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Commentary

PEEK Vs. Titanium: The Biomaterial Battle of in Dental, Oral, and Maxillofacial Surgery

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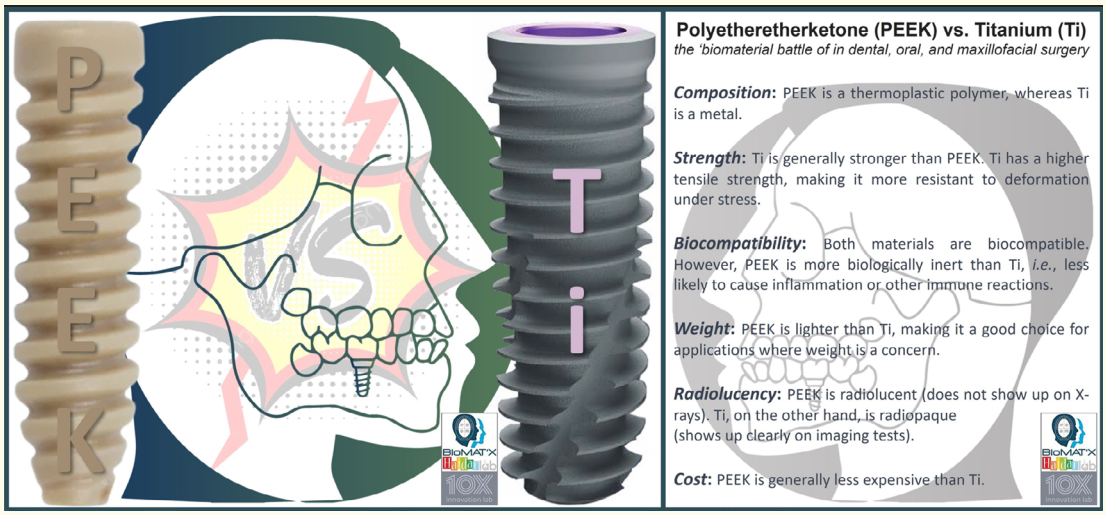
Graphical Abstract



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Precis

The dental and oral maxillofacial surgery fields have seen a rise in the use of PEEK as an alternative to traditional titanium (Ti) implants. This article provides a comprehensive yet summarized review of the advantages and disadvantages of both materials, including their mechanical and biocompatibility properties, clinical outcomes, and applications. Despite the growing interest in PEEK, Ti remains the gold standard in dental implantology. However, with ongoing research and development and innovation (R&D&I), PEEK may become a viable alternative in the future. Ultimately, the choice between PEEK and titanium depends and will depend on a range of factors, including the specific application itself, patient needs, and budget. Herein, dentists, oral, and/or maxillofacial surgeons are recommended to carefully evaluate the pros and cons of each material and determine which is the best suited for each individual case.

Briefly, biomaterials play a crucial role in the dental, oral and cranio-maxillo-facial fields of speciality, particularly in the fabrication of dental implants, orthodontic appliances, and prosthetics. Two materials that have gained popularity in recent years are titanium (Ti) and polyetheretherketone (PEEK). While both materials have their advantages and disadvantages, the choice of material depends on the specific application and patient needs, in addition to cost. Indeed, PEEK and Ti are both widely used biomaterials. On one hand, Ti has been used in the dental, oral and cranio-maxillo-facial field for decades and has a proven track record of success. It is biocompatible, corrosion-resistant, and has excellent mechanical strength, making it ideal for dental implants, orthodontic appliances, and other dental and facial prosthetics. Additionally, Ti is highly osteoconductive, meaning it encourages bone growth and can integrate well with surrounding bone tissue. PEEK, on the other hand, is a relatively *new* biomaterial in odontology and the head and face medicine; nonetheless, it has gained popularity due to its unique and attractive properties. PEEK is biocompatible, lightweight, and has a high strength-to-weight ratio, making it an excellent choice for implantable biomaterials and devices, such as dental implants and prosthetic joints. Further, PEEK is radiolucent, making it easier to visualize the surrounding bone and tissue during surgical procedures. Now, while both materials have their advantages, there are some key differences to consider. For instance, Ti is a more rigid material, which may make it more suitable for some applications, such as implant-supported dentures. PEEK, on the other hand, is more flexible and may be better suited for applications where shock absorption is required, such as in the fabrication of dental splints. In terms of budget and cost, PEEK is generally more expensive than Ti; may be offset by superior performance in certain applications.

Property	PEEK	Ti
Strength/ Tensile Strength (MPa)	Lower	Higher
Elastic modulus (GPa)	Lower (3.6 - 4.3)	Higher (110)
Density (g/cm^3)	Lower (1.32)	Higher (4.6)
Flexibility	Higher	Lower
Radiopacity	Low	High
Corrosion resistance	High	Moderate
Fatigue Resistance	Good	Excellent
Biocompatibility	Excellent	Good
Cost	Higher	Lower
Note: Values for PEEK and Ti may/will vary depending on processing methods and testing conditions.		

Table 1: *Summarizes the main differences between PEEK and Ti in terms of bio-mechanical properties, biocompatibility, radiopacity, and cost.*

The above summarizes several key properties of PEEK versus (vs.) Ti, including density, elastic modulus, tensile strength, radiopacity, biocompatibility, corrosion resistance, and fatigue resistance. n general, Ti has higher strength properties than PEEK. For example, Ti has a higher tensile strength than PEEK, with values ranging from 880 MPa to 1200 MPa, while PEEK has a tensile strength of around 97 MPa. Similarly, Ti has a higher flexural strength than PEEK, with values ranging from 1100 MPa to 1500 MPa, while PEEK has a flexural strength of around 160 MPa. In terms of compressive strength, Ti also has higher values than PEEK, with compressive strength values ranging from 1500 MPa to 1800 MPa, while PEEK has compressive strength values of around 110 MPa. When it comes to fatigue resistance, Ti generally has higher fatigue strength than PEEK. Fatigue strength refers to the ability of a material to resist failure under repeated cyclic loading, and is an important property to consider for implant materials that will be subjected to repeated mechanical stress over time. Ti, as afore-mentioned is a popular choice for load-bearing implant applications such as dental, orthopedic, and spinal implants because of its high fatigue strength. It has been extensively studied and its fatigue resistance has been well documented. In contrast, PEEK has a lower fatigue strength than Ti, which may limit its use in certain load-bearing applications. However, it is also important to note that PEEK has some advantages over Ti in terms of fatigue resistance. Specifically, PEEK has a lower modulus of elasticity than Ti, which can help reduce stress shielding and promote bone remodeling. Additionally, PEEK has been shown to have good resistance to creep, which is the gradual deformation of a material under prolonged stress. As is evident above, PEEK also has excellent biocompatibility, making it a potentially attractive material for dental and medical applications. Yet, Ti is more radiopaque, which may make it more suitable for applications where visibility is critical.

Both, PEEK and Ti have a range of applications in the dental, oral and maxillofacial field. While Ti is traditionally used for dental implants, abutments, and orthodontic appliances, PEEK is today commonly used for implantable devices, such as dental splints and prosthetic joints. Further, PEEK has gained popularity in recent years as a potential alternative to replace Ti in implantology. In addition to dental applications, PEEK has also been used in cranio-maxillo-facial surgery, particularly in orbital reconstruction, where its radiolucency allows visualizing the orbital structure.

Application	PEEK	Ti
Single-tooth replacements	✓	✓
Orthodontic brackets	✓	✓
Endodontic files	✓	✓
Full-arch reconstructions	✓	✓
Maxillofacial prosthetics	✓	✓
Implant abutments	✓	✓
Temporary crowns and bridges	✓	✓
Permanent crowns and bridges	✓	✓
Implant-supported dentures	✓	✓
TMJ replacement	✓	✓
Orbital reconstruction	✓	✗
Cranial reconstruction	✓	✗
Orthognathic surgery	✓	✓
Ongoing R&D&I aims to optimize properties and develop new biomaterials. For example, researchers are exploring ways to improve the strength and radiopacity of PEEK, while also reducing its cost. Additionally, new materials, such as Zirconia and carbon fiber reinforced polymers, are being developed.		

Table 2: *Summarizes some of the current (State-of-Art) applications/uses of PEEK and Ti.*

Perspective

Although Ti remains the gold standard for dental implants, the radiolucency and favorable mechanical properties of PEEK have made it an attractive alternative. Further R&D&I studies are needed to confirm the long-term success and safety of PEEK implants, particularly in load-bearing applications. Advances in PEEK technology, such as the incorporation of nanotechnology, surface functionalization and anti-microbial agents, may expand its use in implantology and beyond. Indeed, researchers are exploring ways to modify the surface of PEEK to improve properties. For example, surface coatings could be applied to improve osseointegration and reduce the risk of implant failure. Incorporating anti-microbial coatings could help reduce the risk of infection and so, different types of coatings, involving silver or copper nanoparticles, that could be applied to the surface of implants to inhibit bacterial growth are being explored. Nanotechnology to modify and improve surfaces and properties can help mimic the structure of bone and promote better integration with surrounding tissues. It can also help introduce drug-eluting biomaterials and implants. In addition, the use of 3D printing and computer-aided design and manufacturing or CAD/CAM techniques may allow for the customization of PEEK implants and improve their accuracy and fit. In some cases, combining PEEK and Ti may offer enhanced advantages over using either biomaterial alone. For example, a PEEK-Ti composite implant could combine the radiolucency and biocompatibility of PEEK with the strength and stiffness of Ti, for superior results.

Closing Remarks

As researchers and clinicians gain more experience with PEEK, its use is likely to continue to increase in a variety of medical, dental, and surgical applications. The choice between PEEK and Ti will depend on a range of factors, including the specific application, individual patient needs, and budget, amongst others. Basically, dentists, oral, and cranio-maxillo-facial surgeons should carefully consider the mechanico-biological properties, surface characteristics, risk of adverse effects and the potential for complications when deciding between PEEK and Ti implants or prosthetics. We, therefore, are to carefully evaluate the *pros* and *cons* and determine which biomaterial is the best-fit/-suited for each specific case. A thorough understanding of such factors will/can help improve clinical decision making and ultimately improve the quality of life for patients.

When opting between PEEK vs. Ti implants/prosthetics for you patient, you may want to consider:

- First, consider the mechanical and biological properties of the materials. While both materials have high strength and biocompatibility, PEEK has a lower elastic modulus and density, which may reduce stress on surrounding bone and potentially result in less bone resorption over time.
- Second, consider the surface characteristics of the materials, as the surface properties can significantly affect osseointegration and overall implant success. Studies have shown that certain surface modifications can enhance the osseointegration of both PEEK and Ti implants.
- Third, consider the potential for post-operative complications, such as infection or inflammation. While PEEK has been shown to have a lower risk of bacterial adhesion compared to Ti, there is still limited clinical data on the long-term outcomes of PEEK implants.
- Finally, consider the individual needs and preferences of your patient, as some patients may have allergies or sensitivities to certain metals, which may make PEEK a better option for them [1-10].

Conflict of Interest

None.

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