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Review Article

PEEK: A NEW PEAK OF DENTISTRY

Juhee Naresh Mehta., Madhumita Sachdeva and Maya Dalaya

Bharati Vidyapeeth Dental College and Hospital, Sector 7 CBD Belapur, Near Kharghar Railay Station, Navi-Mumbai, Maharashtra India

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ABSTRACT

Poly Ether-Ether Ketone also known as PEEK is a thermoplastic composite polymer from the group of polyaryl ether ketone. PEEK is characterized by excellent mechanical and chemical properties. Due to its combination of superior biocompatibility and ideal mechanical properties, it is ideal for CAD/CAM framework fabrication in prosthetic dentistry.It is of great interest as an alternative to titanium because of its biocompatibility and low elastic modulus. In dental technology, the uses of PEEK include abutments, fixed prosthetic frameworks and removable partial denture frameworks including precision attachments.

INTRODUCTION

Polyetheretherketone (PEEK) is a synthetic, tooth coloured polymeric material that has been used as a biomaterial in the field of orthopedics for many years[1].The monomer unit ofetheretherketone monomer polymerizes via step-growth dialkylation reaction of bis-phenolates to form polyetherether-ketone. PEEK can be modified by the addition of functionalized monomers (pre-polymerization) or post-polymerization modifications by chemical processes such as sulphonation, amination and nitration[2]. The major beneficial property for orthopedics implant application remains its lower modulus of elasticity (3-4 GPa) being close to human bone[3]. PEEK can be easily modified by incorporation of other materials like carbon fibres which increases the elastic modulus upto 18GPa[3]. The titanium and its alloys have elastic modulus significantly higher than bone and resulting in severe stress-shielding and failure[4]. The modulus of carbon-reinforced PEEK is also comparable to those of cortical bone and dentin so the polymer could exhibit lesser stress shielding when compared to titanium which is used as an implant material. Moreover, tensile properties of PEEK are also analogous to those of bone, dentin and enamel, making it suitable restorative material as far as the mechanical properties are concerned.

In contrast to titanium, PEEK has very limited osteoconductive properties[5]. Hence, to improve the bioactivity of PEEK implantsa considerable amount of research has been conducted. There are a number of methods that have been proposed to improve the bioactivity of PEEK which includes coating PEEK with synthetic osteoconductive hydroxyl apatite[6], increasing its surface roughness and chemical modifications and incorporating bioactive particles[7]. PEEK has white colour with excellent mechanical properties, hence it has been proposed for other prosthodonticapplications such as fixed prostheses and removable prostheses[8]. The effects of surface modification of PEEK have been investigated for bonding with different luting agents and extracted teeth[9]. The potential of PEEK for various dental applications has been shown in Fig. 1. Moreover, PEEK can also be used an esthetic orthodontic wire. Compared to other polymers, such as polyether sulfone (PES) and polyvinylidenedifluoride (PVDF), PEEK orthodontic wires are able to deliver higher orthodontic forces but at a cross-section of that similar to metallic wires such as cobalt- chromium (Co-Cr), titanium-molybdenum (Ti-Mo) and nickel-titanium (Ni-Ti)[10]. Due to these unique physical and mechanical properties, PEEK is a promising material for dental applications. The aim of this review is to summarize the outcome of research conducted on the material for prosthodontic applications. In addition, future prospects of PEEK in the field of clinical dentistry has been highlighted.

Corresponding author:* **Juhee Naresh Mehta
Bharati Vidyapeeth Dental College and Hospital, Sector 7 CBD Belapur, Near Kharghar Railay Station, Navi-Mumbai, Maharashtra India

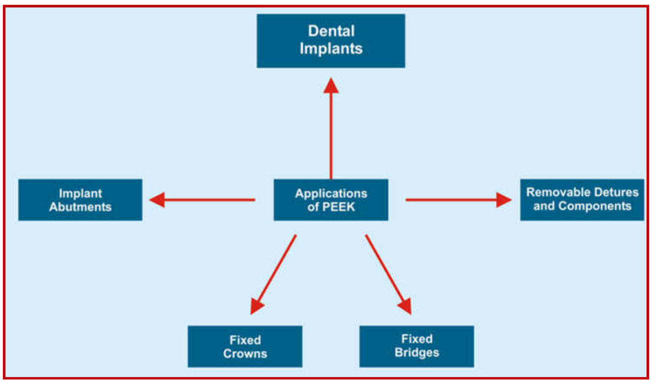

Fig 1 Major applications of polyetheretherketone (PEEK) in dentistry

PEEK as an implant material

Dental implants have a centuries-long history; indeed there is evidence that prehistoric peoples sought this technology. As dentistry progressed in the past century, experimental implant designs focused on materials and techniques that might serve as quality anchorages for conventional dental prostheses.

By the mid-20th century, a number of sophisticated techniques had been developed, including subperiosteal, transosteal and bladeimplants[11]. Highest degree of interplay between biological and physical properties of a material is needed in case of replacing entire tooth or multiple teeth using dental implant.

Many times the biomaterial fails clinically because of fracture or deformation. The reasons for such failure are either due to failure of compliance by the patient or inability of the biomaterial to match the physical and the biological requirements[11].

Factors like detailed understanding of the biological environment, exposure to various functional and para-functional forces, condition of the tissues receiving the material and medical co-morbidities should be always considered while developing and selecting a biomaterial[12].
In recent decades predictable dental implants were introduced and have revolutionized dentistry. However, none of these were able to meet the all ideal requirements of the implant material.

The requirements of successful implant biomaterial include: biologic compatibility, mechanical compatibility, morphologic compatibility, imaging and esthetic compatibility[13].

The properties like formability, adhesion, tensile strength, compressive strength, ductility, fatigue resistance, wear resistance, young's modulus, toughness and the physical properties like density, thermal conductivity, electrical conductivity, optical property, thermal expansion are considered for any material to be used as dental implants[14].

The primary advantage of PEEK composite implant biomaterial include

1. Improvement of biocompatibility.
2. Diminution of the stress shielding effect on the surrounding bones that regularly occurs.
3. Improvement of biomechanical requirement.
4. Esthetic compatibility.
5. Precluding the marginal bone loss and peri-implantitis by reducing the micro gap between implant and soft tissue interface.
6. Added advantages like no galvanic side-effects, lack of immunogenicity and MRI compatibility.

The added advantages of the modified PEEK are greater than the conventional PEEK material. Fig. 2 shows various modifications of PEEK to increase its bioactivity.

PEEK can be modified easily by incorporation of other materials. For example; incorporation of carbon fibers can increase the elastic modulus up to 18 GPa. The modulus of carbon-reinforced PEEK is also comparable to those of cortical bone and dentin[15], so the polymer could exhibit lesser stress shielding when compared to titanium which used as an implant material.

Unmodified PEEK is inherently hydrophobic in nature, with a water-contact angle of 80-908 and bioinert[16]. Indeed, studies have shown that there is no significant effect of unmodified PEEK on the proliferation rate of cells in vitro[17]. On the contrary, some studies have observed an increased protein turnover in cells in contact with conventional- and CFR-PEEK[18].

In order to improve the mechanical and biological proper-ties, a number of modifications have been attempted in PEEK materials. However, PEEK dental implants have not been extensively used clinically and there is insufficient data to deduce their long-term efficacy in human subjects.

Table 1 shows the tensile strength and elastic moduli of PEEK, CFR-PEEK, PMMA and mineralized human tissues.

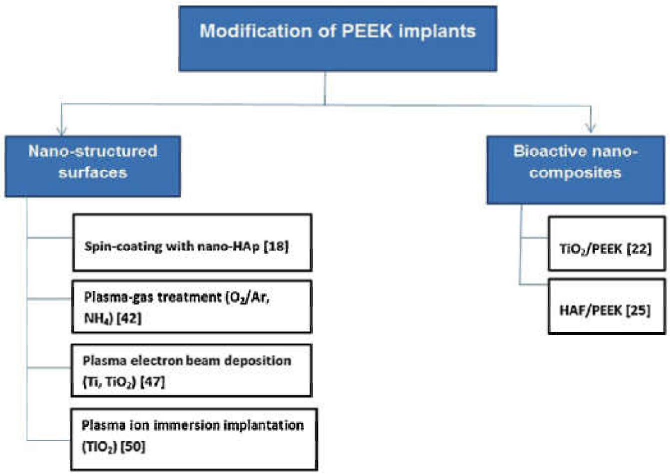

Fig 2 Nano-modification of polyetheretherketone (PEEK) to increase its bioactivity

Table 1 The tensile strength and elastic moduli of PEEK, CFR-PEEK, PMMA and mineralized human tissues

MATERIAL	TENSILE STRENGTH(MPa)	YOUNG'S MODULOUS(GPa)
PEEK	80	3-4
CFR-PEEK	120	18
CORTICAL BONE	104-121	14
PMMA	48-76	3-5
DENTIN	104	15
ENAMEL	47.5	40-83
TITANIUM	954-976	102-110

Considering adequate biocompatibility, implant healing abutments can be constructed using PEEK[19-20].A close match of elastic moduli of bone and PEEK surface reduces the stress shielding effects and encourage bone remodeling. Hence, PEEK could prove to be a viable alternative to titanium in constructing implant abutments.

PEEK as a removable prosthesis material

Dentures can be constructed by using PEEK computer-aided design and computer-aided manufacture systems[21].Tannous *et al*. has suggested that denture clasps made of PEEK have lower retentive forces compared to cobalt-chromium (Co-Cr) clasps[22]. Another application of PEEK is the construction of a removable obturator[23].

PEEK crowns

A variety of procedures have been suggested to condition the surface of PEEK in order to facilitate its bonding with resin composite crowns. Even though air abrasion with and without silica coating creates a more wettable surface[24], etching with sulphuric acid creates a rough and chemically altered surface which enables it to bond more effectively with hydrophobic resin composites (shear bond strength: 19.0 _ 3.4 MPa)[25].It has been observed that etching with sulfuric acid for 60-90 seconds can exhibit shear bond strength to resin composite cements as high as 15.3±7.2 MPa after being stored in water for 28 days at 37.8ºC[26]. Etching with piranha acid and using a bonding agent have been shown to produce tensile bond strength to composite resin as high as 23.4±9.9 MPa in aged PEEK specimens[27].

These studies suggest that PEEK can be used under resin-composite as a coping material. Because the mechanical properties of PEEK are similar to those of dentin and enamel, PEEK could have an advantage over alloy and ceramic restorations.

PEEK CAD-CAM milled fixed partial dentures

Using CAD-CAM to manufacture restorations makes it possible to produce dental prostheses chair-side[28]. CAD-CAM designed composites and polymethylmethacrylate (PMMA) fixed dentures have superior mechanical properties compared to conventional fixed dentures[29-30]. PEEK is another material that can be used an alternative to PMMA forCAD-CAM restorations. Three-unit PEEK fixed partial denture manufactured via CAD-CAM has been suggested to have a higher fracture resistance than pressed granular- or pellet-shaped PEEK dentures[29]. 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].The abrasive properties of PEEK are excellent. Despite of significantly low elastic moduli and hardness, abrasive resistance of PEEK is competitive with metallic alloys[32]. Considering good abrasion resistance, mechanical attributes and aforementioned adequate bonding to composites and teeth, a PEEK fixed partial denture would be expected to have a satisfactory survival rate.

CONCLUSION

Because of its mechanical and physical properties being similar to bone and dentin, PEEK can be used for a number of applications in dentistry including dental implants. Increasing the bioactivity of PEEK dental implants without affecting their mechanical properties is a major challenge. PEEK is also an attractive material for producing CAD-CAM fixed and removable prosthesis owing to its superior mechanical properties compared to materials such as acrylic. Further research and clinical trials are required to explore this material and possible modifications for further dental applications.

Conflict of interest

No conflicts of interest.

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