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Can Poly-Ether-Ether-Ketone (PEEK) Perform as Orthodontic Mini-Screws? A Review Article

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Abstract

Background: Orthodontic mini-screws (OMSs), also known as temporary anchorage devices (TADs), are essential for managing complex malocclusions. However, the use of traditional materials, such as titanium and stainless steel, has restrictions that include stress shielding, aesthetic limitations, and incompatibility with various imaging modalities. Poly-ether-ether-ketone (PEEK), a biocompatible thermoplastic polymer, possesses mechanical properties close to that of bone and therefore presents an excellent alternative.

Objective: To assess the suitability of PEEK as a material for OMSs, outline benefits of PEEK compared with metallic counterparts, and identify gaps in current research.

Methods: An existing literature search was performed, utilizing internet sources, such as Google Scholar and PubMed, focusing on properties, dental and orthodontic applications of PEEK.

Conclusion: PEEK's favorable biomechanical compatibility, radiological advantage, and existing success in other dental applications make it a potential candidate for OMSs. However, there is a remarkable lack in studying the possibility of PEEK based OMSs. Further research is needed to confirm their performance trends, optimize design parameters, and set guidelines for incorporation in the field of orthodontics.

Introduction:

Malocclusion is one of the most common oral conditions marked by malalignment of the teeth and is considered a major concern for oral hygiene and dental health (1). Extra-oral anchorage devices were widely used in complex malocclusion treatment, but they still depend on patient cooperation, while intra-oral anchorage devices (such as transpalatal arch) eliminate the need for patient compliance, but they are insufficient for absolute anchorage (2). Orthodontic mini-screws (OMSs) are relatively new devices which supply stable anchorage without the need of patient compliance (3). Poly-ether-ether-ketone (PEEK) has been suggested for OMSs due to its biocompatibility and Young's modulus which is closer to bone which may lead to reducing the stress shielding phenomenon. A new finite element analysis study showed an acceptable PEEK mini-screw performance in comparison with titanium controls (4). Although PEEK based dental implants have inferior osseointegration in comparison to conventional materials, this is not necessarily a drawback in case of OMSs since they are used temporarily (5). However, there is a complete lack in literature of actual fabrication of PEEK based OMSs.

Methodology

This review aimed to summarize and analyze existing evidence on the mechanical, biological, and clinical performance of PEEK in orthodontic applications, and to compare its potential with conventional metallic materials. A comprehensive electronic search was carried out using PubMed, Scopus, Web of Science, and Google Scholar databases, covering publications from January 2000 to September 2025. The search employed various combinations of the terms "polyetheretherketone," "PEEK," "orthodontic," "mini-screw," "temporary anchorage device," "TAD," "biocompatibility," "osseointegration," "mechanical properties," "retainer," and "surface modification", refined with the Boolean operators AND and OR. Studies were included if they examined PEEK or PEEK-based composites in orthodontic or dental applications and reported relevant mechanical, biological, or clinical outcomes. Articles focusing on unrelated polymers, case reports without quantitative data, or non-English publications were excluded. Additional references were identified through manual screening of the bibliographies of included papers. Due to variability in study designs and objectives, a narrative synthesis was adopted rather than a quantitative meta-analysis. The collected literature was categorized into three main domains—mechanical properties, biological performance, and orthodontic and dental applications. Following the selection process, the reviewed studies were analyzed and discussed under key themes, including the evolution of orthodontic anchorage systems, design considerations of mini-screws, and the material and biological characteristics of PEEK, as summarized in the following sections.

Orthodontic anchorage

Orthodontic anchorage is an important factor in orthodontic treatment, allowing for the optimal guiding of teeth into desired positions with minimal displacement of structures in the vicinity (6). That is key to the effective prioritization and management of treatment, and it can be described with reference to Newton's Third Law of motion (7, 8). Traditionally, orthodontists have controlled anchorage with teeth, intraoral devices, and extraoral devices, but these methods often do not allow for genuine 3D control of the tooth. However, recent developments of anchorage techniques either by using temporary anchorage devices (TADs) or OMS techniques had provided some degree of absolute anchorage and better treatment outcomes (9).

Classification of anchorage

Orthodontic anchorage can be classified by therapeutic demands into four classes; Class A (maximum anchorage), where anchorage loss must be minimized to protect the anchor segment; Class B (moderate anchorage), involving reciprocal movement between active segment and anchorage segment; Class C (minimum anchorage), where significant anchorage loss is knowingly permitted to aid with space closure; and Class D (absolute anchorage), which blocks any movement of the anchor unit, maintaining 100% extraction space integrity. Temporary anchorage devices act by either; direct anchorage (anchored directly to the tooth being moved) or indirect anchorage (associated teeth linked mechanically to a TAD-stabilized skeletal unit for controlled movement) (10).

Orthodontic mini-screws

Since these mini-screws are used as orthodontic anchorage, they are referred to as TADs (temporary anchorage devices). Mini-screws are regarded as absolute anchorage, minimally invasive, safe, well-tolerated, and cost-effective. Available studies regarding the mini-screw dictate that its success is affected by initial stability, cortical bone thickness, insertion method, loading forces, design, and proximity to the root (11).

Parts of OMSs

Mini-screws, used in orthodontics, consist of several key components that influence their functionality and clinical performance. The head varies in design, including cross-cut, hole, hook, mushroom, bracket, and others, each serving specific purposes. Cross-cut heads, common in surgical screws, are bulky for orthodontic use, while hole heads allow attachments but show patient discomfort and structural weakness. Hook heads facilitate elastic placement but may cause tissue irritation if misaligned. Mushroom heads are compact and patient-friendly, whereas bracket heads mimic orthodontic brackets but are costly and less versatile (12). The transgingival collar/neck, connecting the head to the shank, comes in cylindrical, conical, poly-angular, or collarless forms. Conical collars reduce tissue pressure and bleeding (13). Proper collar-head diameter (head $\leq$ collar) minimizes inflammation (14). The shank and thread geometry are biomechanically critical, with thread pitch, shape, and depth affecting stability (15). Smaller pitch and deeper threads enhance pullout strength (16). Dual-thread designs aim to balance insertion ease and stability, though evidence on their superiority is mixed (17).

Thread shapes (e.g., buttress, trapezoidal) influence stress distribution, with reverse buttress threads offering highest pullout resistance (18). Optimal thread depth (0.4–0.6 mm in cortical bone) and core-to-external diameter ratio equal to 0.68 function best mechanically (14, 19).

Stability of OMSs

Mini-screw retention is the condition of not experiencing bone bed dislocation after OMS has been placed (20). Permanent dental implants have pores and irregularities on their surfaces so that osteoblasts and supportive connective tissue can flow to them (21, 22). The smoothed surface of the mini-screw does not integrate into the bone and can easily be withdrawn without anesthesia (23). Primary stability is a biomechanical phenomenon that refers to the mechanical retention of the screw within bone, primarily dictated by the surface character and quantity of the bone contact to the OMS, in particular the cortical bone (24, 25). The biologic attachment of the screw to the surrounding bone provides secondary stability which depends on OMS threads surface, properties of bone, turnover rates and mechanical system. There is a simultaneous primary stability decrease with a secondary stability increase over time (26).

Materials of OMSs

The American Iron and Steel Institute recommends the utility of low carbon type 316L stainless steel alloy for the OMSs fabrication. Its use is associated with the reduced risk of inter-granular corrosion because of the low carbon that reduces the formation of chromium carbide (27). Titanium alloys are mainly used in clinical applications because they have electrochemical degradation resistance, benign biological reaction, low weight and density, low modulus and high strength. Successful use of Ti-6Al-4V type of titanium is attributed to the stability and corrosion resistance as its characteristics as an α-β alloy (28). The utility of PEEK is suggested due to excellent mechanical properties and its biocompatibility (4). PEEK is a polyaromatic semi-crystalline thermoplastic polymer with a chemical formula $(-C_6H_4-O-C_6H_4-O-C_6H_4-CO-)_n$ (29), and one of the biomaterials studied for the orthopedics and dental needs (30).

Properties of PEEK

Physical properties

It is a grey opaque material with different physical forms that include powder, pellets, rods or sheets (31). It is metal-free, and therefore suitable for metal allergic patients and considered inert with imaging procedures such as MRIs or x-rays (32, 33). PEEK exhibits the high thermal stability due to the chemical structure and resistance to chemical and radiation destruction, compatibility with reinforcing agents and radiolucency is observed while its water solubility and moisture absorption are lower than other polymethylmethacrylate (32), while it's resistance to the gamma and electron beams used in sterilizing the medical devices is optimistic (34).

Mechanical properties

PEEK is an extensively used material with favorable mechanical properties that can be employed for various applications including implants, coatings, abutments, and CAD/CAM fabrication (32). Next, its elastic modulus is 3-4GPa, which is similar to cortical bone and dentin. PEEK has a much lower elastic modulus than zirconium oxide and other non-precious metals, which means that stress on the abutment tooth and cementation area is lower (35). It also provides similar wear resistance to metal alloys (36). The flexural strength and creep resistance of PEEK are highly desirable properties for use in prosthetic frameworks (37).

Biological properties

So far, sufficient scientific work has also been carried out to testify the biocompatibility either for PEEK and PEEK composite (38, 39). Negative test was performed for sensitivity and gene toxicity tests with an assumption of no chromosome abnormalities (40). Earlier data have not been able to show credibility of cytotoxic, carcinogenic, mutagenic or immunogenic activity (41).

Composites of PEEK

Carbon-fiber-reinforced PEEK (CFR-PEEK) and glass-fiber-reinforced PEEK (GFR-PEEK)) have been studied for orthodontics, orthopedic surgery, and biomedical applications (42). The elastic modulus and the tensile strength both increase with increasing carbon fiber ratios for CFR-PEEK (43), while GFR-PEEK contains 10% random, chopped glass fibers similar to the elastic modulus of cortical bone (44). There are studied composites that improve biological properties; beta-tricalcium phosphate and PEEK (b-TCPPEEK) and hydroxyapatite and PEEK (HA-PEEK) (45, 46). While a new one combining Calcium silicate and PEEK (CS-PEEK) based on 30% Calcium Oxide and 70% SiO_2 has also been developed (47).

PEEK in dentistry

PEEK is a biomaterial with similar mechanical and physical properties to bone, and a good biocompatibility that is increasingly used in clinical practice, with positive effects on bone resorption and tissue inflammation (48, 49). It has been studied widely to use PEEK as a material for dental implant body (5) It plays an increasing role in prosthodontics due to insignificant difference in healing with titanium healing screws (50). PEEK is favored for patients with metal allergies or refusing metal taste (51), and because it is lightweight, PEEK-based clasps provide less retention if compared to cobalt chromium but maintain stability over time (52). PEEK overdenture frameworks enhance proprioception and have a cushioning effect on the underlying teeth and supporting structure (53). The modified PEEK is needed in single crown frameworks and fixed dental prosthesis frameworks, indicating that it is an ideal material for patients with metal allergies, intense masseter habits or parafunctional habits. Such patients are at higher risk for dental complications, which is why materials like modified PEEK are preferred for restorations — they offer better shock absorption and durability under high occlusal forces (54). Fixed dental prosthesis framework can be also fabricated by CAD/CAM system from modified PEEK (55).

PEEK in orthodontics

In 2017, Lerardo et al. used PEEK as a space maintainer; three kinds of space maintainers were used (lingual arch, band and loop, and removable plate). The devices were well tolerated by patients at nine months follow-up, stable with no reports of discementation or fracture, no allergic reaction or plaque accumulation, and effective at space maintenance (56). In 2017, Tada et al. examined PEEK as an orthodontic wire in comparison to NiTi arch wire (57). Shirakawa et al. and Maekawa et al. have also investigated PEEK in the role of orthodontic wire (58, 59). Beretta et al. used Zero-Expander from PEEK in CAD/CAM technology for 5 years old child, reporting it efficient in treating bilateral crossbite with no complaint from the patient (60) Some studies were made on orthodontic retention with a PEEK fixed retainer, which was found it to be stable and ideal (61, 62). Kadhum and Alhuwaizi reported similar findings to fixed retainers made of conventional metal (63). In 2024, Jasim and Kadhum (64) performed a randomized clinical trial of PEEK- versus dead-soft coaxial fixed retainers.

Possible benefits of PEEK OMS as compared to metallic OMS

1. Increased biocompatibility: The remarkable biocompatibility of PEEK minimizes the risk of metal allergies or sensitivities, which is advantageous for allergic patients (32).
2. Radiolucency: Because PEEK lacks metal, OMSs gain a better view of surrounding bone and tissues on diagnostic radiographs, as PEEK is radiolucent (33).
3. Non-magnetism: PEEK enables an MRI with mini-screw in place, preventing interruptions of imaging procedures and treatments (65).
4. Aesthetic optimization: PEEK mini-screws can be made tooth-colored, granting better aesthetics (66).
5. Mechanical compatibility: PEEK is closer in modulus of elasticity to bone. Such similarity may generate minimum stress shielding effects and enhance the stability of the implant over time due to a physiological load transmission (4).
6. Corrosion resistance: The high-performance polymer of PEEK in the oral environment enhances its longevity and reliability (67).

Conclusion

Although there is currently a lack of studies regarding PEEK as an OMS material, the current evidence supports that it can be used for this purpose. Utilizing PEEK may be beneficial due to its biocompatibility, radiolucency, and mechanical properties. Considering the similarities of OMSs with other orthopedic and dental implants, the establishment of PEEK mini-screws seems feasible. Further research and clinical trials are required to examine their actual performance and long-term viability in orthodontics.

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