DENTAL-3078; No. of Pages 8
ARTICLE IN PRESS
DENTAL MATERIALS XXX (2018) XXX–XXX

Available online at www.sciencedirect.com
ScienceDirect
journal homepage: www.intl.elsevierhealth.com/journals/dema

Wear of polyetherketoneketones — Influence of titanium dioxide content and antagonistic material

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ARTICLE INFO

Article history:
Received 17 July 2017
Received in revised form 18 December 2017
Accepted 21 December 2017
Available online xxx

Keywords:
PEKK
Chewing simulator
Wear
TiO_2
Laser scanning microscope
Thermal cycling

ABSTRACT

Objective. The aim of this laboratory study was to analyze the influence of titanium dioxide (TiO_2) content and antagonistic material on the wear of polyetherketoneketones (PEKKs).
Methods. Twenty-four disk-shaped specimens of two PEKK materials containing either 10 wt% or 20 wt% TiO_2 particles (P10 and P20) were dynamically loaded in a chewing simulator with 49 N and additional thermal cycling (5–55 °C). Subgroups of 8 specimens each were loaded with spherical antagonists made from either steatite ceramic (St), zirconia (Zr), or the same PEKK material (P10 or P20). After 120,000, 240,000, 480,000, 840,000, and 1,200,000 loading cycles the vertical substance loss and the volume loss of the loaded specimens were evaluated using a laser scanner. Data were checked considering the normal distribution (Shapiro–Wilk test) and were inspected for significant differences by means of single factor variance analyses and post hoc pair comparison (Games-Howell test).
Results. After 1,200,000 chewing cycles, statistical analyses revealed a significant influence of the antagonistic material. A significant difference was also found between the tested PEKKs if Zr was used as the antagonist. The volume loss ranged from between 0.073 mm^3 (P20-P20) and 0.228 mm^3 (P10-St), and the vertical substance loss ranged between 73.71 μm (P20-P20) and 115.268 μm (P10-Zr).
Significance. The inclusion of TiO_2 particles influences the wear behavior of PEKK materials.

1. Introduction

Because of the constantly increasing demands of patients for aesthetic and high-quality dental restoratives, metals have been replaced as dental restoratives by ceramics and polymers [1]. The corrosion of metals can increase surface roughness that could serve as retention sites for plaque [2,3], and galvanic corrosion can result in a metallic taste and pain [4]. Moreover corrosion products can cause diseases such as gingivitis, lichenoid reactions or mucosal necrosis [5].

Ceramics in dentistry have – in addition to positive characteristics such as good biocompatibility [6], natural appearance [7], low plaque accumulation [8] and high compressive strength [2] – the disadvantages of lower bending and tensile strength than metals [9]. Their brittleness is

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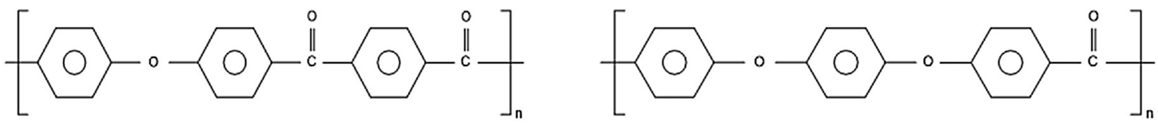
https://doi.org/10.1016/j.dental.2017.12.009



Poly-Ether-Ketone-Ketone (PEKK) Poly-Ether-Ether-Ketone (PEEK)

Fig. 1 – Chemical structures of PEKK and PEEK.

responsible for spontaneous fractures or chipping when the strength of the ceramic is exceeded [10]. Also, ceramics are sensitive to processing and application errors [11]. As an alternative to ceramics, the indications for polymers in dentistry have expanded in recent years. The thermoplastic polymers, polyetheretherketones (PEEKs) have long been used in orthopedics and traumatology as a substitute for metal components because of their positive material characteristics [12]. In dentistry, PEEKs have been used as materials for removable dentures and implant superstructures [13]. In an in vitro study, the accumulation of biofilm was lower on implant abutments made of PEEKs than on those made of zirconium dioxide or titanium [14]. Furthermore, a maxillary obturator prosthesis made of PEEK was reported to have good mucosal reactions in areas where the mucosa was in contact with the denture [15]. PEKKs are also thermoplastic polymers with good biocompatibility [16,17] and improved chemical and mechanical qualities because of the additional ketone group [18]. In addition, Moore et al. found in a rat study that PEKKs had a lower inflammatory response than polymethylmethacrylates [19].

Attrition and abrasion are important phenomena in the wear of restorative materials [20]. The wear of natural teeth is to a certain degree a physiological process and should not be disrupted by dental restorations. Ideally, the wear of enamel in contact with restorative materials should not exceed the physiological wear [21] of about 20 μm–40 μm per year [22]. If restorative materials have a wear behavior that differs from natural tooth structure, the wear of the antagonistic natural teeth might be affected [23]. Therefore, an ideal dental restorative material should replicate the wear behavior of natural tooth structure. Reduced wear of the occlusal surface of artificial dentures can lead to extended strain on antagonist teeth and their periodontium that may result in periodontal or functional problems due to occlusal interferences [24–26].

Both PEKK and PEEK belong to the polyaryletherketone (PAEK) family and are thermoplastic resins. The chemical structure of all PAEKs is based on the same aromatic rings and differs according to their ratio of keto- and ether-groups (Fig. 1). According to the manufacturerís specification, the physical characteristics of PEKKs can be similar to those of dentin, and oxide particles can influence the mechanical characteristics and the color of PEKK materials (Cendres + Métaux, Biel, Switzerland). PEKK materials have been successfully used for implanted prostheses [27–29].

The aim of this study was to evaluate the influence on wear against different antagonistic materials of two TiO_2 concentrations in PEKK.

The null hypothesis of this study was that no different wear behavior would be found for P10 and P20 loaded with antagonists made from St, Zr, or the same PEKK material.

Table 1 – Group codes of the tested material combinations.

Group code	Tested material	Antagonistic material
P10-St	PEKK + 10 wt% TiO_2	Steatite
P20-St	PEKK + 20 wt% TiO_2	Steatite
P10-P10	PEKK + 10 wt% TiO_2	PEKK + 10 wt% TiO_2
P20-P20	PEKK + 20 wt% TiO_2	PEKK + 20 wt% TiO_2
P10-Zr	PEKK + 10 wt% TiO_2	Zirconia
P20-Zr	PEKK + 20 wt% TiO_2	Zirconia

2. Materials and methods

2.1. *Sample preparation*

Two PEKKs with a different portion of TiO_2 particles were investigated. The percentages of TiO_2 were 10 wt% (Pekkton ivory, Cendres + Métaux, Biel, Switzerland) and 20 wt% (Pekkton pearl, Cendres + Métaux, Biel, Switzerland). The size of the TiO_2 particles was in the micrometer range. The specimens were manufactured by milling technology (VhF, Ammerbuch, Germany). The shape of the examined PEKK-specimens was a flat, oval plate with a width of 8 mm and a length of 11 mm. The specimens were polymerized into metal sleeves with denture acrylic resin (ProBase cold, Ivoclar Vivadent, Ellwangen, Germany). These were clamped in special holders for the chewing simulator. Afterwards, the specimens were ground under water cooling with rotating silicon carbide paper (600 grit) and polished (2500 grit silicon carbide paper).

2.2. *Wear measurements*

Twenty-four specimens of each investigated material were loaded into a chewing simulator (Chewing Simulator CS-4, SD Mechatronic, Feldkirchen-Westerham, Germany). The specimens were randomly allocated to three subgroups with different antagonists. Six-mm diameter balls of St (Hoechst Ceram Tec, Wunsiedel, Germany), Zr (BCE Special Ceramics GmbH, Mannheim, Germany) and PEKK (Cendres + Métaux, Biel, Switzerland) (n = 8 each group) were used as the antagonists to simulate physiologic occlusal point contacts (Table 1). Table 2 shows the materials used.

The antagonistic balls were attached in special holders with modeling resin (Pattern Resin, GC Europe N.V., Leuven, Belgium). Before each test series, impressions of the surfaces of the unloaded specimens were made with low-viscosity silicone (Express 2 Ultra-Light Body Quick, 3 M, St. Paul/Minnesota, USA). Afterwards, the specimens were each loaded dynamically with the parameters presented in Table 3 in the chewing simulator with thermal cycling (5–55 °C) and a loading force of 49 N. After 120,000, 240,000, 480,000, 840,000

Please cite this article in press as: Kewekordes T, et al. Wear of polyetherketoneketones — Influence of titanium dioxide content and antagonistic material. Dent Mater (2018), https://doi.org/10.1016/j.dental.2017.12.009