REVIEW ARTICLE

An Insight into a Novel Material: PEEK

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ABSTRACT
Advancements in dentistry bombard us daily, these advancements have resulted in improved materials and techniques and also offer additional choices in how dentists care for patients. The field of prosthodontics has embraced many new techniques and technologies to improve its ability to restore the oral health of patients to a level of precision and predictability that could not be previously achieved. The advent of newer materials with better properties is always on the rise. One such material with an increasing use in prosthodontics is polyether-ether ketone (PEEK).

INTRODUCTION
Newer treatment modalities, materials and techniques have not only expanded the dental literature but also the prosthetic treatment alternatives available to dentist and their patients. Technology has brought some exciting advances in dentistry. Advances in dentistry as well as increased desire of patients to maintain their dentition have led to treatment of teeth that once would have been removed.1

Prosthetic treatment should focus at rehabilitation of mastication, phonetics and aesthetic function of the patients. There is a continued improvement of materials and techniques used in dentistry especially in the branch of prosthodontics. One such material is polyether ether ketone (PEEK). It is a high-temperature semi crystalline thermoplastic polymer related to group of poly aryl ether ketone (PAEK), consisting of an aromatic backbone molecular chain, interconnected by ketone and ether functional groups with the density of 1.3–1.5 g/cm3,2 which offers a good combination of high tensile strength, stiffness, toughness, good wear resistance, low coefficient of friction, excellent chemical resistance, very low moisture absorption and a high melting point (about 343°C), resistance to fatigue and has been increasingly used in dentistry due to its biocompatible nature as healing caps, temporary abutments, crowns and bridges and also as alternatives to metal framework.

PEEK has resistance to chemical and radiation damage and compatibility with many reinforcing agents (such as glass and carbon fibres) and greater strength (on a per mass basis than any metal). It has chemical stability to nearly all-organic and inorganic chemicals which makes it an interesting material for metal-free prosthodontics.3

HISTORY OF PEEK
By the late 1990s, PEEK had emerged as the leading high performance thermoplastic candidate for replacing metal components, especially in orthopedics and trauma. In 1992, PEEK was used for dental applications, first in the form of aesthetic abutments and later as implants, since then many variations in composition have been carried out to modify and improve upon working characteristics of the implant.4 In recent years with confirmation of its biocompatibility, PEEK has been increasingly employed as an effective biomaterial for implantable medical devices such as orthopaedic, spinal and cranial implants.5 The availability of polyaromatic polymers arrived at a time when there was growing interest in development of “isoeelastic” hip stems and fracture fixation plates with stiffness comparable to bone.

ADVANTAGES OF PEEK

• Excellent dimensional stability.
• High mechanical properties, tough and durable, melting point 340°C.
• Good wear and frictional resistance, elastic modulus similar to bone.
• High temperature resistance and high comfort due to immediate absorption of body heat.
• Metal free hence no metal allergy and no metallic taste.
• Digitally designed to match patient’s anatomy.
• Pure material, no additives, no colouring.
• No abrasion of antagonist.
• No veneer chipping, no framework fracture.

KEYWORDS polyether-ether ketone, prosthodontics, RPD framework
APPLICATIONS OF PEEK

Crowns and Bridges

Mechanical properties and biocompatibility of PEEK allows for permanent metal free crowns and bridges. It also allows diagnostic treatment without substructure removal. It has stiffness compared to metal which is aimed at improving comfort with excellent preservation of antagonist natural tooth. In contrast to ceramic and metal materials it was shown that peek dental 3 unit bridge substructure were not weakened by in vitro ageing. PEEK crowns withstand very high compressive loads.6

PEEK as an Alternative to RPD Framework

Traditional removable dental prostheses (RDPs) with chrome cobalt frameworks and clasps have been an inexpensive and predictable treatment option for the rehabilitation of partially edentulous patients.7,8 The aesthetically unacceptable display of metal clasps, the increased weight of the prosthesis, the potential for metallic taste, and allergic reactions to metals led to the introduction of a number of thermoplastic materials in clinical practice such as nylon and acetal resins.

An alternative restoration material (PEEK) has been successfully used over the last years in the medical field, and orthopaedics, specifically. A modified PEEK material containing 20% ceramic fillers is a high performance polymer which presents high biocompatibility, good mechanical properties, high temperature resistance, and 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. Furthermore, the white colour of PEEK frameworks provides a different aesthetic approach than the conventional metal framework (Fig. 1) display does.7 Additional advantages of this polymer material are elimination of allergic reactions and metallic taste, high polishing qualities, low plaque affinity, and good wear resistance (Fig. 2).

PEEK as an Implant Material

For decades, universal choices of implants material have been titanium and its alloys, often tagged as the wonder metal. Titanium’s strength, low weight and biological inertness made it the prime candidate for making “fit and forget” implants. Titanium can undergo corrosion due to breaking down of stable oxide layer. Galvanic coupling of titanium to other restorative materials may also generate corrosion.4

Figure 1: Previous metal framework.
Another controversy that has generated much speculation is that of titanium allergy or hypersensitivity. Problem could occur due to the gradient difference in the elastic moduli of a titanium implant and its surrounding bone. This may cause stress in the implant-bone interface during load transfer, probably resulting in peri-implant bone loss. Also, titanium can cause aesthetic problems due to its lack of light transmission. This can provoke a dark shimmer of the peri-implant soft tissue in cases of thin biotype mucosa and/or mucosa recession around a titanium implant. This can be problematic especially in the presence of a high smile line.

A biocompatible material with an elastic modulus of 3.6 GPa, which is closer to that of bone, is PEEK. Its modulus can be modified by reinforcing it with carbon fibres, for example, to achieve a modulus of 18 GPa, similar to that of cortical bone. Several studies show that PEEK abutments are a viable alternative to titanium abutments for use in aesthetic zone of maxilla. It has been demonstrated that PEEK abutments can withstand intra oral masticatory forces similar to that of titanium abutments. PEEK abutments provide a cost effective versatile solution allowing chair side modification in the dental surgery at the time of implant placement.

Furthermore PEEK's proven soft tissue behaviour supports the good recovery of gingival tissue. There are many ways in which PEEK can be modified at a nanometre level to overcome its limited bioactivity. Nanoparticles such as TiO$_2$, HAF and HAP can be combined with PEEK through the process of melt-blending to produce bioactive nanocomposites. Additionally, HAF has antibacterial properties which could prevent peri-implantitis and early implant failures. Spin-coating, gas plasma etching, electron beam deposition, and plasma-ion immersion can be used to modify or coat the surface of PEEK implants at a nanometre level.

**PEEK in Veneering System**

Standard techniques can be used to fabricate restorations from the PEEK-based dental polymer substructure. Good results can be achieved with a range of commercially available veneering composite. In case of veneer chipping, PEEK substructure can allow repair without the need for crown or bridge replacement.

**Cement Systems and Surface Preparations of PEEK Substructure**

Restorations fabricated with PEEK-based dental polymer can be cemented using a range of commercially available systems. Certain studies have demonstrated...
that sulphuric acid etching can improve bond strength of resin cements to PEEK surfaces. However, no general recommendations can be made for individual dental luting materials on the market. The use of methyl methacrylate (MMA)-based adhesives allows bonding between PEEK and self-adhesive resin cements, however plasma treatment has no impact on bond to resin cements.\textsuperscript{11}

**Colour and Radiolucency**

PEEK polymer is naturally radiolucent and compatible to imaging techniques such as X-ray, MRI and CT. PEEK dental polymer allows clinical diagnostics and treatment through PEEK substructure without need for substructure removal and replacement. PEEK is available in natural and white for improved aesthetics.\textsuperscript{6}
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CAD/CAM Machining

PEEK dental injection molded shapes allow CAD/CAM machining of dental substructure with reduced tool wear and improved margin control allowing for tight fit restorations. PEEK blocks can be successfully machined using CEREC milling machine and standard burs.5

LIMITATIONS OF PEEK

Carbon reinforced PEEK dental implants demonstrated higher stress peaks due to reduced stiffness compared to titanium. Further experimental studies on chemical modulation of PEEK seem necessary to minimise stress distribution to peri-implant bone. Endless carbon fibres give PEEK high stability. Further investigations are necessary to evaluate whether there is distinct amount of endless carbon fibers causing optimal stress distribution behaviour of CFR-PEEK.

Titanium abutment screws had higher fracture resistance in comparison with PEEK and 30% carbon reinforced PEEK abutment screws.2

Non-etched PEEK demonstrated no bond strength to resin composite cements. Self-etching resin composite cement showed significantly lower shear bond strength values when compared to groups luted with the conventional resin composites.11

CONCLUSION

Dentistry is a rapidly progressing field with innumerable advances taking place on a day to day basis. The application of newer technologies and materials has advanced the specialty of prosthodontics and the services rendered to the patients. There will always be a continued improvement of materials and techniques used in dentistry especially in prosthodontics. Due to their properties and advantages innovative techniques must be regarded as potential alternatives to traditional materials, and a dentist should always be on a lookout for such materials.

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