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Research Article

Comparison of the Thermoplastic Resins Reinforced With Ceramic Particles with Conventional Thermoplastic Resins in Fixed Dental Prostheses

Mohammad Ali Hemmati [1], Ali Jamali Ghomi [1*],
Farnoosh Taghavi Damghani [2], Daryush Talei [3],
and Farnaz Taghavi Damghani [4]

[1]Assistant Professor, Department of Prosthodontics,School of Dentistry,Shahed University,Tehran,lran
[2]Assistant Professor, Department of Prosthodontics, School of Dentistry,
Shahid Beheshti University of Medical Sciences, Tehran, Iran
[3]Medical Plant Research Center, Shahed University, Tehran, Iran
[4]Postgraduate Student ,Department of Prosthodontics,School of Dentistry,
Hamadan University of Medical Sciences, Hamadan,Iran
*Corresponding Author: Dr Ali Jamali Ghomi. Address: Keshavarz Boulevard,
Italia St, Vesale Shirazi St, Shahed Dental School,
Phone: 88959210, 09123025075 Email: dr.ajamali@yahoo.com

ABSTRACT

Background: Polyetheretherketone (PEEK), a semi-crystalline polymer with excellent function is used to fabricate Bio HPP dental prostheses. Bio-XS, the previous generation belongs to the PEEK without ceramic filler content. **Aim:** The present study compared the flexural and tensile strength of Bio-HPP and Bio-XS thermoplastic resins used to fabricate dental fixed prostheses. **Methods:** 15 Bio-XS specimens by Thermopress 400 device and 15 Bio-HPP specimens with for 2 press system were fabricated. Wax specimens were cylindered into the flasks for the fabrication of Bio-XS specimens after sprue insertion by two sprues of 3×3mm dimension using type III gypsum. Wax models were also cylindered by type III gypsum used for 2 press device to fabricate Bio-HPP specimens. Melting of Bio-HPP granules were done for 20 minutes in the 400°C and the pressing was completed automatically in 30 minutes. The flexural and tensile strength of the specimens were measured using ISO 178 and ISO 527 standards and were compared using Student's t-test. **Results:** flexural strength values of Bio-XS and Bio-HPP were 138.22±9.23 MPa and 151.49±10.7 MPa, respectively (P=0.34). Furthermore, tensile strength values of Bio-XS (115.82±5.11 MPa) were significantly lower than Bio-HPP resins (131.3±3.9 MPa) (P<0.05). **Conclusion:** due to the similar flexural strength values of Bio-HPP and Bio-XS as well as the higher tensile strength of Bio-HPP in comparison with Bio-XS; it seems Bio-HPP polymer can be used as a proper material for the fabrication of different dental prostheses using press and CAD/CAM systems.

Keywords: Thermoplastic resins, Polyetheretherketone, Flexural strength, Tensile strength

INTRODUCTION

The CAD/CAM milling of resin blocks for temporary fixed dental prostheses (FDPs) fabricated under controlled and optimized manufacturing conditions provides the production of higher flexural strengths reconstructions (Stawarczyk et al. 2012). Since the fabrication of the resin blocks is done under standardized parameters at high temperature and pressure by CAD/CAM, this leads to increase mechanical properties of the resin blocks which exhibit constant quality (Giordano, 2006). Hence, the resin CAD/CAM blocks can be considered for long-term reconstructions (Lin et al. 2008). Also, FDP materials must maintain long-term color stability in order to avoid replacement of restorations. Regardless of their chemical composition, dental resins tend to absorb liquids (Hallmann et al. 2012).

Knowledge of the mechanical properties of a material is important in order to be able to determine the envisioned indications from it. Polyetheretherketone (PEEK) is a family of high-temperature thermoplastic polymers, consisting of an aromatic backbone molecular chain which is interconnected via ketone and other groups (Stawarczyk et al. 2012).

PEEK is a strong, stiff and hard polymer which good friction and wear properties has been reported for this fabric (Noiset et al. 2000). PEEK is introduced as provisional abutment in implant dentistry as well as prosthodontics and removable dental prostheses (Kurtz et al. 2007). Also, it is biocompatible and has natural tooth-colored appearance (Tannous et al. 2012).

The Bio-XS material is a thermoplastic high-performance polymer and suitable to use for bridges as an alternative to metal alloys and zirconium oxide. The latter materials have high degree of rigidity which can increase stress and far-reaching consequences (Kim et al. 2009). Processing of the Bio-XS material is laborious and requires dental technicians to have considerable expertise in terms of this concept. CAD/CAM technology promises much in this area, since it makes it possible to minimize the more laborious work steps (Kim et al. 2009).

Bio high-performance polymer (Bio-HPP) is the new generation of these polymers which based on the manufacturer report; it has higher strength for application as CAD/CAM material. Based on the literature there is no report to compare flexural and tensile strength of Bio-HPP and Bio-XS. There is report on application of the PEEK in FDPs which PEEK three-unit FDPs has higher fracture load especially in load-bearing areas (Stawarczyk et al. 2013).

The difference between Bio-XS and Bio-HPP lies in the fact that a slightly grey PEEK exists in Bio-XS, and white PEEK strengthened with ceramic particles and with improved mechanical properties in Bio-HPP (Göncü Başaran et al. 2011).

However, as a material for restorative and prosthetic dentistry, less attention was paid to the PEEK because of the difficulties in establishing a strong and durable adhesion to composite resins as a layering and reparative material due to its low surface energy and resistance to surface modification by chemical treatments (Schmidlin et al. 2010). So, the present study compared the flexural and tensile strength of Bio-HPP and Bio-XS thermoplastic resin used to fabricate dental fixed prostheses.

MATERIAL & METHODS

In this in vitro study a total of 30 Bio-XS and Bio-HPP (Bredent. Co. Germany) specimens were used (n=15 in each group) to compare their flexural and tensile strengths. The flexural and tensile strengths of the samples were measured using ISO 178 and ISO 527 standards respectively based on the manufacturer instructions [New Material Options For Innovation in Restorative and Prosthetic Dentistry (Invibio Biomaterial Solutions 2011)]. Metallic molds were fabricated using CNC technique and then the wax patterns were made in this metal molds.

Bio-XS specimens were fabricated by Thermopress 400 device and BioHpp samples were made using For 2 press system (Bredent. Co., Germany). For flexural strength test (ISO 178:2013), 30 (15 Bio-XS and 15 Bio-HPP) wax patterns (4×10×80 mm) were transferred to thermopress 400 and For 2 press devices in order to provide thermoplastic resin samples. To indicate the tensile strength, 30 (15 Bio-XS and 15 Bio-HPP) wax patterns (2×5×75) were fabricated

(ISO 527:2012) and transferred to the mentioned devices. Bio-XS specimens were invested in the flasks using type IV gypsum after application of two sprues of 3×3mm dimension for each sample.

The pre-heating temperature was 380°C for 20 minutes. Then injection of the BioXs material was done in a period of 60 seconds and flasks were carried out of the device and cooled to beneath 80°C under water.

Then samples were taken out of the flasks and sprues were cut. For Bio-HPP samples, wax patterns were invested by type IV gypsum. The pre-heating temperature was 630-850°C. Melting of Bio-HPP granules was done for 20 minutes at 400°C and after transferring the mold to the For 2 Press , the pressing procedure was completed automatically in 35 minutes .

Then all samples were mounted in Universal Testing Machine (Zwick / Roell, Z020, Germany)for further investigation. To determine the flexural strength, two supporting spots were adjusted with 60 mm distance and a 10 mm diameter loading edge applied the preload of 1 mm/min by the speed of 100 mm/min and the flexural strength force was recorded in the deflection equivalent to 5% strain (ISO 178; 2013).

For tensile strength, two supporting spots with 60 mm distance were used and tensile force was applied by the speed of 100 mm/min, and the force at which rupture occurred was recorded.

STATISTICAL ANALYSIS

Data was presented as mean ± standard deviation (Sd) and the Obtained results for flexural strength and tensile strength were analyzed and compared using Student's t-test by SPSS 22. $P<0.05$ was considered as significant differences between treatments.

RESULTS

Flexural strength values of Bio-XS and Bio-HPP were 138.22±9.23 MPa and 151.49±10.7 MPa, respectively ($P=0.34$). Furthermore, tensile strength value of Bio-XS (115.82±5.11 MPa) was significantly lower than Bio-HPP resins (131.3±3.9 MPa) ($P<0.05$).

DISCUSSION

Along with recent advances in dental materials , dentists want to offer their patients modern and high-quality materials for prosthetic restorations. Many patients become enchanted by the possibilities offered by modern dentistry, but get greatly disappointed when they hear just how costly these kinds of restorations are to carry out (Voßhans et al. 2013). It has long been the goal for dental material scientists to develop a material with similar mechanical behavior to that of natural human enamel and dentin.

The polymer infiltrated ceramics (He and Swain, 2011) and ceramic infiltrated resin materials suggest a successful step toward such a goal. As observed in this study, flexural strength values of Bio-XS and Bio-HPP were 138.22±9.23 MPa and 151.49±10.7 MPa.

Furthermore, tensile strength values of Bio-XS (115.82±5.11 MPa) were lower than Bio-HPP resins (131.3±3.9 MPa). To our knowledge this is the first report on flexural and tensile strength of Bio-HPP and Bio-XS.

PEEK polymers present high chemical resistance with extremely low levels of extractable and leachable ingredients, allowing for excellent stability and inertness in the mouth. PEEK displays very low thermal conductivity and is electrically non-conductive, providing excellent natural feel for the patient. PEEK's excellent strength to weight ratio provides low weight substructures, improving comfort.

Patients have reported natural mouth feeling and no foreign object sensation when using PEEK based dental prosthesis (Kern and Lehmann, 2012).

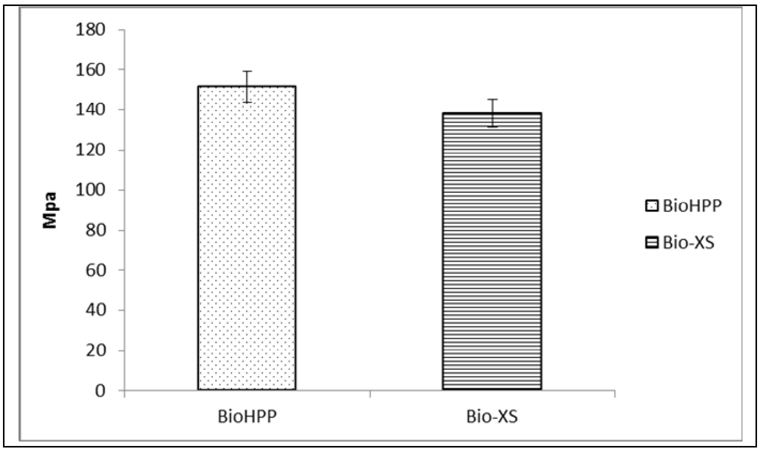

Figure 1. flexural strength of Bio-XS and Bio HPP thermoplastic resins

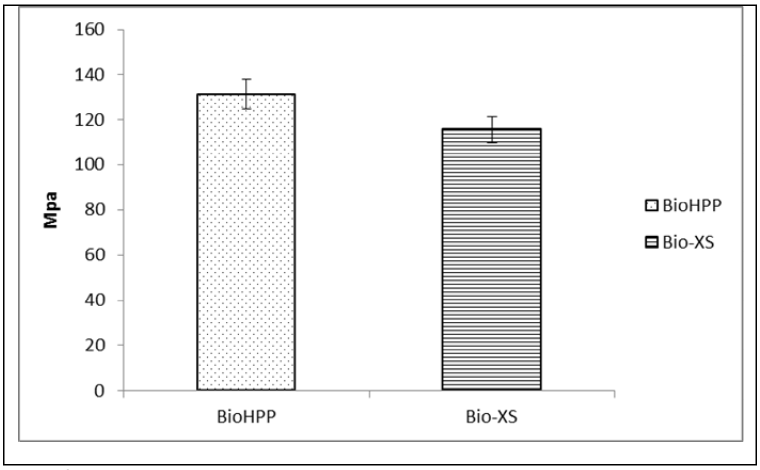

Figure 2. tensile strength of Bio-XS and Bio HPP thermoplastic resins

Bio-HPP, approved as a Class IIa medical device, is a semi-crystalline thermoplastic material. Its base material is PEEK and it contains about 20% ceramic filler. With a modulus of elasticity of around 4 GPa, Bio-HPP is about as elastic as bone, which helps mitigating any stress that might develop and reduces 'stress shielding', a welcome effect for wide-span framework structures in particular (Siewert and Parra, 2013). Restorations fabricated with PEEK based dental polymer have the advantage of being able to be cemented using a range of commercial available systems. The internal configuration of the PEEK substructure should be roughened using a diamond bur and degreased using acetone. This procedure will increase the bond strength of the PEEK dental material and the luting systems (Behr et al. 2001). A close consideration of the procedures involved suggests it would be possible to recommend the use of the high-performance polymer Bio-HPP to dental technicians and dentists as a metal-free but still cost-effective and attractive solution (Siewert and Parra, 2013).

Several advantages have been reported for Bio-HPP. This material is opening up a new range of indications for removable prosthetic restorations. PEEK is credible because of its long track record within the field of medical technology, among other things. The outstanding physical and chemical properties are due to the structure of the polymer, which consists of tightly connected molecules. Its high melting point (above 280 °C) means it can be treated using hot sterilization methods. The good flexural strength and high modulus of elasticity prevent material fracture and give it a consistency similar to that of bone (Appleton et al. 2005).

The main property of filler is high tensile strength. Thus, the highest tensile strength effect can be achieved when the filler is positioned as far as possible on the tension side of prosthesis rather than at the compression side or at the center (Kim et al. 2009). In a previous report the tensile bond strength of resin cement combined with additionally adhesives on etched and/or air-abraded PEEK surfaces was evaluated. Higher bond strength values were measured when the adhesive was applied on air-abraded and -etched PEEK (21.4 MPa) compared to the solely etched surface (11.8 MPa) (Hallmann et al. 2012). The larger contact surface, which was penetrated by the adhesive led to more functional groups after chemical treatment and thus enabling a better crosslinking of the polymers (Hallmann et al. 2012). Results of mechanical stress tests with PEEK materials are limited and the available literature varies considerably in terms of investigated prosthetic applications. The fracture strength of provisional crowns on PEEK implant abutments was investigated and showed similar values as titanium temporary abutments (Wood et al. 2011). Previously, the fracture load of three-unit composite-and PMMA-based FDPs was tested. The results were lower and ranged between 268 and 467 N, depending on resin material (Santing et al. 2012). This material characteristic value comes from the field of materials technology and describes the relationship between stress and expansion when a solid body becomes distorted (Siewert and Parra, 2013).

In conclusion due to the similar flexural strength values of Bio-HPP and Bio-XS as well as the higher tensile strength of Bio-HPP in comparison with Bio-XS; it seems Bio-HPP polymer can be used as a proper material for the fabrication of different dental prostheses using press and CAD/CAM systems. The low specific weight, bone-like elasticity, metal-free character and toughness combined with virtually non-existent material fatigue make it an ideal material in prosthetic dentistry. The CAD/CAM-supported processing of PEEK opens up new possibilities and the physical properties of this material allow approximately the same design dimensions as those of metallic materials.

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