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Review Article **Prosthodontics**

Current Applications of Polyetheretherketone (PEEK) in Dentistry: A Review

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Abstract

Polyetheretherketone (PEEK), a member of the polyaryletherketone family, has gained increasing attention in dentistry because of its favorable biomechanical properties, low density, radiolucency, chemical stability, and biocompatibility. Compared with metallic materials, PEEK and especially fiber-reinforced PEEK exhibit a lower elastic modulus, which may contribute to more favorable stress distribution in selected implant and prosthetic applications. PEEK has been investigated for dental implants, implant abutments, fixed and removable prostheses, post-core systems, maxillofacial prostheses, periodontal splints, occlusal splints, and orthodontic appliances. However, pure PEEK is biologically inert and has low surface energy, which may limit osseointegration and adhesive bonding. To overcome these limitations, surface treatments such as plasma activation, sulfonation, and hydroxyapatite coating, as well as bulk modifications including ceramic or fiber reinforcement, have been proposed. This review summarizes the current dental applications of PEEK, its main advantages and limitations, and future perspectives for clinical use. Although PEEK is a promising dental biomaterial, most applications still require further long-term clinical validation before routine use can be recommended.

Keywords: PEEK, polyetheretherketone, biomaterials, prosthodontics, implant dentistry, surface modification, maxillofacial reconstruction.

INTRODUCTION

Titanium has long been considered the gold standard material in implant dentistry. However, esthetic limitations and the mismatch between the high elastic modulus of titanium and peri-implant bone have encouraged the search for alternative biomaterials with improved biomechanical behavior [1].

In recent years, thermoplastic polymers have gained increasing attention in dentistry because of their favorable mechanical properties, low density, and high biocompatibility. Polymeric materials are widely used in denture bases, removable appliances, and restorative applications [2].

The polyaryletherketone (PAEK) family consists of high-performance thermoplastic polymers with excellent chemical and mechanical properties. Among this family, polyetheretherketone (PEEK) and polyetherketoneketone (PEKK) are the most commonly used members and were initially introduced for engineering applications in the 1980s [3].

PEEK possesses a linear aromatic polyether-ketone structure that provides chemical resistance, thermal stability, and mechanical performance [4,5].

Owing to these properties, PEEK has attracted considerable interest in both medical and dental applications [6,7]. High-performance polymers have therefore emerged as promising metal-free materials for contemporary dental applications. Their biocompatibility, resistance to thermal and chemical degradation, and high wear and fatigue resistance have further increased their popularity in modern dentistry [8].

Therefore, this review summarizes the major dental applications of PEEK with emphasis on its advantages, limitations, surface-related challenges, and clinical translation potential.

GENERAL PROPERTIES OF PEEK

PEEK is a homopolymer composed of repeating monomer units and demonstrates excellent chemical and mechanical properties with high thermal resistance. Owing to its resistance to thermal and chemical degradation, PEEK can tolerate common heat-based sterilization procedures without major deterioration [4]. Its melting temperature is approximately 335°C, and it can tolerate sterilization procedures without major deterioration [5].

One of the most clinically relevant characteristics of PEEK is its elastic modulus. Pure PEEK has an elastic modulus of approximately 3–4 GPa, whereas carbon fiber-reinforced PEEK may reach values closer to cortical bone. This lower modulus may contribute to stress modulation in selected implant-related and prosthetic applications; however, the clinical relevance depends on the PEEK formulation, restoration design, and loading conditions [9,10]. PEEK is also radiolucent, lightweight, and biologically compatible. These properties make it useful in prosthetic and implant-related applications where radiographic evaluation and patient comfort are important [10]. However, its opaque grayish-white color and limited translucency limit may restrict its use as a monolithic esthetic restorative material [8].

ADVANTAGES AND LIMITATIONS

PEEK has several advantages, including high resistance to chemical degradation, favorable biocompatibility, low density, and a lower elastic modulus than metallic materials. Fiber-reinforced PEEK formulations may reach modulus values closer to cortical bone. In addition, carbon fiber reinforcement may further improve its mechanical performance. However, PEEK also presents certain limitations, such as the requirement for high processing temperatures, relatively high cost, low surface energy leading to reduced cell adhesion, and manufacturing difficulties. Although PEEK is thermally stable, processing parameters and thermal aging may influence its mechanical properties. [11,12].

MODIFIED PEEK MATERIALS

In recent years, numerous modifications have been investigated to improve the bioactivity and osseoconductive properties of PEEK. These approaches include surface modification techniques and the incorporation of nano-scale fillers such as titanium dioxide (TiO_2), hydroxyapatite fibers, beta-tricalcium phosphate (β-TCP), calcium silicate, carbon fibers, and hydroxyapatite particles into the PEEK matrix [13].

The properties of PEEK composites may vary depending on the type, size, distribution, and concentration of the reinforcing materials [14]. Studies evaluating β-TCP-modified PEEK composites have shown that increasing the β-TCP content may improve the elastic modulus; however, excessive filler concentration can reduce tensile strength and may not significantly enhance osteogenic cell proliferation [13]. Calcium silicate-reinforced PEEK composites have also shown promising results. Kim *et al.,* reported improved flexural strength and mechanical performance in calcium silicate-containing PEEK composites, together with hydroxyapatite formation on the material surface after exposure to body fluids, suggesting potential bioactive behavior and improved bone integration [15].

One of the most widely investigated modifications is carbon fiber-reinforced PEEK (CFR-PEEK). While pure PEEK has an elastic modulus of approximately 3–4 GPa, reinforcement with carbon fibers may increase this value up to 18 GPa, approaching the elastic modulus of cortical bone [16,17]. CFR-PEEK is also radiolucent and produces minimal MRI artifacts while maintaining high rigidity and favorable flexural strength [16,10]. In addition, the orientation and length of carbon fibers may influence the mechanical behavior of CFR-PEEK; therefore, findings from non-PEEK carbon-fiber composite systems should be interpreted cautiously [18].

PEEK IN DENTAL IMPLANTS

PEEK has been investigated as an alternative dental implant material because of its low elastic modulus compared with titanium, radiolucency, and potential esthetic advantages. It may reduce stress concentration at the bone-implant interface and may be considered in selected patients with concerns regarding metallic materials, although clinical validation remains limited [16].

However, pure PEEK is not as bioactive as titanium and has limited osseointegration capacity. Plasma treatment, sulfonation, titanium coating, and hydroxyapatite coating have been proposed to improve cellular response and bone integration [19]. Although experimental findings are promising, long-term clinical evidence remains insufficient to recommend PEEK implants as routine substitutes for titanium implants [16].

Recent surface engineering strategies aim to create multifunctional PEEK surfaces with osteogenic, angiogenic, and antibacterial properties. Ion-releasing coatings and bioactive glass nanoparticles are promising approaches for improving peri-implant biological response [20]. Nevertheless, most of these multifunctional surfaces remain at the experimental or preclinical stage.

PEEK AS AN IMPLANT ABUTMENT MATERIAL

Implant abutments require both mechanical stability and favorable soft tissue response. Titanium abutments are mechanically reliable, but their metallic color may compromise esthetics in patients with thin gingival biotypes. Zirconia provides better esthetics than titanium, but its high elastic modulus has raised concerns regarding stress transmission to peri-implant structures [21].

Because of its high strength, low density, and elastic modulus similar to bone, PEEK has been proposed as an alternative material for various implant abutments, including healing, provisional, and prosthetic abutments [22].

Limited clinical studies have reported favorable soft tissue responses and satisfactory biological performance around PEEK abutments. Enkling *et al.,* reported no significant differences among titanium, zirconia, ceramic-coated zirconia, and PEEK abutments in terms of soft tissue health, marginal bone levels, and inflammatory response after a 3-month healing period [23].

In esthetic implant restorations, PEEK abutments have also shown promising long-term outcomes. Ayyadanveettil *et al.,* reported that PEEK and zirconia abutments demonstrated comparable esthetic performance, biological compatibility, and clinical survival after 5 years of follow-up [24].

PEEK IN FIXED PROSTHESES

PEEK has been investigated and used as a framework material for fixed dental prostheses because of its low weight, stress-modulating behavior, and CAD/CAM compatibility. For single crowns, both milled and pressed PEEK restorations have been reported to provide clinically acceptable marginal and internal fit [25].

In crown restorations, PEEK has shown favorable wear behavior and fracture resistance in laboratory studies. However, the opaque color of PEEK usually requires veneering in esthetic areas, and potential deformation, veneer-related complications, and fatigue behavior under long-term cyclic loading remain concerns [26]. Therefore, additional clinical studies are needed to determine its long-term performance in fixed prosthodontics [27].

PEEK frameworks have also been evaluated for implant-supported fixed prostheses. Finite element studies suggest that PEEK and PEKK frameworks may influence stress distribution differently from metallic frameworks, especially in full-arch implant-supported prostheses [28].

Failure analysis studies suggest that high-performance polymers may be considered for implant-supported fixed prostheses but framework design, cantilever length, veneering material, and connector dimensions should be carefully considered [29].

PEEK IN POST-CORE SYSTEMS

Among the materials commonly used for endodontic post systems are metals, glass fiber, and quartz fiber posts. Although conventional metal posts exhibit high fracture resistance, their high elastic modulus may result in unfavorable stress distribution within the root and increase the risk of root fracture [30]. Fiber posts are frequently preferred in esthetic restorations because of their lower elastic modulus and improved esthetic properties compared with metal posts [31].

Pure PEEK has a lower elastic modulus than dentin, whereas reinforced PEEK formulations may approach dentin-like modulus values. Owing to its fatigue resistance and stress-modulating behavior, PEEK has been proposed as an alternative material for post-core systems [32]. Özarslan *et al.,* compared the fracture resistance and fracture patterns of maxillary central incisors restored with glass fiber, custom PEEK, and custom zirconia post-core systems. The authors reported that custom PEEK post-core restorations demonstrated sufficient fracture resistance and more favorable, repairable fracture patterns than more rigid post-core systems in maxillary anterior teeth [33].

In addition, carbon fiber-reinforced PEEK composites have shown promising results for endodontic post applications. Nahar *et al.,* demonstrated that carbon fiber-reinforced PEEK posts generated lower von Mises stress values within dentin compared with several conventional post materials in three-dimensional finite element analysis [34].

PEEK IN REMOVABLE PROSTHESES

Conventional removable partial denture (RPD) frameworks are commonly fabricated from cobalt-chromium alloys. However, these materials have been associated with disadvantages such as allergic reactions, poor esthetics, and galvanic effects in the oral environment. Because of its metal-free appearance, low density, and patient comfort-related advantages, PEEK has been proposed as an alternative material in removable prosthodontics [22].

When used as an RPD framework or clasp material, PEEK may reduce metallic taste and allergy-related concerns associated with conventional cobalt-chromium frameworks [35]. Studies evaluating PEEK clasps have reported acceptable retentive behavior and esthetic advantages compared with cobalt-chromium clasps; however, retention may depend on clasp thickness, undercut depth, and thermomechanical aging [36].

Finite element analyses have further demonstrated favorable biomechanical behavior of PEEK-based removable prosthetic frameworks. Experimental and finite element studies suggest that PEEK-based removable prosthetic components may show favorable mechanical behavior and fracture resistance under simulated occlusal loading [37,38].

PEEK IN MAXILLOFACIAL PROSTHETICS AND RECONSTRUCTION

Titanium and titanium alloys are considered the gold standard materials for maxillofacial reconstruction because of their excellent mechanical properties and biocompatibility [39]. However, their high elastic modulus compared with human bone may lead to stress shielding, which can contribute to implant loosening and reduced prosthetic stability over time. In addition, hypersensitivity reactions associated with metallic materials have also been reported [40]. Although ceramic materials demonstrate favorable biocompatibility, their brittleness limits their use in load-bearing implant applications [41].

In contrast, PEEK exhibits a bone-like elastic modulus together with high strength, low density, resistance to heat and radiation, and excellent biocompatibility.

Recent case reports and experimental studies have demonstrated encouraging outcomes for PEEK-based reconstructive implants. Li *et al.,* evaluated six patients who underwent mandibular reconstruction using patient-specific 3D-printed PEEK implants. During the 10–24 month follow-up period, no postoperative complications were observed in five patients, and satisfactory esthetic and functional outcomes were reported. One patient developed implant exposure after 10 months, which the authors associated with compromised systemic and local conditions rather than a material-specific failure [42].

Chen *et al.,* used three-dimensional printing technology to fabricate hydroxyapatite-reinforced PEEK (HA/PEEK) scaffolds for mandibular reconstruction. Their findings demonstrated that low-crystalline HA/PEEK structures containing 20% hydroxyapatite provided favorable mechanical properties, promoted mesenchymal stem cell proliferation and osteogenic differentiation in vitro, and enhanced bone regeneration and osseointegration in vivo [43].

PEEK IN PERIODONTAL SPLINTS

Periodontal splints are commonly used for the management of mobile teeth by redistributing occlusal forces to adjacent healthy teeth and reducing the load on periodontal tissues [44]. Fiber-reinforced composite (FRC) materials have long been preferred for periodontal splinting because of their favorable mechanical properties, flexibility, esthetics, and biocompatibility. However, prolonged clinical application time, discoloration, deformation, plaque accumulation, and long-term instability remain important disadvantages of FRC splints [45]. Because of its favorable physical and biological properties together with low plaque affinity, PEEK has been proposed as an alternative material for periodontal splints [46]. Liu *et al.,* evaluated the biomechanical behavior of PEEK, FRC, and titanium periodontal splints using computer-assisted chewing simulation and finite element analysis. The authors reported similar stress distribution patterns among the materials, although PEEK splints demonstrated lower stress values within periodontal tissues [45].

Despite these advantages, several limitations still restrict the widespread clinical use of PEEK in periodontal splinting. The inert surface properties of PEEK may result in insufficient adhesive bonding with conventional resin systems, negatively affecting long-term stability; however, most available evidence is derived from post, prosthetic, or laboratory bonding studies rather than periodontal splint-specific clinical trials [47,48]. In addition, the natural grayish-brown color of PEEK may compromise esthetics, particularly in anterior regions. Furthermore, clinical evidence regarding the long-term performance of PEEK splints remains limited. Therefore, additional clinical studies are required to evaluate their durability, biological behavior, and clinical effectiveness under different periodontal conditions [22].

PEEK IN OCCLUSAL SPLINTS

Occlusal splints are appliances used to cover the surfaces of natural teeth and modify occlusal contact relationships without changing tooth position. They are commonly used in the management of occlusal trauma, temporomandibular disorders, neuromuscular dysfunctions, and periodontal complications. Conventional occlusal splints are generally fabricated from acrylic resins; however, these materials present several disadvantages, including allergic reactions, low wear resistance, biological aging, and limited service life. Therefore, interest in alternative materials such as PEEK has increased in recent years [22].

Borg *et al.,* evaluated enamel wear caused by polyamide, acrylic resin, and PEEK occlusal splints using an in vitro chewing simulation model. The authors reported smoother enamel surfaces and lower enamel wear in the PEEK group, whereas acrylic resin demonstrated the highest abrasive effect. These findings suggest that PEEK may serve as a biocompatible and less abrasive alternative material for occlusal splints [49].

A case report has also described favorable clinical outcomes with PEEK occlusal splints. Delrieu *et al.,* described the use of a PEEK occlusal splint in a patient with histamine intolerance who had developed allergic symptoms associated with prolonged use of resin-based splints. Following replacement with a PEEK splint, oral symptoms and temporomandibular joint pain were markedly reduced, and the patient remained symptom-free during follow-up [50].

Despite these advantages, several limitations remain associated with PEEK occlusal splints. The material is relatively expensive and difficult to repair, often requiring complete replacement in case of fracture [51]. In clinical situations with pronounced undercuts, the rigidity of PEEK may complicate insertion and removal; therefore, appliance design should be carefully planned [38]. Proper polishing procedures are also essential because inadequate surface finishing may increase antagonist tooth wear and compromise esthetic performance [51].

ORTHODONTIC APPLICATIONS

Conventional orthodontic archwires are generally fabricated from metallic alloys; however, limitations such as poor esthetics, risk of metal hypersensitivity, and release of metal ions have increased interest in alternative materials [52]. Because of its favorable mechanical and esthetic properties, PEEK has been investigated as a potential esthetic orthodontic wire material. Polymeric coatings, including PEEK-based approaches, have been discussed as potential strategies to improve the esthetics and biocompatibility of metallic orthodontic wires [53].

Despite these advantages, limited evidence is available regarding the long-term mechanical performance and stability of PEEK orthodontic wires under oral conditions. Intraoral challenges such as mastication, brushing, and saliva exposure may alter the surface characteristics, frictional behavior, and coating stability of esthetic orthodontic wires; therefore, long-term simulation studies are required for PEEK-based systems [54].

PEEK has also attracted attention in interceptive orthodontics because of its dimensional stability, wear resistance, biocompatibility, and low water absorption. Digital fabrication techniques have enabled the production of PEEK-based space maintainers, lingual arches, and palatal appliances for pediatric patients [55].

Nevertheless, several limitations still restrict the widespread orthodontic use of PEEK. The material does not completely reproduce natural tooth color and translucency, and its adhesive bonding performance remains limited.

CONCLUSIONS

PEEK has emerged as a promising high-performance polymer in contemporary dentistry because of its favorable mechanical properties, biocompatibility, low density, radiolucency, and lower elastic modulus compared with metallic materials. Current evidence supports its potential use in selected prosthodontic, implant-related, orthodontic, periodontal, occlusal splint, and maxillofacial applications; however, the level of evidence differs considerably among indications.

Compared with conventional metallic materials, PEEK may provide advantages in stress distribution, patient comfort, corrosion resistance, and esthetics. In addition, recent surface modification techniques and reinforcing agents may improve its biological and mechanical performance.

However, limitations such as low bioactivity, inadequate adhesive bonding, esthetic opacity, and insufficient long-term clinical evidence still restrict its routine clinical use in several dental applications. Therefore, further long-term clinical and experimental studies are required to optimize the properties of PEEK and establish standardized clinical protocols.

Within the limitations of the available literature, PEEK should be regarded as a promising adjunctive biomaterial rather than a universal replacement for established dental materials.

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