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Polyether Ether Ketone (Peek) in Restorative Dentistry: A Narrative Review

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ABSTRACT:

Polyether Ether Ketone (PEEK) has gained prominence in restorative dentistry due to its remarkable mechanical strength, biocompatibility, and aesthetic attributes, offering a flexible alternative to traditional dental materials. In prosthodontics, implantology, and various restorative applications, PEEK demonstrates exceptional adaptability and durability. This narrative review explores the extensive potential of PEEK in enhancing prosthetic restorations, post-endodontic treatments, and implant-supported prostheses. It highlights the material's ability to provide superior stress distribution, fracture resistance, and bioactivity, making it suitable for challenging restorative scenarios. The review emphasizes the importance of ongoing research and development to ensure responsible use and to advance future applications of PEEK within the dynamic landscape of dental practice. By focusing on PEEK's role in prosthodontics, restorative procedures, and implantology, this review underscores its transformative potential in modern dentistry, offering a promising pathway for improved clinical outcomes and patient care.

1. INTRODUCTION

Modern dentistry has taken a keen interest in Polyether Ether Ketone (PEEK), a novel substance with a wide range of uses. Many of the drawbacks of conventional restorative materials like metals and ceramics are perfectly addressed by its special blend of mechanical, physical, and aesthetic qualities. The remarkable lightweight nature, extraordinary mechanical strength, and exceptional biocompatibility of PEEK make it a high-performance polymer. For demanding dental applications including load-bearing prosthesis, implant components, and restorative devices, these qualities make it especially appropriate. PEEK provides a strong and inert substitute that can endure the severe oral environment, in contrast to metals, which can corrode or induce hypersensitivity, and ceramics, which are fragile under extreme stress. Its capacity to replicate the mechanical characteristics of human cortical bone is one of its most impressive features, offering restorative and implant dentistry a biomechanical edge. By ensuring ideal load distribution, this bone-like flexibility lowers the chance of bone resorption and implant failure. Its flexibility and low density also make it easy to handle and comfortable for patients. Its potential extends beyond function; its ability to be customized for aesthetic restorations ensures it meets modern patients' demands for visually appealing and minimally invasive dental treatments. This positions PEEK as a cornerstone in the evolution of dental materials [1,2].

Historical Background and Development of PEEK in Dentistry

Ether Ketone, or PEEK, was first created for aerospace engineering but was later used in biomedical applications due to its exceptional stability and versatility. The need for materials that could effortlessly blend mechanical strength, biocompatibility, and aesthetics propelled its entry into dentistry. In contrast to conventional dental materials like metals and ceramics, PEEK provided a special blend of strength and light weight, which made it a desirable option for prosthetic and restorative applications. Its adaptability has been further increased by the creation of PEEK-based biomaterials, such as Bio High-Performance Polymer (BioHPP), a ceramic-reinforced form of PEEK. These cutting-edge formulations are especially useful in intricate dental restorations because they offer better mechanical qualities, increased bioactivity, and superior cosmetic results. PEEK and its derivatives have grown to be

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essential in implantology and prosthodontics throughout time, supporting more consistent and long-lasting treatment results. This development demonstrates how PEEK has revolutionized contemporary restorative dentistry [2,3].

Evolution of Dental Materials

The search for materials with superior biocompatibility, durability, and aesthetics has led to notable improvements in restorative dentistry. Despite their historical dominance, traditional materials like metals and ceramics have significant drawbacks. While metals are prone to corrosion and frequently lack aesthetic appeal, ceramics can be brittle and prone to fractures under stress, even if they look like genuine teeth. Due to these limitations, a great deal of research has been done on substitute materials that might better satisfy the requirements of contemporary dentistry. With its remarkable biocompatibility, mechanical robustness, and aesthetic adaptability, PEEK has become a game-changing solution. PEEK is especially well-suited for load-bearing applications since it has better resistance to wear and deformation than conventional materials. Its potential to revolutionize restorative dentistry procedures is further supported by its ability to blend in perfectly with the surrounding tissues. The transition to materials like PEEK, which raise the bar for both functionality and aesthetics in contemporary dentistry, is highlighted by this trend [3,4].

This narrative review examines the clinical and mechanical properties of Polyether Ether Ketone (PEEK), emphasizing its diverse applications in prosthodontics, implantology, and restorative dentistry. By integrating findings from an extensive body of literature, this review aims to offer a detailed analysis of PEEK’s advantages, inherent limitations, and prospective advancements, highlighting its transformative potential within the field of dentistry.

2. MECHANICAL PROPERTIES OF PEEK

PEEK is an excellent material for dental restorations because of its unique mechanical qualities. Its high-performance polymer properties, including as exceptional strength, durability, and fracture resistance, are comparable to those of human cortical bone, according to Moby et al. (2022) [5]. The mechanical properties of PEEK are essential for its use in load-bearing dental components such crowns, bridges, and implants. The material provides a more resilient option because its flexural strength, modulus, and impact resistance are on par with or even better than those of conventional dental metals and ceramics [6,7]. According to comparative research, PEEK performs better mechanically than metals and ceramics while lowering the likelihood of mechanical failures like fractures or deterioration in the oral environment [6,8]. The mechanical properties of PEEK are thoroughly examined in the systematic review by Moby et al. (2022) [5], which validates the material's potential for dental restorations using techniques including fused deposition modeling. Moreover, PEEK’s ability to endure mechanical forces without significant wear or breakage supports its viability in demanding dental applications, making it a preferred choice over other materials in restorative dentistry [6].

3. BIOCOMPATIBILITY OF PEEK

A key element in PEEK's acceptability for clinical application is its biocompatibility. Positive tissue responses and low cytotoxicity observed in both animal and human studies [10] demonstrate its compatibility with biological tissues. Long-term investigations [9] highlight PEEK’s stability and bioactivity, which are crucial for its use in prosthodontics and implantology. PEEK’s inert nature reduces the risk of adverse tissue reactions commonly associated with metal allergies or ceramic failures [7]. Surface modifications, such as plasma etching and chemical bonding, can significantly enhance PEEK’s bioactivity, improving its ability to integrate with bone and facilitate osseointegration [9]. These advancements are essential for the clinical success of PEEK implants, promoting bone-implant contact and long-term stability. Consequently, PEEK’s biocompatibility, combined with progress in surface treatments, positions it as a promising material for dental applications [7,9].

4. SURFACE CHARACTERISTICS OF PEEK

PEEK's clinical performance is greatly influenced by its surface properties. According to Schwitalla and Müller (2013) [6], surface changes are crucial for increasing the bioactivity of PEEK. Techniques like sandblasting, plasma etching, and the application of bioactive coatings improve PEEK’s surface energy, facilitating better adhesion of restorative materials and the formation of a stable interface with the surrounding tissue. The longevity and clinical results of PEEK-based restorations are enhanced by these changes, which also help to stop bacterial colonization.Reda et al. (2022) [8] describe how improvements in surface treatments and cleaning methods have improved PEEK's surface qualities even more. Plaque accumulation and the development of peri-implantitis are reduced by adding coatings that encourage bioactivity and streamlining cleaning procedures. Maintaining dental hygiene and avoiding issues related to dental implants depend on these advancements. The well-established effects of these surface alterations on adhesion and integration support the material's potential for use in restorative dentistry [6,8].

5. LIMITATIONS OF PEEK IN DENTISTRY

Despite its many advantages, PEEK also has limitations that may influence its widespread adoption in dental practice.

❒ Mechanical Challenges: Wear Resistance and Longevity

PEEK exhibits excellent strength and resilience; however, concerns about its wear resistance remain. **Alexakou et al. (2019)**[1] emphasize that while PEEK demonstrates durability under load, its wear resistance, particularly in highly abrasive environments like the oral cavity, may be inferior compared to metals and ceramics. This can affect its longevity in certain applications, especially in areas with high masticatory forces, such as molar restorations or load-bearing implant components. Moreover, long-term studies have suggested that surface wear and degradation in PEEK-based restorations can lead to decreased functionality over time [2,4].

❒ Aesthetic Limitations: Comparison with Gold-Standard Materials

Although PEEK’s color can mimic natural tooth shades, it falls short of the aesthetic qualities offered by ceramics such as zirconia or porcelain. **Ortega-Martinez et al. (2017)** [3] note that PEEK's opaque appearance limits its use in highly visible anterior restorations. Efforts to enhance its aesthetic properties, such as veneering with composite materials or integrating pigment additives, have shown potential but also introduce bonding and longevity concerns [4].

❒ Addressing Bonding Issues with Conventional Materials

PEEK’s chemically inert and non-polar nature makes it challenging to achieve strong and durable adhesive bonds with conventional materials like composite resins or luting agents. Studies by **Bathala et al. (2019)** [4] and **Benakatti et al. (2019)** [7] highlight that surface modifications, such as sandblasting, plasma treatment, or applying primers, are often required to improve adhesion. These extra steps increase procedural complexity and may not always provide long-lasting results, particularly under dynamic oral conditions. Thus, while PEEK holds significant promise as a restorative material, addressing these limitations particularly in wear resistance, aesthetics, and bonding remains critical for its broader application in modern dentistry.

6. DISCCUSSION

PEEK is a highly versatile material in restorative dentistry due to its mechanical strength, biocompatibility, and aesthetic properties. It is widely utilized in post-core systems, crowns, and endocrowns, providing superior stress distribution, fracture resistance, and preservation of tooth structure [4, 5]. Studies also demonstrate its effectiveness in long-term dental restorations, with the potential to outperform traditional materials in durability and patient comfort [3, 7]. Its use as an alternative to metal and ceramic materials highlights its adaptability to various restorative applications. PEEK’s unique blend of properties continues to revolutionize restorative dentistry by offering reliable and patient-friendly treatment options [1]. PEEK is becoming increasingly popular in both endodontics and restorative dentistry. Its lightweight design and biomechanical advantages are evident in its application for frameworks in detachable partial dentures, as well as its ability to tolerate occlusal stresses in fixed prosthodontics [1,7,8]. PEEK’s mechanical properties and bioactivity play a crucial role in endodontics, with studies by Almasi et al. and Nieminen et al. highlighting its long-term effectiveness [9,10]. Ongoing research continues to support PEEK’s role in various restorative dental clinical scenarios, offering innovative solutions for improved outcomes in endodontics and restorative dentistry.PEEK has recently undergone developments aimed at improving its mechanical and adhesive qualities for usage in dental

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applications. These advancements seek to broaden the application of PEEK in restorative dentistry and address certain issues. According to the current research in this field, PEEK is constantly being optimized for a range of therapeutic settings [11]. PEEK is a useful resource for dentists, as demonstrated by the narrative review on its numerous applications in restorative dentistry. PEEK is an innovative dental material that combines mechanical strength, biocompatibility, and aesthetic appeal. This narrative review highlights PEEK's position in prosthodontics, implantology, and restorative dentistry. By offering insights into PEEK's diverse contributions, it seeks to challenge preconceived notions and progress dental care through ongoing research.

Clinical and Experimental Insights into PEEK's Role in Restorative Dentistry

The adaptability and efficacy of polyetheretherketone (PEEK) as a restorative dental material are highlighted by an expanding body of research. These investigations, which are compiled in Table 1, use a variety of approaches, such as case reports, finite element analysis, in vitro evaluations, and clinical follow-ups. Together, they demonstrate PEEK's robustness, biomechanical capabilities, and potential uses in difficult restorative situations.

PEEK's remarkable long-term stability and dependability as a post and core material in restorations subjected to high clinical demands was shown in five-year clinical follow-up research [12]. With improved stress distribution seen in post-core systems, finite element analysis has further confirmed PEEK's biomechanical advantages and highlighted its potential for better restoration results and less material fatigue [13].PEEK's greater fracture resistance over more conventional materials like fiberglass and Ni-Cr has been investigated in in vitro tests, confirming its appropriateness for high-resilience restorations [14]. Furthermore, in endocrown restorations, PEEK has demonstrated a tensile bond strength that is comparable to that of lithium disilicate, making it a feasible substitute in these applications [15]. Stress distribution in endocrowns was investigated in another finite element study, which demonstrated how the mechanical behaviour of PEEK and the optimization of margin design support successful restorative outcomes [16]. PEEK's capacity to preserve tooth structure while preserving function is demonstrated by clinical insights from case studies, which validate its efficacy in reconstructing molars with significant coronal destruction [17]. Lastly, comparative studies on crown materials have identified PEEK's high load-bearing capacity, establishing monolithic PEEK crowns as strong alternatives to zirconia and hybrid ceramics for fixed prostheses [18].Hence, these studies collectively illustrate PEEK's adaptability, mechanical robustness, and functional efficacy across restorative dental applications, reinforcing its transformative potential in modern dentistry.

The diverse applications of Polyether Ether Ketone (PEEK) in prosthetics, restorative dentistry, and implantology have established it as a pivotal material in modern dentistry. Its unique properties, including biocompatibility, mechanical resilience, and adaptability, make it well-suited for a variety of clinical scenarios, providing reliable outcomes in challenging restorative cases [1,8]. Research on PEEK's role in prosthetic dentistry emphasizes its superior performance and suitability for restorative applications, particularly in achieving long-term durability and compatibility with the oral environment [1]. Furthermore, the clinical behavior of BioHPP, a PEEK-based biomaterial, highlights its critical role in prosthetic dentistry, underscoring its significance in enhancing restorative procedures [8]. Numerous studies in prosthodontics and implantology have clarified the extensive applications of Polyether Ether Ketone (PEEK). Its potential benefits in implant-supported prostheses are well-documented, with research highlighting its suitability for both temporary and long-term provisional implant restorations [2,19,20]. Its adaptability is further demonstrated in post-core systems and endocrowns, where it serves as a high-performance polymer and an alternative post-and-core material, offering advantages in durability, biomechanical performance, and stress distribution [12,13,14,16,21]. These findings collectively emphasize the versatility of PEEK across diverse clinical applications in prosthodontics and implantology.

PEEK in Restorative dentistry

Studies highlight that PEEK offers significant benefits for restorative dentistry. Its adaptability is evident in its exceptional performance and clinical applications in prosthodontics, as shown by [1, 8]. Stawarczyk et al. (2016) provide valuable insights into the aesthetic potential of PEEK by comparing it with traditional core

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materials for aesthetically pleasing restorations [22]. The role of PEEK as an alternative post and core material, a high-performance polymer in post-core systems, and its application in endocrowns are explored in studies by [12,13,14,16], emphasizing its durability and clinical advantages in restorative treatments. These findings underscore the importance of PEEK in achieving both functional and cosmetic excellence in restorative dentistry.

PEEK in Post-Endodontic restorations

Following endodontic operations, physicians now have viable options for restoring teeth thanks to the emerging potential of Polyether Ether Ketone (PEEK) as a material for post-endodontic restorations. Research has investigated the use of PEEK in large coronal restorations, endocrowns, post and core systems, and other post-endodontic applications.

♦ ***PEEK as post and core material:-*** A five-year follow-up study by Kasem et al. (2022)[12] showed that PEEK may be used successfully as a post and core material, with improved long-term stability and durability. This demonstrates how PEEK can be used to stabilize and support teeth after endodontic therapy when the coronal structure of the tooth is impaired.

♦ ***Endocrowns with PEEK:-***Research on the application of PEEK in endocrown restorations has been conducted by Riyad et al. (2020)[3] and Dogui et al. (2018)[4]. Comparable tensile bond strengths were discovered by Riyad et al. between PEEK and lithium disilicate in endocrown restorations, demonstrating the effectiveness of PEEK in facilitating functional restoration. Dogui et al.[17] successfully restored molars with significant coronal destruction by employing PEEK-fabricated endocrowns, maintaining tooth structure and guaranteeing long-term success.

♦ ***Biomechanical evaluation:-***3D finite element analysis was used by Lee et al. (2017)[5] to assess the biomechanical characteristics of teeth repaired with PEEK post and core systems. Their results further supported the use of PEEK in post-endodontic restorations by revealing superior biomechanical characteristics and stress distribution.

Advantages and considerations in Post-endodontic restorations:-PEEK has a number of benefits for post-endodontic applications, including its biocompatibility, attractive appearance, and advantageous mechanical qualities. Research has demonstrated that PEEK is a good choice for post-endodontic restorations due to its improved durability, fracture resistance, and similar bond strength to more conventional materials like lithium disilicate.

● **Durability and stability-**PEEK post and core systems showed improved durability and long-term stability over a five-year period, as shown by Kasem et al. (2022)[12], demonstrating its dependability in clinical application.

● **Fracture resistance -**According to Pourkhalili and Maleki (2022)[6], PEEK has a greater fracture resistance in post-core systems when compared to other materials like Ni-Cr and fiberglass. This highlights the material's capability for withstanding occlusal stresses and guaranteeing the success of long-term restorations.

● **Functional restorations -**PEEK's effective use in large coronal restorations and endocrowns indicates that it has demonstrated promising outcomes in delivering functional restoration following endodontic therapy. Its stress distribution qualities and biomechanical attributes support post-endodontic restorations' long-term viability.

PEEK's mechanical properties are essential to its use in dental restorations. Its properties in fused deposition modeling and its application as an implant material have been studied, and the results have shown both benefits and drawbacks [6,5].Surface properties are essential for PEEK's incorporation into biological tissues; studies are concentrating on surface treatments to improve osseointegration and bioactivity [23,24]. Furthermore, research on PEEK's tissue reactions, biocompatibility, and long-term safety [25,10] provide important information about its clinical applicability. Together, these investigations advance our knowledge of the mechanical and biological characteristics of PEEK in dental applications.

Disadvantages of PEEK

Although PEEK's mechanical characteristics are generally good, there are some restrictions. Although promising, the mechanical qualities of PEEK Fused Deposition Modeling may not be universally appropriate for all dental restorations, as noted by Moby et al. (2022)

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[5]. Schwitalla et al. (2013) address the mechanical features of PEEK dental implants and draw attention to any potential issues [6]. These restrictions highlight the necessity of carefully analyzing the mechanical specifications of any unique dental application. PEEK may face difficulties when it comes to restorative dentistry aesthetic issues. A spectrophotometric analysis by Stawarczyk et al. (2016)[22] comparing PEEK with gold standard core materials shows that although PEEK performs well mechanically, obtaining the same degree of aesthetics may be difficult. This drawback implies that PEEK would not be the best material option for restorations when aesthetics is important, even with its strong mechanical properties. Furthermore, wear resistance and longevity may be issues when using PEEK in the oral environment. For materials utilized in dental applications, wear characteristics and long-term durability restrictions are critical factors to consider. PEEK dental implant durability is discussed by Schwitalla et al. (2013), who emphasize the need for continued study to evaluate the implant's effectiveness over an extended length of time [6].

Future directions and clinical implications

The use of Polyether Ether Ketone (PEEK) in endodontic and post-endodontic restorations is gaining recognition, with promising potential for future clinical applications. Advances in material science are expected to enhance PEEK's biocompatibility, durability, and aesthetic qualities, making it a viable option for restoring teeth after endodontic procedures. Research focusing on optimizing PEEK's surface properties for improved osseointegration and bioactivity could further expand its role in endodontic treatments, leading to more predictable clinical outcomes. Developments in digital dentistry, particularly CAD/CAM technology, allow for the precise fabrication of PEEK restorations, offering dental practitioners greater flexibility and accuracy in post-endodontic therapy. These innovations open the door for PEEK to be more widely integrated into general dentistry, enhancing restorative options and improving patient outcomes. Continued research and clinical testing are crucial to optimizing PEEK's application in post-endodontic restorations. Improved surface treatments and manufacturing processes can enhance PEEK's bioactivity and adhesive properties, promoting better integration and long-term success in clinical settings. Educating dental professionals about PEEK handling and its clinical applications will further support its adoption, ensuring both functional and aesthetic results in post-endodontic restorations.

7. CONCLUSION

By combining data from several studies, this narrative review provides a thorough examination of Polyether Ether Ketone (PEEK) in dentistry. PEEK is a flexible material that can be used in implantology, prosthetic dentistry, and surface alterations to improve bioactivity. PEEK can be further integrated into regular clinical protocols because of its mechanical strength, biocompatibility, and variety of dental uses. Its versatility may be seen in its positive prosthetic dentistry results, oral environment compatibility, and post and core material efficacy. Judicious use of PEEK in dental treatment is guided by a thorough analysis of its mechanical, cosmetic, biocompatible, and durable qualities. For PEEK to reach its full potential and propel dental practice improvements, continuous research and development are essential.

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Table/Figure 1: Previous studies eliciting the use of PEEK in the field of restorative dentistry

Sl no.	Author/year	Study type/design	Materials used/ methodology/use of PEEK	Advantages of PEEK	Principal outcome of using PEEK in restorative dentistry (in respective studies)
1.	Kasem et al. (2022) [12]	Five-year follow-up	Clinical follow-up study with PEEK as post and core material	Enhanced durability and long-term stability	Demonstrated the successful use of PEEK as a post and core material over 5-year period
2.	Lee et al. (2017) [13]	3D finite element analysis	Biomechanical evaluation using 3D finite element analysis. Post-core system in tooth restoration	Improved biomechanical properties and stress distribution	Biomechanical evaluation showed improved properties and stress distribution with PEEK post and core system.
3.	Pourkhalili and Maleki (2022) [14]	In vitro study	In vitro study comparing fracture resistance of different post-core systems. Polyetheretherketone (PEEK) in comparison with Ni-Cr and fiberglass post-core systems	Higher fracture resistance when compared to other materials	Demonstrated higher fracture resistance of PEEK in comparison with NI-Cr and fiberglass post-core systems.
4.	Riyad et al. (2020) [15]	In vitro study	In vitro study comparing tensile bond strength of PEEK vs Lithium disilicateendocrown. Polyetheretherketone (PEEK) vs Lithium disilicate in endocrown restoration	Comparable tensile bond strength between PEEK and Lithium disilicate	Found comparable tensile bond strength between PEEK and lithium disilicate in endocrown restorations.
5.	Zheng et al. (2022) [16]	3D finite element analysis	3D finite element analysis evaluating stress distribution of endocrowns. Influence of margin design and restorative material, including PEEK	Stress distribution analysis for various restorative materials.	Investigated stress distribution in endocrowns and evaluated the influence of margin design and materials, including PEEK
6.	Dogui et al. (2018) [17]	Case report	Endocrown as an alternative approach for large coronal destruction. Endocrown restoration with PEEK	Preservation of tooth structure and successful restoration	Demonstrated the successful use of endocrown with PEEK in restoring molars with large coronal destruction
7.	Tartuk et al. (2018) [18]	In vitro study	Comparative study on load-bearing capacities of monolithic PEEK, zirconia, and hybrid ceramic molar crowns. Monolithic PEEK crowns in comparison with zirconia and hybrid ceramic crowns	High load-bearing capacity of monolithic PEEK crowns	Compared load-bearing capacities of different crown materials, highlighting high capacity of monolithic PEEK crowns. PEEK could be an alternative crown material for fixed dental prostheses