and sizes, according to information provided by the manufacturers and it can influence its milling process.

PEEK can be used as an alternative to PMMA for CAD-CAM restorations. For three-unit PEEK fixed partial denture manufactured via CAD-CAM resistance to fracture is much higher than pressed granular- or pellet shaped PEEK dentures. The fracture resistance of the CAD-CAM milled PEEK fixed dentures is much higher than those of lithium disilicate glass-ceramic (950N), alumina (851N), zirconia (981-1331N).[31]

In removable prosthesis

PEEK is used in removable prosthodontics as an alternative to metal braces and hooks in removable partial prostheses. In comparison with chrome-cobalt-based partial prostheses, PEEK hooks have been shown to have lower retentive strength[45]. The patients who are allergic to metals, or who dislike the metallic taste, the weight, and metal display of framework and clasps, this material can be used safely. The modified PEEK i.e. BioHPP, is non-allergic, rigid biomaterial with flexibility comparable to bone.[26] Another application of PEEK is the construction of a removable obturator.[46,47] Nevertheless, more studies are needed to evaluate the efficacy of PEEK obturators compared to conventional acrylic prostheses. To date, no clinical studies or systematic reviews focusing on the use of PEEK dentures have been published. However, owing to the superior mechanical and biological properties of PEEK, it will not be surprising if dentures constructed from the polymer are routinely constructed in near future.[13]

Bonding of PEEK Material to Composites

The main benefit of this material is that it can bind to indirect composites polymerized with light. To accomplish all esthetic needs, this material can be glazed with composite resins. High bonding is necessary between composite resins in the formation of the gingival tissue emergence profile and the gingiva shaping when PEEK is used as temporary abutment. Cleaning and roughening of the surface is usually needed for bonding between PEEK and composite. In most cases, the application of opaque material is known to increase resistance to shear forces. Successful surface bonding is provided by surface activation with roughening followed by processing with acetone, phosphate-based methacrylate linings or tribochemicals.[45]

The acid etching with sulfuric acid for 60–90s increases bond strength to resin composite cements as much as 15.3±7.2 MPa after being stored in water for 28 days at 37^0C. Acid etching with piranha acid and use of bonding agent to bond with composite resin produces a bond strength as high as 23.4±9.9 MPa. But no significant differences were found between bonding of PEEK crowns and dentin abutments using air abrasion and sulphuric acid etching techniques. The researches proposed that PEEK might be used under resin composite as a coping material. Due to similar mechanical properties of PEEK to those of dentin and enamel, PEEK have an added advantage over alloy and ceramic restorations[13].

PEEK and CAD/CAM

PEEK is high-performance polymer that has been used for industrial purpose for long time and was also successful in areas of medicine. Due to increased weight of prosthesis, display of metal and metallic taste of prosthesis have led to the introduction of a number of thermoplastic materials for use in dental practice.[48,49] It is now also finding increased uses in dentistry as a direct result of CAD/CAM technology. The biocompatibility and superior mechanical properties of this material leads to its use for various dental restorations and made it ideal for CAD/CAM framework fabrication. The advantage of a CAD/CAM fabricated framework is its mechanical properties that PEEK material are not adversely affected by the milling process, if followed manufacturer's specification. Fixed bridge frameworks milled from a high-grade, industrially manufactured block undergo no physical changes during the fabrication process and possess the same material/technical properties.[50]

Clinical significance

This review describes that as most of the properties of PEEK being similar to dentin and bone, hence may be used in prosthodontic for implants, abutment, fixed and removable dental prosthesis. PEEK can also be used as material for generating CAD-CAM fixed and removable prosthesis due to its better mechanical properties compared to materials such as acrylic.

Conclusion

Due to various enhanced chemical, mechanical and physical properties, PEEK is a modern material to use in prosthodontics. It can be used or both fixed and removable prostheses. However, more in vivo studies are necessary to be carried out to ascertain the suitability & applicability of this material.

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None.

Conflict of Interest

None.

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