REVIEW ARTICLE
ISSN 2645-4351
https://doi.org/10.22037/jds.v43i4.47162

Polyetheretherketone (PEEK) in Dental Implantology: A Systematic Review

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Submitted: 4 January 2025
Revised: 10 May 2025
Accepted: 16 May 2025
Published: Autumn 2025

How to cite:
Jahangiri M, Bakhtiari F, Shayegh SS. Polyetheretherketone (PEEK) in Dental Implantology: A Systematic Review. J Dent Sch 2025;43(4):216-224.

Abstract:

Objective(s): Polyetheretherketone (PEEK) is a thermoplastic, semi-crystalline, aromatic polymer known for its excellent physical, mechanical, and electrical properties. This review has explored PEEK's properties and its diverse applications in the field of implantology. **Methods:** This systematic review was conducted based on the PRISMA guideline. All articles up to 2025 were searched in the PubMed, Google Scholar, Scopus, Springer Link, Science Direct, and Wiley databases using the relevant keywords. Among 170 relevant articles, the abstracts of 49 articles with the highest relevance to the topic were studied, and 25 articles with the highest relevance were selected and reviewed. **Results:** This study categorized the diverse applications of PEEK in implantology as follows: Implant fixtures, Temporary abutments, Permanent abutments, Scan bodies, Temporary implant prostheses, and Healing abutments. While numerous studies suggest that PEEK represents the future of dental materials science, further clinical research is warranted. **Conclusion:** The use of PEEK fixtures can prevent stress shielding due to its closer elastic modulus to the surrounding bone. However, the use of PEEK as an implant fixture faces challenges due to low osseointegration, and the use of surface coating is recommended. The probability of gaps in the abutment and implant margin in PEEK is higher than in titanium. Screw loosening in PEEK abutments is twice that of titanium types. But PEEK can be a good alternative for temporary abutments. Plaque accumulation to coarse PEEK particles is higher and is not recommended as a healing abutment. Due to the lack of light reflection, some believe that the PEEK scan body is more accurate than titanium types; however, studies have shown the opposite. Because PEEK is more flexible than titanium and moves during torque, it reduces the accuracy of the final scan.

Keywords: Prostheses and Implants; Dental Implants; Dental Materials; Biocompatible Materials

Introduction

Polyetheretherketone (PEEK) is a semi-crystalline polymer that also contains aromatic rings in its chemical structure.[1] This polymer was first invented in 1978 by researchers at the British company Imperial Chemical Industries (ICI), and since 1980, it has been used in the aerospace and other industries due to its favorable mechanical properties.[2, 3] Since 1998, the use of PEEK in medical and orthopedic implants has flourished.[4]

Unlike other polymers, this material has very desirable physical and chemical properties, making its use widespread in industry and medical field. These properties include: an elastic modulus of 3.6 GPa, which is close to that of teeth and bone, high resistance to thermal structural change, thermal stability, low weight, and insolubility.[5]

For the use of PEEK in dentistry, a series of changes must be made in its structure to achieve maximum similarity with teeth and bone in terms of elastic modulus and other features. By reinforcing this polymer with various fillers, it is prepared for dental use. Fillers can be made of glass fibers and carbon (GFR-PEEK) or ceramic fillers (CFR-PEEK). CFR-PEEK types, which contain approximately 20% ceramic fillers, show mechanical properties closer to teeth and bone. In this way, CFR-PEEK is the most widely used PEEK polymer in dentistry.[5-7]

Today, PEEK is widely used in dentistry. The applications of PEEK in dentistry are classified into the fields of implantology, tooth restoration, removable and fixed prostheses, maxillofacial surgery, and orthodontics.[8] In this systematic review, the applications of this emerging material in implantology was examined.

Methods

This systematic review was conducted following the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) statement and the PICO(S) approach (Patient or Population, Intervention, Control or Comparison, Outcome, and Study types). The PICO question was formulated as follows: In dental implantology (P), can the use of PEEK (I) be substituted (O) for other routinely used materials (C)?

The search was conducted in Scopus, Science Direct, Web of Science, Cochrane Library, PubMed, and Google Scholar databases using the following keywords:

Biocompatible Materials, Dental Implants, Prosthodontics, Polymers, Dental Implant Abutments, dental biomaterial

The search strategy for this review included three stages, as shown in Figure 1: reviewing the titles, studying abstracts, and finally selecting articles and analyzing the full texts. To find articles relevant to the topic, inclusion and exclusion criteria for the search were defined (Table 1).

The inclusion criteria for the search were: studies published up to February 2025, published in English, which included all or part of the keywords in their title or abstract. The exclusion criteria defined the studies that did not answer the PICO question.

Table 1- Study inclusion and exclusion criteria	
Exclusion criteria	Inclusion criteria
Studies that were not relevant to the PICO question Studies that did not reported applications of PEEK in dental implantology. Studies that did not mention the methods of PEEK manufacturing	Studies in English Studies that answered the PICO question Studies that report applications of PEEK in dental implantology Studies that mention the methods of PEEK manufacturing

Results

Findings:
In the initial search, 746 articles were collected from all databases. After removing duplicates and irrelevant articles based on title and older articles, 170 articles were selected. After reviewing the 170 articles whose titles were related to the keywords, the abstracts of 49 articles were studied. Articles that were not related to the PICO question were excluded from the study, and finally, the full text of 25 articles that met the inclusion criteria were included in the study.[9-33] Information extracted from the studies is summarized in Table 2.

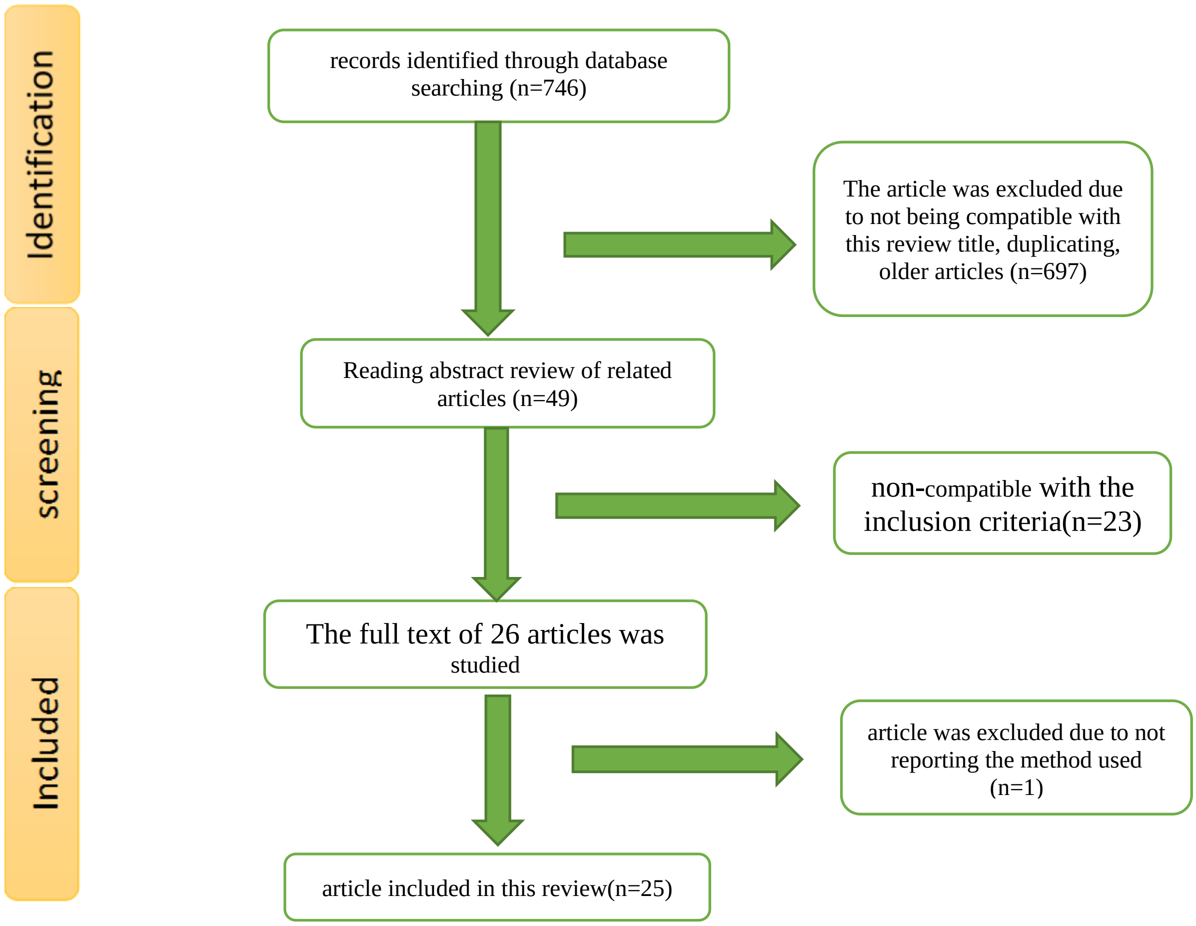

Figure 1: Search strategy diagram

Table 2 - Description of the articles included in the study				
Classification	**Applications in detail**	**year**	**authors**	**results**
PEEK in Implantology	Fixture	2020	Alotaibi et al.	The amount of osseointegration and BIC in Pure PEEK implants is almost half of titanium implants.
		2010	Koch et al.	The amount of osseointegration and BIC in Pure PEEK implants is almost half of titanium implants.
		2012	Webster et al.	Less osseointegration of PEEK implants is due to less antibacterial properties of this material.
		2013	Zhao et al	Review of Different Coating Methods for PEEK Implants
		2014	Wang et al	Review of Different Coating Methods for PEEK Implants
	Abutment	2022	Ortega-Martínez et al.	It reports the amount of screw loosening of titanium abutments

Table 2 - Description of the articles included in the study

				under mechanical stress of 10% and in PEEK abutments over 50%.
		2022	Matos et al.	Non-titanium abutments are less resistant to mechanical forces than titanium ones.
		2021	Blanch-Martínez et al.	Due to the elastic modulus similar to bone, these materials have a good resistance to fracture and provide the possibility of distributing tensile forces and stretching to the tissues around the implant during chewing.
		2013	Stawarczyk et al.	The use of PEEK as a permanent abutment is not recommended due to disadvantages such as less compatibility with the connection and plaque accumulation, peri-implantitis, less resistance against very strong mechanical forces above 680 Newtons.
		2016	Najeeb et al.	
		2023	Wiessner et al	Plaque accumulation around PEEK abutments is higher than around other types of abutments.
	Healing abutment	2017	Rea et al.	It showed the most bone and soft tissue resorption around PEEK healing abutments with titanium base, and the least resorption was reported for titanium abutments healing.
		2023	Hung et al.	This study showed that the microbial accumulation in PEEK types is similar to titanium, but the effect of disinfectants on PEEK is more significant and reduces red complexes.
	Provisional implant prosthesis	2016	Zoidis et al.	This article introduced the possibility of debonding of PEEK due to the elastic modulus close to the tooth of this material and the reduction of shear stresses in the bonding area, compared to metal types.
	Provisional implant abutment	2022	Supangul et al	The light color of PEEK provides greater aesthetics compared to titanium types and does not pose a problem in MRI imaging.
		2012	Santing et al	In the anterior region, it had strength comparable to titanium types.
		2014	Agustin-Panaderp et al	It is less strong than other types of temporary titanium abutments.
		2021	Abhay et al	The strength of PEEK is increased by adding filler.
	Scan body	2023	Althubaitiy et al	PEEK scan bodies have higher accuracy.
		2024	Tawfik et al	PEEK scan bodies have lower accuracy than titanium.
		2021	Lee et al	PEEK scan bodies have lower accuracy than titanium.

Review of Study Findings

The articles included in this study were evaluated, categorized by topic.[9-33] The articles were reviewed in six general categories: the use of PEEK as an implant fixture, permanent abutment, temporary abutment, healing abutment, temporary prosthesis, and scan body.

1) Implant Fixture

Today, the use of titanium implants has become very widespread due to their ability to osseointegrate, high durability, and good mechanical properties.[9] However, there are disadvantages such as the higher elastic modulus of implants compared to bone, marginal bone destruction and peri-implantitis, sensitivity to titanium, interference with MRI or CT images, and aesthetic problems.[10] Therefore, researchers are constantly looking for alternatives to titanium with better properties. PEEK is one of the materials that can be a suitable alternative to titanium implants.[10]

The important issue in the use of PEEK dental and orthopedic implants is osseointegration. The amount of osseointegration and Bone Implant contact (BIC) in Pure PEEK implants is approximately half that of titanium implants.[9, 11] Webster et al. attributed the lower osseointegration of PEEK implants to the lower antibacterial properties of this material.[12] The proposed solution to increase the osseointegration capability of PEEK implants is surface treatment. Various articles propose different surface treatments. These surface treatments are summarized in Figure 2.[9]

Surface coatings of implant fixtures can create antibacterial properties and increase the success of osseointegration.[13] One of these methods is plasma spraying. In this method, the implant surface is sprayed with osteoactive hydroxyapatite. This method is performed with the aid of a plasma torch, melting and placing the coating particles on the implant surface.[34] The high temperature generated in this method damages the semi-crystalline structure of PEEK and is not a suitable option.[35] In the plasma-gas method, bioactive materials in nano size are placed on the implant fixture surface with the aid of a low-pressure gas.[7]

A desirable method to increase the bioactivity of PEEK implants is to create changes in the material's composition. This method is called Bioactive PEEK nanocomposites. In this method, nano-hydroxyapatite fillers are added to PEEK to improve its properties.[29]

In chemical preparation, the PEEK fixture surface is etched with sulfuric acid and after washing with distilled water, it is ready to use. This methodincreases the bioactivity of the PEEK fixture by increasing the surface tension.[30]

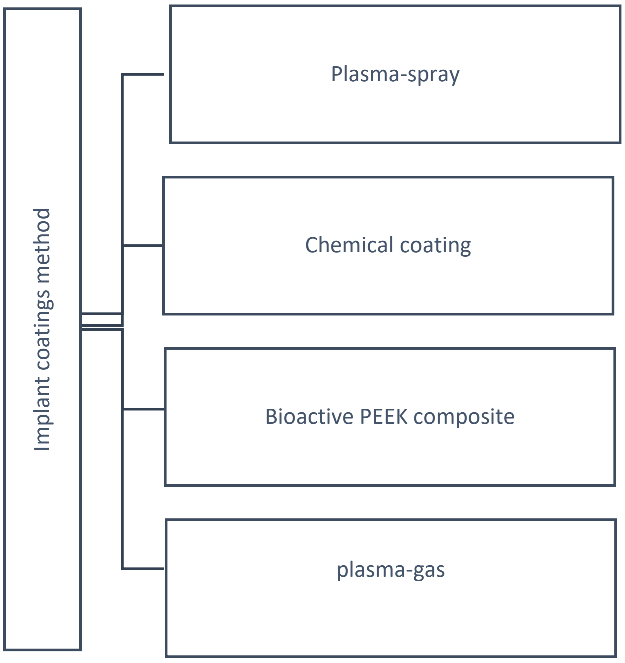

Figure 2: Types of surface preparation methods for PEEK implants

2) Permanent Abutment

The greatest advantage of PEEK is its elastic modulus of 3.6 GPa, which is similar to bone.[13] Moreover, this material is very resistant to temperature increases. The major disadvantage of PEEK is its low osseointegration capability. Considering these issues, the use of PEEK as an implant fixture requires further investigation, but this useful material can be used in other implant components such as abutments.[14]

The study by Ortega-Martínez et al. evaluated screw loosening and microleakage in PEEK and titanium abutments. This in vitro study reported the amount of screw loosening in titanium abutments under 10% and in PEEK abutments above 50%. Therefore, the amount of microleakage in PEEK abutments was much higher than in titanium types.[14]

Matos et al. investigated the effect of mechanical forces on the internal connection and Morse taper of 4 and 5.5 mm PEEK abutments. This study showed greater stress in the crestal area of the 5.5 mm PEEK fixture and abutment compared to the 4 mm types (Figure 3).[15] Thus, non-titanium abutments have less resistance to mechanical forces compared to titanium types.[15] But they show better compatibility with the internal connection of the fixture than other non-titanium materials.[16, 17]

Due to the elastic modulus similar to bone, PEEK materials have good resistance to fracture and allow the distribution of tensile and compressive forces to the tissues around the implant during chewing.[16] The use of PEEK as a permanent abutment is not recommended due to disadvantages such as lower adaptation to the connection and plaque accumulation, peri-implantitis, and lower resistance to very high mechanical forces above 680 Newtons.[18, 19] Due to good resistance to moderate forces, PEEK can be used as a temporary abutment in the anterior regions and in patients who do not have parafunctional habits.[15] In addition, high plaque accumulation around the PEEK abutment, compared to zirconia and titanium, makes its use as a permanent abutment inappropriate.[28]

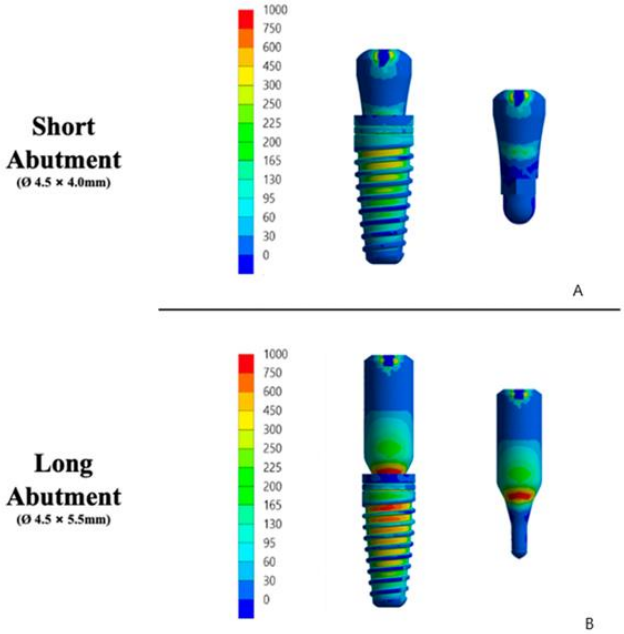

Figure 3: Stress in the crystal region of long PEEK abutments is higher compared to shorter ones.

3) Temporary Abutments

PEEK polymer has very good mechanical, biological, and chemical properties.[7, 27] This material is thermoplastic and due to its low elastic modulus, is more flexible than other materials. However, the hardness of PEEK is adjustable by adding carbon.[25] In addition, PEEK causes less sensitivity for the patient, is more esthetic due to its color, and does not cause problems in MRI.[27]

A study in 2012 compared PEEK as a temporary abutment with a titanium abutment. In this study, the abutments were in the maxillary central areas. This study showed no difference between the strength of the two abutments.[26] However, an in vitro study in 2015 reported the weakest strength and mechanical results for the PEEK abutment.[24] By summarizing the results, the use of the PEEK abutment in aesthetic areas and as a temporary abutment can be considered permissible. Although in areas that are under severe stress, PEEK is better to be the last choice.

4) Healing Abutments

In an animal study by Rea et al., 16 implants were placed in four dogs, and four types of healing abutments were used:

titanium, PEEK with a titanium base, pure PEEK, and PEEK textured with a bur. After four months, the placement areas of the implant fixture and healing abutment were examined. This study showed the highest bone and soft tissue loss around PEEK healing abutments with a titanium base. The pure PEEK and burred PEEK types did not show a significant difference and showed lower loss. The least amount of loss was reported for titanium healing abutments. The reason for this greater loss in the types with titanium base can be attributed to the accumulation of food particles and microorganisms at the junction of titanium and PEEK. This study stated that if a non-titanium healing abutment is used, it is better to use pure PEEK types instead of PEEK with titanium base (Figures 4,5).[20]

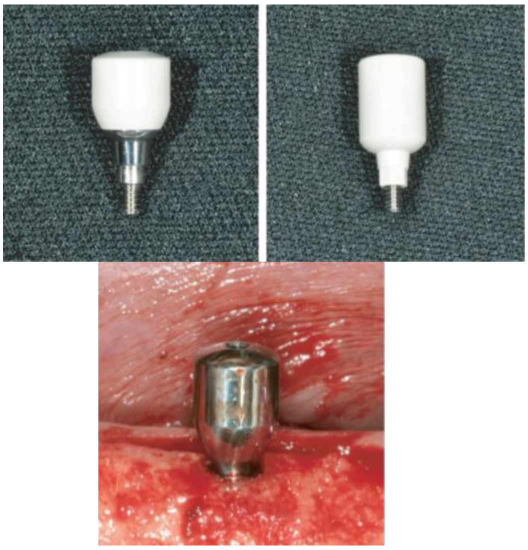

Figure 4: Titanium, Pure PEEK, PEEK with titanium base healing abutments

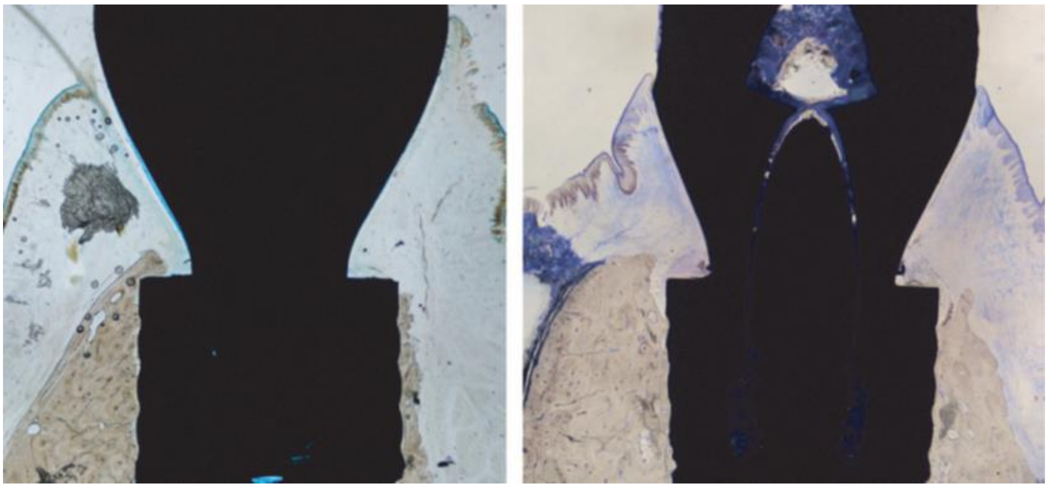

Figure 5: The amount of bone loss around PEEK and titanium healing abutment

An in vitro study by Hung et al. compared the accumulation of microorganisms around titanium and PEEK healing abutments. In this study, Ti (N=35) and PEEK (N=35) healing abutments were evaluated in vitro for initial adhesion (one hour) or biofilm accumulation (48 hours) of Candida albicans and other microbes using stimulated human saliva. This study showed that both PEEK and Ti healing abutments have similar fungal adhesion. After 48 hours of biofilm accumulation, the microbial load was similar. Er:YAG laser disinfection was more effective on PEEK surfaces than Ti surfaces and reduced microbial accumulation by approximately 11 times. This study showed that microbial accumulation in PEEK types is similar to titanium, but the effect of disinfectants on PEEK is greater and reduces Red complex bacteria.[21]

5) Temporary Implant Prostheses

During the period required for implant osseointegration, maintaining the patient's aesthetics is essential. This is achieved with the help of temporary prostheses. These prostheses come in various types and can be made using different materials. One of the most common methods is the use of resin-bonded bridges.[22]

Zoidis et al. suggested the use of PEEK resin-bonded bridges as a framework with Gradia laboratory composite veneer for temporary prostheses. To increase the composite bonding, Visio.link (Bredent GmbH) bond and Panavia21 self-cure cement were used. The study introduced the probability of PEEK debonding as lower than metal types due to the closer elastic modulus of this material to the tooth and the reduction of shear stresses at the bonding site.[23]

6) Scan Bodies

One of the factors that greatly affects the accuracy of digital implant impressions is scan bodies.[36] Scan bodies are scannable components that accurately transmit information such as the angle and location of the implant to the laboratory.[37] 3i Biomet introduced the first implant scan body component, the Bellatek Encode, in 2004.[37] The initial goal of introducing this scannable healing abutment was to eliminate all conventional steps and determine the location of the implant and the distance from adjacent teeth with the help of scanners.[38] After that, various companies introduced different types of scan bodies.[39, 40]

Scan bodies consist of three main parts: the scannable part, the body, and the base.[41] To increase accuracy, the scannable part should preferably not have a symmetrical shape. The body of the scan body is the boundary between the scannable part and the base. The base of the scan bodies has anti-rotation components such as hex and Morse taper. This section has the most important function in the accurate connection of the scan body to the fixture, and multiple sterilization processes can lead to stripping of the anti-rotation and reduce the accuracy of the scan body's seating on the fixture and consequently errors in transmitting the exact location of the fixture to the laboratory.[37] The scannable part can have different shapes in terms of material, height, and size.[39]

Althubaitiy et al. compared scan bodies with two materials, PEEK and titanium. The study showed higher accuracy of PEEK scan bodies.[31] Contrary to them, in 2024, Tawfik et al. reported higher accuracy of titanium scan bodies compared to PEEK types.[32] Similarly, the study by Lee et al. in 2022 showed higher accuracy of titanium scan bodies.[33]

Discussion

Since the introduction of implants by Branemark and before the advancement of dental material science, titanium was the only material of choice for manufacturing various implant-related products.[42] The characteristic that made titanium special for implants and osseointegration was its good strength, high stress resistance, biocompatibility, and lack of tendency to react with other elements and corrosion. However, since titanium is a metal, its elastic modulus was approximately ten times that of teeth and bone.[43]

Now the question arises: why is the difference in elastic modulus important? This difference in elastic modulus causes stress concentration and creates an effect called stress shielding.[44] In this phenomenon, the difference in elastic modulus causes stress to accumulate in the area with high elastic modulus and prevents stress from being applied to the surrounding tissues. As a result, bone remodeling around the implant is disrupted, and the surrounding marginal bone around the implant fixture gradually resorbs.[45] With marginal bone resorption exceeding the normal amount (1-2 mm in the first year and less than 0.2 mm annually) [46], the implant gradually fails.[47]

Due to the importance of this issue and the advancement of dental material science, PEEK was introduced. PEEK is a semi-crystalline polymer that has an elastic modulus similar to bone and teeth.[48] The special feature that distinguishes PEEK from other polymers is its high resistance to thermal structural change, thermal stability, low weight, and insolubility.[48, 49] In addition to these desirable properties, there is no possibility of allergy to PEEK, and its light color makes it better than titanium types for aesthetic purposes.[49, 50]

Considering these beneficial properties, studies were conducted to investigate various PEEK fixtures.[9-11, 51] Studies have shown that the osseointegration property in PEEK polymer implants is approximately half that of titanium.[11] The reason for this is the low bioactivity of the polymer implant surface.[11] Bioactivity is defined as the ability to stimulate and react with adjacent living tissue and bone.[52] For creating bioactivity, several methods exist, such as plasma spraying, gas spraying, chemical coating with the help of sulfonic acid, and the bioactive composite technique.[9, 29, 34, 35, 52] Among these methods, the bioactive composite technique is preferred over others for increasing the bioactivity of the PEEK implant.[29] In this method, a series of changes are created in the structure of PEEK. By reinforcing this polymer with various fillers, its antibacterial and bioactivity properties are increased. The fillers can be made of glass fibers and carbon (GFR-PEEK) or ceramic fillers (CFR-PEEK). CFR-PEEK types, which contain approximately 20% ceramic filler, are the most widely used PEEK polymer in dentistry.[5-7]

The use of PEEK in implantology is not limited to the fixture; it is also used for prosthetic components and abutments.[14] The probability of screw loosening in the PEEK abutment is much higher than in titanium types.[14] The internal connection in the PEEK abutment is less than in titanium types. This issue leads to plaque accumulation and increases the risk of marginal bone resorption.[16, 17] In addition, due to the inherent roughness of PEEK, plaque accumulation increases and can cause peri-implantitis.[28] By summarizing various articles, it seems that PEEK is acceptable as a temporary abutment, but there are many ambiguities as a permanent abutment.

PEEK can also be used in the construction of scan bodies. PEEK scan bodies reflect less light, and from this point of view, the general belief is that they should increase scan accuracy.[31] However, another group of studies reported higher accuracy of titanium scan bodies. These studies attribute the higher stability and strength of titanium scan bodies as the main reason for this higher accuracy. In fact, they believe that since PEEK is flexible, it moves more with increasing torque and negatively affects the final accuracy.[32, 33]

Due to the inherent microscopic roughness of PEEK, the tendency for plaque accumulation is high in this material.[28] This issue leads to plaque accumulation, making it inappropriate to be used as a healing abutment. An animal study has also confirmed this issue. As a result, titanium healing abutments are preferred over PEEK types.[20]

The aim of this study was to review the various applications of PEEK in the field of dental implantology. For this purpose, different implant components made with PEEK were examined. By summarizing what was reviewed in this study, it seems that the use of PEEK as a scan body and temporary abutment is generally acceptable, although it is not recommended as a permanent abutment and healing abutment. Therefore, the use of PEEK fixtures requires more clinical studies and improved surface coating to increase bioactivity and osseointegration.

Conclusion

1. The use of PEEK as an implant fixture is challenged by low osseointegration, and the use of surface coating is recommended.
2. Different PEEK coating methods include spray-plasma, gas-spray, chemical coat, and bioactive composite.
3. Among the various surface coating methods, bioactive composite PEEK is preferred.
4. Screw loosening in PEEK abutments is twice that of titanium types, but PEEK can be a good alternative for temporary abutments.
5. The probability of gaps in the abutment and implant margin in PEEK is higher than in titanium. This incomplete seating increases the likelihood of food impaction and subsequent marginal bone loss.
6. Plaque accumulation to coarse PEEK particles is higher, and is not recommended as a healing abutment.
7. Due to the lack of light reflection, some believe that the PEEK scan body is more accurate than titanium types. However, studies have shown the opposite. Because PEEK is more flexible than titanium and moves during torque, reducing the accuracy of the final scan.

Acknowledgement: The authors declare no acknowledgements.

Author Contributions: M.J.: Conceptualization, Methodology, Investigation, Writing – Original Draft; F.B.: Validation, Formal Analysis; S.S.S.: Review & Editing, Visualization, Supervision, Project Administration.

Funding: No funding was received for this research.

Ethical Approval Code: This study is a systematic review.

Informed Consent Statement: Not applicable.

Data Availability Statement: No new data were created or analyzed in this study.

Using AI: No generative AI was used in the preparation of this manuscript.

Conflict of Interest: The authors declare no conflict of interest.

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