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Review

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The use of PEEK material as an occlusal splint

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ABSTRACT

Occlusal splint is a treatment alternative that gives positive results in reducing the symptoms of temporomandibular diseases. This treatment involves placing an appliance made of various materials specifically for the cutting and chewing surfaces of the teeth. The most popular materials used in the construction of occlusal splints are soft and hard acrylic-based materials such as polymethylmethacrylate, ethylene vinyl acetate, polycarbonate, polyethylene terephthalate and polyetheretherketone. PEEK is a high performance, semi-crystalline, thermoplastic and thermally stable polymer belonging to the polyaryletherketone family. PEEK, which has very good dimensional stability against intraoral temperature changes, is not affected by the intraoral chemical environment. Since PEEK material is chemically stable, has high biocompatibility and abrasion resistance, its use as an occlusal splint material has become widespread today. The aim of this review is to provide information about occlusal splints produced using PEEK material and digital procedures, which are becoming increasingly popular in dentistry, and to contribute to the literature.

Keywords: Polyetheretherketone, PEEK, occlusal splint, TME

INTRODUCTION

Temporomandibular disorders are a collective term for dysfunction and pain of the temporomandibular joint (TMJ) and masticatory muscles.[1] Symptoms of temporomandibular disorders include myofascial pain, restriction of jaw movement and mouth opening, and sounds heard during function. Pain is often the hallmark of this disease and can be exacerbated by palpation of the TMJ or surrounding muscles.[2] The prevalence ranges from 3.2% to 17.6%, with a 2.1 times higher incidence in women than in men.[3] The most common types of TMJ disorders include pain-related disorders (e.g. myalgia, headache and arthralgia) and TMJ-related disorders (primarily disc displacements and degenerative diseases).[4]

The aims of the treatment of temporomandibular disorders are: to reduce joint and muscle pain, to reduce the limitation of movement of the mandible, and to prevent soft tissue degeneration of the TMJ.[5] Treatment options for these disorders include physical therapy, occlusal splints and/or occlusal adjustments, pharmacologic therapy and surgical approaches.[5,6] Occlusal splints, also known as interocclusal splints, night guards, oral appliances, oral orthoses and bite guards, and the use of the bite plane are treatment alternatives that give positive results in reducing the symptoms of temporomandibular disorders. This treatment involves the placement of an appliance made of various materials specifically for the cutting and chewing surfaces of the teeth.[6]

Indications for occlusal splint use are joint sounds due to temporomandibular disorders, disc slippage and displacement, myofascial arthritis and dysfunction syndrome, osteoarthritis, retrodiscitis, bruxism, hypertonic facial muscles, parafunctional habits, vertical dimension determination and change, recurrent chronic sinusitis and postoperative care.[7-11]

HISTORY OF STABILIZATION SPLINT

Oral appliances were first used by Karolyi in 1901 for the treatment of bruxism. After 1901, many types of occlusal splints were produced for different purposes. In 1950, Posselt presented the current version of occlusal appliances. Posselt aimed to solve the problems associated with temporomandibular disorders in occlusal dysfunction with an orthosis applied to both jaws simultaneously.[12] The stabilization splint designed by Shore in 1959 is the most common appliance in the literature.[13]

While previous studies often described bruxism as a type of "disorder", Lobbezoo et al.[14] in a 2018 review suggested that bruxism should be considered a type of "behaviour" in healthy individuals. Although the absolute pathogenesis of nocturnal bruxism is still unclear, many studies have shown that bruxism is the result of many factors, including

anatomical structure and mental state.[15,16] Researchers have various opinions regarding nocturnal bruxism, but the consensus is that occlusal splinting should be used for treatment. It has been confirmed as a preferred treatment by the majority of the literature and is recommended for use at night.[17]

The most popular materials used to make occlusal splints are soft and hard acrylic-based materials. Generally, polymethyl methacrylate (PMMA), ethylene vinyl acetate (EVA) polycarbonate (PC) and polyethyleneterephthalate (PETG) are commonly used. Polyetheretherketone (PEEK), on the other hand, has found its place among occlusal splint materials by expanding its use in dentistry.[18]

Currently used appliances relax the temporomandibular muscles and maintain the condyle in the centric relationship and protect the teeth in bruxist patients with clenching.[9] Splints are produced conventionally by a dental technician, usually with plaster models taken on a semi-adjustable articulator. The conventional method is a time-consuming process that depends on the experience of the technician and is prone to errors.[19]

Advances in computer-aided design/computer-aided manufacturing (CAD/CAM) and intraoral scanning (IOS) technologies may have the capacity to overcome the shortcomings of conventional splinting and provide better results. In addition, the workflow is simpler than conventional methods. Many studies have shown that CAD/CAM splints have superior properties compared to conventional ones.[20,21]

PEEK MATERIAL

PEEK is a high-performance semi-crystalline thermoplastic polymer belonging to the polyaryletherketone family.[22] It is a material with high thermal stability. Its dimensional stability against intraoral temperature changes is very good.[23] Being an inert material, PEEK is not affected by the chemical environment in oral conditions. The chemical stability of PEEK material ensures that it does not undergo oxidation and toxic by-products are not released.[24]

PEEK material is available in powder and granular forms. Materials such as ceramics, glass or carbon can be added to PEEK, which can also be produced as bees, to increase its physical and chemical properties. Material addition can be done before or after polymerization.[25]

Thanks to its stability, PEEK is not affected by some sterilization processes. Processes such as ethylene oxide, gamma and steam sterilization do not change the physical properties of the material.[26] PEEK is a biologically compatible, tissue-friendly material. Clinical applications have shown that it has no mutagenic and toxic effects. In addition, it does not cause inflammatory response in tissues.[27] As a result of studies with PEEK material, it has been reported that the tissue response is very low, it does not have a negative effect on cell culture, and does not show cytotoxicity on cells with proliferation and repair ability such as osteoblasts and fibroblasts.[28]

The elastic modulus of PEEK material is low without the addition of filler and is approximately 3-4 GPa. By adding various additives, the elastic modulus of PEEK is brought closer to cortical bone (10-19 GPa). In this way, dental implants prepared with PEEK are a good alternative with good cortical bone compatibility and similar properties.[29]

It has been claimed to absorb masticatory forces due to its elastic modulus being close to the bone. For this reason, it prevents crestal bone resorption in the preimplant area by absorbing the incoming forces.[30] PEEK also has a low rate of allergic reaction, very good polish ability and therefore low plaque retention.[31]

Bacterial adhesion is influenced by the surface energy and chemical structure of the material, as well as the presence of surface defects that favour microorganism growth.[31] Hahnel, Wieser, Lang, and Rosentritt[33] compared biofilms on different abutment materials in an in vitro study and found that the amount of biofilm on PEEK was equal to or lower than the biofilm formation on titanium and zirconia. Studies have shown that an increase in surface roughness facilitates bacterial adhesion and biofilm formation. In support of this, the PEEK surface used in Hahnel's[33] study was significantly rougher than titanium and zirconia. The high polish ability of PEEK allows for less biofilm formation.

It is good at absorbing incoming forces with adequate fatigue strength and low yield strength. PEEK material has high mechanical strength, good dimensional stability, no polymerization shrinkage, and the material has low water absorption.[34] It is very lightweight, so prostheses made of PEEK material are reported to be comfortable to use by patients.[35]

PEEK is radiolucent, making it compatible with X-ray imaging and magnetic resonance imaging. Since it is radiolucent, changes in bone tissue can be easily visualized.[36] By adding barium sulphate, its radiological visibility and contrast can be changed.[37] PEEK in its pure state is skin-coloured. PEEK material changes colour according to the fillers added. Pure PEEK scaffolds have a greyish and very opaque appearance.[38]

The wettability of PEEK material is low, so modification of the PEEK surface is necessary to increase its bond strength to materials.[26] To ensure adequate adhesion, mechanical and chemical pretreatments such as laser and plasma roughening, sulfuric acid treatment, sandblasting, etching with piranha solution, followed by the application of an adhesive containing methyl methacrylate (MMA), 10-methacryloyloxydecyl dihydrogen phosphate (MDP) or acetone are recommended.[39]

One of the main reasons why PEEK material is preferred is that it does not cause damage to the antagonist teeth. In an in-vitro study by Muhsin et al.,[40] it was determined that PEEK caused less wear on the enamel of the antagonist natural tooth and had better wear resistance compared to PMMA and nanohybrid composites.

In today's dentistry, PEEK is used in fixed prostheses, removable partial dentures, implant supported prostheses, telescopic overdenture prostheses, occlusal splints.

USE OF PEEK MATERIAL IN OCCLUSAL SPLINT CONSTRUCTION

The disadvantages of conventional acrylic occlusal splints have led to the search for alternative materials. These disadvantages include leaving residual monomers, poor taste, volumetric changes, color changes over time, fragility, irritation of the oral mucosa and allergic reactions in some patients. These reasons cause patients to experience difficulties

in daily use.[41] PEEK material is lighter than PMMA, EVA, PC, PETG splints and has higher abrasion resistance and force absorbing properties against excessive occlusal loads, making it possible to use it in occlusal appliance construction.[41,42]

In their study, Wang et al.[43] compared the preclinical effects of digitally prepared occlusal splints and conventionally prepared rigid splints in patients with nocturnal bruxism. While the digitally prepared PEEK splints saved time, they also showed ease of use and clinically less wear. However, because of the study, both conventionally prepared splints and digitally prepared PEEK occlusal splints were found to be clinically usable. As a result, they stated that the occlusal appliances prepared from PEEK material showed less wear at the end of the 12th week compared to the conventionally prepared splints and had the qualities to meet the clinical requirements. In addition, due to their superior physical properties, occlusal splints made of PEEK material were produced thinner, increasing patient satisfaction.

In the study by Wang et al.[43] it was seen that with the advancement of digital technology, the accuracy of design and production has been greatly improved. As a result of the study by Dedem et al.[44] in which they compared occlusal splints produced by digital technique and those produced by conventional impression method, the main advantages of splints produced by digital technique over impression-based production were found to be time saving, high material quality and the opportunity to produce multiple copies of splints.

Waldecker et al.[45] produced an interocclusal splint with a completely digital procedure using an intraoral scanner and 3D printed resin. They tested the comfort of use, occlusion, and fit of the splint and concluded that although only minor occlusal abrasions were required, the digital method is suitable for the production of occlusal splints. PEEK occlusal splints are also designed and produced with this production technique.

Although materials routinely used for splinting such as EVA, PC and acrylic resin have good impact resistance, controlling their shape in the heat moulding procedure is not simple. However, PEEK is an engineering plastic with almost perfect qualities such as excellent biocompatibility, lubricity, heat resistance and wear resistance.[46] The main component of acrylic resins used to make hard splints is PMMA, and the molecular mass of PEEK is approximately three times that of PMMA. In a study on the wear of dental materials in clinical use, some researchers claimed that the greater the mass of the material, the better the toughness and wear resistance of the material.[47] In their study, Wang et al.[43] found that because of its excellent properties, the ability to produce a thinner thickness of PEEK occlusal splint increased patient comfort and reduced foreign body sensation.

Digitally produced interocclusal splints for nocturnal bruxism patients have features such as a faster workflow, simpler working method, improved occlusal surface design compared to conventional production and saving medical resources. In addition, the digital workflow gives physicians the opportunity to archive patients' dental data. Furthermore, since the STL format is widely used, interocclusal appliances can also be manufactured by additive manufacturing methods (e.g. 3D printing) using PEEK.[43]

In the study by Benli et al.[18] in which they investigated the wear resistance of different occlusal splint materials, the changes in the surface roughness of different materials against upper molar teeth and volume losses after wear were investigated by two-body wear simulation. As a result, the results of PEEK material were found to be higher than PMMA, EVA, PC, PETG materials whose wear resistance and volume losses were investigated. As a result of this study, Benli et al.[18] concluded that PEEK material is suitable for making occlusal splints.

Grymak et al.[48] looked at the wear resistance of occlusal appliances produced by various methods. While vacuum-formed materials showed the highest wear rate among all other groups, no significant difference was found between materials produced by computer-aided milling, heat polymerization, or 3D printing. As a result, PEEK material showed the best properties in both in vitro and in vivo studies.

In a case study by Delrieu et al.[49] a PEEK occlusal splint was used in a patient with histaminases. PEEK material is considered hypoallergenic because it is biocompatible and contains no residual monomers compared to other splint materials such as PMMA, EVA, PC. They concluded that PEEK material is suitable for occlusal splinting because it is hypoallergenic and has superior properties compared to other materials.

CONCLUSION

In our review, we have mentioned that it is possible to use PEEK material produced by digital procedure as an occlusal splint material and its advantages and disadvantages compared to frequently used materials. Studies on the subject are insufficient. Clinical follow-up and in vitro studies should support the use of PEEK material as an occlusal splint.

ETHICAL DECLARATIONS

Referee Evaluation Process

Externally peer-reviewed.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

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Author Contributions

All of the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

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