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Review Article

Polyether-Ether-Ketone (PEEK) and its Application in Prosthodontics: A Review

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Abstract: Polyetheretherketone (PEEK) material is a polycyclic, aromatic, thermoplastic polymer that is semi-crystalline and has a linear structure. Polyether Ether Ketone (PEEK) material is a modern material attracting interest for use in dentistry. Metal-free restorations are gaining popularity in current dental therapies due to aesthetic concern and PEEK is one among the metal free restorations that has many potential uses in dentistry. Due to its excellent properties, PEEK is gaining importance in oral implantology and prosthodontics. According to existing articles, peek is a viable alternative for dental implants. Due to its excellent mechanical and aesthetic properties, it is non-allergic and has low plaque affinity PEEK can also be used as a framework for removable and fixed dental prosthesis. Polyether Ether Ketone (PEEK) meets all the demands and has proven its versatility in a very short span of time in recent prosthetic advancements. This review provides a glimpse into recent trending material in the discipline of prosthodontics and its applications.

Keywords: PEEK, Polyetheretherketone, prosthodontics, implant, prosthesis.

INTRODUCTION

Advance in dentistry and development of technologies can be achieved by improving materials. Modern materials used in advanced dentistry must have biocompatibility, low plaque affinity, good aesthetics, and characteristics that are similar to the dental structure. It aids in the restoration of tooth and dentition defects and satisfies even the most demanding patients. In view of aesthetic concerns, metal free restorations are gaining popularity in current dental therapies.

PEEK is one among the metal free restorations that has many potential uses in dentistry. Due to its excellent properties PEEK is gaining importance in oral implantology and prosthodontics [1]. Titanium (Ti) and its alloys have been used as dental implants since their introduction by Branemark. Ti materials have a number of clinical problems, including metal hypersensitivity and allergies, periimplantitis-related surface degradation and contamination, a high modulus of elasticity, and a metallic colour that is less acceptable in aesthetic regions. Due to its excellent mechanical and aesthetic properties PEEK can also be used as framework for removable and fixed dental prosthesis, orthodontic wires [2]. The properties and applications of PEEK in prosthodontics are summarised in this article.

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HISTORY OF PEEK

Historically, the availability of PEEK arrived at a time when there was growing interest in the development of "isoelastic" hip stems and fracture fixation plates, with stiffnesses comparable to bone [3]. 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 [1, 4].

In the 1990s, researchers characterized the biocompatibility and in vivo stability of various PAEK materials, along with other "high-performance" engineering polymers, such as polysulfones and polybutylene terephthalate. However, concerns were raised about the stress-induced cracking of polysulfones by lipids, and use of these polymers in implants was subsequently abandoned. By the late 1990s, PEEK had emerged as the leading high-performance thermoplastic candidate for replacing metal implant components, especially in orthopedics and trauma.

Not only was the material resistant to simulated in vivo degradation, including damage caused by lipid exposure, but starting in April 1998 PEEK was offered commercially as a biomaterial for implants (Invibio, Ltd.: Thornton Cleveleys, United Kingdom). Facilitated by a stable supply, research on PEEK biomaterials flourished and is expected to continue to advance in the future. Numerous studies documenting the successful clinical performance of PAEK polymers in orthopedic and spine patients continue to emerge in the literature.

Recent research has also investigated the bio tribology of PEEK composites as bearing materials and flexible implants used for joint arthroplasty. Due to interest in further improving implant fixation, PEEK biomaterials research has also focused on compatibility of the polymer with bioactive materials, including hydroxyapatite, either as a composite filler, or as a surface coating. As a result of ongoing biomaterials research, PEEK and related composites can be engineered today with a wide range of physical, mechanical, and surface properties, depending on their implant application [3].

What is a Polymer?

Polyaryletheretherketone (PEEK) belongs to a class of materials known as polymers, or in lay terms more simply as plastics. PEEK is known as a linear homopolymer in particular. The definition of polymer has its origins in the Greek, "polumeres", meaning "having many parts." The repeating units, or monomer segments, of a polymer can all be the same. In such a case, we have a homopolymer. Polymers may be linear or branched. The tendency for branching in a homopolymer depends strongly on its synthesis conditions. The distinguishing feature of a polymer—as compared with a metal or ceramic—is its molecular size. In a polymer such as PEEK, the molecule is a linear chain of hundreds monomer units with an average molecular weight of 80,000–120,000 g/mol[4].

What is PEEK?

Polyaryletheretherketone, commonly referred to as PEEK, is a member of the PAEK polymer family. Commercialized for industry in the 1980s, PAEK is a family of high-performance thermoplastic polymers, consisting of an aromatic backbone molecular chain, interconnected by ketone and ether functional groups [5]. PEEK is composed of repeating units of three phenyl rings, two ester groups and on keto group. As a result, PEEK is part of a larger family of PAEK polymers known as polyetherketones or simply polyketones [6]. The chemical structure of PEEK, like its PAEKK cousins, confers stability at high temperatures. It is a suitable biomaterial for orthopedic and spine implants. PEEK is available as tan pellets or powder, which can be converted into implant parts by standard polymer processing techniques. PEEK implants can be fabricated by machining from extruded rods or compression molded sheets.

Peek Properties

1. It is a semi-crystalline polymer having melting point - around 335 °C [7].
2. It has Elastic modulus (3-4 GPa) which is close to human cortical bone [2].
3. Thermal stability up to 335.8° C9 [3].
4. It is a Radiolucent material [3].
5. Resistant to radiation damage [3].
6. Wear-resistant [8].
7. Biocompatible & does not cause mutagenic effect or Non-toxic [8, 9].
8. PEEK shows resistance to deterioration during various sterilisation procedures; hence it can be sterilised with heat sterilisation methods without affecting its properties
9. Its chemical structure makes it highly resistant to chemical and radiation damage, thus making PEEK compatible with many reinforcing agents such as glass and carbon fibers [9].

Peek as Dental Implant

PEEK with an elastic modulus of (3–4 GPa), which is closer to that of bone, while that of titanium is (102-110GPa). Modulus can be modified by reinforcing it with carbon fibers, for example, to achieve a modulus of 18 GPa, similar to that of cortical bone [10].

Modification of Peek Implants

A variety of improvements to PEEK materials have been attempted in order to enhance mechanical and biological properties[2].

1. **Nano Structured Surfaces**

• Spin Coating with Nano-HAP
• Plasma- gas treatment (O_2/ Ar/NH_4)
• Plasma electron beam deposition(Ti,TiO_2)
• Plasma ion immersion implantation(TiO_2)

2. **Bio-Active Nano-Composites**

• TIO_2/PEEK
• HAF/PEEK USES OF PEEK

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.

Incorporating nano-sized particles like those of hydroxy fluorapatite has been suggested to impart anti-microbial properties against Streptococcus mutans, a common oral pathogen, in addition to improving osseointegration in vivo. Nano-hydroxyapatite, Nano hydroxy fluorapatite and Nano-titanium oxide particles can be used [11, 12].

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. Unmodified PEEK is not used as a definitive abutment material because its fracture resistance is lower than that of titanium. However, the introduction of ceramic reinforced PEEK (Bio-HPP) made its use as a permanent abutment.

Because of the high mechanical properties, it has been advocated that this material can be used both as an abutment and prosthetic material. Abutments are made from a variety of materials, including titanium, gold, zirconium, and ceramics [13]. Despite the fact that titanium and alloys have several drawbacks, such as corrosion and over-sensitivity reactions, they are the most commonly used materials in the manufacture of implants and abutments and have been accepted as the gold standard [14]. However, optimal results are impossible to achieve in some situations where aesthetics are a top priority. When fine biotype gingival tissue is present, aesthetic issues are more likely to occur. Furthermore, gold has a limited potential for use in terms of cost [13]. Zirconium abutments wear out intraorally over time.Furthermore, since the mechanical resistance is low, changes in the internal structure occur. This material is characterized by disadvantages such as deterioration in water and water solutions and at low temperatures, and transition from a tetragonal phase to a monoclinic phase. Results of in vitro and in vivo studies have shown that the use of aluminum and zirconium ceramic abutments is limited with full ceramic prosthesis over a single tooth implant [15]. Since the elastic property of PEEK material decreases the forces produced during chewing that are transmitted to the implant, it has been believed that the stresses occurring both in abutment teeth and in the cement interface are reduced to a minimum because of the low elastic modulus of this material. It is thought that the stress-based problems of PEEK in implantology could be overcome. Furthermore, because of the high mechanical properties, it has been advocated that this material can be used both as an abutment and prosthetic material.

Peek as Removable Partial Denture

Because of its light weight and superior biologic, aesthetic, and mechanical properties, PEEK can be used by CAD CAM systems to create clasps and dentures. Another use would be to create removable obturators. Biocompatibility, resistance to cracking, flexural bone modulus, machinability and ease of polishing of PEEKOPTIMA (reinforced poly-ether-ether ketone) allows material to be used in the palatal section of maxillary obturator prostheses.

In a partial denture framework made of PEEK, patient comfort is enhanced because of its strength and lightweight, digital design customises individual anatomy, absence of metallic taste, no thermal and electrical conductivity, scanner and x-ray friendly, non-allergic. PEEK frameworks are shock absorbent during mastication and have an excellent resistance to decay and abrasion [16].

The retentive force of BioHPP 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. BioHPP clasps are gentler to the enamel and porcelain restorative materials than conventional Cr-Co clasps are. Clasps made of BioHPP result in healthy periodontium, especially in cases of tissue proximity, due to the material's low plaque affinity properties [17].

Disadvantages of metallic RPD:	Advantages of PEEK RPD:
■ Esthetically unacceptable display of metal clasps. ■ Increased weight of the prosthesis. ■ Potential for metallic taste. ■ Allergic reactions to metals.	■ High biocompatibility. ■ Good mechanical properties. ■ High temperature resistance. ■ Chemical stability. ■ Due to a 4 GPa modulus of elasticity, it is as elastic as bone and can reduce stresses transferred to the abutment teeth.

Peek as Crowns and Fixed Partial Dentures (Fpd) Frameworks

PEEK is processed in two ways for crown and bridge framework: vacuum pressing and CAD CAM. PEEK granules are vacuum pressed or milled into a framework for a long-span FPD, which is then layered with a Nano composite. Due to its poor translucency and greyish pigmentation, it also needs veneering.

As PEEK material can be more easily repaired than ceramics, it does not wear down within the mouth and no deterioration is seen in the material properties during processing, this increases the possibility of its use as crown material. Furthermore, despite its low modulus of elasticity and hardness, the material's high wear resistance allows it to compete with metallic alloys [18].

PEEK WITH REINFORCED MATERIALS

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. There are many ways in which PEEK can be modified at a nanometer level to overcome its limited bioactivity.

- Carbon-fiber reinforced PEEK (CFR-PEEK) [19].
- Glass-fiber reinforced PEEK (GFR-PEEK) [20].
- Ceramic reinforced PEEK (Bio-HPP) [21].
- Hydroxyapatite reinforced PEEK [22].
- Nano-TiO2/PEEK(n-TiO2/PEEK) [23].
- Nano-fluroapatite PEEK (n-FA/PEEK) [24].

Conclusion

PEEK is quite a new material in prosthodontics. Compared to the metals used in dentistry, PEEK is more aesthetic, stable, biocompatible, lighter and has reduced degree of discoloration. This makes it more attractive to patients with high aesthetic requirements. Due to its favorable chemical, mechanical and physical properties, it is used in producing fixed and removable prostheses. The mechanical properties of the PEEK are similar to dentin and enamel. Thus, it has superiority over metal alloys and ceramic restorations. Studies have shown that it performs well as a dental implant after surface modification to render it bioactive and increase osseointegration.

Bone replacement material for nasal, maxillary and mandibular reconstructions, osteosynthesis plates, skull implants and dental implants will be possible applications of PEEK. Reinforcement with carbon fibers has improved the mechanical properties of PEEK; hence, CFR-PEEK has become a more promising alternative to metallic materials. PEEK polymers are inherently strong, inert, and biocompatible, with neither the bulk material nor its particulates elicit any adverse biological response when compared to other available biomaterials that have been in clinical use for many years. Long term clinical studies are needed for eligibility of PEEK as a dental biomaterial considering that it is still a new material.

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