Journal of Advanced Zoology
ISSN: 0253-7214
Volume 44 Issue S-5 Year 2023 Page 1377:1382

Metal-Free Alternative "Revolutionary PEKK": An Emerging Material for Removable and Fixed Prosthesis Usage in Dentistry: A Critical Review

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Article History

Received: *25 June 2023*
Revised: *01 Sept 2023*
Accepted: *27 Oct 2023*

Abstract

Polyaryletherketone polymers have been widely used for biomaterials in orthopaedic, trauma, and spinal implants. Polyaryletherketone has three different variants viz: Polyetheretherketone (PEEK), Polyetherketoneketone (PEKK) and Polyetherketone (PEK). In this research work, an emergent critical review of the material (PEKK) which are used in removable and fixed prosthesis in dentistry. The following databases were identified in systematic research which comprises certain inclusion and exclusion criteria. The databases are EMBASE, cochrane library, MEDLINE, PUBMED, Ovid MEDLINE, web of science. This study assesses the eligibility screening, data extraction and quality assessment. Many studies were assessed to improve PEKK containing osseointegration, surface modification of PEKK, etc. In animal models, in vivo studies were performed. To the best of my knowledge any author targeted for the evaluation of the removable and fixed prosthesis usage of PEKK as a biomaterial. This review showed that the wide application of PEKK is used in different aspects of dentistry. The PEKK materials in comparison of PEEK have suitable physical, mechanical, and chemical qualities (discussed in details in following sections) and can be employed in a variety of applications, including framework for an implant-supported and crown and bridge fixed prosthesis, endo crowns, restorative material, and dental biomaterial implants. Wider uses in clinical dentistry may also result from modifications and improved material qualities. As PEKK has only lately been used in dentistry and there are little research available, long-term evaluations are required for extensive validation of the same.

Keywords: *Biomaterials, Composite, DentalImplant, Dentistry, PEKK, Polyetherketoneketone, Sustainability*

Introduction

Biocompatible materials highly require such defects in teeth, fracture of bone, and replacement of joints etc. Because of longevity, incorporation of biocompatible materials includes dental procedures like replacement of Dental crown. Metals and their alloys have excellent mechanical properties and corrosion resistance. Good properties such as mechanical and resistance to corrosion. Because of superior properties PEKK can be used in hard tissue in most of the clinical applications. There is a difference in modulus of elasticity and mismatch between bone tissue and bio metallic prosthesis. It may cause allergies to the patients. The researchers needed to solve the above problem so they discovered new biomaterials. Improved strength and biocompatibility available in polymer based prosthetic materials.[1] The Current scenario in dentistry includes: Dental implants, fixed and partial dentures, monolithic and multi usage crowns which are generally built with zirconia and its substitutes. For decades, Titanium and Zirconia has been extensively used for biocompatibility and osseointegration properties in dentistry for various applications viz: Dental

implants, crowns, FPD (fixed partial dentures), Dental crowns, posts. In the current scenario, ceramic restorations as an alternative because of their own special properties. [2] The new materials used in prosthetic dentistry are 3- mol yttria-stabilized tetragonal zirconia polycrystal (3Y-TZP) or lithium disilicate because of its prominent techniques. The drawbacks of above-mentioned materials are break in nature and marginal leakage.[3] The materials such as polyaryletherketone (PAEK), Polyetherketoneketone (PEKK) are in huge demand because of attained esthetics and superior properties. PAEK has been used in the aerospace andorthopeadic materials because of promising properties. The Promising esthetic material named PEEK was used in the year 1990. PEEK was introduced as a candidate for replacing unaesthetic implants in several medical fields. The materials are Polyetheretherketone (PEEK), Polyetherketoneketone (PEKK), Polyetherketoneketone are the polymers of PAEK (Polyetheraryleketone) family.[4] They are thermoplastic high-performance polymers being extensively used in engineering as well space applications. As these high- performance polymers are very promising for mechanical strength, scientists found that it would be the best material for performance in healthcare applications where strength is the crucial parameter. Dentistry and medical science have few applications viz: ortho implants (craniofacial, knee replacement, hip joints, shoulder joints etc.) and maxillofacial trauma patient specific implants, dental screws, FPD, RPD where their polymers can perform better. [5,6]

Polymeric biomaterials such as Polyetheretherketone (PEEK), Polyetherketoneketone (PEKK), Titanium (Ti) coated PEEK is becoming popular and applied in orthopedics because of their commendable physical properties i.e., high mechanical strength, biocompatibility and biostability with elastic modulus similar to human hard tissue. It helps to avoid the stress shielding which is the reason for many implantation failures.[7] The Polyaryletherketone (PAEK) family is superiorly used in spinal fusion, dental, trauma and joint replacement, even in cranio-maxillofacial repair. Polyetherketoneketone PEKK, it is a member of the aryl ether ketone family of polymers.[8] It has elastic modulus equal to cancellous bone with increased crystallinity, reactivity and cellular protein adhesion. PEKK and PEEK are used to facilitate bone regeneration and osseointegration with different coating strategies like bone morphogenetic protein-2, nano hydroxyapatite coating. [9] Though these coatings were done, implant failure did not reduce due to periimplantitis.[10] So, it is essential for any biomaterial coated on the implants to possess osteogenic bioactivity for bone regeneration and antimicrobial properties to prevent infection and bacterial colonization.

According to the previous research, Silicon nitride with tantalum in sulfonated PEKK showed high antibacterial activity and promoted bone regeneration and osseointegration.[11] Omnia M Rafia et al. [12] reported that double crown retained RPDs from PEEK have minimal increase in dislodging force whereas PEKK has significant rise in dislodging force. Pekkton Ivory showed high in biomechanic and lightness when used in three-unit FPD.[13] PEEK is a biomaterial used for vertebral fusion but it promotes the inflammatory and fibrotic tissue growth which encapsulates implant leading to impaired osteoconduction, on the other hand titanium influences the protein, cells and other body fluids with its metallic property. Titanium has its own flaw by being more radiopaque, which prevents the evaluation of bone fusion. Walsh WR et al [14] has tried coating PEEK with titanium as the physical property of PEEK is maintained but the surface interface would react preferably to the host.[15] But the PEEK coated with titanium has reduced bond strength which leads to failure as it causes wear debris. That is why the PEKK is considered superior to these biomaterials. So, this is a review on the topic as a contribution to the field of research to improvise the application of polymeric biomaterials such as PEKK and PEEK in dentistry and to explore more about this material in the domain of dentistry. Thus, the aim of the current review is to emphasize the application of PEKK in dentistry as well as its current scenario in single crown copings.

Structure of PEKK:

A benzene ring is sequentially joined by the ether or ketone-groups to form PEKK, a linear thermoplastic polymer. Aluminum chloride (AlCl3), nitrobenzene, diphenyl ether, and iso- and terephthaloyl chlorides can be used to make PEKK. Ultra-High molecular weight polyethylene serves as the representative of the linear aromatic polyether ketone known as the PAEK. PEEK and PEKK differ by ether- keto group.[16] The PEKK contains a second Ketone group especially for increasing the polarity, rigidity and glass transition temperature. PEKK shows both amorphous and crystalline properties which helps it to be molded into different products.The composition of PEKK contains sixty percent straight and forty percent linked which is 305℃ as a melting temperature.[17] Because of extra ketone, the compound contains eighty percent straight and twenty percent kinked which is a melting temperature at 360℃.

Physical and chemical properties of PEKK:

In comparison to other polymeric materials, PEKK exhibits superior physical and mechanical qualities, such as melting temperature and compressive strength and PEKK exhibits superior properties.[18] When compared to PEEK that isn't reinforced, Pekkton® ivory (Cendres Métaux, SA, Switzerland), a PEKK product, has a compressive strength that is 80% higher.[19] The hardness and wear resistance of PEKK are increased by the addition of titanium dioxide (TiO2). The feasibility of employing PEKK as a restorative material is increased by its fracture resistance and shock absorbance with an acceptable strength (65 MPa).[20] When compared to dentin, the PEKK's compression strength is comparable, but its elastic modulus is lower. PEKK's elastic modulus is comparable to bones. There are certain following properties unique to PEKK: High impact resistance, tensile and compressive strength, and stiffness [21], Substantial breakdown voltage [14,15], Exceptional barrier qualities (CO2, H2S)[14–16], Outstanding wear-rate and COF control (coefficient of friction), Excellent combustion resistance features, including being naturally flame-resistant and producing little smoke, minimal smoke toxicity.[17]

Biological properties of PEKK:

As a prospective replacement for titanium in long-term orthopedic applications, PEKK has high biocompatibility. Oro-maxillofacial and spinal surgery have been given FDA approval and PEEK is also widely utilized in dentistry as a prosthetic and implant biomaterial. It provides metal-free restorations and is advantageous for people who have allergies.[18] Yuan et al. examined the chemistry and surface microstructure of osseointegration in PEKK as an implant material. The potential of surface chemical alteration is said to be enhanced by the other ketone group in PEKK. The amount of -SO3H will be greater on PEKK than PEEK due to the presence of more ketone groups. As a result, the surface of PEKK becomes more complicated in terms of surface topography, has a larger surface area, and is more micro-rough.[19]

Osseointegration of PEKK

The osseointegration property was positively impacted by the surface alteration, which increased porosity and incorporated HA. According to converse, whisker et al. incorporate porous PEKK which comprises different techniques. The author Walsh et al. stated that plasma sprayed titanium along with superimposed PEKK which exhibits best osseointegration in comparison with uncoated PEKK.[8]

Antibacterial activity of PEKK:

Compared to PEEK, which is used in the orthopedic industry, PEKK exhibits less bacterial adherence on its surface. Staphylococcus epidermidis adhered to the PEKK surface with 37% less adhesion. After five days of culture, they discovered a roughly 50% reduction in Pseudomonas aeruginosa adhesion and development of with or without antibiotics incorporated with PEKK.In a rat investigation, Moore et al. discovered that PEKK caused a less inflammatory response than PMMA.[17]

Function of PEKK in dentistry:

The research material PEKK has been used as prosthetic material. Due to its extraordinary behavior, it can be used in many applications in dentistry. The PEKK is thought to be an as tentative for metal-free restorations and has great biocompatibility.[8]

Prosthodontic performance of PEKK:

The characteristic feature of PEKK is good wear resistance, less modulus of elasticity and increased strength. It might be suitable for use as a one of the components in restorative fixed prosthodontics. With the help of computer aided design (CAD) and Computer aided manufacturing (CAM) more restorative and prosthetic materials were introduced. Recently, PEKK prosthetic restorations have been created using CAD/CAM technology. With an indirect composite veneer, Pekkton® ivory (PEKK) is utilized for monolithic and bi-layered materials.[18] Another crucial element in prosthetic dentistry is the fit of the dental repair. Plaque buildup, recurrent cavities with periodontal damage, and restorative failure are all caused by poor marginal fit. For CAD/CAM fixed restorations, 24-110 m has been suggested by a number of researchers as the acceptable marginal discrepancy.[20] They found that the marginal fit (internal fit) was within acceptable limits. When compared to zirconia, the PEKK coping had greater fitness and showed reduced stress distribution around its loading zones. [21]

PEKK can be used in oral implantology because of its iso-elastic properties.[22] At the same time various characteristics like strength, lesser weight, lesser wear resistance and more likely modulus of elasticity which is nearer to the dentin of the tooth structure.[23] The importance of implant material manufacture from thermoplastic resins having biocompatible higher with contact of the bone.[24] The abutments and framework of implants can be used with the new material called PEKK.[25,26,27,28]

Oh et al. [29] stated that PEKK is used as implant framework materials, with evidence showing that it is a biocompatible material because of less compressive stress.[30] The choice of site using PEKK material is more important. For example, if used in removable prosthesis it showed galvanic effect and allergic reactions to patients few in nature.[31] Recents PEKK can be used in RPD with digital technology because of its thermoplastic materials and Digital technology use of PEKK also agreed by sun et al. as previously mentioned.[32] Tannous et al. [33] conducted a study about retentive features of co-cr alloy with three thermoplastics. The results showed that resin made clasps (1.05/1.5mm thick in 0.5 mm undercuts) less retentive than cobalt- chromium clasps group (1.0 mm thick with 0.25mm undercuts). So according to this study, PEKK can be used in RPD. Choi et al. [34] conducted the study stating that PEKK has higher retention than nylon inserts. A higher level of evidence, Keilig et al.[35] conducted the study by using PEKK under finite element analysis. He states that PEKK can be used as a alternative to other unesthetic framework.

Restorative Performance of PEKK:

In restorative dentistry, the bonding of PEKK to restorative materials is not satisfactory. Different surface preparation techniques for PEKK have been developed in order to bond utilizing different adhesive systems. By experimenting with different surface treatment techniques for PEKK bonding, Lee et al. described that shear bond strength of PEKK has higher implications than non-thermal plasma surface modifications with sandblasting.[36]

The amount of tooth/enamel wear brought on by dental restorations varies depending on the choice of restorative materials. Dental restoration-related tooth/enamel wear should ideally not exceed physiological tooth wear. For the purpose of minimizing/retarding the negative and irreversible effects of tooth/enamel wear, it is crucial to choose restorative materials that are practically as durable as enamel. [37,38] In this study of five CAD/CAM-fabricated materials, the study conducted by Choi et al. results showed that PEKK has greater wear resistance than opposing teeth when compared to other materials.[34]

Dental Implant performance of PEKK:

Potential uses for PEKK's high-performance, isoelastic properties include oral implantology. PEKK has the benefit of having an elastic modulus that is nearly identical to that of dentin, sufficient strength, light weight, and wear resistance. The percentages of bone contact for dental implants made of thermoplastic resins have likewise yielded satisfactory results. PEKK is a biomaterial that can be utilized in oral implantology as an implant abutment, implant prosthesis framework, prosthetic crown material and implant biomaterial. PEKK is a non-metal alternative to titanium for use in implants.[26] The PEKK abutments advantages include adjustability, compatibility with a range of veneering materials, and the ability to serve as the framework for an implant-aided prosthesis.[27]

A conventional complete denture (CCD) faces the challenge of replacing acrylic posterior tooth wear when compared to implant prosthesis (ICF DP). The most frequently impacted are complete dentures (47.7%), followed by ICFDP (19.6%). These problems can be resolved by adding CAD/ CAM zirconia teeth to full dentures or other implant prostheses to increase their wear resistance. According to the Dawson et al. compared the usage of CCD and single lithium disilicate glass ceramic crown using PEKK framework in ICFDP.[36] So, this study proved that PEKK can be used as an alternative marker in a single ceramic crown. It may be used in maxillofacial rehabilitation.[29] When compared to tensile stress, the PEKK framework exhibits less stress on the implant prosthesis and soft tissue.Stress distribution is good in rigid framework prosthesis. In future PEKK may be a good candidate for use in implant dentistry at the same time chemical modulation of PEKK to Increase the implant- contact.[30]

Removable prosthetics performance of PEKK:

Removable prosthetics with metal clasps have the drawbacks of being unsightly, and they can also lead to allergic reactions in some individuals as well as oral galvanism. These issues have been partially resolved by thermoplastic materials. [39,40] The usage of PEKK as dental clasps and frames in removable partial dentures (RPD) has recently become more common. Using PEKK in removing speech bulb prostheses requires a digital workflow, which Sun et al. presented.[32] The procedure involved digital milling of the PEKK structure, designing, 3D printing, manufacturing, and delivery.[38]

Keilig et al. finite element analysis showed that the framework material of small bridges was greatly influenced by equally distributed stress (three and four units). The choice of material also ensured that the surrounding tissues were not impacted by the tension around them. This demonstrated that the PEKK polymer could replace metal framework.[35]

Endodontics post and cores performance of PEKK:

PEKK, the new biomaterials built by high mechanical strength, shock absorbing milling technology have drawn attention to the post-core systems. The PEKK exhibits higher biomechanical behavior when compared to other systems. PEKK demonstrated superior fracture resistance over post-core systems which are made of metal and fiberglass. Lee et al. conducted the study between mechanical behavior and high durability of intra-radicular post and core material. Even Though, PEKK has lesser modulus of elasticity and flexural strength than fiberglass and gold. The results stated that PEKK to have potentially been used in endodontic post and core systems because of its good fracture resistance.[30]

Conclusion

The PEKK materials have suitable properties like physical, mechanical, and chemical qualities and can be employed in a variety of applications, including framework for an implant-aided fixed prosthesis, endo crowns, crown, bridge, restorative material and dental biomaterial implants. Wider uses in clinical dentistry may also result from modifications and improved material qualities. As PEKK has only lately been used in dentistry and there is little research available, long-term research are required.

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