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Revolutionizing Dentistry: The Mechanical Edge Of Peek Over Traditional Materials

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ABSTRACT:

A Polyetheretherketone (PEEK) is an advanced polymeric material with exceptional mechanical and chemical properties, making it an ideal choice for a variety of medical and industrial applications, including dentistry. PEEK is characterized by its high strength, corrosion resistance, and mechanical flexibility similar to human bone, making it ideal for use in dental prostheses such as implants, bridges, and dentures. It also has excellent biocompatibility, reducing the potential for adverse interactions with human tissues.

PEEK is increasingly being used in dentistry as an alternative to traditional materials such as zirconia and metallic materials such as titanium due to its light weight and ease of fabrication. Compared to zirconia, PEEK offers better flexibility, making it a more suitable choice for applications requiring stress absorption. It also has excellent corrosion resistance, enhancing its durability in complex oral environments.

Overall, PEEK is an innovative material that opens up new opportunities in dentistry due to its unique properties that combine durability, comfort, and high performance.

Keywords: Polyether Ether Ketone (PEEK), Biomaterials, Mechanical properties, Dentistry.

INTRODUCTION

The field of dentistry has witnessed remarkable development in recent decades thanks to technological advances and innovation in biomaterials. Among these proven materials, polyetheretherketone (PEEK) stands out as one of the promising options that combines excellent performance and biocompatibility. PEEK is a high-performance polymer with exceptional mechanical and aesthetic properties, making it a preferred material for multiple applications in dentistry [1].

PEEK was initially developed for industrial uses, but its continuous development has allowed its use to be expanded to the medical field. This polymer is characterized by its flexibility similar to human bone, its high resistance to corrosion, and its ability to withstand mechanical stress, making it a strong competitor to traditional materials such as zirconia and other biomaterials[2].

With the increasing need for innovative medical solutions that meet functional and aesthetic requirements, PEEK has become the focus of attention of researchers and practitioners in the field of dentistry[3]. This material is characterized by its light weight, its ability to achieve biocompatibility with surrounding tissues, and its natural appearance that suits dental prostheses. Despite these advantages, the use of PEEK faces challenges related to its high cost and the need to modify its surface to improve its bonding with bone [4].

This paper aims to provide a comprehensive review of the properties of PEEK, evaluate its advantages and limitations compared to conventional materials, and focus on its clinical applications in dental implants and restorative dentistry. It

also highlights the challenges facing its use, and reviews future research directions to improve its clinical performance and expand its applications.

POLYETHERETHERKETONE (PEEK) DEFINITION:

It is a semi-crystalline thermoplastic polymer belonging to the Polyaryletherketones (PAEK) family, which is characterized by its excellent thermal and mechanical properties. This material was first developed in the late 1970s and has gained wide popularity in the industrial and medical fields due to its unique combination of physical and chemical properties. Today, PEEK is considered one of the most high-performance polymers, combining strength, light weight and biological resistance [5].

SCIENTIFIC DEFINITION

Does this definition include (Polyetheretherketone, (PEEK) also called polyketones, obtained from dihalides and bisphenol salts by nucleophilic substitution. The bisphenol salt consists of bisphenol and ether with sodium or alkali metal carbonate or hydroxide added [6].

PEEK is partially crystalline, has a glass transition point of 143 °C and a melting point of 334 °C. It is also resistant to organic environments and solutions. It is used in bearings, piston parts, pumps, air compressor valve plates, and cable insulation applications [2].

PEEK is also a thermoplastic material and has unusual mechanical properties. Its Young's modulus is 3.6 GPa and its tensile strength is 170 MPa. PEEK is also considered a biomaterial and is used in medical applications.

Due to unique properties, PEEK has become a basic material in many industrial fields, such as aviation and aerospace, automotive, and medicine, especially in dentistry, where it is used in the manufacture of dental implants and prostheses that require high performance and a natural appearance [7,8].

BASIC PROPERTIES OF POLYETHER ETHER KETONE (PEEK):

Polyether Ether Ketone (PEEK) has a range of physical and chemical properties that make it a unique material for many industrial and medical applications. The basic properties of this material are summarized as follows:

1. MECHANICAL STRENGTH and Rigidity:

PEEK has a high tensile strength (about 170 MPa), making it extremely strong in withstanding mechanical forces. The Young's Modulus of PEEK is about 3.6 GPa, indicating its high rigidity and ability to resist deformation under pressure[9]. It has a mechanical flexibility similar to human bone, making it suitable for use in medical applications such as dental and bone implants[4]. PEEK has a stress-strain relationship that may provide advantageous flexibility and shock-absorbing abilities. Such features could be useful in dental applications where the capacity to adjust to changing oral environment stress is required. PEEK is used for particular dental applications because of this feature, which also improves the satisfaction of patients [10].

2. THERMAL RESISTANCE:

The glass transition temperature of PEEK is about 143 °C, indicating its degree of flexibility at high temperatures. PEEK has a high melting point of 334°C, which means it can be used in high temperature environments without losing its properties. The coefficient of thermal expansion, which was identified as 47 ppm/°C, was considered matching the normal expansion of human teeth, so it reduces the possibility of mechanical failure brought on by thermal cycling [11].

3. CHEMICAL RESISTANCE:

PEEK is a chemical made from car-bonyl groups (R-O-R), ether groups (R-O-R), & phenylene (aryl) rings. These phenylene groups are not reactive. As a result, PEEK has a better resistance to chemical attack [12].

As well as resistant to most acids, alkalis, and organic solvents, making it ideal for use in harsh chemical environments[4]. PEEK also has excellent resistance to UV rays, which increases its durability in applications exposed to sunlight or radiation [13].

4. BIOCOMPATIBILITY:

PEEK is a biocompatible material, as it does not interact with human tissue and does not cause allergic or toxic reactions. These properties make it an ideal material for dental and orthopedic applications, such as implants. As well, it does not interact with body fluids, ensuring its durability in the human internal environment for long periods [14].

5. CORRSION AND FRICTION RESISTANCE:

PEEK has excellent corrosion resistance, making it ideal for use in applications that require wear resistance such as moving mechanical parts. The PEEK surface offers friction-resistant properties that make it an ideal material for use in applications that involve constant movement or sliding[11].

PEEK SURFACE TREATMENTS

The surface treatment of PEEK is one of the most important topics. the polymer known as a bioinert material, which makes it difficult for it to adhere to bone tissue, dental cement types, and other prosthetic materials. A number of surface modifications have been undertaken to increase PEEK's bioactivity[6].

Physical treatments is one of the existing methods to increase PEEK's bioactivity, which include laser irradiation, photodynamic therapy, accelerated neutron atom beams (ANAB), sandblasting, and plasma treatment [15].

In recent decades, studies have looked into using the laser method to increase the bioactivity of PEEK surfaces. The low cost, high accuracy, high operating speed, and the fact that lasers only treat a specific surface rather than altering the implant's bulk characteristics are some benefits of this technique [16].

In order to integrate the benefits of both chemical states and microstructures for osteoblast responses, Zheng et al. propose a work that shows a dual modification technique that combines laser and plasma surface treatment. This work provides useful information on the possible application of PEEK in orthopedic or dental implants by demonstrating improved osteoblast responses to the dual-treated surface [17].

Surface coating is another common method for surface treatment that includes titanium coating, hydroxyapatite coating, and polymer coating[6]. Based on this type of treatment, Devine et al. try to examine implant removal torque and bone/implant contact area in order to compare the properties of bone apposition on three screw surfaces: untreated CF/PEEK, PVD Ti-coated CF/PEEK, and VPS Ti-coated CF/PEEK, and they found that the VPS Ti coating performed effectively in adjusting the surface to greatly increase the amount and quality of bone development [18].

Composite preparation strategies are currently searched in order to improve the surface characteristics and mechanical properties of PEEK by using different metals, oxides, polymers, and inorganic fibers [19]. For instance, Hoppe et al. evaluate the performance of a novel titanium-coated carbon/polyetheretherketone (PEEK) cage under first-use clinical settings using vacuum plasma spraying (VPS).They were able to obtain minimal implant-related complication rates, favorable clinical results, and elevated fusion rates without the need for additional iliac bone grafts or rhBMP [20].

COMPARING PEEK TO ZIRCONI And MINERAL BIOMATERIALS:

PEEK and traditional dental materials are discussed in **Tables 1** in order to facilitate material selection for dental prosthesis, taking into consideration the particular requirements and application conditions [8,21–25].

Table 1. Comparison of polyether ether ketone (PEEK) with conventional materials:

Field	PEEK	Zirconia	Metallic Materials
Mechanical properties	PEEK has a mechanical elasticity similar to human bone, allowing it to effectively absorb stress and mitigate mechanical forces, making it ideal for applications that require flexibility such as dental implants.	Zirconia offers high stiffness but lacks elasticity, making it less able to absorb stress. Its stiffness can lead to cracks or fractures in some applications that are subjected to high stress or vibration.	As titanium has a modulus of elasticity five times higher than compact bone, it is challenging to obtain the ideal stress distribution since either insufficient or excess stress might cause bone resorption.
biocompatibility	PEEK has excellent biocompatibility, as it does not interact with tissues or fluids in the body. This property makes it ideal for longterm medical applications, such as dental implants.	Zirconia is also a biocompatible material but may be less resilient to long-term mechanical stress than PEEK.	Metallic materials such as titanium also have very good biocompatibility, but can sometimes cause mild reactions with surrounding tissue due to the accumulation of metal ions.
Corrosion resistant	Corrosion resistant and has the ability to survive in oral environments for years without reacting with surrounding chemicals, making it an excellent choice for dental implants.	Zirconia has good corrosion resistance, but in applications involving constant stress, it can become more susceptible to cracking over time.	Like titanium, metal materials are also corrosion resistant but can be prone to the formation of metallic oxide on their surface, which can affect their performance in some cases.
Cost	PEEK is more expensive than traditional materials such as acrylic but less expensive than	The production of zirconium requires the use of advanced technology. This process is more	Metallic materials such as titanium are often more expensive due to complex manufacturing processes, and

	zirconia and metal materials such as titanium.	expensive as well as complicated then alternatives.	they also require additional maintenance techniques.
Manufacture	PEEK is lighter than metal materials such as titanium or stainless steel. PEEK is also easy to manufacture using techniques such as injection molding and 3D printing, allowing it to be easily manufactured into complex shapes.	Modern equipment is necessary for the manufacture of zirconium. Compared to other options, this method becomes more complicated and difficult.	Metal materials as titanium are very strong, but they are heavier and more difficult to process. Advanced techniques such as laser cutting or milling are required to obtain the desired shapes.

The **Tables 2** displays a comparison to understanding the advantages and limitations of PEEK in dental applications. PEEK exhibits reduced fatigue strength compared to titanium; yet, it is suitable for numerous dental applications, particularly where flexibility and biological compatibility are needed [11]. Since the PEEK material and cortical bone have extremely similar elastic modulus and tensile strengths relative to titanium and zirconia, PEEK shows enhanced shock absorption and less stress on adjacent bone tissue, and this is essential for implants. PEEK could represent a more acceptable option than metal-supported porcelain since it is lighter [7].

Table 2: Comparison of polyether ether ketone (PEEK) with conventional materials.

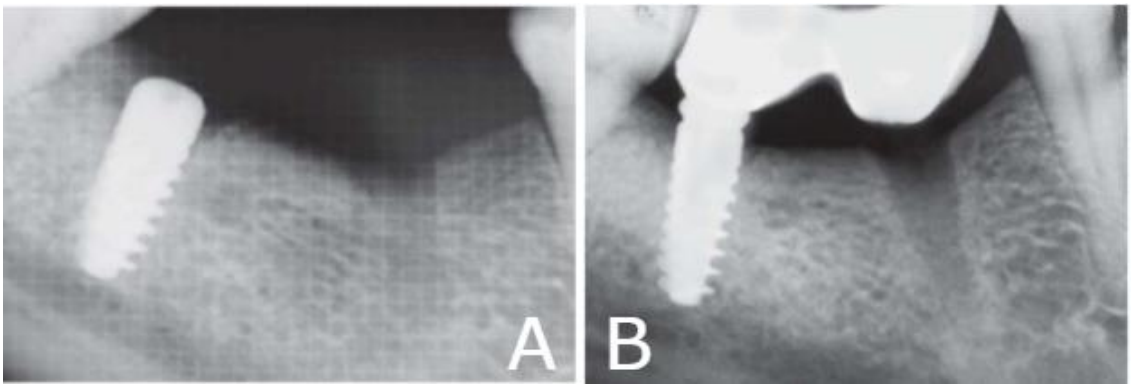
Material Property	Zirconia	Titanium	PEEK
Elastic Modulus (GPa)	200	110	14
Fatigue Strength (GPa)	0.5	0.9	0.1
Tensile Strength (MPa)	330	220	99
Thermal Conductivity (W/mK)	2	22	0.25
Density (g/cm^3)	6	4.5	1.32

USES of POLYETHERETHERKETONE (PEEK) IN DENTISTEY:

It is an innovative material that has proven effective in many dental applications thanks to its unique properties, such as durability, biocompatibility, and the ability to resist corrosion. The most prominent uses of PEEK in this field are:

1. Dental implants:

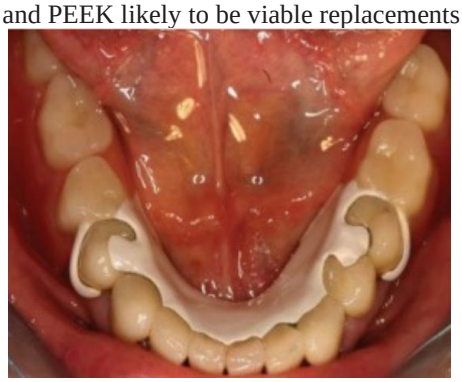
PEEK is used in the manufacture of some types of dental implants or as a cover for the metal surfaces of implants (such as titanium), as it provides a lightweight alternative with good mechanical properties It is characterized by providing excellent biocompatibility with bone tissue and has mechanical flexibility similar to natural bone, which reduces stress on the bones surrounding the implant and is resistant to acids and alkalis, which ensures its sustainability in the oral environment.[10]. Marya et al. presents a clinical case of implantation by an IOTA implant that were made of the unique PEEK/TiO2/beta-TCP combination, this implant were position to replacement mandibular first molar in a narrow ridge. After six months of use, the implant is stable, and the radiograph reveals minimal reduction in crestal bone, **Figures** 1.



Figures 1: (A)Postoperative X-ray showing titanium implant and PEEK implant (B) X-ray revealing increasing peri-implant bone density in three months after loading.

2. Dentures:

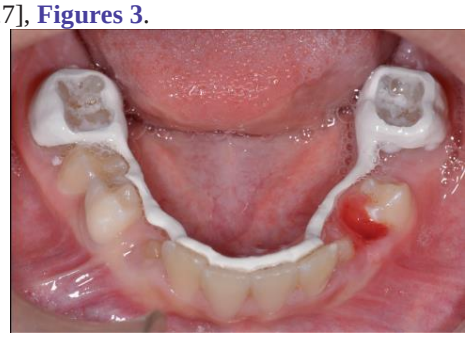
PEEK is used in the manufacture of complete and partial dentures, as it has mechanical properties that make it more flexible and stronger compared to other materials such as acrylic, as it contributes to improving patient comfort due to being light and durable and reducing the risk of erosion of surrounding tissues and mucous membranes in the mouth It is an ideal alternative to traditional dentures that may cause discomfort or sensitivity [25], **Figures** 2. Systematic review present by We-Fang Lee et al. to evaluate Ti along with PEEK's performance in RPD by comparing them to the CoCr metal framework. The biological (plaque indices, ion release, and biocompatibility) and mechanical (retention force, fatigue life, deformation strength, machinability, stiffness, porosity, and surface roughness) aspects have been examined. They came with the conclusion that Ti and PEEK likely to be viable replacements for CoCr frameworks in RPD[24].



Figures 2: Removable partial denture made by PEEK polymer.

3. Orthodontic appliances:

PEEK is used in the manufacture of some parts of orthodontic appliances such as brackets and orthodontic wires as it contributes to reducing the overall weight of the orthodontic appliance and is characterized by mechanical flexibility, which makes its application in orthodontics more comfortable and effective [1,26]. In the same field, G. Ierardo et al. by using a digital method, present an experiment focused on developing orthodontic space maintainers using PEEK. It was determined that these devices were appropriate for maintaining the area. PEEK proved to be an excellent material as space maintainers and can be applied as an replacement to Ni-Ti. The workflow made it possible to simulate the treatment plan with improved patient acceptability [27], **Figures 3**.



Figures 3: orthodontic space maintainers made by PEEK polymer.

DISCUSSION

Polyetheretherketone (PEEK) is an advanced polymeric material with unique properties that make it an ideal material for use in many medical and industrial applications, especially in the field of dentistry. By reviewing the properties and uses of PEEK, we can see its increasing importance as an alternative to traditional materials such as zirconia and titanium in many dental implants [7,28,29].

Its ability to absorb stress and adapt to the movement of the jaw and teeth gives it a significant advantage in applications that require flexibility, such as dental implants. Compared to zirconia, which provides high hardness but lacks this flexibility, PEEK is the better choice in some dental cases that require enhanced adaptation to biting pressure during chewing. Thus, this enhances the biocompatibility of materials used in dental implants and reduces the risk of fractures or destruction of adjacent teeth [11,26].

As for the second property, which is corrosion resistance, PEEK is superior to many other materials such as traditional metals and [21]. The oral environment is characterized by fluctuations in temperature and acidity, which makes dental materials susceptible to corrosion and rust. With its excellent resistance to these factors, PEEK can be said to provide long-term sustainability for dental implants, enhancing their quality and reducing the need for frequent maintenance or replacement [7].

The biocompatibility of PEEK is one of the most important reasons why it is the ideal choice for medical applications. PEEK has an excellent ability to adapt to human tissues, reducing the possibility of adverse reactions. This feature makes PEEK an ideal material for dental implants that are left in the mouth for long periods of time, as it does not cause irritation or inflammation of the surrounding tissues[3,5].

Despite these advantages, there are some challenges that must be taken into account. First, despite PEEK's excellent properties, its cost may be high compared to traditional materials. Also, the manufacturing process may require advanced technologies, which may increase the complexity of the production process. This may limit its use in some markets or regions that lack advanced technologies or face economic challenges [16,19].

There is great potential to expand the use of PEEK in other areas such as orthodontic appliances, dentures, and perhaps even in the treatment of jaw problems. As research into the development of this polymer continues, its properties may be improved to meet additional needs, such as improving its aesthetic properties or making the material more customizable[25,27].

CONCLUSION

In conclusion, polyether ether ketone (PEEK) is an innovative material in dentistry, combining exceptional mechanical and chemical properties that make it an ideal choice for many dental applications. With its properties such as high strength, corrosion resistance, and mechanical flexibility, PEEK is a suitable alternative to traditional materials such as zirconia and metals in many dental prostheses. In addition, PEEK exhibits excellent biocompatibility, minimizing adverse interactions with human tissues, making it a long-lasting and suitable choice for use in complex oral environments.

The clinical applications of PEEK in dentistry are wide-ranging, as it is used in dental implants, bridges, dentures, and dental fillings. It also represents a major advance in improving comfort and performance for patients. With the increasing interest in this material, its uses are expected to increase in the future, contributing to the development of new techniques and methods in the field of dentistry.

Continued research and development in this field will undoubtedly contribute to improving the uses of PEEK and enhancing its usefulness in the field of dentistry, leading to more efficient and safer solutions for patients.

CONFLICT OF INTERESTS

No conflict of interest.

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