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Review

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Use of polyetheretherketone (PEEK) in prosthodontics

Seçkin Gül

Department of Oral and Dental Health, Diyarbakır Oral and Dental Health Hospital, Diyarbakır, Turkiye

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ABSTRACT

Polyetheretherketone (PEEK) is a high-performance material that stands out among semi-crystalline thermoplastic polymers. Due to its chemical and physical durability, biocompatibility, and elastic modulus similar to that of human bone, it has become increasingly popular in dentistry. PEEK can be used in inlay, onlay, and endocrown restorations; as substructures for crowns and bridges; in removable denture frameworks; as an implant material; in implant-supported fixed or removable prostheses; and in the fabrication of occlusal splints. The aim of this review is to evaluate the current literature on the structure, properties, and use of PEEK material in prosthetic dentistry, which has recently become widely used, and to discuss its advantages and limitations compared to alternative materials.

Keywords: Polyetheretherketone, PEEK, dental prosthesis, polymers

INTRODUCTION

The primary objective of prosthetic dentistry is the functional and aesthetic rehabilitation of missing teeth, loss of tooth structure, and defects in the surrounding oral tissues through prosthetic restorations. Dental materials used for this purpose are required to exhibit biocompatibility, aesthetic properties similar to natural teeth, and sufficient mechanical strength under masticatory forces. To fulfill these requirements, metal-, ceramic-, and polymer-based materials are commonly utilized in prosthetic dentistry.[1]

Over the past three decades, advancements in computer-aided design and manufacturing (CAD/CAM) technologies have enabled the introduction of various forms of these material groups into clinical practice, significantly expanding the range of prosthetic material options. Consequently, clinicians have gained the ability to select the most appropriate material based on aesthetic and functional requirements.[1,2]

The inherent disadvantages of conventional metal and ceramic materials have paved the way for the introduction of high-performance polymers in the dental field. These polymers, characterized by a combination of high mechanical strength and low elastic modulus, stand out for their advantages such as rapid manufacturing, low cost, and biocompatibility. Among this group, polyetheretherketone (PEEK) was introduced into medicine in the late 1990s as a high-performance thermoplastic material in orthopedic and trauma treatments. Due to its chemical inertness, high wear resistance, adequate mechanical strength, low elastic modulus, and light weight, it has also become a significant alternative for dental applications.[3]

GENERAL PROPERTIES OF PEEK

PEEK is a semi-crystalline polymer belonging to the polyaryletherketone (PAEK) family, characterized by an aromatic and linear molecular structure composed of ketone and ether functional groups and aryl rings. Its melting temperature is 334°C, crystallization temperature is 343°C, and glass transition temperature is 145°C. Owing to its high thermal stability, it can be used at operating temperatures up to 260°C and maintains dimensional stability under temperature changes. Additionally, PEEK is a chemically inert material.[4,5]

Thanks to its excellent mechanical properties, biocompatibility, and high resistance to organic and inorganic chemicals, PEEK is an advantageous material for dental applications.[6] It is non-allergenic and non-toxic; with an elastic modulus of 3-4 GPa, it exhibits mechanical properties closer to bone compared to metal alloys and ceramics.[7] Its mechanical strength is unaffected by steam autoclaving, ethylene oxide, and gamma sterilization processes.[8] Its natural radiolucency ensures compatibility with imaging methods such as CT, MRI, and X-Ray.[9] Studies on PEEK have reported that it elicits a very low tissue response, has no adverse effects on cell cultures, does not harm osteoblasts or fibroblasts, and shows no cytotoxicity.[3]

PEEK offers significant advantages such as shock absorption, corrosion resistance, high wear and fracture resistance, excellent polishability, low plaque accumulation, and being lighter than metal restorations. Owing to its high resistance to friction and wear, it can also serve as a suitable framework material for precision attachment structures, such as bars and telescopic crowns.[10,11]

Corresponding Author: Seçkin Gül, dtseckingul@hotmail.com

Unfilled PEEK exhibits an elastic modulus of approximately 4 GPa and a tensile strength of around 100 MPa.[5] PEEK can be modified with structural additives to match the elastic modulus of cortical and cancellous bone density. Carbon fiber-reinforced PEEK (CFR-PEEK) can achieve tensile strength exceeding 200 MPa and an elastic modulus of approximately 20 GPa. The elastic modulus of carbon-reinforced PEEK, which is similar to that of cortical bone and dentin, contributes to reduced stress compared to titanium.[5,12] These mechanical properties help distribute stress transmitted to the bone more evenly, reducing the risk of bone resorption seen with more rigid materials like stainless steel and titanium. This makes PEEK a viable biomaterial alternative to titanium and stainless steel in medical and dental applications today.

In dentistry, PEEK has been employed as an implant material, implant abutment material, implant-supported digital impression post, implant-supported bar material, substructure material in implant-supported hybrid prostheses, healing cap material, substructure material in fixed prostheses, temporary crown material, major connector and clasp material in removable prostheses, and occlusal splint material.

USE OF PEEK IN REMOVABLE PARTIAL DENTURES

Removable partial dentures fabricated from cobalt-chromium (Co-Cr) material are an affordable and predictable treatment option for the rehabilitation of partially edentulous patients. However, due to the aesthetic limitations of metal clasps, increased prosthesis weight, metallic taste, and the risk of allergic reactions to metal alloys, thermoplastic materials such as polyamide and acetal resins have been developed for clinical use.[13] Polyamide materials reduce rotational forces transmitted to supporting teeth due to their low elastic modulus. However, their main disadvantages include the inability to reline the prosthesis and insufficient clasp retention compared to rigid prostheses. In contrast, acetal resins exhibit greater rigidity and mechanical durability than polyamide materials, yet they lack the natural translucency and vitality of conventional prosthetic materials.[13,14]

As an alternative to these materials, PEEK has increasingly been used as a framework material in removable partial dentures. A modified PEEK material (BioHPP; Bredent GmbH, Senden, Germany) with 20% ceramic fiber added, used in the fabrication of removable prostheses, is a high-performance polymer offering high biocompatibility, good mechanical properties, high thermal resistance, and chemical stability. It exhibits elasticity similar to bone and can reduce the stresses transmitted to the abutment teeth.[5,10,12] The white color of BioHPP frameworks provides an aesthetic alternative to conventional metal frameworks. Additionally, this material offers several advantages, including the prevention of allergic reactions and metallic taste formation, high polishability, low plaque affinity, and good wear resistance.

Despite all these advantages, Tannous et al.,[15] reported that clasps fabricated from PEEK material exhibit lower retention forces compared to Cobalt-Chrome (Co-Cr) clasps. However, PEEK clasps designed appropriately can provide sufficient retention at an undercut depth of 0.5 mm.

In PEEK frameworks, the stress caused by masticatory forces transmitted to periodontally weak teeth is lower compared to metal frameworks. However, it has been reported that the force transmitted to the mucosa is higher in PEEK frameworks in distal extension cases.[16] Chen et al.,[17] compared the stresses created by PEEK, titanium, and Co-Cr alloy frameworks on the mucosa in a distal extension case and noted that PEEK created more stress on the mucosa compared to other materials.

The weight of removable dentures can directly affect patient satisfaction. BioHPP enables the fabrications of lighter prostheses thanks to its low specific gravity, thereby increasing patient comfort and satisfaction. In a study, BioHPP-framed prostheses were reported to be 27.5% lighter than conventional Co-Cr framework partial dentures with a lingual bar design.[10]

The use of PEEK for reinforcing the base of complete dentures has been studied; however, it was reported that when designed with a thickness of 0.5 mm, it did not exhibit sufficient strength under the stresses encountered in the palatal region of the complete denture.[18]

USE OF PEEK IN FIXED PROSTHESES

Metal-free restorations are gaining increasing importance in dentistry due to patients' growing aesthetic expectations. PEEK is used as an alternative material in fixed prostheses due to its non-metallic color, low weight, and high strength.[19]

Its lighter weight compared with metal-ceramic restorations makes PEEK a suitable treatment option in cases where the weight of prosthetic restorations increases.[20] Low wear resistance, low solubility in oral fluids, an elastic modulus similar to dentin, and the ability to absorb masticatory forces highlight PEEK as an ideal material for fixed restorations. It is also an appropriate framework material for patients with metal allergies or sensitivity to metallic taste.[10]

Although it possesses optical properties closer to dental tissue compared to metals and metal alloys, it has been reported that the monolithic use of PEEK material is not suitable for restorations where aesthetics are important.[21] Due to its resistance to chemical agents, low surface energy, and resistance to surface modification processes, achieving strong bonding between PEEK and resin can be challenging. To achieve effective adhesion on the PEEK surface, mechanical and chemical pretreatments such as sandblasting, etching with a piranha solution (sulfuric acid and hydrogen peroxide mixture) or sulfuric acid (60-90 seconds), laser application, and plasma roughening are recommended. Following these processes, it is recommended to use an adhesive containing acetone, methyl methacrylate (MMA), or 10-metacryloyloxydecyl dihydrogen phosphate (MDP).[22] Due to PEEK's high resistance to chemical agents, etching with 9.5% hydrofluoric acid (HF), which is effective on glass-containing ceramics, is ineffective in altering the surface morphology of PEEK.[13]

Rocha et al.[23] evaluated the dentin bonding performance of PEEK using various surface treatments, including different application times of 98% sulfuric acid; sandblasting with 45 µm aluminum oxide particles; and sandblasting with 45 µm aluminum oxide particles followed by silica coating with 110 µm silicon oxide sand. Prolonged sulfuric acid application decreased bond strength, whereas sandblasting was found to be an effective method for modifying the PEEK surface.

For veneering PEEK frameworks, both light-cured composite resins and CAD/CAM-fabricated veneer layers can be

employed. It has been reported that PEEK restorations veneered using the CAD/CAM method exhibit a higher load-bearing capacity compared to those veneered with conventional composites. However, light-cured composites offer the advantage of allowing modifications to the restoration and the repair of minor fractures in the clinical setting.[24]

Stawarczyk et al.[25] reported that the fracture strength (1383 N) of a three-unit PEEK bridge fabricated using CAD/CAM was higher than that of lithium disilicate glass ceramic (950 N) and zirconia (981-1331 N). PEEK can be used in patients with bruxism.

USE OF PEEK IN IMPLANTS AND IMPLANT-SUPPORTED PROSTHESES

In implantology, PEEK is used as an implant material, and in the prosthetic phase, it serves as a healing cap, abutment, digital impression post, and restoration material.[26] Due to its biocompatibility and elastic modulus being very close to that of bone, PEEK has been proposed as an alternative to titanium as an implant material. However, its hydrophobic, bioinert nature and high contact angle reduce its osteoconductive effect and adversely affect osseointegration.[27] Therefore, to enhance the osteoconductive effect of PEEK, additional procedures such as laser surface modification, coating with bioactive materials, creating a wet chemical surface, and incorporating bioactive components such as hydroxyapatite and titanium dioxide into the PEEK matrix have been recommended.

In a finite element analysis, Lee et al.[28] reported that carbon fiber-reinforced PEEK implants may result in lower force transmission compared to titanium implants. Conversely, another finite element analysis suggested that there is no difference between PEEK and titanium implants in terms of stress distribution.[29] PEEK implants are not widely used, and there is insufficient data to evaluate their long-term efficacy in human subjects.

Custom healing abutments can be fabricated from PEEK material to achieve an optimal emergence profile around the implant. Due to its lower fracture resistance compared to zirconia and titanium, PEEK is generally used as a temporary abutment material.[30] In a randomized controlled clinical trial, Koutouzis et al.[31] reported no significant differences between PEEK and titanium abutments in terms of soft tissue inflammation and bone resorption.

One of the most common complications associated with implant-supported overdenture attachments is the loss of retention due to wear over time. To improve the retention of the prosthesis by increasing bite force and wear resistance, retentive caps and clips made from PEEK have been developed. With a flexural strength of approximately 140-170 MPa, PEEK exhibits a stress-breaking effect by absorbing functional stresses.[32]

In a study comparing different clip types used in Locator attachments, PEEK and nylon materials were evaluated. PEEK clips demonstrated higher bite force and lower wear rates throughout all evaluation periods, leading to the conclusion that they could serve as an alternative to nylon clips.[33]

USE OF PEEK IN OBTURATORS

Maxillary obturator prostheses are typically made from polymethyl methacrylate (PMMA) in completely edentulous patients and from a combination of a cast metal framework and PMMA in partially edentulous patients. As the surgical resection area increases, the area covered by the prosthesis and, consequently, its weight also increases. PEEK offers advantages in obturator prostheses due to its high biocompatibility and light weight. Digital design and fabrication of PEEK obturators can be performed using computed tomography images.[2,15] Costa Palau et al.[34] reported in their clinical study that the PEEK obturator prosthesis fabricated using the CAD/CAM system for a patient with an oronasal defect was superior to conventional obturators in terms of function, retention, and aesthetics, and was also lighter.

USE OF PEEK IN OCCLUSAL SPLINTS

Occlusal splints are commonly used appliances for the diagnosis and management of temporomandibular joint (TMJ) disorders and are traditionally fabricated from acrylic resin. Traditionally, occlusal splints fabricated from acrylic resin have disadvantages such as an unpleasant taste, dimensional changes, residual monomer release, color changes, and susceptibility to fracture, which create difficulties for patients in terms of use. PEEK is used as an alternative material in the fabrication of occlusal splints due to its high wear resistance, lightweight nature, and ability to absorb shock under severe occlusal forces.[35]

In a study comparing the surface roughness and wear resistance of occlusal splint materials, PEEK was found to yield better results than other materials.[36] Wang et al.[37] compared the preclinical effects of digital occlusal splints with conventional hard splints in patients with sleep bruxism and reported that PEEK occlusal splints showed less wear after 12 weeks of follow-up and possessed properties capable of meeting clinical requirements. Furthermore, owing to their physical properties, PEEK splints can be fabricated in thinner forms, thereby increasing patient satisfaction.

CONCLUSION

PEEK has emerged as a significant alternative material in prosthetic dentistry owing to its high mechanical strength, biocompatibility, low specific weight, bone-compatible elastic modulus, and chemical stability. Its applications range from fixed, removable, and implant-supported prostheses to occlusal splints and maxillofacial prostheses. Nevertheless, it presents certain limitations, including aesthetic constraints, challenges in adhesive bonding due to surface characteristics, and variations in mechanical performance in specific clinical situations. While current literature supports the short- and medium-term clinical success of PEEK, further studies are required to evaluate its long-term clinical outcomes and performance across various prosthetic indications.

ETHICAL DECLARATIONS

Referee Evaluation Process

Externally peer-reviewed.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

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Author Contributions

All of the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

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