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Use of polyetheretheretherketone in dentistry: Literature review

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Abstract
The use of polyetheretherketone (PEEK) in dentistry has gained increasing attention due to its unique properties, including high biocompatibility, fracture resistance, esthetics, radiopacity, and bone-like mechanical properties. Evidence shows that PEEK is a promising material in dentistry and its potential as an alternative to traditional implant and dental prosthesis materials is evident. Although much remains to be investigated in terms of clinical applications and long-term tissue integration of this material, its high biocompatibility and aesthetics are indicative of future success. In this article, a review of the most relevant scientific literature on the use of PEEK in dentistry is carried out and its applications are highlighted, from the manufacture of abutments and restoration scaffolds, dental posts and cores, to the use in dental implants and scaffolds for bone regeneration.

Keywords: polyetheretherketone, implants, titanium, zirconia, biofilm, osseointegration

Introduction
In 2010, 2.3% of the world's population (this percentage being a total of 158 million people worldwide) was partially and totally edentulous, with a peak incidence at 65 years of age [1]. As treatment to this incidence we have a variety of materials to achieve the restoration of the remaining structures of the oral cavity, from dental crowns to periodontal tissues [1]. These materials should mimic the natural characteristics of the structures and be biocompatible with the area to be treated, restoring the configuration, functionality and esthetics [2].
Among these materials of choice is polyetheretheretherketone (PEEK), which is a biocompatible ceramic [3] with an acceptable elastic modulus in its composition for the resistance of occlusal loads, biocompatible and accessible for the creation of implants, with the possibility of modifying its structure with different materials, among them carbon fibers for greater stability [4], which was used for the first time at the end of the 90's in the medical area within the orthopedic and traumatological branches for the creation of splints and hip prosthesis [5] giving positive results for biocompatibility and satisfactory osseointegration within the body [6].
The proposal of PEEK in the dental area started in 2010, and to date PEEK is used in prosthodontics and implantology [7], making it relevant because it presents an elastic deformity of 8.3 Gpa (Gigapascals), corrosion resistant, biocompatible, resistant to hydrolysis, presenting thermal conductivity of .29 W/mK, glass temperature transmission at 143°C, and critaline melting transition at 343°C, thus providing resistance to occlusal loads, stability for attachments and scaffolds for crowns and prosthesis, biocompatible and accessible for the creation of implants [8] with the possibility of modifying its structure with different materials, including carbon fibers for greater stability [9].
The aim of this article is to conduct a narrative literature review of polyetheretheretherketone in dental practice.

Materials and Methods
This narrative literature review was elaborated with the search for the crossing of words such

as “polyetheretherketone”, “implants”, “titanium”, “zirconia”, “biofilm”, “osseointegration” in the English database of PurbMed, Google Academic and Scielo sources.

Background

PEEK provides a unique combination of strength, stiffness and light weight while remaining resistant to corrosion and degradation, which is why it began to be used in the medical field [10, 11]. In addition, PEEK has a thermal expansion rate close to that of bone, which reduces the risk of fractures or damage to the surrounding bone [12].

This polymer has been used in a variety of medical applications, particularly in the manufacture of surgical instruments, fixation devices, implants and prostheses. Studies have demonstrated the efficacy of PEEK in the fabrication of spine implants and knee arthroplasty [13]. One study reported that the rate of bone fusion after surgery was 96% in patients who received a PEEK implant, suggesting that PEEK is a viable alternative to conventional spine implant materials [10].

Another application of PEEK is in the production of customized orthopedic implants. Custom implants made from PEEK have proven useful in the reconstruction of damaged bones or in the correction of bone deformities. These implants have the advantage of adapting to the curvatures and contours of the surrounding bone, which reduces the need for further surgery after implantation [14].

In the field of biomedical engineering, PEEK's modulus of elasticity has also been used to improve the stability of artificial joints. One study used PEEK to fabricate an ankle prosthesis that had a modulus of elasticity closer to that of human cortical bone than conventional metal prostheses [15]. Overall, it has been shown that PEEK's modulus of elasticity makes it ideal for use in medical and dental applications, as it has an elasticity similar to that of human cortical bone and can improve the stability and biocompatibility of implants and prostheses.

PEEK in Dentistry

Applications

PEEK has been used in a variety of applications in dentistry, including.

- **Dental crowns:** Dental crowns made of PEEK are highly resistant and esthetically attractive, making them ideal for dental restorations in the vestibular area.
- **Dental bridges:** PEEK has been used for the fabrication of dental bridges due to its strength and ability to withstand occlusal loads.
- **Dentures:** Partial or complete dentures can be fabricated with PEEK, which can reduce the need for metal in the design and improve esthetics and biocompatibility.
- **Orthodontic devices:** PEEK has also been used in orthodontics as an alternative material to traditional metal brackets and wires.
- **Dental implants:** PEEK has also been studied as a dental implant material due to its biocompatible properties and its ability to chemically bond to the bone surface.

Features

PEEK is considered a high-performance thermoplastic polymer due to its biocompatibility and mechanical strength. Physical characteristics of PEEK include a density of 1.3-1.5 g/cm³, a melting point of 343°C, and a translucent finish [16].

In terms of chemical characteristics, it has excellent resistance to industrial chemicals and solvents, including strong acids and bases [17]. In addition, PEEK is resistant to thermal degradation and hydrolysis, making it suitable for use in oral environments [18]. In terms of mechanical characteristics, PEEK has high impact strength and is extremely stiff, making it ideal for use in dental implants and other devices. PEEK also has a high resistance to fatigue as well as to occlusal loads and excellent vibration absorption capacity, as well as abrasion, making it ideal for dental use [19].

According to a systematic review study, PEEK has been shown to have high biocompatibility and excellent response to mechanical loading, making it ideal for use in dental implants and prostheses [20]. In addition, PEEK has also been used in the fabrication of dental bridges and crowns by computer milling, allowing for better precision and customization of dental solutions [21]. Regarding the mechanical properties of PEEK with those of metals and ceramics in the fabrication of dental implants, it was found that PEEK was comparable in terms of mechanical strength and stiffness, but offered better vibration absorption and higher biocompatibility [20].

Modulus of elasticity

Polyetheretheretherketone, due to its modulus of elasticity of 8.3 Gpa (Gigapascals), is used from aeronautical engineering to medical and dental devices. The modulus of elasticity is an important mechanical property in many of these fields. In particular, for medical and dental applications, the modulus of elasticity is a key characteristic that determines the long-term stability and biocompatibility of the material [22].

PEEK has been shown to have a modulus of elasticity comparable to that of human cortical bone, making it a promising material for use in medical and dental implants. An in vitro study comparing the elasticity of human cortical bone with that of different orthopedic implant materials found that the modulus of elasticity of PEEK was closest to that of bone, resulting in a better choice in terms of biocompatibility than titanium [23].

In addition, in the field of dentistry, PEEK has been found to have mechanical properties that make it ideal for use in dental and orthodontic prosthetics. One study compared the stiffness of a PEEK orthodontic archwire with that of stainless steel and found that the PEEK archwire exhibited similar stiffness to steel, but with a higher deformation capacity [24].

Biomechanics (tensile strength)

PEEK has mechanical and physical properties that make it an ideal material for the fabrication of dental prostheses and implants in dentistry. In a recent study, the biomechanics of PEEK was analyzed in comparison to other materials commonly used in dentistry, such as titanium and ceramics. The study found that PEEK implants have higher strength and lower deformation under repetitive loads compared to titanium and ceramic implants [25].

Another study examined the flexural strength of different materials used in dental prostheses, including PEEK, acrylic and cobalt-chromium. The study found that PEEK showed significantly higher flexural strength compared to the other materials tested, taking into account that it can be reinforced with carbon fibers in its composition [26].

The chemical and physical properties of PEEK make it ideal for the fabrication of customized dental devices, such as dental aligners and orthodontic splints [27].

Biocompatibility

One study looked at the peri-implant tissue response after placement of PEEK implants and found that PEEK is

biocompatible and does not induce inflammation or osteolysis [28]. In addition, another study evaluated the peri-implant connective tissue response to PEEK implants and found that PEEK promoted connective tissue adhesion and cellular response when used as a dental and orthopedic implant material, and it is emphasized that there are various methods to enhance its bioactivity [29].

Several studies have also compared the biological effects of PEEK implants with those of conventional titanium implants in dogs, finding that PEEK implants have no significant inflammatory response [30]. In addition, an in vitro study demonstrated that human bone cells adhere to and propagate on the surface of PEEK, suggesting its potential application in the production of dental implants [31].

Another study compared the cell and tissue response between PEEK implants and other alloy materials such as titanium and zirconia. The results of the study suggest that PEEK promotes greater cell adhesion and exhibits better corrosion resistance in oral environments [32].

Osseointegration

Osseointegration is an essential process for the long-term stability and success of dental implants. PEEK offers excellent biocompatibility and a survival rate comparable to conventional dental implant materials [33].

It has been shown that PEEK can promote osseointegration of dental implants. An in vitro study, using human bone cells, found that bone cells had an increased ability to adhere to and proliferate on the surface of PEEK implants compared to titanium implants [34].

It is also argued that PEEK can improve peri-implant osseointegration, and another study mentions that induced porosity can promote more effective osseointegration [35]. Likewise, one study evaluated the peri-implant connective tissue response to PEEK implants and found that PEEK promoted connective tissue adhesion and cellular response during the osseointegration process [36].

Bacterial adhesion

Several studies have examined the ability of PEEK to resist bacterial adhesion compared to other materials commonly used in dentistry. A systematic review demonstrated that a properly polished PEEK implant can influence the structure of biofilm and reduce the chances of peri-implant inflammation [6]. Another study found that bacterial adhesion to PEEK dental prostheses was significantly lower compared to acrylic prostheses [37].

However, bacterial adhesion to PEEK has been shown to increase when the surface is damaged or roughened, making it important to maintain the PEEK surface in a smooth and undamaged state [38].

Modification of structure and surface (carbon fiber reinforcement, etc.)

A variety of surface and structure modification techniques are currently available to improve the adhesive properties of PEEK, including carbon firb reinforcement, acid etching, plasma treatment, air particle abrasion, laser treatment and adhesive systems.

One way to modify the structure of PEEK is through the use of coating techniques. One study demonstrated that the use of PEEK coatings containing silver nanoparticles can significantly reduce bacterial adhesion on PEEK dental implants [39]. Another study found that the coating of PEEK with calcium sulfate significantly increased cell adhesion to PEEK implants [40].

In addition, it has been shown that the physical and mechanical properties of PEEK can be improved by the addition of certain materials. One study examined the effects of carbon fiber reinforcement (CFR) to PEEK and found that carbon fiber-modified PEEK had higher stiffness and flexural strength compared to unmodified PEEK [41]. Another study found that the addition of glass fiber to PEEK resulted in higher tensile strength and stiffness [42].

PEEK as restoration attachment/scaffold

A study examined the efficacy of PEEK as a restorative material in the reconstruction of central incisors. The results showed that the use of PEEK combined with different filling materials provided a successful and durable treatment both esthetically and functionally [43]. In addition, PEEK is an ideal material for the fabrication of dental posts and cores due to its high strength and stiffness, which allows for better fracture resistance [44].

Another study examined the use of PEEK as a scaffold system for bone regeneration in dental applications. The research showed that PEEK as a scaffold has low cytotoxicity, is highly biocompatible, and that its microporous surface stimulated bone cell adhesion and proliferation [45].

Comparison TI, ZrO, PEEK

It should be kept in mind that polyetheretheretherketone is still considered a material under testing and studies, which still seeks to reach the ideal composition for its daily application in dentistry, specifically in the implantology area, for this reason it is important to mention the properties that this material presents in comparison with its alternatives available today [46].

These materials used in the manufacture of dental implants and prostheses must meet several requirements, such as biocompatibility, fracture resistance, fatigue resistance and long-term stability. Three of the most commonly used materials in dentistry are titanium (Ti), zirconia oxide (ZrO), and polyetheretheretherketone (PEEK) [47].

Titanium is the most commonly used dental implant material due to its superior biocompatibility, strength and durability. However, the metallicity of titanium implants and the risk of corrosion are one of the problems to consider [48].

Zirconium oxide is a highly resistant and esthetic ceramic material that has been increasingly used in dentistry in the last two decades. ZrO has demonstrated high strength and mechanical stability, it also exhibits a very low ionization rate, making it a safe and predictable option for surgery [49].

Finally, polyetheretheretherketone (PEEK) is a thermoplastic material with high biocompatibility that has been used in dentistry for the last few years. The quality of the parts manufactured with PEEK provides excellent visibility in radiographic techniques [6].

In terms of clinical applications, titanium remains the material of choice in the fabrication of dental implants due to its high biocompatibility and strength. ZrO is a good option for patients with visible teeth, due to its esthetics and lack of metallic effects. PEEK may be an option for people with titanium allergy and for those looking for a lighter alternative to titanium implants [50].

For practical terms, the choice of material for dental implants and prostheses depends on the patient's specific needs and esthetic goal. However, titanium remains the most widely used material in dentistry due to its durability, reliability and superior biocompatibility, while zirconium oxide and PEEK

offer a good alternative in specific cases.

Conclusion

The use of polyetheretheretheretherketone in dentistry is a growing research trend due to its unique properties, versatility in handling and high biocompatibility. Studies have shown that PEEK is an ideal material for the fabrication of restorative attachments and scaffolds, dental posts and cores, and as a scaffold for bone regeneration in dental applications. In addition, PEEK dental implants have high biocompatibility, radiolucency and ability to integrate into bone tissue, demonstrating its potential as a material for the fabrication of dental implants.

As we continue to investigate the possibilities of PEEK in dentistry, it is possible that this material could become a viable alternative to traditional dental implant and prosthetic materials. It is important to continue research into the properties of PEEK and its behavior in different clinical applications in order to provide patients with the best treatment options that meet the highest standards in dentistry.

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