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Unveiled traits of Polyether Ether Ketone (PEEK) in Prosthodontics: A Systematic Review

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Abstract:

Background/Objective: Polyetheretherketone (PEEK) is a modern, innovative high performance polymer material which has proven to be successful in many areas of dentistry and a promising alternative to metal in fixed partial dentures along with removable prosthesis due to its toughness, based on its properties similar to bone. This systematic review highlights the characteristics, prosthodontic applications and future prospects of PEEK in the field of clinical dentistry.

Methods: A retrospective literature searches which spanned from April 1990 through August 2023 were performed using the keywords "PEEK", "polyetheretherketone", "dentistry", "dental implant" on the Medline via Pubmed, Scopus and Google Scholar databases. Search included in-vitro and in-vivo studies published in English language and the relevant articles of references were also analyzed and summarized.

Results: A great number of in vitro studies with only few clinical studies were found and data obtained were organized according to characteristics of PEEK and its different applications in dentistry. PEEK was recommended for fixed, removable and implant prosthesis along with other uses like, occlusal splints, intra-radicular posts, customized healing abutments and provisional restorations.

Conclusion: PEEK is a high and innovative approach with prosthetic solution for removable, fixed and screw retained prosthesis. In the near future, PEEK is expected to be a clinical alternative to the use of metal even in crown and bridges along with traditional dentures and more clinical studies are needed in the same direction.

Keywords: PEEK, Dental implant, Dentistry, Dental Prosthesis, Clinical applications

Introduction:

Polyetheretherketone (PEEK) may be a high-performance polymer which has proven to appreciate success in many areas of medicine and dentistry. PEEK (-C6 H4 -OC6 H4 -O-C6 H4 -CO-) n may be a semicrystalline linear polycyclic aromatic polymer. and via a singular step-growth dialkylation reaction of bis-phenolates to form polyetheretherketone, the monomer unit of etheretherketonemonomer polymerizes. In 1978, it had been developed by a gaggle of English scientists. Later PEEK was commercialized for industrial applications. PEEK may be a high-performance thermoplastic candidate for replacing metal implant components by the late 1990s. PEEK is synthesized by the reaction between 4,40 -difluorobenzophenone and also the disodium salt of hydroquinone during a polar solvent like diphenyl sulphone at 300 8C. it's a semicrystalline material having a melting point around 335 8C. With the assistance of chemical processes like sulphonation, amination and nitration, modification of PEEK may be done either by the addition of functionalized monomers (pre-polymerization) or post-polymerization modifications.[1,2]

Methods:

The literature search covered sources dated between April 1990 through April 2021 via the databases like, Medline via PubMed, Scopus and Google Scholar. The search terms included “PEEK”, “Polyetheretherketone”, “Dentistry” and “Dental implant”. Articles were selected based on the kind of investigation and type of scientific articles like, case reports, original researches, review articles. The titles and abstracts were reviewed along with full text of its relevant articles.

Inclusion criteria: Articles of in - vitro and in-vivo studies written in English language about PEEK only related to Prosthodontics were included.

Exclusion criteria: Articles not related to prosthodontics, not written in English language and articles prior to 1990.

Results:

Characteristics PEEK as a material:

PEEK appears as a white, radiolucent, rigid material with great thermal stability up to 335.8°C. It has low plaque affinity and does not cause any allergic reactions. PEEK’s Flexural modulus varies from 140 to 170 MPa with a density of 1300 kg/m3 and thermal conductivity of 0.29 W/mK. It’s mechanical properties hardly change even during sterilization process with steam, gamma and ethylene oxide. Young’s (elastic) modulus of PEEK is 3-4 GPa. Young’s modulus and tensile properties are close to human bone, enamel and dentin making it a suitable restorative material. Polyether ether ketone is resistant to hydrolysis, non-toxic and has one of the best biocompatibilities. Special chemical structure of PEEK exhibits stable chemical and physical properties: stability at high temperatures (like sterilization processes), resistance to most substances apart from concentrated sulfuric acid and wear-resistance. PEEK has the

lowest solubility and water absorption values than poly methyl methacrylate (PMMA) and composite resin.[3-13]

The elastic modulus of PEEK can be increased easily up to 18 GPa by incorporation of other materials like carbon fibers. Some alloys like titanium have elastic modulus significantly higher than bone which results in severe stress-shielding and failure of a prosthesis. An implant material used like carbon-reinforced PEEK can exhibit lesser stress shielding when compared to titanium and its modulus is comparable to those of cortical bone and dentin.[14-17]

PEEK has very less osteoconductive properties when compared to titanium. There are a number of methods that have been proposed to improve the bioactivity of PEEK including coating PEEK with synthetic osteoconductive hydroxyl apatite, increasing its surface roughness and chemical modifications and incorporating bioactive particles. PEEK can also be used an aesthetic orthodontic wire at a cross section of that similar to metallic wires such as cobalt–chromium (Co–Cr), titanium–molybdenum (Ti–Mo) and nickel–titanium (Ni–Ti).[18-23]

Practice areas of PEEK:

PEEK can be used for a number of applications in dentistry including as a framework material for metal-free fixed dental prostheses, removable dental prostheses, implant-supported fixed prostheses, implant-retained overdentures, endo-crowns and resin bonded fixed dental prostheses. In the manufacturing of dental implants, implant abutments, healing abutments and occlusal splint, etc PEEK has been used.[6,9, 24-32]

A. Implant Prosthodontics

Usually by casting metal alloys or milling either titanium or zirconia, frameworks required for implant-supported fixed dental prostheses are fabricated and recently few clinical works observed use of PEEK frameworks veneered with composite resin as a solution for patients experiencing metal allergies. Risk of many mechanical complications have been reduced because of other properties of PEEK frameworks like its reduced weight and higher elasticity compared to zirconia frameworks. Also, PEEK with such elasticity further reduces occlusal forces to the restoration and the opposing dentition whenever it is combined with other materials like veneers with poly (methyl methacrylate) (PMMA) or veneering composite resin, thus becoming an advantageous material in implant-supported fixed dental prostheses where lack of proprioception is evident by the absence of periodontal ligaments and avoids clicking sound or veneer fracture expected with metal-ceramic or monolithic zirconia restorations. Compared to zirconia customized abutments on implant components, crown and cortical bone, PEEK customized abutments have lower stress values and PEEK prostheses are able to withstand occlusal forces in the molar region with a higher fracture strength than the physiological maximum posterior masticatory of 870 N. PEEK three-unit implant supported frameworks has good marginal fit values of 19 ± 4 μm and no bacterial leakage of screw-retained PEEK crowns during masticatory simulation has been reported along with high fracture resistance comparable to zirconia and lithium disilicate crowns supported by titanium

and zirconia implant abutments. A common complication like chipping of the veneering materials implant-supported fixed dental prostheses with a titanium framework has been solved by PEEK as an alternative framework material with study reports of stronger bonding of PEEK three-unit implant-supported frameworks (31.1 ± 3.5 MPa) with composite resins than titanium frameworks (20.5 ± 1.8 MPa) and because of its durable bonding, intraoral repair of PEEK restorations with composite resin has become easier. A high esthetic outcome can be achieved in combination with composite veneering materials because of its white colour framework compared to grayish appearance of metal frameworks PEEK is radiolucent thus helps in cement removal and screw loosening problems and makes the prosthesis less weight, because of its and is of low specific weight. Good biocompatibility combined with low water solubility and high chemical and thermal stability makes PEEK prostheses suitable for patients demanding metal-free restorations. Also, a study concluded that the chemical modifications using sulfuric acid SPEEK 90 and especially, the piranha solution PEEK-PS 2:1-90, were demonstrated to be promising in promoting the rapid bioactivation of PEEK-based implants. [24, 26, 30, 36, 43-46, 52]

B. Fixed Prosthodontics

PEEK has good mechanical properties and because of its good bonding with veneering composite materials it is used in the framework of fixed dental prosthesis. Pre-pressed PEEK blanks showed lower deformation and higher fracture loads (2354 N) than those pressed in granular form (1738 N) for three-unit fixed dental prostheses milled using CAD-CAM technology. PEEK could be regarded as a suitable material for restorations in load bearing areas, if 870 N is considered the average maximum posterior mastication force. The CAD-CAM milled PEEK FDPs stands higher as its fracture resistance is much higher than those of lithium disilicate glass-ceramic (950 N), alumina (851 N) and zirconia (981-1331 N). Compared to PMMA, composite resin pastes and fiber-reinforced composite materials PEEK has the highest load bearing capacity. Like gold alloy, even PEEK showed higher modulus of resilience (elastically absorbing capacity of destructive fracture energy) than lithium disilicate. Also, PEEK acts as a stress breaker by reducing forces which will be transferred to the abutment teeth by allowing absorption of functional stresses due to its low modulus of elasticity. With comparison to Composite resins, a hybrid material and PMMA-based materials, PEEK demonstrated the lowest solubility and water absorption values. It was found that digital veneering is more reliable than conventional techniques, as PEEK three-unit fixed dental prostheses digital veneers showed the highest fracture load values. When loaded laterally and comparable wear of enamel antagonists PEEK showed higher wear resistance than a nanohybrid composite and a poly (methyl methacrylate) material. So, it's clear that PEEK can be used for CAD-CAM FDPs due to its good mechanical and bonding properties.[13, 25, 28, 33-42]

C. Removable Prosthodontics

The problem of aesthetically unacceptable display of metal claps and the risk for metallic taste and allergies of conventional RDP metal frameworks has been eliminated by PEEK's many favourable properties by permitting the fabrication of lighter metal-free RPDs. PEEK frameworks combined with acrylic resin denture teeth and heat-cured acrylic resin denture

bases can be served as an alternative to conventional Co-Cr frameworks has been suggested by a clinical report. Milled PEEK frameworks can be used for the fabrication of a removable maxillary obturator prosthesis and has shown high patient satisfaction with regard to esthetics, retention and comfort. PEEK RPDs could be recommended for patients with poor periodontal conditions as it reduces stress and distal torque on the abutment teeth during function because of its high elasticity and its frameworks caused lower stress values on periodontal ligament than cobalt-chromium and Ti-6Al4 V alloy. PEEK clasps used with 5 mm undercuts were considered sufficient for clinical use and milled PEEK clasps demonstrated higher retentive force than thermo-pressed ones with regard to fabrication method of PEEK frameworks and higher retaining forces at deeper undercuts with a thicker clasp design was showed by both milled and thermo-pressed PEEK clasps than Co-Cr clasps. Methods such as direct milling of PEEK blanks or 3D printing of a resin/wax pattern framework which is then thermo-pressed using the conventional lost-wax/resin technique can be used for fabrication of CAD-CAM PEEK RDP frameworks and clinically acceptable fit values were found for both techniques but directly milled PEEK frameworks had higher fit and trueness values than indirectly fabricated frameworks. Directly milled PEEK RPD frameworks had better precision and fit (43 ± 23 mm horizontal, and 38 ± 21 mm vertical) than cast metal frameworks fabricated using the conventional lost-wax casting technique, indirect rapid prototyping or direct rapid prototyping, which was found in continuation with many studies on above mentioned methods along with high-quality finish achieved by the milling technique. PEEK could also be used as a framework material to prevent denture deformation responsible for midline fractures in complete dentures and PEEK denture bases had higher impact and tensile strength than PMMA. With this reason, PEEK could be regarded as a material suitable for denture bases providing resistance to notch concentration and fracture with better stain resistance and lower surface roughness after polishing of PEEK materials compared with PMMA. PEEK may be used as an attachment retaining implant-supported overdentures and 80% success rate for implant-supported overdentures was found. High patient satisfaction with function and esthetics was reported with the use of an implant-supported overdenture with the receptor part of the bar milled from PEEK polymerized into a zirconia framework for the rehabilitation of an edentulous patient. [6, 47 – 51]

D. Other areas of interest (Double-crown-retained removable dental prostheses, Occlusal splints, intra-radicular posts, implant abutments, healing abutments and provisional restorations)

The use of primary metal copings and secondary CAD-CAM PEEK framework veneered with composite resin for the fabrication of double-crown-retained interim removable dental prosthesis and use of primary zirconia copings and secondary PEEK framework veneered with monolithic zirconia for the rehabilitation of an edentulous patient with intolerance to titanium was suggested by case reports along with study which reported high chewing comfort and patient satisfaction with low weight, very good fit and retention. Telescopic attachments fabricated from zirconia primary crowns and PEEK secondary crowns provided a reduction of stresses transmitted to the implants due to the stress-breaking capacity of PEEK which could be a viable solution for retaining implant overdentures. Also, secondary PEEK crowns provide stable retentive forces after 10 years of simulated aging and comparable values at baseline with

well-established electroformed crowns with another advantage of reproduction of digitally fabricated telescopic crowns using the stored data in case of loss of retention or other technical complication any part of the double crown system. Thus, PEEK could be considered as viable solution for double-crown-retained RDPs with primary zirconia crowns in cases of high retention which was confirmed by another similar study which showed that milled 0° tapered PEEK crowns presented the lowest retention force and milled 2° tapered PEEK crowns had the highest retention force values. Many studies showed that milled PEEK could be also used as primary crown material with high retentive forces in combination with secondary zirconia, cobalt-chromium or electroformed crowns. [27, 51]

For CAD-CAM fabricated occlusal splints, the use of PEEK was additionally recommended and milled PEEK intra-radicular posts could be an alternative to glass-fiber and cast-metal posts as PEEK posts presented higher tensile bond strength than metal and glass-fiber posts when used with the appropriate surface treatment and adhesive system. Higher stress values in restorative crowns were showed for CADCAM fabricated implant abutments, customized healing abutments and provisional crowns with regard to performance. A study reported that conventional provisional crowns showed lesser fit and fracture strength than digitally produced PEEK provisional restorations. It was confirmed by a study which evaluated the use of CAD-CAM fabricated customized healing abutments and standard healing caps placed at the surgical stage for the creation of the desired emergence profile that after a healing period of 1–3 months PEEK customized healing abutments created a natural gingival architecture and required fewer prosthetic steps for the formation of the emergence profile compared to the use of standard healing caps in a study [30-32, 51]

Conclusion:

In the field of prosthetic dentistry, because of its toughness and with excellent mechanical and chemical resistance properties, **PEEK** is a semi-crystalline thermoplastic material that are retained even at very high temperatures. Being bio-inert, tissue-compatible, non-cytotoxic, electrically non-conductive and thermally insulating, PEEK is known to have good mechanical properties, high temperature stability and an outstanding chemical-resistance. Thus, these properties of PEEK make it an ideal and safe material for use within the oral cavity by preventing any intra-oral reactions along with saliva and widely accepted. Also, because of its favourable mechanical, chemical and physical properties, several in vitro studies and clinical reports suggested that PEEK could be suitable for CAD-CAM fabricated fixed and removable dental prostheses. However, long term in vitro and clinical studies are needed in this regard.

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