Effect of Different Surface Treatment on Shear Bond Strength of Veneering Composite to Polyetherketone Core Material

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ABSTRACT:

Background and Objective: The purpose of this in vitro study was to assess the effect of different surface treatment methods on shear bond strength of the veneering composite to polyetherketone (PEEK) core material.

Materials and Methods: In this in vitro, experimental study, 60 PEEK discs were fabricated, polished with silicon carbide abrasive paper and divided into five surface treatment groups (n=12) namely air abrasion with 110µm alumina particles at 0.2MPa pressure for 10 seconds, 98% sulfuric acid etching for one minute, air abrasion plus sulfuric acid etching, application of cyanoacrylate resin and a no surface treatment control group. Visio.link adhesive and GC Gradia veneering composite were applied on PEEK surfaces and light-cured. Shear bond strength was measured using a universal testing machine and the data were analyzed by one-way ANOVA and Tukey’s test.

Results: The mean ± standard deviation (SD) values of shear bond strength of the veneering composite to PEEK surfaces were 8.85±3.03, 15.6±5.02, 30.42±5.43, 26.14±4.33 and 5.94±4.49MPa in the control, air abrasion, sulfuric acid etching, air abrasion plus sulfuric acid etching and cyanoacrylate resin groups, respectively. The control and cyanoacrylate groups had significant differences with air abrasion, sulfuric acid etching and air abrasion plus sulfuric acid etching groups in terms of shear bond strength (P<0.0001). Higher bond strength values were noted in sulfuric acid etching, air abrasion plus sulfuric acid etching and air abrasion groups compared to the control and cyanoacrylate groups (P<0.0001).

Conclusion: Sulfuric acid etching, air abrasion and a combination of both are recommended as efficient surface treatments to increase the shear bond strength of the veneering composite to PEEK core material.

Keywords: Polyetheretherketone; PEEK; Shear Strength; Composite Resins

[II] INTRODUCTION

Resin materials are increasingly used in the computer aided design/computer-aided manufacturing (CAD/CAM) systems and they have been suggested as optimal alternatives to ceramics due to their favorable properties (1). High-density polymers manufactured by the CAD/CAM technology have been recommended as alternatives to glass ceramics due to higher fracture strength, more uniform stress distribution and less wear of the opposing teeth (2).
Polyetheretherketone is a polymer in the polyaryletherketone family; (3) it is a thermoplastic material with semi-crystalline structure (4). This methacrylate-free polymer is composed of aromatic benzene rings attached to ether or ketone functional groups (2). Also, PEEK is biocompatible and has a tooth-colored appearance compared to metal restorations. It can be easily shaped with bur and is radiolucent. Thus, it is compatible with computed tomography, magnetic resonance imaging and X-ray radiography (2).

In medicine, PEEK has long been used in orthopedics and trauma management and for spinal cord implants (5). It remains stable when exposed to most organic and inorganic chemical agents (1). It also has several applications in dentistry as implant, temporary abutment or implant-supported bar or clamp due to its excellent physical and biological properties (1). It is used in fixed prosthodontics as well. A three-unit fixed partial denture fabricated of PEEK can averagely tolerate 1383N load, which is favorable for use in the clinical setting considering the maximum reported masticatory force of 600N (3). Despite numerous advantages, PEEK has some esthetic problems due to its low translucency and grayish color, which limits its application for full-coverage restorations (1). Thus, a layer of veneering composite should be applied over it for esthetic reasons. However, considering the low surface energy of PEEK and its resistance to surface modifications caused by the application of chemical agents (surface conditioning), achieving adequate bond strength between the veneering composite and PEEK is challenging (1,3). Therefore, enhancing the surface properties of PEEK is an important priority, which needs to be addressed.

A previous study indicated that bond between untreated PEEK surfaces and adhesive resin cements could not be obtained (4) but etching of PEEK surfaces with sulfuric acid alone or in combination with hydrogen peroxide significantly enhanced the bond strength (4,6). However, chairside use of sulfuric acid is hazardous and has its own shortcomings. Bond strength of temporary resin to PEEK following different surface treatment and conditioning methods was evaluated in another study, which revealed that air abrasion and application of primer significantly increased the tensile bond strength of samples (7). However, water sorption often causes hydrolytic degradation and compromises the bond of resin to oxide ceramics, and whether the bond to PEEK can withstand such effects is an issue in need of further investigation (8,9).

Adequate durability and sufficient bond strength are among the prerequisites for intraoral application of bonded PEEK restorations. In industry, conventional abrasive treatments, acid etching, laser irradiation and plasma techniques along with the use of epoxy adhesives are commonly used to bond elastomers to PEEK; however, most of the aforementioned techniques require special equipment or have some limitations and are therefore not applicable in dental clinical setting (4). Chemically, PEEK is resistant to all acidic substances except for high concentrations of sulfuric acid (5). On the other hand, achieving reliable bond between PEEK and the veneering composite is a requirement for long-term clinical service of restorations. Such a bond can be achieved via chemical adhesion, micromechanical retention (interlocking) or a combination of both (2).

Veneered restorations with a core material are the cornerstone of prosthodontic treatments. A strong core along with esthetic veneering ceramic has long been regarded as a successful prosthetic treatment. Thus, a strong bond between the veneering and the core material is required in order to benefit from the optimal properties of the strong core as well as the esthetic appearance of the veneering. The bond must be strong enough to transfer functional stresses from the veneering to the underlying framework. This study sought to assess the shear bond strength of the veneering composite to PEEK core material following different surface treatment methods.
[II] MATERIALS AND METHODS
This in vitro, experimental study was conducted on 60 PEEK (Bio-HPP, Bredent, Senden, Germany) discs measuring 2×7×7mm fabricated by the sectioning machine. The disc surfaces were polished using 400-1000 grit silicon carbide abrasive papers (Matador, Wasserfest, Germany). For this purpose, the discs were mounted in an acrylic mold in such a way that only one side of the disc (measuring 7×7mm) remained out of the acrylic resin. The samples were immersed in an ultrasonic bath containing deionized water for 10 minutes and were then randomly divided into five groups (n=12) for the following surface treatments:
Group 1. Disc surfaces were subjected to air abrasion by 110μm alumina particles at 0.2MPa pressure and 45° angulation for 10 seconds.
Group 2. Disc surfaces were etched with 98% sulfuric acid (Asiapajohesh, Amol, Iran) for one minute.
Group 3. Disc surfaces were subjected to air abrasion by 110μm alumina particles at 0.2MPa pressure and 45° angulation for 10 seconds and were then etched with 98% sulfuric acid for one minute.
Group 4. One layer of cyanoacrylate resin (Loctite adhesive 4013, Henkel, Düsseldorf, Germany) was applied on the surface of discs in this group and allowed to air dry.
Group 5. This group served as the control group and the samples did not receive any surface treatment.
An empty plastic cylinder (Tytong tube, Saint-Gobain, Courbevoie, France) with an internal diameter of 3mm and height of 1.5mm was placed on the surface of samples. Visio-link adhesive (LOT142655, Bredent, Senden, Germany) was applied on the surface of samples using a microbrush and light cured for 90 seconds (Ultradent Inc., South Jordan, Utah, USA). One increment of GC Gradia (LOT140627A, GC, Tokyo, Japan) veneering composite was applied with 1.5mm thickness and light cured for 180 seconds using a light-curing unit (Signum, Heraeus Kulzer, South Bend, USA) according to the manufacturer’s instructions. The samples were stored in distilled water at 37°C for 24 hours. The samples were then subjected to shear bond strength test using a universal testing machine (STM-250, Santam, Tehran, Iran) with a crosshead speed of 1mm/minute. Load at failure was recorded in N and divided by the bonding surface area (in mm²) to obtain the shear bond strength value in MPa.
The data were analyzed using SPSS version 21 (SPSS Inc., IL, USA). One-way ANOVA was applied to compare the shear bond strength of the groups. Since the shear bond strength was significantly different among the groups, Tukey’s test was applied for pairwise comparisons. P<0.05 was considered statistically significant.

[III] RESULTS
The mean (±SD) bond strength of the veneering composite to PEEK discs was 8.85±3.03MPa in the control group, 15.6±5.02MPa in air abrasion group, 30.42±5.43MPa in the sulfuric acid etching group, 26.14±4.33MPa in air abrasion plus sulfuric acid etching group and 5.94±4.49MPa in cyanoacrylate resin group. (Table 1, Figure 1) According to the results of one-way ANOVA, the difference in shear bond strength of the veneering composite to PEEK discs was statistically significant among the five groups (P<0.0001). Pairwise comparisons were then made using Tukey’s test, which revealed that the control group had significant differences with air abrasion (mean difference of 6.75MPa, P<0.005), sulfuric acid etching (mean difference of 21.57, P<0.0001) and air abrasion plus sulfuric acid etching group (mean difference of 17.29MPa, P<0.0001); however, the difference between the control and cyanoacrylate resin groups was not statistically significant (mean difference of 2.9MPa, P=0.52). Also, significant differences were noted in shear bond strength of air abrasion group with that of sulfuric acid etching (mean difference of 14.82, P<0.0001), air abrasion plus sulfuric acid etching (mean difference of 10.54 MPa, P<0.0001) and
cyanoacrylate resin group (mean difference of 9.66MPa, P<0.0001). Moreover, significant differences were found in shear bond strength of composite to PEEK between sulfuric acid etching and cyanoacrylate resin groups (mean difference of 24.48MPa, P<0.0001) and also between air abrasion plus sulfuric acid etching and cyanoacrylate resin groups (mean difference of 20.2MPa, P<0.0001); however, the difference in this regard between the sulfuric acid etching and air abrasion plus sulfuric acid etching groups was not statistically significant (mean difference of 4.28MPa, P=0.16).

[IV] DISCUSSION
Based on the current results, the mean shear bond strength of the veneering composite to PEEK surfaces was the lowest in cyanoacrylate resin group (5.94MPa) followed by no surface treatment control group (8.85MPa), air abrasion (15.6MPa), air abrasion plus sulfuric acid etching (26.14MPa) and sulfuric acid etching (30.42MPa) groups. As noted, sulfuric acid etching alone and in combination with air abrasion yielded the highest shear bond strength values while cyanoacrylate resin application and no surface treatment yielded minimum shear bond strength values. Air abrasion alone provided moderate shear bond strength value.

Prior to the bonding procedure, PEEK surfaces must be sufficiently roughened to provide adequate mechanical retention. However, PEEK is a highly strong resin material and its high strength limits the use of available techniques for surface roughening. Several methods have been proposed for surface treatment of PEEK to enhance its bond to composite resin. Etching is conventionally performed for surface treatment of different materials. It creates a porous surface and enables penetration of resin into the porosities and formation of resin tags, which provide micromechanical retention by interlocking. Although air abrasion with/without silica coating can also enhance surface wettability (10), sulfuric acid etching creates a rougher surface. It chemically modifies the surface and enhances the bond to hydrophilic composite resins. Shear bond strength as high as 19.0MPa has been previously reported following sulfuric acid etching of PEEK surfaces (4), which is of course lower than the value obtained in the current study (30MPa).

Evidence shows that PEEK can be used as a core material and is superior to alloy and ceramic restorations due to having mechanical properties similar to those of enamel and dentin. Zhou et al, in 2014 increased the bond strength of Rely X Unicem and SE Bond/Clearfil AP-X to PEEK composite by etching with 98% sulfuric acid and treatment with argon plasma compared to no treatment, sandblasting and hydrofluoric acid etching (11), which was in accordance with our findings. The reported bond strength values in their study ranged from 1.4MPa in sandblasted group to 7.4MPa in sulfuric acid etching group. Their findings were in agreement with the current results, and indicated optimal efficacy of sulfuric acid etching for enhancing the bond of composite resin to PEEK substrate. Similarly, 98% sulfuric acid was used in the current study, but it should be noted that 98% sulfuric acid cannot be used chair-side in the clinical setting due to its health hazards. It should be only applied in a laboratory setting under controlled conditions.

Following its application on PEEK surfaces, sulfuric acid attacks the functional ether and carbonyl groups present between benzene rings and increases the number of available functional groups for bond to adhesive components. As the result, the polarity of surfaces increases and adhesive can better diffuse into PEEK polymer. Consequently, the bond strength of the veneering composite to PEEK surface increases (6).

On the other hand, air abrasion or sandblasting of restoration surfaces is among the simplest surface treatment methods. It has been documented that sandblasting changes the surface morphology of PEEK and enhances the penetration of adhesive cement into composite material and subsequent micromechanical interlocking, resulting in higher
bond strength of the veneering composite to PEEK surfaces (6).
Zhou et al, in 2014 evaluated the bond strength of PEEK to two luting agents after air abrasion of PEEK surfaces with 50µm alumina particles. Scanning electron microscopic analyses revealed that grooves and surface defects of PEEK composite were eliminated by air abrasion (11). They showed that air abrasion increased the shear bond strength of the two adhesive cements to PEEK compared to the control group. In the current study, bond strength of the veneering composite to PEEK surfaces was significantly higher in air abrasion group with 110µm alumina particles compared to the control and cyanoacrylate resin groups; however, the shear bond strength value in the air abrasion group was lower than that in sulfuric acid etching and air abrasion plus sulfuric acid etching groups. Another finding of the current study was lower shear bond strength of the veneering composite to PEEK surfaces in air abrasion plus sulfuric acid etching group compared to that following sulfuric acid etching alone (26.14 versus 30.42 MPa), which indicates absence of synergy between these two methods.
Application of cyanoacrylate resin did not increase the bond strength of the veneering composite to PEEK, which may be attributed to absence of micromechanical retention between the two and easy degradation of the bond between Visio-link bonding agent and PEEK polymer surface. Due to the absence of standard laboratory conditions, accurate comparison of the results of different studies on bond strength of veneering composite to PEEK surfaces is not feasible. Several factors such as the variable geometry of the samples, different modulus of elasticity of materials and variability in loading conditions can affect the bond strength values (12). Also, macro tests yield lower bond strength values due to larger bonded surface area compared to micro tests (12). Moreover, the results of tensile and shear bond strength tests cannot be compared due to different patterns of stress distribution at the interface and variability in loading conditions. The current study had an in vitro design and suffered the limitations of in vitro studies; thus, interpretation of the results and their generalization to the clinical setting must be done with caution. Future studies are recommended to assess the long-term clinical service and success of the bond of the veneering composite to PEEK surfaces in oral clinical conditions.

[V] CONCLUSION
Within the limitations of this in vitro study, the results showed that sulfuric acid etching, air abrasion and combination of both may serve as efficient surface treatments to enhance the shear bond strength of the veneering composite to PEEK core material.

ACKNOWLEDGEMENT
The authors thank the Dental Material Research Center, Dental School, Babol University of Medical Sciences, Babol, Iran for supporting this study.

REFERENCES
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Table 1 - Mean and Standard Deviation of shear bond strength (MPa) of veneering composite to PEEK with different surface treatments

<table>
<thead>
<tr>
<th>Treatment Method</th>
<th>Mean</th>
<th>Standard Deviation</th>
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<tbody>
<tr>
<td>control</td>
<td>8.85</td>
<td>3.03</td>
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<tr>
<td>air-abrasion</td>
<td>15.6</td>
<td>5.02</td>
</tr>
<tr>
<td>sulfuric acid etching</td>
<td>30.42</td>
<td>5.43</td>
</tr>
<tr>
<td>air-abrasion plus sulfuric acid etching</td>
<td>26.14</td>
<td>4.33</td>
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<tr>
<td>cyanoacrylate resin</td>
<td>5.94</td>
<td>4.49</td>
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