REVIEW
DOI:10.5152/EssentDent.2024.24016

Exploring the Versatility of Polyetheretherketone in Prosthodontics: A Comprehensive Review

Manu Rathee, M Stalin, Sarthak Singh Tomar, Kritika Diwan, Surbhi Mittal, Balavignesh S

Department of Prosthodontics, Post Graduate Institute of Dental Sciences, Pandit Bhagwat Dayal Sharma University of Health Sciences, Rohtak, Haryana, India

Cite this article as: Rathee M, Stalin M, Singh Tomar S, Diwan K, Mittal S, S B. Exploring the versatility of polyetheretherketone in prosthodontics: a comprehensive review. *Essent Dent.* 2024;3(3):121-128.

Abstract

Prosthodontics is seeing a rise in the use of polyetheretherketone (PEEK), a material with many advantages over conventional materials like metals and glass. The characteristics, uses, and therapeutic efficacy of PEEK in prosthodontics are examined in this extensive case study. Crowns, bridges, implant abutments, and detachable prostheses are just a few of the prosthetic applications for which PEEK is a good fit because of its exceptional biocompatibility, mechanical qualities, and ease of manufacture. Patient comfort and durability are improved by its high strength-to-weight ratio and chemical stability. The review also discusses the potential challenges and limitations associated with PEEK, such as its aesthetic limitations and the need for further long-term clinical studies to validate its performance. This review attempts to provide a comprehensive overview of PEEK's function in contemporary prosthodontics and its potential to enhance patient outcomes by synthesizing recent research and clinical data.

Keywords: Polyetheretherketone, prosthodontics, dental Implant, removable prosthesis

INTRODUCTION

In 1978, a group of English researchers developed polyetheretherketone (PEEK), a semicrystalline linear polycyclic aromatic polymer (Figure 1), notable for its unique properties. Since its commercialization, PEEK has found diverse industrial applications, gaining prominence in the late 1990s as a highly desirable thermoplastic material, especially for substituting metal implant parts.[1] Polyetheretherketone's remarkable properties, including rigidity, radiolucency, thermal stability, low plaque affinity, and non-allergenic nature, make it particularly suited for biomedical applications. Its density of 1300 kg/m^3, thermal conductivity of 0.29 W/mK, and flexural modulus between 140 and 170 MPa, combined with mechanical characteristics unaffected by various sterilization methods, underscore its durability and versatility.[2] Polyetheretherketone's Young's modulus of 3-4 GPa closely aligns with human bone (14-20 GPa), making it ideal for dental use. It offers a balance between flexibility and strength, similar to dentin (15 GPa) and enamel (40-83 GPa), enhancing its biocompatibility and reducing stress shielding, unlike traditional titanium implants. These attributes make PEEK a synthetic, tooth-colored polymeric material ideal for prosthodontics.[3] The advent of innovative materials such as PEEK has catalyzed significant advancements in CAD-CAM systems, enhancing the success of dental restorations for patients.[4] The unique physical and mechanical properties of PEEK position it as a promising material for advancing dental technology and improving clinical outcomes in dentistry.[5]

REVIEW OF LITERATURE

In their 2018 study, Gowda et al[6] found that PEEK implants subjected to immediate loading had a higher failure rate compared to those loaded using an early loading protocol.

Corresponding author: M Stalin
e mail: stalinclan@gmail.com

Received: May 28, 2024
Revision Requested: August 16, 2024
Last Revision Received: September 3, 2024
Accepted: September 23, 2024
Publication Date: October 23, 2024

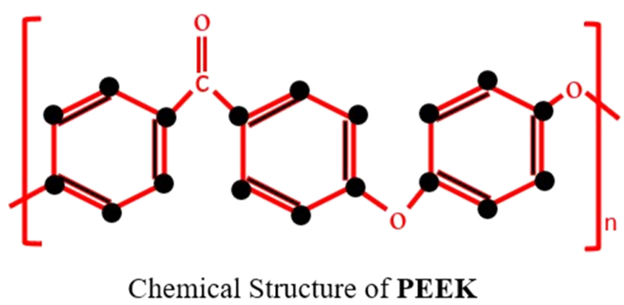

Figure 1. Chemical structure of PEEK.

Tekin et al[7] propose that PEEK material's exceptional mechanical and biological attributes position it favorably for future integration into routine dental applications. They suggest that polymer-based prostheses, including PEEK material, may become commonplace, particularly in dental post structures and endodontics.

Bathala et al's article[8] underscores PEEK's potential due to these properties, which are crucial for various dental applications beyond implants, such as in different clinical situations. Modified forms of PEEK have demonstrated enhanced characteristics compared to unmodified versions, further supporting its potential in dental practice.

Buck et al[9] examined surface modification techniques designed to improve poly(ether ether ketone) (PEEK) and its composites' osseointegration. In order to help patients who ultimately need these implants, their analysis finishes with a discussion of potential future prospects for the field and recommendations for advancing the clinical application of surface-modified PEEK implants.

According to Chen et al[10], incorporating TiO_2 into the composite resin significantly improved its antibacterial properties when compared to pure PMMA resin. Moreover, the addition of TiO_2 (1 wt.%) along with PEEK (1-3 wt.%) synergistically enhanced the mechanical strength, surpassing the effects of TiO_2 alone. Consequently, the reinforced composite resins, such as PMMA (TiO_2-1%-PEEK-1%), demonstrated considerable potential as functional materials for dental restoration, boasting excellent mechanical strength, high antibacterial activity, and minimal cytotoxic effects.

In their 2020 review, Qin et al[11] outlined the latest methods for modifying PEEK, encompassing techniques such as acid etching, laser treatment, air particle abrasion, plasma treatment, and the fabrication of PEEK composites with unique filler particles. Notably, the utilization of 98% sulfuric acid emerged as the most efficient approach for enhancing bonding strength, without introducing any new functional groups. Additionally, various other strategies were found to enhance the bonding of veneering materials with PEEK.

In their 2020 study, Sikder et al[12] reported the successful development of bioactive amorphous magnesium phosphate (AMP)-PEEK composite filaments through the melt-blending technique. The AMP particles were uniformly dispersed within the PEEK matrix, and they remained thermally stable during high-temperature processing. Rheological studies validated the suitability of AMP-PEEK composites for 3D printing, as they exhibited high zero-shear and low infinite-shear viscosities, indicating their potential as viable materials for additive manufacturing applications.

In their 2020 study, Peng et al[13] conducted finite-element analysis and optimization of the mechanical properties of PEEK clasps for removable partial dentures. Their findings revealed that PEEK clasps exert lower stresses on abutments in comparison to standard alloy clasps while still offering sufficient retention and meeting esthetic requirements. This suggests that PEEK represents a viable alternative to traditional metal clasps, offering promising prospects in dental applications.

In their 2021 study, Gao et al[14] investigated the fused deposition modeling (FDM) of PEEK. Their findings revealed that platform temperature had the most pronounced effect on warpage deformation, whereas printing speed and nozzle temperature significantly influenced tensile strength. By optimizing these parameters, they achieved nearly negligible warpage deformation in the samples and increased tensile strength by 19.6% (from 40.56 to 48.50 MPa). These results offer valuable support for the advancement of FDM techniques for PEEK materials.

In their 2021 study, da Cruz et al[15] investigated the impact of bioactive enhancements on PEEK dental implant materials. The findings suggest that biological responses are more influenced by the chemical composition rather than the physical properties of the materials. Specifically, the addition of 5% hydroxyapatite (HA) or beta-tricalcium phosphate (βTCP) via functionally graded materials (FGM) did not improve the mechanical properties of PEEK or affect the behavior of periodontal cells.

Bankole I. Oladapo et al[16] conducted a review on the 3D printing of PEEK and its composites aimed at enhancing bio-interfaces for biomedical applications. They explored various methods for combining PEEK with CHAp (Carbonated Hydroxyapatite), including composite material coating, extrusion, and multilayer structures. Additionally, the review discusses surface treatment as an alternative approach to enhancing the properties of structures for promoting bone regeneration, with a focus on the thermal shock impact resulting from the thermal crystallinity process of CHAp on PEEK and its thermomechanical properties. The study also compares manufacturing parameters between injection molding and coating, drawing insights from existing literature.

In their 2021 study, Özarslan et al[17] compared the fracture strength of endodontically treated teeth restored with PEEK, zirconia, and glass-fiber post-core systems. They found that PEEK post-cores exhibited adequate fracture strength comparable to the other 2 materials in the anterior region. However, PEEK post-cores showed a higher incidence of decementation and repairable fractures at lower forces, whereas restoration failure was predominantly catastrophic for glass-fiber and zirconia posts.

In their 2021 study, Peng et al[18] delved into biofilm formation on PEEK surfaces and assessed the in vitro antimicrobial effectiveness of photodynamic therapy (PDT) on peri-implant mucositis. Their findings revealed that PEEK displayed markedly reduced susceptibility to biofilm formation in comparison to titanium alloys (Ti-6Al-4V) while exhibiting MG-63 osteoblast cell viability similar to that of Ti-6Al-4V and zirconia-based ceramic materials (Y-TZP). Additionally, PDT demonstrated comparable antimicrobial efficacy to antibiotics and facilitated biofilm removal.

In their 2021 study, Manzoor et al[19] investigated 3D-printed polyether ether ketone/hydroxyapatite (PEEK/HA) composites for bone tissue engineering applications, exploring the impact of material formulation on mechanical performance and bioactive potential. Polyetheretherketone nanocomposites containing 10 wt% of HA, SrHA, and ZnHA were extruded into filament and subsequently 3D printed using FDM technology. This approach offers a solution for the rapid prototyping of customized and cost-effective bioactive orthopedic and dental implants.

In their 2021 review, Blanch-Martínez et al[20] examined the performance of PEEK in dental implant prostheses. The review concludes that PEEK presents advantages such as being lightweight, having favorable esthetics, biocompatibility, and a modulus of elasticity closer to that of bone compared to other commonly used materials. However, it also notes potential drawbacks such as a higher risk of fracture and abrasion. To provide clearer guidance on its suitability for implant prostheses, further long-term clinical studies are deemed necessary.

In their 2021 systematic review, Dua et al[21] explored the applications of 3D-printed PEEK via fused filament fabrication (FFF).The review highlights PEEK's versatility and its increasing utilization across various industries. However, many of these applications remain in the research phase. Nonetheless, with the ongoing advancements in PEEK research and additive manufacturing techniques, it is anticipated that PEEK will soon be commercialized for a wide array of applications across multiple industries.

In their 2022 systematic review, Ghazal-Maghras et al[22] assessed the properties of PEEK implant abutments. The review suggests that PEEK implant abutments currently lack the necessary biomechanical properties to fully substitute definitive titanium abutments. Nevertheless, PEEK is regarded as a viable alternative, particularly for provisional use, and may be more suitable for placement in the anterior region.

In their 2022 study, Wang et al[23] discuss the application of PEEK in fixed dental prostheses and methods for enhancing its adhesion. They summarize various strategies investigated for improving the adhesive properties of PEEK, encompassing techniques such as acid etching, plasma treatment, airborne particle abrasion, laser treatment, and the use of adhesive systems.

In their 2024 review, Balavignesh[24] explored the application of PEEK in implant dentistry. They highlight PEEK as a modern and stylish material suitable for use in prosthodontics. Its favorable chemical, mechanical, and physical properties make it a versatile option for fabricating both fixed and removable prostheses.

EVOLUTION OF POLYETHERETHERETHERK ETONE IN DENTISTRY

The evolution of PEEK in dentistry has been marked by significant advancements and innovations. Developed in the 1980s, and renowned for its exceptional mechanical properties, biocompatibility, and chemical resistance, PEEK stands out as a high-performance thermoplastic polymer. This makes it highly sought-after in a variety of industries including aerospace, automotive, and medicine, as well as dentistry. Researchers began exploring its potential in dentistry in the late 20th century, focusing on its suitability for dental implants and prosthetic frameworks. Early studies focused on evaluating PEEK's suitability as a material for dental implants and prosthetics due to its elasticity, which closely mimics the properties of bone.[6] This biocompatibility, combined with its strength and resistance to wear, positioned PEEK as an alternative to traditional materials like metals and ceramics. However, the initial challenge was enhancing PEEK's bondability with other dental materials. To address this, surface modification techniques such as air abrasion, silica coating, and acid etching were developed, significantly improving PEEK's adhesion to composite resins and other restorative materials. The integration of PEEK into CAD/CAM systems enabled the precise fabrication of customized dental prostheses, increasing its popularity due to accuracy and reliability. To further enhance its properties, researchers incorporated fillers and reinforcements, leading to modified formulations like BioHPP, which offered improved stability, aesthetics, and mechanical strength. Clinical studies validated the effectiveness and safety of PEEK-based dental restorations and implants, leading to widespread adoption in dental practice. Ongoing research continues to optimize surface treatments, refine material formulations, and explore new applications to address challenges like bonding with dental materials and long-term performance. The evolution of PEEK in dentistry highlights a collaborative effort among material scientists, engineers, and dental professionals aimed at improving patient outcomes and expanding treatment options in prosthodontics and implant dentistry.[7]

PROPERTIES OF POLYETHERETHERETHERK ETONE

Polyetheretherketone boasts numerous positive properties that make it highly valuable in various applications, particularly in dentistry. It is resistant to hydrolysis and possesses superior mechanical properties, allowing it to withstand high temperatures and chemical wear.[3] Polyetheretherketone, being biologically inert, exhibits no cytotoxicity, mutagenicity, carcinogenicity, or immunogenicity in its inert form. Additionally, it withstands deterioration during diverse sterilization procedures, boasting a melting point exceeding 280°C (Table 1), rendering it suitable for high-temperature sterilization methods. Furthermore, the mechanical properties of PEEK can be bolstered by integrating other materials, like carbon fibers, which can elevate its elasticity modulus to better align with that of bone. Additionally, it is lightweight with a low density of 1.32 g/cm^3 and compatible with magnetic resonance imaging (MRI). Polyetheretherketone demonstrates resistance to disintegration from radiation heat and has simple laboratory processing stages. Its affordability and ease of preparation within the mouth further underscore its practicality. These characteristics collectively establish PEEK as a versatile and reliable material in the medical and dental fields.[24]

TYPES OF POLYETHERETHERETHERKETONE

Unfilled PEEK: This is the basic form of PEEK, which offers excellent mechanical and chemical resistance properties. It is inherently pure and used in applications where the intrinsic qualities of PEEK—such as high-temperature performance, resistance to chemicals, and wear resistance—are needed without modification.[25]

Glass-Filled PEEK: This type of PEEK contains glass fibers that enhance its mechanical and thermal properties. Glass-filled PEEK has increased rigidity and improved dimensional stability. It is often used in applications where higher load-bearing capacity is required and where the material must maintain its properties over a wide temperature range[25] (Table 2).

Table 1. Properties of PEEK

S.No.	Properties	Values
1.	Tensile strength	90-100 Mpa
2.	Flexural strength	140-170 Mpa
3.	Young's modulus	3-4 Gpa
4.	Density	1300 kg/m^3
5.	Thermal conductivity	0.29 W/mK
6.	Specific gravity	(g/cm^3) 1.31
7.	Vitreous transition temperature	143°C
8.	Melting temperature	343°C

Table 2. Properties of Glass-Filled PEEK

S.No.	Properties	Values
1.	Tensile strength	~110 MPa
2.	Flexural strength	~170 MPa
3.	Elastic modulus	4.6 GPa
4.	Density	1.51 g/cm^3
5.	Thermal conductivity	0.25 W/m·K
6.	Impact strength	20-40 kJ/m^2
7.	Wear resistance	10^5 mm^3/N

Carbon-Filled PEEK: Incorporating carbon fibers into PEEK significantly increases its strength and stiffness. Carbon-filled PEEK also has a higher fatigue resistance and improved compression strength, making it suitable for structural applications that require superior strength, stiffness, and stability under sustained loads[26] (Table 3).

Medical Grade PEEK: This variant of PEEK is manufactured under stricter controls and regulations required for biocompatibility and suitability in medical implants and devices. It offers excellent mechanical properties and chemical resistance, and it is resistant to sterilization processes, making it ideal for applications in the medical and dental fields.[26]

APPLICATION OF POLYETHERETHERETHERK ETONE IN PROSTHODONTICS

Dental Implant

Dental implants, favored for their biocompatibility and osseointegration, often use titanium. However, titanium implants can release metal ions, corrode, and have limited imaging compatibility, and their high elastic modulus can cause stress shielding and bone resorption, affecting esthetics, especially in thin gingiva. The delay in functional loading also poses challenges. Polyetheretherketone is a promising alternative. This thermoplastic offers excellent mechanical properties, radiolucency, MRI compatibility, and a Young's modulus similar to bone, potentially reducing stress-related issues and supporting bone formation. While PEEK has proven effective in orthopedics, its use in dental implants is still under investigation.[27] Recent advancements in implantology focus on implant shape, surface treatment, and esthetics, with polymers like PEEK gaining attention.[6] Polyetheretherketone's

Table 3. Properties of Carbon-Filled PEEK

S.No.	Properties	Values
1.	Tensile strength	~145 MPa
2.	Flexural strength	~230 MPa
3.	Elastic modulus	7.0 GPa
4.	Density	1.44 g/cm^3
5.	Thermal conductivity	0.64 W/m·K
6.	Impact strength	50-80 kJ/m^2
7.	Wear resistance	10-7 mm^3/N

bioactive polymer composition, reinforced with carbon fiber (CFR-PEEK), mimics bone's elastic modulus, ensuring uniform stress distribution and enhancing bone-implant interfaces. Its chemical inertness and radiolucency offer ease of modification ease and corrosion resistance, outperforming traditional titanium implants.[20] Clinical studies support PEEK's long-term suitability, mechanical compatibility, and masticatory force endurance, highlighting its potential to stimulate bone formation. Despite promising results, issues like crestal bone loss and implant failure necessitate further research to optimize PEEK implant protocols and outcomes.[27] Polyetheretheretherketone is becoming more and more well-known in implantology because of its high elasticity modulus, which is comparable to that of bone and dentin. Its dental applications could be further expanded by increasing osseointegration and bonding with acrylic and composite resins.[28]

POLYETHERETHERETHERKETONE IMPLANT ABUTMENTS

Polyetheretheretherketone emerges as a promising material for dental implant healing abutments owing to its outstanding biocompatibility. Research, exemplified by the randomized controlled trial conducted by Koutouzis et al, demonstrates no significant disparities in bone resorption and soft tissue inflammation between PEEK and conventional titanium abutments. Moreover, oral microbial attachment to PEEK proves comparable to that of titanium, zirconia, and polym ethylmethacrylate. The capacity of PEEK to harmonize with the elastic moduli of bone mitigates stress-shielding effects and fosters bone remodeling, potentially yielding superior long-term outcomes. With its superior mechanical and biological characteristics, PEEK is poised to witness increasing utilization in denture construction, promising enhanced comfort, durability, and biocompatibility compared to traditional materials.[29] The integration of PEEK in both implant healing abutments and dentures signifies a substantial leap forward in dental technology.[23] Its compatibility with the oral environment and favorable mechanical characteristics make PEEK a viable alternative to conventional materials like titanium. As research progresses and more clinicians adopt PEEK-based solutions, it could become a cornerstone in modern dental prosthetics, enhancing functionality and comfort while maintaining optimal oral health.[30] Unlike zirconium abutments, which stay intact but may cause screw breakage, PEEK, a flexible polymer that is frequently made with a titanium base, exhibits deformation but does not break when used as abutments. Because of its semi-crystalline structure, PEEK is less brittle and deforms instead of breaking. As a result, replacing PEEK abutments is made simpler and less complicated by the absence of damaged screws. Forty percent of prostheses with PEEK abutments in one research exhibited no breaking, and the prosthesis could be reused by just switching out the abutment.[31]

POLYETHERETHERETHERKETONE IN FIXED DENTAL PROSTHESES

Polyetheretheretherketone Crown

Ceramic materials such as porcelain are highly regarded for their outstanding esthetics and biocompatibility, making them popular choices for inlays, onlays, veneers, and crowns. Despite these advantages, ceramics can be brittle and require careful handling during preparation and placement.[32] On the other hand, PEEK crowns are becoming increasingly popular due to their exceptional wear resistance and stress distribution, thanks to their lower elastic modulus compared to traditional materials. Studies show that although PEEK crowns might be more susceptible to displacement, they experience less material degradation than zirconia, especially after thermal stress. Additionally, PEEK's high flexural strength improves fracture resistance, making it suitable for long-term provisional crowns.[30] Future research on the impact of crown shape and manufacturing techniques on their durability could further enhance the performance of PEEK crowns.[29]

FIXED PARTIAL DENTURES (FPDS)

The use of PEEK in FPDs shows promise in stress distribution and fracture resistance, owing to its lower Young's modulus relative to other materials. Despite variations in fracture characteristics based on design and manufacturing methods, PEEK FPDs demonstrate satisfactory clinical outcomes and acceptable aesthetics.[30] Continued investigation into the optimal design parameters and manufacturing processes for PEEK FPDs is essential to further to enhance their performance and durability in clinical applications.[7]

POST-AND-CORE RESTORATION

Polyetheretheretherketone stands out as a compelling alternative for post-and-core restorations due to its modulus closely resembling dentin, which aids in distributing stress favorably.[33] Studies suggest that PEEK posts boast high fracture resistance and could deliver performance comparable to that of traditional materials like glass fiber posts. Nonetheless, hurdles remain in achieving optimal fit and performance, particularly when contrasted with materials possessing higher fracture resistance. Further research is imperative to evaluate the long-term effectiveness of PEEK in enhancing both tooth and restoration survival, especially in clinical contexts.[34] Polyetheretherketone is anticipated to be utilized in regular dental posts and endodontic procedures in the future due to its exceptional mechanical and biological qualities. Surface coating technologies for PEEK are crucial, as methods like acid etching, plasma treatment, sandblasting, and laser treatment each enhance adhesion in different ways. Acid etching improves surface roughness and bond strength but requires careful control of etching time and post-treatment.[11] Plasma treatment, especially with nitrogen, boosts bond strength by altering surface energy, though results vary by gas. Sandblasting increases surface roughness but shows mixed results. Laser treatments, notably with Nd: YAG and Nd: YVO4, effectively improve bond strength but need standardized protocols. Combining these methods with adhesive systems further enhances adhesion, highlighting the need for ongoing research to optimize these techniques[17]

POLYETHERETHERETHERKETONE IN REMOVABLE PARTIAL DENTURE (RPD) FABRICATION

Utilizing CAD-CAM techniques, PEEK serves as a versatile material for fabricating removable partial denture (RPD) frameworks, offering a metal-free alternative to conventional Co-Cr frameworks. Its exceptional properties, including excellent biocompatibility, mechanical strength, thermal and chemical resistance, and low weight, facilitate the creation of lightweight RPDs that enhance patient comfort.[8] Studies have demonstrated high patient satisfaction with PEEK RPDs, particularly concerning esthetics, retention, and comfort. Moreover, PEEK's high elasticity enables it to mitigate stresses on abutment teeth during function, rendering it suitable for patients with compromised periodontal conditions.[35] While PEEK clasps may exhibit lower retentive force compared to metal clasps, they are still considered clinically sufficient. Different fabrication methods, such as direct milling or thermo-pressing, yield RPD frameworks with clinically acceptable fit values, with directly milled frameworks demonstrating superior precision and fit. However, caution is advised in distal extension RPDs due to potential issues such as mucosal stress and compromised chewing efficiency.[35]

POLYETHERETHERETHERKETONE IN MAXILLOFACIAL PROSTHESIS

Polyetheretheretherketone is increasingly recognized for its suitability in maxillofacial prosthetics, offering numerous advantages over traditional materials like PMMA resin. Its lightweight nature, coupled with excellent color stability and low water absorption rates, makes it an ideal choice for fabricating maxillary obturators.[36] Polyetheretherketone's resistance to polymerization shrinkage addresses a common issue encountered during the manufacturing of medical devices, ensuring a precise fit and optimal functionality of maxillofacial prostheses. Furthermore, the ability to be polished enhances PEEK's longevity and durability in clinical applications. Integration with 3D printing technology presents exciting opportunities for personalized treatment options, allowing for the tailored creation of prostheses that meet specific patient needs. Polyetheretherketone is biocompatible and resistant to chemical degradation but may be prone to microbial colonization over time.[10] Bonding silicone elastomers to resin materials is challenging due to differing chemical structures, but primers, especially organosilane-based ones, can enhance bond strength. Polyetheretherketone's high cost compared to traditional materials like acrylic resins limits its widespread clinical use. As PEEK continues to revolutionize maxillofacial prosthetic development, it stands at the forefront of technological advancements, driving innovation and improving patient care outcomes.[36]

FUTURE TRENDS IN POLYETHERETHERETHERK ETONE APPLICATIONS

Additive manufacturing is poised to revolutionize PEEK-based 3D-printed products, offering cost-effective solutions for clinical and dental laboratories. Polyetheretherketone implants, known for their longevity and superior wear resistance, meet essential criteria for mimicking natural teeth or bones. The integration of additive manufacturing with PEEK promises increased design efficiency and rapid production of customized products at reduced costs, benefiting traditional dentistry. However, the optimization of bonding performance remains a challenge, necessitating further research into optimal combinations of luting cement and pretreatment methods. The choice of fabrication method, whether 3D printing, milling, or heat pressing, significantly influences PEEK's restoration and bonding properties, requiring further exploration. Enhancements such as incorporating fibers or particle fillers and applying various coatings show promise in improving PEEK's structural integrity and bonding strength, presenting avenues for future research in prosthetic dentistry.[36]

CONCLUSION

Polyetheretherketone stands out as a promising material in prosthetics, thanks to its unique properties. With outstanding biocompatibility, strength, and wear resistance, it's well-suited for a range of dental prosthetic applications. Additionally, its durability reduces the frequency of replacements, and its radiolucency allows for clear imaging. Notably lightweight and customizable, PEEK enhances both patient comfort and esthetic outcomes. As research progresses, PEEK is positioned to play a crucial role in advancing prosthetic solutions, offering considerable benefits to patients and clinicians alike.

Availability of Data and Materials: The data that support the findings of this study are available on request from the corresponding author.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept – M.R.; Design – M.S.; Supervision – M.R.; Resources – S.S.T.; Materials – B.S.; Data Collection and/or Processing – S.M.; Analysis and/or Interpretation – M.R.; Literature Search – S.S.T.; Writing Manuscript – M.S.; Critical Review – S.M.; Other – K.D.

Declaration of Interests: The authors have no conflict of interest to declare.

Funding: The authors declared that this study has received no financial support.

REFERENCES

1. Skirbutis G, Dzingutė A, Masiliūnaitė V, Šulcaitė G, Žilinskas JA. A review of PEEK polymer's properties and its use in prosthodontics. *Stomatologija*. 2017;19(1):19-23.
2. Najeeb S, Zafar MS, Khurshid Z, Siddiqui F. Applications of polyetheretherketone (PEEK) in oral implantology and prosthodontics. *J Prosthodont Res*. 2016;60(1):12-19. [CrossRef]
3. Monich PR, Berti FV, Porto LM, et al. Physicochemical and biological assessment of PEEK composites embedding natural amorphous silica fibres for biomedical applications. *Mater Sci Eng C Mater Biol Appl*. 2017;79:354-362. [CrossRef]
4. Urapepon S, Leelanarathiwat K. Effect of abutment shape on the accuracy of two dental computer-aided-design and computer-aided-manufacturing systems. *Essent Dent*. 2021;1(1):38-42. [CrossRef]
5. Vaezi M, Yang S. A novel bioactive PEEK/HA composite with controlled 3D interconnected HA network. *Int J Bioprint*. 2015;1(1):66-76. [CrossRef]
6. Gowda E, Iyer V, Verma K, Murali Mohan S. Evaluation of PEEK composite dental implants: a comparison of two different loading protocols. *J Dent Res Rep*. 2018;1(1).
7. Tekin S, Adiguzel O, Cangul S, Atas O, Erpacal B. Evaluation of the use of PEEK material in post-core and crown restorations using finite element analysis. *Am J Dent*. 2020;33(5): 251-257.
8. Bathala L, Majeti V, Rachuri N, Singh N, Gedela S. The role of polyether ether ketone (PEEK) in dentistry: a review. *J Med Life*. 2019;12(1):5-9. [CrossRef]
9. Buck E, Li H, Cerruti M. Surface modification strategies to improve the osseointegration of poly(ether ether ketone) and its composites. *Macromol Biosci*. 2020; 20(2).
10. Chen SG, Yang J, Jia YG, Lu B, Ren L. TiO2 and PEEK reinforced 3D printing PMMA composite resin for dental denture base applications. *Nanomaterials (Basel)*. 2019;9(7):1049. [CrossRef]
11. Qin L, Yao S, Zhao J, et al. Review on development and dental applications of polyetheretherketone-based biomaterials and restorations. *Materials (Basel)*. 2021;14(2):408. [CrossRef]
12. Sikder P, Choudhury R, Roy S, et al. Development of bioactive amorphous magnesium phosphate (AMP)-PEEK composite filaments through the melt-blending technique. *Dent Mater.* 2020:36(7)
13. Peng TY, Ogawa Y, Akebono H, Iwaguro S, Sugeta A, Shimoe S. Finite-element analysis and optimization of the mechanical properties of polyetheretherketone (PEEK) clasps for removable partial dentures. *J Prosthodont Res*. 2020;64(3):250-256.
14. Gao R, Xie J, Yang J, Zhuo C, Fu J, Zhao P. Research on the fused deposition modeling of polyether ether ketone. *Polymers* (Basel). 2021 17;13(14):2344.
15. da Cruz MB, Marques JF, Peñarrieta-Juanito GM, Costa M, Souza JCM, Magini RS, Miranda G, Silva FS, Caramês JMM, da Mata ADSP. Bioactive-enhanced polyetheretherketone dental implant materials: mechanical characterization and cellular responses. *J Oral Implantol*. 2021 1;47(1):9-17.
16. Oladapo BI, Zahedi SA, Ismail SO, Omigbodun FT. 3D printing of PEEK and its composite to increase biointerfaces as a biomedical material: a review. *Colloids Surf B Biointerfaces*. 2021;203:111726.
17. Özarslan M, Büyükkaplan UŞ, Özarslan MM. Comparison of the fracture strength of endodontically treated teeth restored with polyether ether ketone, zirconia and glass-fibre post-core systems. *Int J Clin Pract*. 2021;75(9):e14440. [CrossRef]
18. Peng TY, Lin DJ, Mine Y, Tasi CY, Li PJ, Shih YH, Chiu KC, Wang TH, Hsia SM, Shieh TM. Biofilm formation on the surface of (poly)ether-ether-ketone and in vitro antimicrobial efficacy of photodynamic therapy on peri-implant mucositis. *Polymers* (Basel). 2021 18;13(6):940.
19. Manzoor F, Golbang A, Jindal S, Dixon D, McIlhagger A, Harkin-Jones E, Crawford D, Mancuso E. 3D printed PEEK/HA composites for bone tissue engineering applications: effect of material formulation on mechanical performance and bioactive potential. *J Mech Behav Biomed Mater*. 2021;121:104601.
20. Blanch-Martínez N, Arias-Herrera S, Martínez-González A. Behavior of polyether-ether-ketone (PEEK) in prostheses on dental implants: a review. *J Clin Exp Dent*. 2021;13(5):e520-e526. [CrossRef]
21. Dua R, Rashad Z, Spears J, Dunn G, Maxwell M. Applications of 3D-printed PEEK via fused filament fabrication: a systematic review. *Polymers*. 2021;13(22):4046
22. Ghazal-Maghras R, Vilaplana-Vivo J, Camacho-Alonso F, Martínez-Beneyto Y. Properties of polyetheretheretherketone (PEEK) implant abutments: a systematic review. *J Clin Exp Dent*. 2022 1;14(4)
23. Wang B, Huang M, Dang P, Xie J, Zhang X, Yan X. PEEK in fixed dental prostheses: application and adhesion improvement. *Polymers (Basel)*. 2022;14(12):2323. [CrossRef]
24. Balavignesh S. Application of PEEK in implant dentistry: a review. *HTAJOCD*. 2024;3:59-61.
25. Wang P, Lin Q, Wang Y, Liu C, Shen C. Comparative study of the crystallization behaviour and morphologies of carbon and glass fibre reinforced poly(ether ether ketone) composites. *Polym Polym Compos*. 2021;29(8):1229-1239.
26. Okawa S, Taka N, Aoyagi Y. Effect of modification with helium atmospheric-pressure plasma and deep-ultraviolet light on adhesive shear strength of fiber-reinforced poly(ether-ether-ketone) polymer. *J Funct Biomater*. 2020;11(2):27. [CrossRef]
27. Koutouzis T, Richardson J, Lundgren T. Comparative soft and hard tissue responses to titanium and polymer healing abutments. *J Oral Implantol*. 2011;37(Spec No):174-182. [CrossRef]
28. Alqurashi H, Khurshid Z, Syed AUY, Rashid Habib SR, Rokaya D, Zafar MS. Polyetherketoneketone (PEKK): an emerging biomaterial for oral implants and dental prostheses. *J Adv Res*. 2021;28:87-95. [CrossRef]
29. Kongkiatkamon S, Booranasophone K, Tongtaksin A, Kiatthanakorn V, Rokaya D. Comparison of fracture load of the four translucent zirconia crowns. *Molecules*. 2021;26(17):5308. [CrossRef]
30. Tekin S, Cangül S, Adıgüzel Ö, Değer Y. Areas for use of PEEK material in dentistry. *Int Dent Res*. 2018;8(2):84-92. [CrossRef]
31. Santing HJ, Meijer HJA, Raghoebar GM, Özcan M. Fracture strength and failure mode of maxillary implant-supported provisional single crowns: a comparison of composite resin crowns fabricated directly over PEEK abutments and solid titanium abutments. *Clin Implant Dent Relat Res*. 2012;14(6):882-889. [CrossRef]
32. Asgary S. Advancements in dental restorative materials: implications for patient care. *Essent Dent*. 2024;3(1):37-38. [CrossRef]

33. Dal Piva AMO, Tribst JPM, Borges ALS, Souza ROAE, Bottino MA. CAD-FEA modelling and analysis of different full crown monolithic restorations. *Dent Mater*. 2018;34(9):1342-1350. [CrossRef]
34. Hallak AG, Caldas RA, Silva ID, Miranda ME, Brandt WC, Vitti RP. Stress distribution in restorations with glass fibre and polyetheretherketone intraradicular posts: an in silico analysis. *Dent Mater J*. 2022;41(3):376-381. [CrossRef]
35. Harb IE, Abdel-Khalek EA, Hegazy SA. CAD/CAM constructed poly(ether ether ketone) (PEEK) framework of Kennedy class I removable partial denture: a clinical report. *J Prosthodont*. 2019;28(2):595-598.
36. Cevik P, Yildirim AZ, Demir Sevinc EH, Gonder A, Kiat-Amnuay S. Using PEEK as a framework material for maxillofacial silicone prosthesis: an in vitro study. *Polymers (Basel)*. 2023;15(12):2694. [CrossRef]