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# The Use of PEEK in Implantology: A Narrative Review

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**ABSTRACT**

**Purpose: The present paper reviewed the literature on PEEK and its applications in implant dentistry. Materials and Methods: *In vivo* in human and animal models, *in vitro* studies, case reports and cases series that evaluated the use of PEEK in implantology were included in this narrative review. Results: There are ever more studies on the best way to apply PEEK in implant dentistry. The mechanical properties of PEEK, which are close to that of bone tissue, are its strength. However, its low osteointegration capacity and surface bio-inertness have limited its clinical translation. PEEK cannot be used as a dental implant. However, some studies have shown that this material could be used for guided bone regeneration; implant abutments for interim restorations, impression devices, or a crown framework. Conclusion: Further research, including *in vivo* and clinical studies, is needed to determine the feasibility, long-term performance and appropriate indication for this biomaterial.**

**Keywords:** Polyetheretherketone (PEEK), dental implants, biomaterials, dental applications

## INTRODUCTION

In 1978, the development of a semi-crystalline, colourless organic thermoplastic polymer called polyetheretherketone (PEEK) was recognized as a useful material in aeronautics. Following the confirmation of its biocompatibility, PEEK began to be used as a biomaterial in orthopaedics and trauma, among others.[1]

Given the rapid advances in computer-aided design and computer-aided manufacturing (CAD-CAM) technology, PEEK was introduced to dentistry for manufacturing fixed dental prostheses,[2–4] removable dental prostheses,[5] resin-bonded fixed dental prostheses[6] and occlusal splints.[7] Later, its use was extended to dental implantology.

The elastic modulus of titanium and zirconia measures some 110 and 210 GPa, respectively, which is 5-14 times higher than compact bone (15 GPa). The gradient difference between the elastic modulus of a titanium implant and the surrounding bone may cause stress in the implant-bone interface during load transfer, resulting in peri-implant bone loss.[8] In addition, pre-clinical *in vivo* studies have indicated that titanium can release metal ions, contributing to local allergic reactions, which might be a potential factor in dental implant failures that are often misdiagnosed.[9,10] Moreover, titanium may pose an aesthetic risk to patients with a high smile line, particularly in cases of a thin gingival biotype and/or gingival recession.[11] Such drawbacks to titanium have led researchers to consider PEEK for use in implant dentistry.

However, the greatest challenge of using PEEK as an implant substrate stems from its bio-inertness. Many *in vitro* studies have shown that unmodified PEEK is inherently hydrophobic, with a water-contact angle of 80–90°, which decreases the proliferation rate of the surrounding cells. A comparative study on titanium, PEEK and zirconia implants has demonstrated that PEEK has the lowest bone implant contact (BIC), compromising osseointegration.[12] Accordingly, the techniques employed to enhance the bioactivity of this material include surface coating and surface treatment, or a combination of the two.[13] These treatments were able to successfully modify the roughness and wettability of PEEK and had a positive influence on the BIC.[14]

PEEK is also used for peri-implant soft tissue integration, also known as mucointegration.[15,16] The formation of an early and durable soft tissue barrier appears crucial for initial healing and long-term implant survival. Consequently, PEEK was later introduced as a supragingival component, either as a healing abutment, a provisional crown or even a definitive prosthetic restoration.

Despite the many applicable and attractive properties of PEEK, its use in implantology remains limited and controversial. Therefore, the aim of this narrative review was to focus on the properties of PEEK and its multiple uses in implant dentistry.

## MATERIALS AND METHODS

### Search strategies

An online search of the literature was conducted in three academic databases (Medline/Pubmed, Cochrane Library, and Web of Science). In addition, a handsearching was performed in journals on implantology and prosthodontics.

Four mesh terms and their combinations were used as basic concepts in the search strategy: (((Ketones [Mesh Terms]) OR Polyethylene Glycols [Mesh Terms])) AND ((Dental Abutments) OR Dental Implants)

Inclusion criteria were papers related to PEEK and its applications in dental implants published only in English between 2015 and January 2021. There were no restrictions on the study design; thus, all clinical, experimental, and animal studies were included. Papers not related to PEEK and their applications in implants or implant prosthodontics were excluded. The search was performed on 22th October 2020.

### Data extraction

Data on the author, publication year, study design, objective, summary and results were retrieved from the abstracts and titles of the selected papers.

## RESULTS

As illustrated Figure 1, the initial search of the literature yielded 129 papers related to the aim of the present study. Hand searches of the leading implantology journals returned 10 additional studies. Finally, screening of the abstracts produced 49 papers. Fourteen papers were excluded for several reasons: 4 were not in English; 6 were unavailable in full-text version through the library of the university; and 4 had an unclear methodology description. Thus, the final sample of the present narrative review comprised 35 papers (Supplemental material).

## DISCUSSION

PEEK was first recognized as a potential material for dental implants due to its elastic modulus similar to that of bone, which avoids high-stress peaks during load transfer at the bone-implant interface.[17] Accordingly, many authors[17,18] were able to adjust the mechanical properties of PEEK to bone tissue by adding multiple reinforcements to its matrix, such as carbon fibre.

Finite element analysis (FEA) studies, on this type of carbon fibre reinforced PEEK (CFR-PEEK), have reported conflicting results.[8,19,20] Although orthopaedists are convinced by the results of CFR-PEEK polymers, in terms of their distribution of constraints within a bone-implant complex,[19] these findings have still not been unanimously accepted in dental research.[8,21]

One study that used a combination of a CFR-PEEK implant reinforced with 60% carbon fibre to increase its strength showed results similar to that of a titanium implant in terms of stress distribution; thus, 45% carbon fibre may be considered an adequate amount.[20] Further investigations are required to confirm this and include a more complex setup to better understand the load distribution of a PEEK implant.

Bataineh et al.[22] used three-dimensional (3D) models of dental implants designed from a computed tomography scan to study the stress distribution in peri-implant bone of two different implant materials: carbon fibre reinforced PEEK (CFR-PEEK) and titanium (Ti6AL4V-ELI). The FEA results found no significant difference in the stress distribution pattern at the implant-bone interface among the models studied.

While PEEK and CFR-PEEK have good mechanical properties, their surfaces are bioinert, which has limited their clinical translation. Some studies have reported minimal osteoblast differentiation and a lack of osteoconductive properties.[23] Consequently, various modifications have been proposed to enhance the bioactivity and osseointegration of PEEK implants, including physical blending, chemical treatment and surface coating.[9,23,24]

Some studies[23] have demonstrated that sandblasting improves the osseointegration of PEEK. For example, El Awadly et al.[9] compared the osseo-integrative behaviour of untreated (UCFP) and sandblasted ceramic filled PEEK (SCFP) implants to titanium implants by measuring bone implant contact (BIC) and bone density (BD). Their study showed that the BIC and BD were significantly higher in titanium and SCFP than with UCFP.

Many advances in surface modifications for PEEK-based implants have been made to improve their osseointegration. However, while the surface treatments have shown adequate results, they need to be evaluated over a longer period.

In their *in vitro* study on the mechanical and functional properties of PEEK implant abutments and those made of titanium, Ortega-Martinez et al.[25] reported that titanium implant abutments performed better in all mechanical tests, and their torque loss was approximately 10%, versus 50% for PEEK.

Regarding biofilm formation, Hanel et al.[26] found that implant abutment surfaces made of PEEK and polymethylmethacrylate (PMMA) had a lower surface roughness than those made of titanium and zirconia. Moreover, biofilm formation on PEEK was equal to or lowers than on zirconia and titanium abutment surface materials.

To summarize, few studies have clinically evaluated PEEK abutments; therefore, further clinical trials are needed to assess the hard and soft tissue responses to PEEK and its low rate of biofilm formation.

In a comparative study on soft tissue response to closure caps made of PEEK and of titanium, Caballé-Serrano et al.[27] observed significantly higher numbers of multinucleated giant cells on the PEEK closure caps.

Rea et al.,[28] in 4-month comparative study on soft and hard tissue healing around titanium and PEEK healing implant abutments in animals observed a higher resorption of buccal bone crest in PEEK bonded to titanium base abutments, showing that PEEK is viable as healing abutments over titanium implants. Therefore, it would also be relevant to test the behaviour of PEEK abutments over ceramic or PEEK dental implants.

In a study on retention and internal adaptation of different implant-supported frameworks fabricated from zirconia, PEEK, or composite, Ghodsi et al.[29] demonstrated that zirconia had significantly better marginal/internal adaptation than the other materials. In addition, no statistically significant difference was found in the mean retention force across the three groups of materials.

Cabello-Domínguez et al.,[30] in a case report, reviewed the rationale of combining different restorative materials to restore a completely edentulous patient with a zirconia framework and a facial ceramic veneer placed in the maxillary arch, and a modified polyetheretherketone (PEEK) framework with gingival composite resin and cemented lithium disilicate crowns in the mandibular arch. The authors based their choice on the fact that the PEEK framework was lighter and had less flexural strength than the antagonist zirconia prosthesis, which may lead to fewer mechanical complications. However, the cost of the prosthesis was higher than metal ceramic or metal acrylic resin restorations.

However, the results of a prospective cohort study[31] on thirty-seven patients rehabilitated with a full-arch hybrid PEEK-acrylic resin prosthesis supported by implants through the all-on-four concept found veneer-adhesion-related complications in six patients. Other mechanical complications included prosthetic screw loosening and fracture of the acrylic resin teeth.

These studies suggest that PEEK is a viable option, but clinical trials are needed to evaluate different combinations of PEEK with other materials over time.

Various methods have been described to reconstruct bone defects to facilitate implant placement. For example, in a randomized clinical trial, Mounir et al.[32] assessed three-dimensional (3D) maxillary ridge augmentation, where a test group received patient-specific polyetheretherketone meshes and a control group a mix of particulate autogenous and xenogenic bone grafts loaded in a titanium mesh. The study reported no statistical significance between the amounts of 3D bone gain in the two groups, concluding that PEEK meshes can be used for guided bone regeneration.

In a randomized controlled trial to evaluate the influence of implant scan body (ISB) material, position and operator on the accuracy of a confocal microscopy intraoral scanning (IOS) for complete-arch implant impression, Arcuri et al.[33] demonstrated that the IOS was influenced by the ISB material with PEEK, which yielded the best results, followed by titanium and peek-titanium respectively.

In a case report, Yue et al.[34] enabled a common path of insertion for an overdenture using prefabricated angulated abutments and PEEK inserts, which decreased insert wear in the attachment housings.

Similarly, a comparative study by Abdraboh et al.[35] showed that a PEEK attachment housing of a milled bar might offer an alternative to conventional metal housings for inclined implants supporting mandibular overdentures. Indeed, this combination was associated with favourable clinical, prosthetic, and patient-based outcomes.

While PEEK has proven itself in orthopaedic surgery, it has only recently been applied in dental surgery. Moreover, biocompatibility, biomechanics and aesthetic considerations make implantology hugely demanding.

## CONCLUSIONS

According to the present narrative review, the advantages of PEEK are its mechanical properties, which are similar to those of bone tissue, but its low osteointegration capacity and surface bioinertness has primarily limited its application in dentistry. Consequently, despite research on different surface modification protocols, the results remain inconclusive. Hence, PEEK cannot be used as a dental implant at present.

However, some studies have shown that PEEK could be used as a material for guided bone regeneration through virtually designed PEEK sheets, although further studies on larger samples and with control groups are needed.

Compared with titanium abutments, most studies have shown that the use of PEEK as an implant abutment significantly lowers mechanical fatigue resistance and increases higher torque loss and microleakage. Hence, definitive PEEK abutments are currently less reliable, although they might be suitable for interim restorations, principally in the anterior area in patients and those without parafunction.

PEEK as a scan body for impressions could be a valid option in terms of accuracy, but further studies are needed to confirm this.

PEEK as a crown framework has shown favourable results, but clinical trials are needed to evaluate the performance of different combinations over time.

The widespread adoption of a new material is a slow, challenging and rigorous process. Moreover, most of the studies on the use of PEEK in implantology are experimental, and the results must be extrapolated with care. Hence, further research, including in vivo and clinical studies, is needed to determine the feasibility of PEEK, find ways to improve its biomechanical and clinical behaviour and determine the appropriate indication for this hugely potential biomaterial.

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## FIGURES

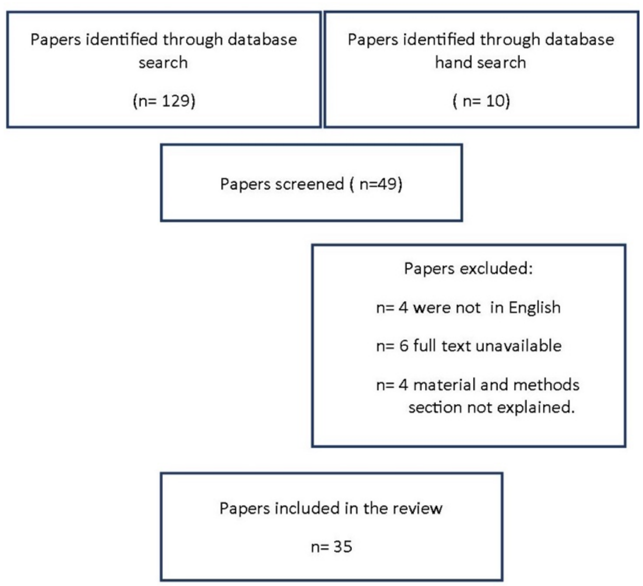


**Figure 1. Flowchart of selection process**