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Poly Ether Ether Ketone(PEEK) – Forging A New Path In The Dentistry: A Narrative Review

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ABSTRACT

Prosthodontics is versatile branch which uses various types of materials; among which Poly ether ether ketone (Peek) is the revolutionized material that has greater biocompatibility. Poly ether ether ketone materials and its modifications led to diverse use which include removable / fixed prosthesis, implants, crowns, maxillofacial prosthesis. Peek materials are also used in medical applications - includes spinal implants, for lumbar cage fusions etc. Despite expensive and require 5 axial milling machines for processing; its esthetics & biocompatibility led to its greater usage in recent times. Peek materials are 1. Nontoxic 2. Nonmutagenic 3. Noncarcinogenic 4. Nonimmunogenic making it the most biocompatible material. In order to uplift properties, surface modifications are done on peek materials. Peek reinforcements like carbon reinforced peek improved elastic modulus of peek materials. The modifications, surface treatments led to better outcome with greater physical and mechanical properties of peek improving diverse application in medical, dental fields.

INTRODUCTION

Prosthodontics, generally deals with numerous inter disciplinary approaches and treatment modalities which include Complete dentures, Removable partial dentures, Cast Partial Dentures, Fixed Partial dentures, Implants, Maxillofacial Prosthesis and Splints. For treating such wide variety of cases, different types of materials need to be selected according to the treatment protocol and techniques employed. Biocompatibility is the primary requirement for the materials that were frequently used intra-orally for restorative operations, followed by mechanical and physical qualities that provide adequate function and structural durability over extended periods of time.[1] While treating intra orally parameters like elastic modulus, tensile strength, and low plaque affinity are also to be considered.

Poly Methyl Methacrylate, or PMMA, is frequently utilized in prosthetic dentistry applications, such as the creation of artificial teeth, denture bases, dentures, and dental prosthesis maintenance. It is inexpensive and simple to utilize in the lab and in clinical settings. It continues to be the most common used material for the fabrication of prosthesis.[2] These dentures are more prone to fracture during use or when they are dropped against hard surfaces or in Single complete denture cases. These cracks are caused by impact or flexural fatigue,[3] which are typically connected to the material's characteristics and/or the framework's structural integrity.[4,5,6] PMMA is biocompatible with the oral tissues; nevertheless, Skin and oral mucosa may suffer negative consequences from self-curing PMMA monomers.[7]
Cobalt-chrome metal alloy has a very high specific strength and is commonly used in fixed prosthesis, dental implants & orthopedic implants. It causes modest degrees of irritation and sensitization,

reducing the likelihood of allergic responses.[8] The most prevalent symptoms were soreness, burning feeling in the mucosa, dry mouth, and redness. In a few cases, Co-Cr dental treatments were shown to cause contact dermatitis and palmoplantar pustulosis.[9]

Since Branemark's experiments, titanium and its alloys have been the preferred materials for dental implant systems.[10]Nevertheless, titanium-based implant-supported prostheses are also prone to corrosion when exposed to the oral environment. This results in the release of ions and particles, triggering inflammatory responses surrounding the peri-implant tissues.[11] In addition, there is a mismatch between elastic modulus (E) and bone tissue.[11] Research has revealed that casting processes have a significant impact on the degree of contaminated zone, yield strength, and percentage elongation of titanium casting.[12]According to studies, titanium alloys emit very little titanium. The risk of titanium allergy is considerable for a patient having a history of an allergic response.[13]

To overcome the shortcomings of the above materials, it led to further innovation of the newer material to meet requirements of oral cavity and should be biocompatible; such as Poly Ether Ketone (PEEK).Polyether ether ketone (PEEK) was first invented by DuPont (USA), and is derived from the family (PAEK) Poly Aryl Ether Ketone which is an aromatic, thermoplastic biomaterial and semicrystalline in nature with a chemical formula of (-C6H4-O-C6H4-O-CH2-CO-) n. (Figure 1). PEEK is used broadly in several medical treatments like in Spinal Implants.[14] in trauma, Arthroscopy, and Cranial Defect Repair.[15] Late recently, the usage of PEEK Materials has been introduced into the field of dentistry replacing all the conventional materials and their shortcomings. PEEK in Dentistry can be utilized for different components of implants like abutments, FPD'S; RPD'S and components replacing the ceramic materials and different kinds of metals.[16]

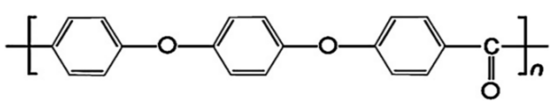


FIGURE 1: CHEMICAL STRUCTURE OF PEEK (POLY ETHER KETONE KETONE)
Chemical Formula: C19H14F2O3

Polyaromatic semi-crystalline thermoplastic polymer with chemical structure (–C6H4–O–C6H4–O–C6H4–CO–)n.

PEEK also has its own drawbacks like other materials; unmodified PEEK implants survival is questionable due to its compromised biocompatibility. Improper Osseo conductivity and bioactivity of the dental implant can cause severe implantitis and failure. To overcome this disadvantage, few surface modifications are done to PEEK in order to improve its biocompatibility.

Chemical structure & crystallinity of peek

PEEK was created from bisphenol salts and aromatic dihalides by nucleophilic substitution PEEK's molecular chain does not remain static; it vibrates and spins in reaction to heat energy and external strain. The presence of aromatic(benzene) rings throughout its backbone, make it relatively stiff; yet, the molecule has the freedom to spin axially about the ether (e-e) bonds and ketone-carbon bonds (-CO-). It is bi-phased semicrystalline polymer with an amorphous and crystalline phase (Figure 2). Injection molded PEEK crystallinity in implants generally ranges between 30 and 35%.

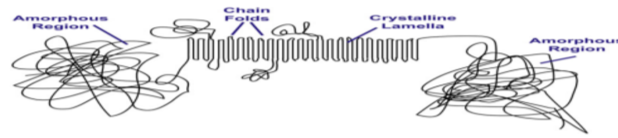
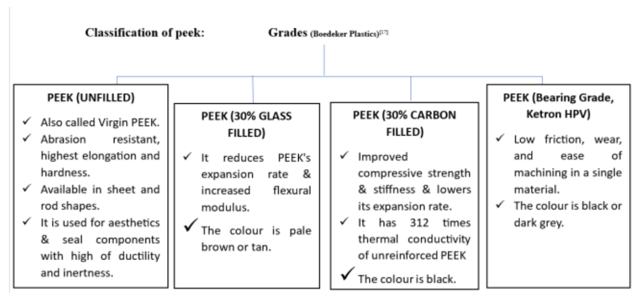


Figure 2: Schematic representation of peek microstructure, consisting of amorphous and crystalline regions



PEEK biomaterials are now known as OPTIMA, a brand name derived from their molecular weight, which influences their melt flow properties.

- LT1: Standard grade.
- LT2: Optimized for melt strength and viscosity, ideal for tubing
- LT3: High-flow grade for injection molding thin-walled products.

Synthesis and Manufacturing of Peek

Medical grade PEEK polymers are manufactured using typical plastic manufacturing techniques, they melt at roughly 340℃.Depending on the processing procedure, PEEK-OPTIMA materials can have a variety of viscosities.

PEEK OPTIMA LT1 is recommended for the majority of medical device component machining and injection molding applications. PEEK OPTIMA LT2 has a high melting strength and low viscosity, making it ideal for extruding thin-walled items like tubing. PEEK OPTIMA LT3 is particularly well suited to the injection molding of thin-walled components.

As Injection molding is not economically feasible, Compression molding or machining PEEK-OPTIMA polymer materials is commonly done. It is also used to process and finish PEEK-OPTIMA polymer. However, carbide or diamond-tipped tools and bits are recommended due to the superior physical features and wear characteristics.

Biocompatibility of peek

Biological performance of materials refers to the relationship amongst materials and biological systems, which essentially involves host and material reaction. The biomaterial should not be 1. Toxic 2. Mutagenic 3. Carcinogenic and 4. Immunogenic. In 2002, Katzer et al. tested PEEK for cytotoxicity and mutagenicity using two different methods: S. typhimurium (Ames Test) and mammalian cells (Chinese hamster fibroblasts, V-79). The findings of incubating polyetheretherketone (PEEK) fiber material with seven distinct genotype variations of Salmonella typhimurium bacteria revealed that the test material had no mutagenic or cytotoxic effect.

Jockish et al. implanted PEEK(Victrex 450G) and 30% CFR-PEEK (Victrex 450CA30) cylinders (3 mm diameter, 10 mm length) into rabbits' paravertebral muscles according to ASTM F981. At 8 weeks, half of the rabbits were put down and the PEEK implants were removed; at 12 weeks, the other half were put to death and the implants were removed. Normal muscle tissue with no adverse tissue reaction, no evident infection, few PEEK particles, and a minor chronic inflammatory response with macrophages and foreign body giant cells were discovered histopathologically according to ASTM F981. Eosinophils, lymphocytes, and plasma cells were not often observed.[18]

PEEK biomaterials are not bioactive; nonetheless, direct bone contact with PEEK implants has previously been established using PEEK spinal interbody cylindrical implants[19] (Figure 3). In the ovine lumbar region approach, histological fusion (continuous cranial to caudal bone development) occurred within the through-growth zone of a PEEK interbody spinal fusion device.

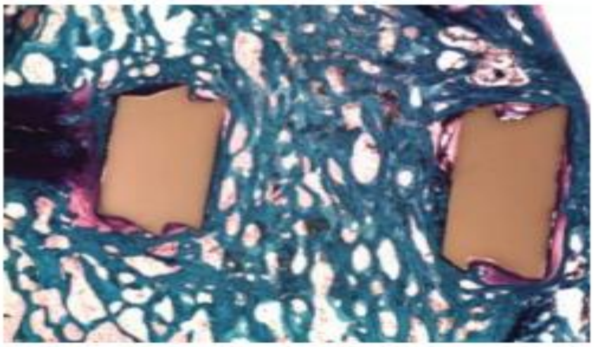


Figure 3: Bone contact is shown along the PEEK device's smooth inner surfaces as well as its threads (trichrome stain)

Properties of peek:

- PEEK has tensile qualities similar to enamel and dentin, making it a viable option for prosthodontic restorations.
- PEEK has good fatigue resistant & exhibit low creep rate.
- PEEK's chemical resistance reduces biocorrosion, preventing the generation of hazardous byproducts.
- It is highly resistant to gamma and electron radiation, commonly used for sterilizing medical equipment.
- Its bioinert and hydrophobic properties limited its ability to directly touch bone.[20]

The impact of increasing crystallinity on different polymer characteristics.[21] (Table.1)

Table.1

Properties that increase's	Properties that decrease's
Dimensional Stability	Tendency to Creep
Yield strength	Thermal Expansion
Elastic modulus	Elongation
Density	Impact Strength

PEEK is utilized in implant superstructures, abutments, and fixtures. The Young's modulus of pure PEEK material is 3.6 GPa, whereas carbon-reinforced PEEK (CFR-PEEK) is around 18 GPa and glass fiber-reinforced PEEK (GFR-PEEK) is 12 GPa. PEEK has a Young's modulus close to the cortical bone hence it displays stress shielding less than the Ti material.[22, 23] Comparative studies of different properties of various peek materials[Table2]

Comparative studies on properties of various peek materials Table .2

Author/year	Design of study	Purpose of Study	Subject specimen	Type & no. of implants/ crowns/screws/ abutments	Study summary	Results	Inference

Maowei Zhong et al (2025) [24]	In vitro	impacts of polyetherether ketone (PEEK) surface treatment techniques on resin luting material's shear bond strength (SBS) during artificial aging.	Concentrated sulfuric acid (SA), alumina blasting + primer (ABP), untreated, alumina blasting (AB), & concentrated SA+primer (SAP)		A universal testing equipment was used to empirically ascertain each group's SBS score.	The initial bond strengths of ABP and SAP were substantially greater than those of AB and SA, according to the SBS tests. Furthermore, both SBS stayed high (>15 MPa) after 20,000 heat cycles.	When compared to concentrated SA etching or alumina blasting alone, both techniques demonstrated an enhanced initial binding strength to resin luting material after being treated with a primer containing functional monomers. Both treatment techniques are very accurate ways to assess how well the PEEK and resin luting material connect.
Gonca Deste G et al(2024) [25]	In vitro	To compare Shear bond strength of Copra PEEK & Bio HPP		Frameworks of Copra Peek, P and BioHPP	Shear strength is evaluated between feldspathic ceramic, hybrid nano ceramic & polymer-infiltrated ceramic blocks cemented to PEEK.	Greater shear strength is found in Bio HPP with feldspathic ceramic	Even though felspathic ceramic with PEEK has greater shear strength, there is no significant difference as framework material.
Andreas Wiessner et al. (2023)[26]	In Vivo	Formation of biofilm on PEEK , titanium & Zirconia implants	Split specimens	PEEK, Titanium & Zirconia	Accumulation of biofilm on abutment is assessed by fluorescence microscopy	Zirconia as abutments showed least biofilm formation	Type of abutment material must be specific to reduce peri-implantitis & implant failure.

Zilin Zhang et al (2023)[27]	In vitro	Immune response following PEEK implantation; strategies to enhance anti-inflammatory efficacy.		PEEK, modified PEEK	Improving via medication delivery methods, surface chemical modification, and surface porous treatment.	Growth of fibrous tissue around implant site-leading to failure.	Developing technological techniques is critical in avoiding the creation of fibrous wrapping following implantation.
Hao Yu et al(2022)[28]	In vitro	Biomechanical properties of prefabricated post made of PEEK and titanium.	Finite element analysis	PEEK, Titanium	Stress & strain of CFR-PEEK & Pure PEEK post is compared	Reduced post -core interfaces of stress but strain of CFR-PEEK is similar to dentine.	As CFR-PEEK strain is similar to dentine it is used as post material in larger tooth defects.
Bankole I. O et al (2021)[29]	In Vitro	To increase bio interfaces of PEEK & cHAP		PEEK, cellular calcium hydroxyapatite (CHAp)	Interfacial biological macromolecular cellular investigations of CHAp implanted in PEEK are evaluated.	PEEK & CHAp is used to repair & replace bone to enhance strength.	The study of cellular interfaces in hybrid cell and bone composites has an enormous opportunity for advancing biomaterial development.

Lakshmana et al (2019)[30]	In vitro	Superior mechanical properties with different uses.		PEEK, modified PEEK	Mechanical properties, advantages, modifications & different uses.	PEEK-based CAD/CAM temporary crowns provide a superior marginal fit and good fracture strength. PEEK and CFR-PEEK have improved osseointegration.	Modified PEEK materials have superior qualities than unmodified PEEK. Because of its elastic modulus, strength, rigidity, and lightweight properties, PEEK uses are not restricted to implant materials.
Zhang et al (2018)[31]	Invitro & In vivo	To promote cell responses, a composite covering with lithium doped silica nanospheres (LSNs) was used.	Simulated bodily fluid (SBF), rBMSCs	LSNs along with PDA treated polyetherether ketone (PK) surfaces (LPPK)	The effects of an LSNs composite (LPC) covering on the biological characteristics of LPPK were investigated.	LPPK greatly enhanced bone tissue responses.	LPPK would be an excellent material for applications of dental implants.
Schwitalla et al (2018)[32]	In-vitro	Calculating the insertion torque (IT) of a unique implant abutment interface design		n = ten unfilled PEEK, ten CFRPEEK, and ten Ti.	The average IT of the implant is calculated to establish its appropriateness for immediate loading.	IT Ti (92.6 2.3 Ncm) outperformed unfilled PEEK (22.6 0.5 Ncm) & CFR-PEEK (20.2 2.5 Ncm).	PEEK and CFRPEEK implants cannot sustain the insertion force required to establish primary stability for instant loading and a two-stage operation.

Kaleli et al (2018)[33]	In-vitro	The biomechanical behaviour of various abutments in terms of stress distribution in implants & peripheral bone is assessed.	3-D models with bone-level implant systems	Translucent zirconia (TZI), lithium disilicate glass ceramic (IPS), polymer-infiltrated hybrid ceramic (VTE), and bespoke PEEK and zirconia abutments.	Load of implants both vertically, obliquely, & also distribution of stress was assessed.	VTE crowns demonstrated minimal stress levels. Compared to PEEK abutment, zirconia demonstrated greater stress values.	All models revealed similar stress distributions in the implant and peripheral bone. Changes in restoration and tailored abutment material had no effect on stress distribution in the implant or peripheral bone.
Kumar et al (2017)[34]	In-vitro	Compare and measure the bone-promoting ability of various PEEK materials.	Human osteosarcoma cells	n = ten untreated PEEK, ten TiO2-coated PEEK, and ten TiO2-blended PEEK.	The samples were examined for the cytotoxicity and the alkaline phosphatase (ALP) activity so as to assess and characterize the bone mineralization	Variations were discovered in the matrix prior to and subsequent to cell attachment.	n-TiO2-coated PEEK was the preferred biomaterial in implant dentistry, subsequent to n-TiO2-blended PEEK and untreated PEEK.
Sampaio et al (2016)[35]	In-vitro	Studied the abrasive resistance to wear of PEEK and Ti6Al4V.	Cylindrical models	Ti6Al4V and PEEK cylinder	Microscale abrasion experiments were done using varying weight percentages of hydrated silica, and wear patterns were measured.	PEEK showed a higher volume loss rate compared to Ti6Al4V.	PEEK was found to have less wear resistance than Ti6Al4V

Modifications of Peek:

PEEK is a biocompatible and bioinert material, thus numerous modifications have been tried in order to render it more osteoconductive. To make PEEK bioactive, its surface has to be changed through a variety of procedures.

There are several ways in which polymer surfaces can be modified for biomedical applications which include: Physical treatments & Chemical treatments (Table.3), Plasma spraying, Acid etching, Spin coating Chemical modification, and Ultraviolet irradiation. Nanoparticles like titanium oxide, hydroxyapatite and hydroxyfluoroappatite can be coated on the surface of PEEK.

Table.3

Modifications on surface	Methods	Material
Coating over surface	Plasma spraying Spin coating EBE PIII	HA, Ti Surfactants, organic solvents, an aqueous solution of $Ca(No_3)_2$ & H_3 $P0_4$ Ti, Silicate TiO_2, Calcium, H_2O, and Argon are all present in nanosized HA crystals.
Surface Topographical modifications	Acid etching Sand blasting	Sulfuric acid TiO_2, Alumina, (Al_2O_3)
Chemical Modifications	Sulfonation Amination Nitration	Sulfonate groups (-SO_3-) Amine functions Nitrate functions
Incorporating with bio active properties	Bioactive inorganic materials	Nano – TiO_3, nanofluorohydroxyappetite
Improving Hydrophilicity	UV Irradiation Plasma Gas treatment	UV – A Light, UV – C Light Oxygen Plasma

Peek reinforcements

PEEK has a lower elastic modulus than cortical bone, titanium dioxide, and ceramic materials. Several reinforced PEEK composites, including Carbon Fiber Reinforced PEEK (CFR-PEEK) and Glass Fiber Reinforced PEEK (GFR-PEEK), have been produced; the elastic modulus of CFR-PEEK and GFR-PEEK may reach 18 GPa. Due to its versatility, compatibility with modern imaging methods, mechanical properties, and biocompatibility, Carbon Fiber Reinforced PEEK (CFR-PEEK) has been the interest of the medical implant community [36, 37].

PEEK can be changed at the nanometer level in a variety of ways to improve its bioactivity. Melt-blending can integrate nanomaterials like TiO2, HAF, and HAP with PEEK to form bioactive nanocomposites with improved tensile characteristics.

Applications of peek:

Medical applications:

- PEEK has now become the material of choice for maxillofacial and Cranial reconstructions.
- Availability of PEEK biomaterials, its radiolucency, and biomechanical performance in spinal fusion applications have sparked interest in its use in posterior dynamic stabilization devices.
- PEEK optima LT1 material has been used in heart surgeries.[38]
- PEEK, as a thermoplastic, material that overcomes the limits of thermosetting polymers by allowing it to be molded to the anatomy of the patient in the operating room.[39]
- Other various applications of PEEK in spinal implants Includes:

PEEK Rods were created for both fusion and non-fusion applications.

Threaded PEEK – For Lumbar Fusion Cages

Interspinous process spacers

PEEK Anchors

Dental Applications:

PEEK was successful as biological material in medicine; its implementation in dentistry involves superior biological compatibility and other biomechanical and cosmetic qualities. Different surface changes have enabled PEEK to connect with a variety of luting agents.

PEEK has tensile qualities equivalent to bone, enamel, and dentin, making it an ideal tooth restorative material. With strong biocompatibility and the previously mentioned qualities, PEEK is effectively employed in dentistry as implants, frames for detachable and fixed prostheses.[37]

Peek as a complete / removable prosthesis material:

PEEK computer-aided design and Computer-Aided Manufacture (CAD-CAM) technologies may be utilized to construct dentures[39] due to its low weight and remarkable biologic, cosmetic, and mechanical properties.[40]

Tannous et al. found that PEEK denture clasps have lower retentive forces than Co-Cr clasps.[41]The fabrication of a detachable obturator[42] is another application of PEEK.

Framework for FPD'S:

To achieve aesthetics, PEEK needs to be laminated with composite materials because it is opaque. Sandblasting, Rocatec process, sulfuric acid surface etching, and piranha solution are some of the surface treatments available[36, 43]

A recent approach of surface modification is using plasma, which eliminates organic residues, micro-etches the surface, and facilitates cross-linking and surface activation.

Surface modification is examined using various luting agents, multifunctional methacrylate-containing resin varnish on air-abraded PEEK surfaces; generates a promising and permanent binding to PEEK; hence, PEEK may be recommended for clinical usage[44.45]

PEEK CAD-CAM milled fixed partial dentures:
Compared to typical fixed dentures, CAD-CAM created composites and polymethylmethacrylate (PMMA) fixed dentures have enhanced mechanical properties.[46] PEEK is a material that may be used in CAD-CAM technology restorations as a substitution to PMMA(Figure 4).

Figure 4: Reinforced peek material as cad cam blank for milling
Three-unit PEEK fixed partial dentures manufactured using CAD-CAM have a higher fracture resistance than pressed granular- or pellet-shaped PEEK dentures.[47]
CAD-CAM machined PEEK fixed dentures offer much stronger fracture resistance than lithium disilicate glass-ceramic (950N), alumina (851N)[48], and zirconia (981-1331N). PEEK has comparable abrasion resistance to metallic alloys while having much lower elastic moduli and hardness.[49]
Nevertheless, no clinical studies have examined the abrasion generated by PEEK crowns on teeth with the abrasion induced by other materials such as metals and ceramics.

PEEK implant fixture
Titanium remains the material preference for dental implants due to the positive outcomes observed. It normally has adequate mechanical characteristics and is biocompatible.
Despite several advantages Titanium lacks a number of crucial qualities. Hypersensitivity to materials has been documented with Titanium, Stress shielding and bone resorption are induced by the difference in elastic moduli of titanium and surrounding bone.
PEEK's Youngs modulus is near to that of human bone, therefore it can create good stress and deformations, lowering stress shielding and bone resorption. The elastic moduli of unfilled PEEK are 3-4GPa.
Carbon-fiber reinforced PEEK (CFR-PEEK) implants were found to have less stress shielding than titanium implants in a finite-element analysis (FEA).[50] Recent FEA investigation by Sarot et al. demonstrates that the stress distribution around PEEK and titanium dental implants is consistent.[51]

PEEK Implant Abutments
Abutments are produced from a variety of materials, including titanium, gold, zirconium, and ceramics. According to Koutouzis et al randomized, controlled clinical trial (RCT), there is no substantial difference in bone resorption and soft tissue inflammation between PEEK and titanium abutments.[52] PEEK can help in bone remodeling. As a result, it has been claimed that this material may be a good alternative to titanium in abutment fabrication.
The adhesion of oral microbial flora to PEEK abutments is comparable to titanium, zirconia, and polymethylmethacrylate abutments.[53,54]
In one research, 40% of prosthesis put over PEEK abutments showed no fracture, with only abutment deformation noted.
A tight match between the elastic moduli of the bone and the PEEK surface reduces stress shielding effects and promotes bone remodeling. As a consequence, PEEK might be a feasible alternative to titanium for implant abutments. (Figure 5).

Figure 5: Peek implant abutments

PEEK Crowns:
PEEK is seldom utilized as a crown material due to its greyish beige hue and limited cement bond strength.
PEEK crowns made with the CAD/CAM technology did not come off, fracture, or have any notable deleterious effect on the marginal gingiva or impairment in the capacity to masticate after six months after implantation, demonstrating that PEEK is a potential alternative to metal crowns for molars.[55]
PEEK can be employed as a coping material under resin composite PEEK as it may have an advantage of better mechanical properties that are identical to those of dentin and enamel on metal and ceramic restorations.

PEEK maxillofacial prosthesis
Because of its biocompatibility and lightweight nature, PEEK might be employed as a maxillofacial prosthetic obturator. Costa-Paulau reports a clinical case where, in front of a loss of Centro-maxillary substance with sinus communication, a hollow shutter (0.5mm thick) could be designed numerically and machined via a 5-axis milling machine, the PEEK's lack of adhesion to the resin could be bypassed by the creation of a retention box in the shutter followed by micro abrasion by silica particles, the appointments con3firm the good maturation of peri-prosthetic soft tissue, the patient report.[56]

PEEK Orthodontic Wires
PEEK orthodontic wires have a better orthodontic strength than other polymers like polyethylene sulfone (PES) and polyvinyl difluoride (PVDF).

Advantages & disadvantages of PEEK:[57]
Benefits include
1. Aesthetically more attractive
2. Lighter in weight due to less density
3. Not made of metal
4. Bio-inert substance with less irritation and allergic reactions.
5. There are minimal waiting time and ease of processing.

6. According to Kurz.SM PEEK Bio Materials, it exhibits resilience to degradation under different sterilization techniques
7. Over 280°C is the melting point. As such, heat sterilization techniques can be applied to it.
8. It has a strong resistance to wear from chemicals.

Disadvantages:
1. Expensive.
2. Chemical processing is difficult because to the low surface energy.
3. Processing requires specific machines (e.g., 5 axial milling machines).

Conclusion:
PEEK although having several drawbacks, it had crossed the several disadvantages of the former materials and properties that are used in several rehabilitation purposes like metal frame works in cast partial dentures, metal copings in fixed partial dentures and implant fixtures and other rehabilitation in maxillofacial prosthesis. Few more studies are yet to be done as to clearly demarcate the superior properties of PEEK over the conventional materials. PEEK now being commonly used material in dentistry will be the innovative material as well as game changer in the prosthetic rehabilitative purposes in the next coming few decades.

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