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Review Paper

Getting Ahead of ourselves with peek in prosthodontics: A Review of Literature

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ABSTRACT:
Introduction: Polyetheretherketone (PEEK), a member of polyaryletheretherketone (PAEK) family is a polyaromatic semi-crystalline thermoplastic polymer that has become increasingly popular and is nowadays used in many aspects in the field of prosthodontics, due to its outstanding properties such as high mechanical strength, better thermal stability, higher chemical resistance, good wear resistance, anticorrosive nature, and a radiolucent material that is resistant to radiation damage. **Methods:** Electronic database searches were conducted through 5 databases: PubMed, Wiley Online Library, EBSCOhost, Science Direct, as well as Google Scholar using the keywords: *PEEK, PEEK in prosthodontics, modified PEEK, PEEK in medical and Dental field, advantages of PEEK, PEEK crowns, PEEK removable partial dentures, PEEK fixed partial denture and PEEK maxillofacial prosthesis and PEEK Implants and implant superstructures.* **Conclusion: -** PEEK is a material that is well-suited for usage in prosthodontics due to its favourable mechanical qualities and biocompatibility. More clinical trials are required in order to evaluate the PEEK prosthetics' long-term performance because there is a lack of clinical data.

Keywords: polyaryletheretherketone, thermoplastic polymer, PEEK

INTRODUCTION:

The polyaromatic semi-crystalline thermoplastic polymer polyetheretherketone (PEEK), a member of the polyaryletheretherketone (PAEK) family, has gained popularity due to its exceptional qualities, including great mechanical strength, improved thermal stability, and enhanced thermal conductivity. chemical resistance, excellent wear resistance, an anticorrosive character, and radiolucent material that is resistant to radiation-damage. [1,2,3] In addition to these, PEEK has the most desirable quality for a future material, which is its resilience to degradation, especially damage from lipid exposure. This makes it ideal for usage in the biomedical, aerospace, and automotive industries. [2,3] PEEK has been employed more and more as a biomaterial to replace metal implant components in the biomedical area, particularly in orthopaedics and trauma. Based on invitro biocompatibility tests PEEK is a bioinert material, because it exhibits neither mutagenic nor cytotoxic activity, nor does it cause any deleterious reactions or release any dangerous components into the human body. [3,4,5] Despite of all these positive aspects of PEEK, PEEK does have one disadvantage, and that is its hydrophobic nature, which restricts cell adhesion and protein absorption on its surface, consequently lowering the wound healing ability on osseointegration. To get over this restriction, PEEK has been modified to improve cell adhesion and proliferation. The polymer is modified by adding bioactive particles, such as hydroxyapatite (HA), either as a filler in a composite or as a surface coating. This offers up a huge market for the creation of PEEK-

based composites.[2,3] PEEK was originally marketed as a biomaterial for implants in April 1998 by Invibio, Ltd. in Thornton Cleveleys, United Kingdom. After being helped by a consistent supply, research on PEEK biomaterials took off and is anticipated to do so in the future as well.[3,5,6] PEEK has proven to be an excellent material for use in medical and dental applications, according to research in the literature. There is always room for improvement, though. In this article, we'll examine numerous different PEEK biomaterial applications in prosthodontics.

HISTORICAL BACKGROUND:

PEEK is a semi-crystalline linear polycyclic aromatic thermoplastic that was first developed by a group of English scientists in 1978.[3] The use of polymers in dentistry has come a long way since 1920. With the development of acrylic resins in the 1940s, polymers were created for use in dentistry with the aim of replacing a single lost tooth, a section of missing teeth, or the entire arch restoration, either as detachable prostheses or as fixed bridges. Any novel dental material must meet the fundamental prerequisites in order to be successfully used in modern dentistry. [1-4] These requirements include excellent physical properties, biocompatibility, resistance to degradation, and most importantly aesthetic acceptance which PEEK polymer possessed. PEEK is becoming increasingly prevalent in oral implantology and prosthodontics as a result of its exceptional qualities. Additionally, diverse surface modifications have made it possible for PEEK to adhere to a variety of luting agents. PEEK is a suitable dental restorative material that is utilized in dentistry as implants and the framework for removable and fixed prostheses because its tensile properties are comparable to those of bone, enamel, and dentin.[4,5]

Figure 1 represents the major application of PEEK in Prosthodontics.

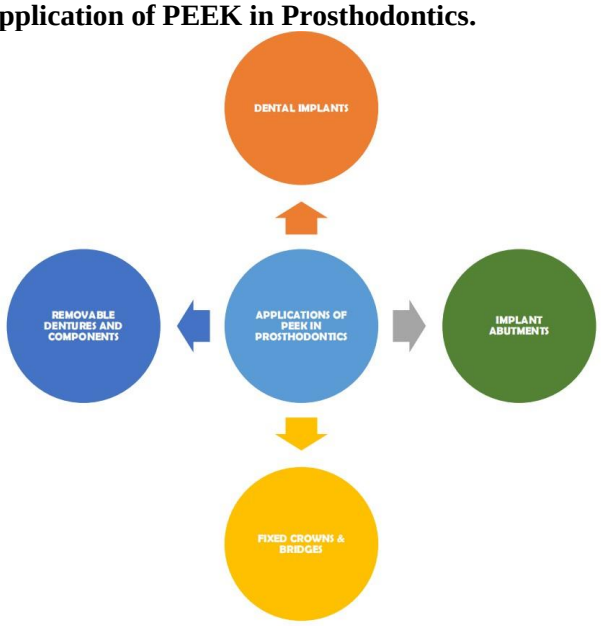

Figure 1: Major applications of polyetheretherketone (PEEK) in Prosthodontics

PEEK AS IMPLANT MATERIAL:

Dental implants are designed and manufactured to serve as an artificial replacement for natural dental roots. They are designed to provide a stable anchorage for fixed or removable dental prostheses, and as a result, they have enhanced quality of life for partially or completely edentulous patients who have dental degenerations. Therefore, one of the most effective tooth replacements is dental implants.[7,8] Titanium (Ti) and its alloys have been employed as dental implants since its introduction by Brånemark in the 1960s.[5] Ti materials have excellent physicochemical properties, mechanical qualities, biocompatibility, and superior resistance to fatigue stress and corrosion. However, titanium lacks a few crucial characteristics for its clinical applications, such as infrequent metal sensitivities and allergies, surface deterioration and contamination linked to peri-implantitis, and lower acceptance in the aesthetics regions due to Titanium's metallic colour. The high modulus of elasticity of titanium (110 GPa) is a major drawback and this may result in inadequate stress shielding, bone resorption, and implant fracture. [6] Unfilled PEEK exhibits elastic moduli of 3- 4Gpa.[3-6] PEEK-based materials can be engineered to overcome this problem and therefore could be recommended for applications in oral implantology. The major benefit of PEEK as an implant material [Figure 2 (D, E & F)] is its Youngs modulus which is close to the human bone (18 GPa), thus it can generate favourable stress and deformations, minimizing stress shielding effect and bone resorption. However, dental implants fabricated by PEEK have not been extensively used clinically, compared with orthopedic implants.

Lee et al. proposed an interesting study about the stress shielding and fatigue limits of PEEK dental implants.[6]

Their studies reported that during compressive strength testing, the titanium rod bent until a 4 mm displacement without fracture, whereas the PEEK (GFR-PEEK and CFR-PEEK) specimens fractured. The fatigue limit of the 4 mm-diameter GFR-PEEK implant was found to be 310 N (a value similar to the minimum fracture strength at 300 N) and is according to the ISO 14801 standard proposed for posterior tooth restorations. The static compressive strength of the 4 mm diameter GFR-PEEK implant was 256 N which is comparable to the maximum bite force in anterior dentitions. This is a promising result because increasing the diameter of the implants may adversely increase the stress-shielding effect and marginal bone loss.

A Finite element analysis (FEA) of CFR-PEEK implants demonstrated that the CFR-PEEK dental implant showed higher stress peaks at the bone-implant interface due to a higher deformation, whereas the titanium implant showed a more homogenous stress distribution.[9] Another FEA study demonstrated that a CFR-PEEK implant with 60 % endless carbon fibres shows that this material distributed the stress in a similar manner as a titanium implant.[10] Other problems for the clinical application of PEEK materials for dental implants are their radiolucency and their osseointegration and osseoinduction capabilities. As PEEK material has the property of radiolucency, this is an advantage in the evaluation of both osseointegration and the tissue surrounding the implant on computed tomography (CT) imaging. Radiolucency facilitates the determination of peri-implant cement remains. However, the radiolucency of PEEK makes the evaluation of the compatibility of PEEK prosthesis with screw retention more difficult on radiographs. To increase the radio-opacity, barium sulfate must be added to be able to observe PEEK material on radiographs more easily.[11] One possible solution for their osseointegration and osseoinduction capabilities was to create a titanium coating on the surfaces of dental implants based on PEEK. First, Cook reported on the in vivo evaluation of bone contact, porosity, bone ingrowth, inflammatory response, and mode of failure of titanium-coated PEEK implants. From 40 titanium-coated and uncoated PEEK implants placed in uni-cortical sites in the femurs of dogs, he found a better osseointegration on titanium-coated implants.[12] Recently electron beam deposition of a thin titanium layer on the PEEK surface was reported which is a promising approach to increase the biological activity of the implant surface.[13]

Clinical Classification of PEEK Implants [14]:

1. PEEK for bone replacement-maxillo-facial and cranial implants.
2. PEEK for spine surgery-spinal cages.
3. PEEK for orthopedic surgery.

(a) for bone and hip-replacement-articulation implants.
(b) orthopedic devices from PEEK material-fixation plates, screws

4. PEEK for tooth replacement-dental implants from CFR-PEEK; dental prosthesis, intra radicular posts.
5. PEEK for cardiac surgery-intracardiac pump; heart valves.

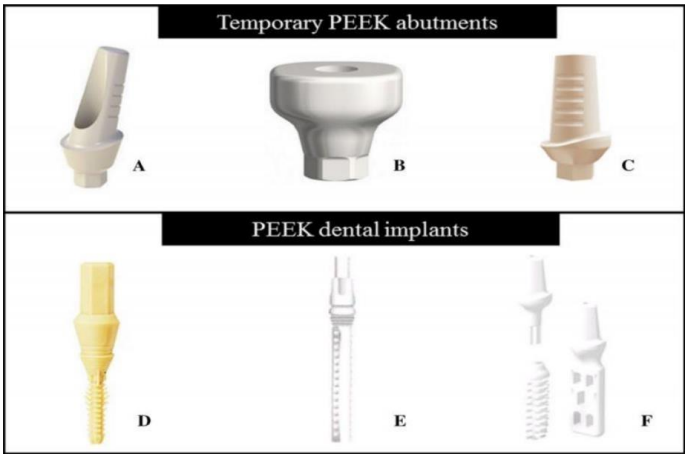

Figure 2: Figure 2: -PEEK for tooth implants: a) PEEK abutment (DENTIN implants technologies LTD); b) PEEK abutment (Nobel Biocare); c) PEEK abutment (SGC Dental); d) PEEK Perso A implant (SisoMM); e) Win! PEEK implant Champions implants; f) Biopik (Biopikimplants)[14].

PEEK AS IMPLANT ABUTMENTS:

The abutment material is crucial in preventing soft tissue recession. The most often utilized materials include titanium, gold, base metals, and ceramics made of zirconium and aluminium oxide. However, people who have metal allergies require an alternate alloy, thus new polymer-based materials are created and sold in the market.[15] Since PEEK has been shown to reduce stress shielding surrounding the implant and has sufficient biocompatibility, it is currently also employed as an abutment material.[3,7,8] PEEK abutments [Figure 2 (A, B & C) and Figure 3] also prevent screw loosening and misfit in the internal connection of the implant, in cases where they are rehabilitated with screw connections. Therefore, these conditions allow for intimate mechanical imbrication,

which results in the prevention of microleakage and bacterial colonization in the interface region.[16] In a study by de Matos et al. they evaluated the biomechanical behaviour of PEEK abutments with different heights on single titanium implants, they suggested that PEEK abutments may be suitable as abutment material, especially in the anterior region and for patients without parafunction habits.[17]

Figure 3: Peek Implant Abutment

PEEK AS CROWN & BRIDGE:

In the field of dentistry, metal-supported ceramics have been used for a long time, and the outcomes have been successful. However, metal alloys are susceptible to corrosion and have the potential to induce allergies, therefore they do have certain drawbacks. Furthermore, the lack of light permeability is one of the negative properties of metal alloys.[18] For the fabrication of provisional and definitive crowns and fixed partial dentures (FPDs)[Figure 4 (c & d), PEEK reinforced with other inorganic fillers is used.[14] The biocompatibility of PEEK material is higher than that of metal-based ceramics. Studies found that PEEK-based CAD/CAM provisional crowns and FPDs have improved marginal fit, excellent patient comfort, and good fracture resistance.[19] According to Shetty et al., crowns with PEEK coping exhibited much greater strength than crowns with zirconia coping. [20] Figure 4(a & b) showing Crowns made of PEEK material.

Figure 4: Clinical photographs of PEEK prostheses: (a) Frontal view of PEEK crowns; (b) Occlusal view of PEEK crowns; (c) Frontal view of PEEK fixed partial dentures; (d) Occlusal view of PEEK fixed partial dentures; (e) Frontal view of PEEK post- and-core; (f) Occlusal view of PEEK post-and-core[21]

PEEK AS POST-AND-CORE:

The stress distribution within the dentin is significantly influenced by the elastic modulus of the post material, which in turn has an impact on how well the restoration and tooth withstand fracture. Zirconia and cast metal alloy posts, which have substantially higher elastic moduli than dentin, create concentrated stress at the root, which could cause the root to fracture while the posts remain intact. However, Fiber-reinforced composite (FRC) posts fracture more easily while having a more evenly distributed load decreasing the risk of root fracture. When used as a post-and-core material [Figure 4(d & f), PEEK has recently been found to exhibit superior aesthetic behaviour than metal alloys and is comparable to FRC; its low elastic modulus (between 3 and 4 GPa) is equivalent to that of dentin (18.6 GPa), as are the elastic moduli of GFR-PEEK (12 GPa) and CFR-PEEK (18 GPa).[21]

PEEK AS A REMOVABLE PROSTHESIS MATERIAL:

In removable partial prostheses, PEEK is utilized as an alternative to metal bracing and hooks (Figure 5). In comparison with chrome-cobalt-based partial prostheses, Tannous et al. have suggested that denture clasps made of PEEK have lower retentive forces compared to cobalt–chromium (Co–Cr) clasps.[22] However they eliminate metallic taste and allergic reactions, can be well polished, and have low plaque retention. According to a study, Zoidis et al., modified, PEEK with 20% ceramic fillers (BioHPP) and was used as an alternate framework material for removable

dental prostheses.[23] PEEK Dentures can be constructed by using computer-aided design and computer-aided manufacturing systems.[3] Consequently, lighter prostheses can be obtained which increase patient satisfaction and comfort.[18] Another application of PEEK in removable prostheses is the construction of a removable obturator (Figure 6). The biocompatibility, flexural bone modulus, resistance to cracking, ease of polishing, and machinability of PEEK-OPTIMA (reinforced poly-ether-ether ketone) allow its use as a material in the palatal section of maxillary obturator prostheses in patients with large oral-nasal defects.[4,24] Moreover, owing to the superior mechanical and biological properties of PEEK, it will not be surprising if dentures constructed from the polymer are routinely constructed in the near future.

Figure 5: PEEK Resin Clasp on Abutment Crown and Partial removable denture framework milled from PEEK and partially covered with the aesthetic components, compared to the traditional version using a chrome framework[22]

Figure 6: Complete Obturator Prosthesis[24]

PEEK AS AN INTRAORAL SCAN BODY (ISB):

ISBs(Figure 7) are intricate implant-positioning-transfer devices that are crucial to the digital workflow for the fabrication of precisely fitting implant-supported restorations. The scan region of ISBs may contain single or multiple scan areas, which helps in enhancing the digital impression's accuracy. The body of the ISBs can be made with varieties of materials including polyetheretherketone (PEEK), which extends from the scan region to the base.[25]

Figure 7: ISBs made from PEEK

CONCLUSION:

PEEK is a modern material that has excellent physical, mechanical, biocompatibility, and aesthetic properties and has led to its usage in many instances in dentistry. It is utilized to create both fixed and removable prostheses due to its superior properties and considering its high elasticity of modulus comparable to that of bone and dentin, there is increasing use of PEEK materials in implantology. It won't come as a surprise whenprostheses constructed from this material are commonly used in prosthodontic procedures in the future.

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