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PEEK AT THE PEAK: A REVIEW ARTICLE

Dental Science

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ABSTRACT

Polyetheretherketone (PEEK) is a polymer from group polyaryletherketone. It is a relatively new family of high-temperature thermoplastic polymers, consisting of an aromatic backbone molecular chain, interconnected by ketone and ether functional groups. In medicine, PEEK has been demonstrated to be an excellent substitute for titanium in orthopedic applications and has been used in prosthetic dentistry as implant, provisional abutment, implant supported bar or clamp material in the field of removable dental prostheses. The purpose of this present review were to investigate the scientific data related to polyether ether ketone (PEEK) and its applications in prosthodontics.

KEYWORDS

PEEK, poly ether ether ketone, polyacryletherketone, polymer

I. INTRODUCTION:

Polyetheretherketone (PEEK) is a synthetically produced polymeric material belonging to the polyacryletherketone family. Because of its excellent chemical, thermal, and mechanical properties and its excellent biocompatibility,[1] PEEK is used in various areas of dentistry.[2-4] In 1978 it was developed by a group of English scientists. Later PEEK was commercialized for industrial applications. By the late 1990s, PEEK became an important high-performance thermoplastic candidate for replacing metal implant components, in vertebral surgery as a material of the inter body fusion cage. With the emergence of carbon fiber reinforced PEEK (CF/PEEK), this new composite material was exploited for fracture fixation and femoral prosthesis in artificial hip joints.[5]

PEEK is white, radiolucent, rigid material with great thermal stability up to 335.8° C [6]. It is non allergic and has low plaque affinity [7-9]. Flexural modulus of PEEK is 140-170 MPa, density – 1300 kg/m3 and thermal conductivity 0.29 W/mK [7,910].PEEK's mechanical properties do not change during sterilization process, using steam, gamma and ethylene oxide (2, 8). Young's (elastic) modulus of PEEK is 3-4 GPa. [10,11] Young's modulus and tensile properties are close to human bone, enamel and dentin[12]. Polyether ether ketone is resistant to hydrolysis, non-toxic and has one of the best biocompatibility[13,14]. Special chemical structure of PEEK exhibits stable chemical and physical properties: stability at high temperatures (like sterilization processes), resistance to most substances apart from deconcentrated sulfuric acid and wear-resistance[5] Lieberman et al.[15] in vitro research comparing PEEK, poly methyl methacrylate (PMMA) and composite resin showed that PEEK has the lowest solubility and water absorption values. As PEEK is quite new material in dentistry comparing to composite, ceramics or zirconia, it is important to find out and summarize its properties. The aim of this review is to evaluate PEEK polymer and its use in dentistry.

II. MATERIAL AND METHODS:

PubMed MEDLINE, Cochrane, EMBASE and Google Scholar databases were electronically searched and enriched by hand searches. Hand searching was performed. The abstracts of the articles were retrieved, reviewed, and sorted based on the following inclusion and exclusion criteria. To be included in the study, the article had to be published in an English peer-reviewed journal. Inclusion criteria: exclusively English articles about dental prostheses from PEEK or modified PEEK were included, despite of the methods of manufacture, surface modifications, the kind of investigation (in vitro or in vivo), type of scientific articles (case reports, original researches, review articles).

III. RESULTS:

PEEK AS AN IMPLANT MATERIAL:

Author	Study outcome
Lee wt et al[16]	Stress shielding is the reduction in volume of the bone around an implant due to the shielding of normal loads by the implant. Finite-element analysis (FEA) of carbon-fiber reinforced PEEK (CFR-PEEK) implants suggested that they could induce lesser stress shielding than titanium
Sarot et al[17]	The aim of this study was to compare, using the three-dimensional finite element method, the stress distribution in the peri-implant support bone of distinct models composed of PEEK components and implants reinforced with 30% carbon fiber (30% CFR-PEEK) or titanium. study suggests there is no difference between the stress distribution around PEEK and titanium dental implants
Huang R, [18] Nieminen T[19]	Unmodified PEEK is inherently hydrophobic in nature, with a water-contact angle of 80–908 and bioinert. Animal studies have suggested that PEEK can survive for up to 3 years while inducing non-remarkable localized inflammation
Wenz l[20]	studies have shown that there is no significant effect of unmodified PEEK on the proliferation rate of cells in vitro.
Morrison C[21]	studies have observed an increased protein turnover in cells in contact with conventional- and CFR-PEEK
koch f[22] Schwitalla a[23].	few studies suggested that there is no significant difference between the osseointegration of PEEK and conventional implant materials such as zirconia and titanium.
Zhao M[24]	Recent proteomic studies have indicated that PEEK inhibits mRNA processing that may lead to a decreased cellular proliferation rate on the surface and cytotoxic effects may be produced in the long-term.the same proteomic studies have found no difference between the bioinertness of PEEK, zirconia and titanium.

PEEK AS A REMOVABLE PROSTHESIS MATERIAL:

Author	study outcome
Tannous Et al. [25]	has suggested that denture clasps made of PEEK have lower retentive forces compared to cobalt–chromium (Co–Cr) clasps. the study was conducted on metal crowns in vitro, it is not known how effective the esthetic PEEK clasps would be in retaining dentures in the clinical setting
Costa-palau s[26]	To treat a patient who needed a replacement for a maxillary obturator prosthesis, a new obturator prosthesis was fabricated from polyetheretherketone (PEEK), his material provided the patient with a better-adjusted, more functional, and lighter prosthesis.
Zoidis p[27]	In combination with high-performance polymer, PEEK can be used with acrylic teeth as an alternative removable partial prosthesis material.
Kurtz sm[28]	Dentures can be constructed by using PEEK computer-aided design and computer-aided manufacture systems.
Heimer s [33]	Changes in the color of PEEK have been observed to be more stable compared to other prosthesis resin materials. The effects have been compared on surface roughness and free surface energy of polishing methods applied in the clinic and laboratory to PEEK, PMMA and a composite resin. Lower surface roughness and free surface energy were obtained in PEEK, which is a harder material.
Whitty t[34]	There are several advantages of PEEK material as the substructure in fixed and partial prostheses. These include that it can be more easily produced compared to metal substructure, and those produced with CAD-CAM systems can be more easily applied with abrasion in a short time without damaging the burs.
Liebermann a[35]	it has been reported that PEEK material can be recommended for long-term restorations because of low water absorption and solubility properties

BONDING OF PEEK MATERIAL TO COMPOSITES:

Author	study outcome
Rosentritt m[29]	PEEK fibers exhibit extremely strong resistance to most chemical substances and are only affected by some high concentration acids (sulfuric acid, nitric acid. Previous studies have shown that acidification with H2SO4 or a combination of H2SO4 and H2O2 applied to the PEEK surface was insufficient in the bonding of composites with PEEK material. The range of current surface processes and application times have yielded conflicting results in respect of shear force
Rocha et al[30]	reported that sulfuric acid only or a mixture of sulfuric acid and hydrogen peroxide can be used to roughen the PEEK surface and with sanding on the PEEK, the surface area and wettability can be increased
Stawarczyk et al.[31]	Various adhesive systems are used to increase the bond between composite resins and PEEK. Study suggest the use of Visolink and Signum PEEK Bonds significantly increased the bond between composite resins and PEEK
Taufell et al[32]	it was concluded that there were advantages such as resistance to wear, standardization, polymerization, low coloration and monomer content of the veneer process made using the CAD-CAM method compared to manual coating.
Stawarczyk b[37]	One of the major advantages of PEEK material is that it can bind to indirect composites polymerized with light. To meet aesthetic requirements, this material which shows low half lucency can be coated with composite resins
Zoidis p[38]	In resin-bonded bridges produced from PEEK material, there is a minimal need for holding elements and retentive abrasions as in metal ceramic resin-bonded prostheses
Harder s[39]	In the use of PEEK material as a temporary abutment, high bonding is required between composite resins in the formation of the gingival tissue emergence profile and the gingiva shaping.

PEEK MATERIAL IN FIXED PROSTHESES:

Author	Study outcome
Alt v40,stawarczyk b[41]	CAD-CAM designed composites and polymethylmethacrylate (PMMA) fixed dentures have superior mechanical properties compared to conventional fixed dentures.
Zok f [42]	As PEEK material can be more easily repaired than ceramics, does not wear down within the mouth and no deterioration is seen in the material properties during processing, this increases the possibility of its use as crown material. Moreover, despite the low elasticity modulus and hardness, the high resistance to wear makes this a material that can compete with metallic alloys.
Stawarczyk b[43]	PEEK is another material that can be used an alternative to PMMA for CAD-CAM restorations. Three-unit PEEK fixed partial denture manufactured via CAD-CAM has been suggested to have a higher fracture resistance than pressed granular- or pellet shaped PEEK dentures.
Beuer f44, kolbeck c[45]	The fracture resistance of the CADCAM milled PEEK fixed dentures is much higher than those of lithium disilicate glass-ceramic (950N), alumina (851N), zirconia (981-1331N)

PEEK IMPLANT ABUTMENTS:

Author	Study outcome
Günal b[46]	Results of in vitro and in vivo studies have shown that the use of aluminum and zirconium ceramic abutments is limited with full ceramic prosthesis over a single tooth implant
Koutouzis et al[47]	suggested that there is no significant difference in the bone resorption and soft tissue inflammation around PEEK and titanium abutments
Hahnel s[48]	Concluded that the oral microbial flora attachment to PEEK abutments is comparable to those made of titanium, zirconia and polymethylmethacrylate .
Al-rabab'ah m[49]	it has been advocated that this material can be used both as an abutment and prosthetic material
Najeeb s[50]	It has been suggested that PEEK can promote the bone remodeling process. Therefore, it has been reported that this material could be a suitable alternative to titanium in abutment production
Schwitalla et al[51]	reported that the stress values occurring around the bone were lower in a group using titanium abutment compared to the group with PEEK abutment
Hendrik[52]	In this study composite resin crowns were applied over PEEK and titanium temporary abutments and the breaking resistance of these were compared. The crowns applied over the PEEK abutments were seen to have lower resistance

IV. DISCUSSION:

Because of its mechanical and physical properties being similar to bone and dentin, PEEK can be used for a number of applications in dentistry including dental implants. Increasing the bioactivity of PEEK dental implants without affecting their mechanical properties is a major challenge. PEEK is also an attractive material for producing CAD-CAM fixed and removable prosthesis owing to its superior mechanical properties compared to materials such as acrylic. n a study in which mechanical tests were applied to prostheses produced from zirconium, metal, ceramic and PEEK materials, it was reported that composite-coated PEEK had lower fracture resistance to occlusal forces than metal ceramic and zirconium restorations. Furthermore, the fractures in the PEEK restorations were seen to be between the PEEK substructure and the composite veneer[53]. When the veneer material is fractured in PEEK material, repair procedures can be intra-orally applied easily with traditional composite resins to restore the aesthetic appearance.

As PEEK material has the property of radiolucency, this is an advantage in the evaluation of both osseointegration and of the tissue surrounding the implant on computed tomography (CT) imaging [54]. Radiolucency facilitates the determination of peri-implant cement remains. However, the radiolucence of PEEK makes the evaluation of the compatibility of PEEK prostheses with screw retention more difficult on radiographs[49]. To be able to observe PEEK material on radiographs more easily, in other words to increase the radio-opacity, barium sulfate must be added[54]. Dual cure resin cements are used for the cementation of PEEK materials. One of the main disadvantages of PEEK material in prosthetic dentistry is the low surface energy. PEEK shows low bonding to resin cements [55]. One of the main reasons for the loss of cement bonding is the high flexibility modulus of metal substructures and another is the negative stress concentration in the cement interface which leads to abutment tooth movement [56].To eliminate this problem, PEEK surface energy is increased using traditional sanding, roughening with acid, plasma spray and laser roughening methods[57]. In a study by Schmidlin et al, resin systems were reported to be successful in PEEK restorations, but it was recorded that no bonding was seen apart from the acidified surface [58]. It has also been shown that surface energy was not increased and no bonding or very little occurred between PEEK material and resin cements [59]. To overcome the limited bioactivity of PEEK, to improve mechanical and biological properties and to increase surface roughness, PEEK can be blended with or coated with bioactive particles at the nanometer level. These methods are spin-coating, gas plasma etching, electron beam, and plasma-ion immersion implantation. In addition, increased bioactivity can be achieved with fusion with the addition of TiO_2 and HA to PEEK material.[60]

V. CONCLUSION:

PEEK is an attractive modern material to use in prosthodontics. Due to the high elasticity modulus close to that of bone and dentin, there is increasing use of the material in implantology. It can be considered that increasing the bonding of the material with acrylic and composite resins and developing the osteointegration properties will further increase dental applications.

Due to its favourable chemical, mechanical and physical properties it is used in producing fixed and removable prostheses. However, more clinical research is necessary to find out the situation, because most of the studies have been carried out in vitro.

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