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REVIEW ARTICLE **OPEN ACCESS**

Applications of Polyether Ether Ketone in Dentistry- An Overview

***J. Raghunathan, R. Kamalakannan, S. Gokul, N. C. Arunprasad, S. Vinoth Kumar, Y. Sameera**
Department of Prosthodontics, Karpaga Vinayaga Institute of Dental Sciences, Padalam – 603308, TamilNadu
*Corresponding author: jraghumds@gmail.com

ABSTRACT
Polyetheretherketone (PEEK) is a colorless, organic, thermoplastic polymer and a semi-crystalline material with a high melting temperature. The mechanical properties of PEEK make it a promising material for several removable and fixed prostheses, implants, and orthodontic wires in dentistry. Due to several advantages, PEEK is used as one of the safe and viable materials for restoring the lost orofacial tissues and in performing metal-free restorations. The metallic color and occasional hypersensitivity have made titanium less acceptable in aesthetic concerns.
Keywords: PEEK, Aesthetics, Biocompatible, Polymers.

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INTRODUCTION

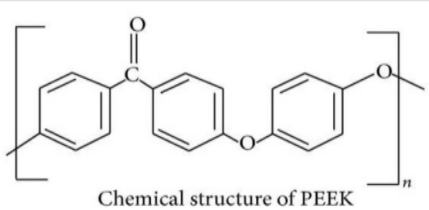
PEEK is a polycyclic, aromatic, thermoplastic polymer of the PAEK (Polyaryletherketone) family. It has been used for several prosthodontic purposes because of its excellent mechanical properties and white color (1). The carbon-reinforced PEEK exhibits lesser stress shielding property when compared to titanium since carbon fibers can increase the elastic modulus of PEEK up to 18Gpa (2). Hence, PEEK is used over titanium in dental implants. PEEK is also used as an alternative to PMMA, CADCAM restorations, copings, metal braces, and hooks in fixed and removable prostheses. PEEK has also been used in orthopedics in joint replacement, spinal surgery, fracture fixation, femoral prosthesis in hip joint replacement, and maxillofacial surgery (3-6). Therefore, this review focuses on the structure, properties, and applications of the PEEK material.

HISTORY

PEEK was originally introduced by Victrex PLC in 1978.In 1980, PEEK was commercialized for engineering and industrial applications such as the manufacture of aircraft, turbine blades, piston parts, etc (7). Later in 1998, PEEK became an important biomaterial in medical and dental clinical cases.

STRUCTURE

PEEK$\{C_6H_4\text{-}O\text{-}C_6H_4\text{-}O\text{-}C_6H_4\text{-}CO\}_n$ is a single monomer homopolymer. It has an aromatic molecular backbone with combinations of ketone and ether functional groups between the aryl rings (fig 1) (8). PEEK's monomer unit polymerizes through dialkylation reaction of bis phenolates to form polyetheretherketone (9).



Chemical structure of PEEK

Figure 1: Polyether ether ketone

PROPERTIES

PEEK is a semi-crystalline thermoplastic material. It has superior chemical and mechanical properties that are maintained even at higher temperatures and resistant to hydrolysis (10). There is no evidence of cytotoxicity, mutagenicity, carcinogenicity, or immunogenicity in the toxic form (11). It is a bioinert

material. PEEK material is also found to be resistant to deterioration during various sterilization procedures (12), disintegration during radiation heat, fracture, and chemical wear (13).
PEEK is a radiolucent, rigid material having greater thermal stability up to a temperature of 335.8°C(14). PEEK has the lowest solubility and water absorption when compared with PMMA and composite resin (15). It allows magnetic resonance imaging (16). The elastic modulus and tensile strength are close to enamel, dentin, and human bone (15). PEEK has a low friction coefficient and exhibits a shock absorption effect. PEEK is highly compatible with oral tissues. PEEK orthodontic wires can deliver higher orthodontic forces compared to other polymers such as polyethersulfone and polyvinylidene difluoride (17). Compared to titanium, the polymer could exhibit less stress shielding but very limited inherent osteoconductive properties (9).

Table 1: Properties of polyether ether ketone

Properties	Unit
Density	1300kg/m3
Flexural modulus	140-170Mpa
Thermal conductivity	0.29W/Mk
Young's elastic modulus	3-5Gpa
Melting temperature	343 ^{0}C
Glass transition temperature	143 ^{0}C (approximately)
Tensile strength	80Mpa

Applications
PEEK was introduced to dental applications in 1992 in the form of aesthetic abutments (18) Later, it was used in various applications such as dental implants, implants supported bars, clamp material in RPD, maxillary obturators, healing caps, crown and bridge materials (17-19).

PEEK as implant fixture
Earlier, Titanium was used in dental implants because of its biocompatibility, resistance to corrosion, and mechanical properties (20). Despite several advantages, there are some disadvantages such as bone resorption, over sensitivity, and allergic reactions. It is predicted that these drawbacks could be overcome with the use of PEEK materials (21). Since PEEK material has an elastic modulus close to human bone, the stresses occurring on bone are reduced with the absorption of forces (22).

PEEK as implant abutments
Since aestheticsarein demand, no satisfactory results are obtained with the use of materials like zirconium, ceramics, titanium, and gold (23) because these alloys have several disadvantages such as over-sensitivity reaction, expense, worn intraorally, screw breakage (13). The tests applied to have shown that PEEK material is resistant to up to 1200 N chewing force, so screws made of PEEK material can be easily removed in case of implant screw breakage (24). The low elastic modulus of this material reduces the stresses occurring in both abutments and the cement interface to a minimum (25).

PEEK in removable prosthesis
Conventionally, metals [mainly chromium - cobalt (Cr-Co)] are used as the framework material, for a removable dental prosthesis. The drawbacks such as aesthetic unacceptability, heaviness, metallic taste lead to the search for newer material (26) owing to its lightweight, superior biological, aesthetic, and mechanical properties, PEEK can be used to construct removable prostheses.
Panagiotis zoidis did a clinical study using conventional Cr-Co mandibular distal extension removable denture. The patient complained of the metallic taste, the weight, the discomfort, and the unpleasant display of the metal clasps of the Cr-Co prosthesis. He retreated the patient with a modified PEEK material framework. In this framework, good clasp retention and color stability were observed(27).

PEEK in fixed prosthesis
PEEK has good abrasion resistance, sufficient bonding to composites and teeth, and low reactivity with other materials (28-29). PEEK restorations have greatly exceeded the fracture resistance required to withstand masticatory forces assumed for the anterior (300N) and posterior region (500-600N) (15). It can also be used for dental crown preparation with a facial coating of veneer composites (26).

PEEK Reinforcements
Various reinforced PEEK composites have been developed, such as carbon fiber-reinforced PEEK and glass fiber reinforced PEEK. The elastic modulus may be as high as 18GPa for CFR-PEEK (30) and 12GPa for GFR-PEEK (31). These are specially used for abutments and superstructures because of their stress

shielding capacity. The surface of the pure PEEK can be modified by various processes such as spin coating acid etching, plasma spraying, chemical modification, and ultraviolet radiation. Nanoparticles such as titanium oxide, hydroxyfluorapatite, and hydroxyapatite can be coated on the surface of PEEK to make it more bioactive (26). Nano-structured PEEK surfaces have been observed to induce accelerated osseointegration on etching with sulfuric acid (sulfonation) and rinsing with distilled water.

CONCLUSION

Although various significant chemical and mechanical properties are found in PEEK, further research and clinical trials are necessary to explore the suitability, applicability, bioactivity, and viability of this material. Due to its high price and certain drawbacks in physical properties, it is still under research. Further studies are required to obtain sufficient evidence to enable its use as a permanent material.

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