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Effect of different treatment modalities on surface roughness and shear bond strength of veneering composite to Polyetheretherketone-based core materials

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ABSTRACT

Purpose: this study was designed to evaluate the effect of surface treatments on the surface roughness and shear bond strength of veneering resin to PEEK using two adhesive systems.

Materials and methods: Sixty square shaped PEEK specimens were divided into three different surface treatment groups. A total of twenty specimens (N= 20) were obtained for each surface treatment modality: Group (A): air abrasion, Group (L): ER:YAG laser, Group (C): control group (no surface treatment). Surface Roughness (SR) was measured for each group. Furthermore each group was subdivided into two subgroups according to the bonding system into:

Subgroup (V): visio.link (N=10) and Subgroup (U): scotchbond universal adhesive (N=10). Shear bond strength (SBS) was measured for each group.

Results: The sandblasting group showed significantly higher SR values than other groups ($p < 0.05$). No statistically significant differences were found between laser and control group. Specimens conditioned with Visio.link after sandblasting showed the highest mean SBS value of 19.86 ± 2.52.

Conclusion: Sandblasting demonstrated the highest SBS values among the pretreatments applied to PEEK while 1.5 W (150 mJ) Er:YAG laser pretreatment of PEEK surface did not influence the bonding effectiveness of veneering resin.

KEY WORDS: polyetheretherketonr, PEEK, surface treatment, air abrasion, laser,

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adhesive, resin composite

INTRODUCTION:

Resin based materials are increasingly used in the computer aided design/computer-aided manufacturing (CAD/CAM) systems and they have been suggested as optimal alternative to ceramics due to their favorable properties. [1] High-density resin-based materials have improved properties such as higher fracture resistance, better stress distribution, and less wear of the opposing dentition. These properties make them an alternative material to glass ceramics. [2]

Polyetheretherketone (PEEK) has been claimed to be an advantageous material for dental applications due to the material's improved mechanical properties and biocompatibility as well as resistance to nearly all organic and inorganic chemicals. It shows good dimensional stability and is radiolucent, making it compatible with imaging techniques such as computed tomography, magnetic resonance imaging, and x-ray. [3]

Polyetheretherketone (PEEK) is a methacrylate-free, high-performance thermoplastic polymer consisting of aromatic benzene molecules, which are connected alternately by functional ether or ketone groups. [2] PEEK's use in dentistry is not limited to manufacturing interim abutments, implant-supported bars, and dental implants. It may also be considered as a material for fixed partial dentures (FPDs) due to the material's improved mechanical properties. [4-8]

However, the material's optical properties and low translucency are the major concerns for FPDs, excluding its use as a monolithic restoration. Thus additional veneering resin is needed for PEEK-based restorations. [5] Nevertheless, PEEK's chemically inert behavior indicates a possible bonding problem at the PEEK core/veneering resin interface. This problem with the poor bond strength between the non-treated PEEK core/veneering resin has already been reported. [5]

In order to investigate the bond strength between PEEK frameworks and resin composites, various studies have been carried out. Largely, two approaches to achieve a strong bonding between resin composite and PEEK have been the focus of recent studies: the alteration of the PEEK surface and conditioning with an adhesive system to enable the chemical interactions. [9-11] Numerous studies have reviewed the bond strength between resin and PEEK material by a variety of pretreatments such as air abrasion, silica coating, treating the surface with sulfuric acid or piranha etching [7-11].

Laser irradiation has been suggested as an alternative method for surface treatment of PEEK. Laser has been used to modify the PEEK surface for increasing roughness and wettability. Er:YAG laser is a generally used laser method for surface modification of dental materials. However, there is no consensus in the literature about the laser parameters for optimal bond strength of resin-based materials. [12-15]

Surface pretreatments arrange the PEEK surface for micromechanical bonding to resin; however, additional adhesives are essential in establishing a strong bond between PEEK and resin. Studies showed that the combination with pretreatments enhances the bond strength because mechanical treatments provide more functional groups to which the components of adhesive systems can bond. [9-11].

All PEEK studies have reported that bonding to PEEK needs to improve in order to achieve a clinically acceptable long term adhesion, however, available data on the prospect and restrictions of PEEK in bonding to resin veneering materials is still inadequate.

MATERIALS AND METHODS:

Samples preparations:

Sixty square shaped PEEK (BreCAM. BioHP, Bredent GmbH&Co KG) specimens were sectioned by IsoMet™ 4000 measuring 12x12x1mm. The specimens were embedded in ready-made plastic mould tubes of 1 inch diameter and thickness 1 cm. Cold cure acrylic resin is injected in the mould. The bonding surfaces of each specimen were polished with 600- and 800-grit silicon carbide paper under running water. Polished specimens were ultrasonically cleaned in distilled water bath for 5 minutes.

Samples grouping:

Specimens were then randomly divided (Table 2) into three groups for further surface treatment procedures. A total of twenty specimens (N= 20) were obtained for each surface treatment modality: Group (A): air abrasion, Group (L): ER:YAG laser, Group (C): control group (no surface treatment). Furthermore, each group was subdivided into two subgroups according to the bonding system into: Subgroup (V): visio.link (N=10) and subgroup (U): scotchbond universal adhesive (N=10).

Surface treatment:

Air abrasion: (Group A): Twenty specimens were air abraded with 50 um Al2O3 particles for 15 seconds at a pressure of 2.5 bar perpendicular to the bonding surface at a 10mm working distance by using a dental sandblaster.

Laser Er:YAG: (Group L): Twenty specimens were irriadiated using Er:YAG with a wavelength of 2940 nm at a 10Hz repetition rate and 1.5 W power output.

laser energy was delivered with a non-contact hand piece perpendicular to the specimen surface. The entire surface of the specimen was scanned manually with the laser beam while being cooled with water and air.

Control: (Group C): Twenty specimens were left untreated and served as control.

Surface roughness measurement:

A stylus profilometer figure (11) (TR220, GmBH, Germany) was used to measure the Ra (average roughness height) in micrometers (μm) after each surface treatment and the data were calculated by three single individual measurements.

Adhesive system application:

After pretreatment, each group was subdivided into two groups according to adhesive system used (n = 10 per subgroup): Subgroup (V): visio.link and Subgroup (U): scotchbond universal adhesive. All adhesives were used according to manufacturer's instructions.

Visio.link application: Visio.link was applied to PEEK surface with a microbrush and light polymerized for 90 seconds with halogen polymerizing unit.

Scotchbond universal application: Scotchbond universal was applied to PEEK surface for 20 seconds and was air dried for 5 seconds.

Veneering:

Visio.lign was placed in a specially designed mold (4mm diameter x 4mm height) located at the center of PEEK surface and polymerized for 180 sec with polymerizing unit according to manufacturer's instruction.

Thermocycling:

All specimens were stored in distilled water at 37°C for 24 hours. Then they underwent 5000 thermocycles between (5 and 55°C) with a 20 second dwell time in each water bath by using an automated thermocycling machine.

Shear bond strength test: (SBS test)

SBS test was performed with a universal test machine at a 1 mm/min crosshead speed. The specimens were positioned parallel to the loading direction in the jig of the testing machine with the PEEK surface. The following formula was used to calculate SBS data:

fracture load/bonding surface area = N/mm^2 = MPa.

Statistical analysis

Statistical analysis was performed using statistical software (SPSS v.17; IBM, Armonk, NY). The Shapiro-Wilk Test was used to confirm that SBS and SR data were normally distributed. One-way ANOVA and Tukey test were used to analyze the SR data, and 2-way ANOVA and Fisher's LSD test were used to analyze the SBS data at a confidence interval of 95% (□ = 0.05).

RESULTS

Surface roughness:

Mean surface roughness values and standard deviations of specimens with. different surface pretreatments are presented in Table 1. The sandblasting group showed significantly higher SR values than other groups ($p < 0.05$). Laser group exhibited slightly higher SR values than control groups; however, no statistically significant differences were found between them

Table 1. Mean and standard deviation of surface roughness values of test groups (µm)

Groups	Mean ± SD
A	2.64 ± 0.28^b
L	1.19 ± 0.20^a
C	1.11 ± 0.09^a

Different superscript lowercase letters indicate statistically significant differences between groups ($p < 0.05$) A: air abrasion, L: Er:YAG laser irradiation, C: control group, no treatment

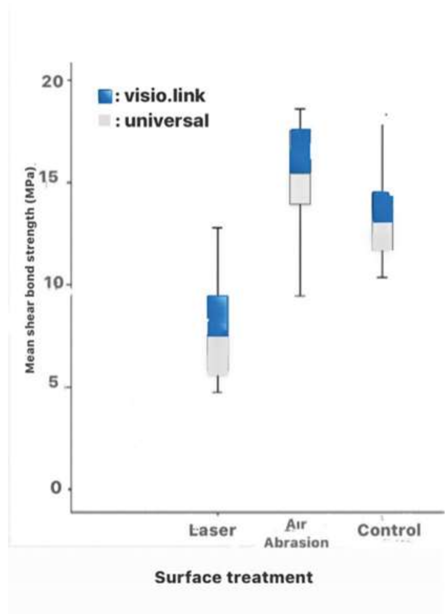
Shear bond strength:

Mean SBS and standard deviation of specimens with different surface treatments and adhesive systems are shown in Table 2. All SBS values were found to be higher than 5 MPa, so all tested specimens met the standard of ISO 10477. [55] The control group showed the lowest mean SBS value. Specimens conditioned with Visio.link after sandblasting showed the highest mean SBS value.

Table 2. *Mean and standard deviation for shear bond strength values of test groups (MPa).*

Group	Adhesive system	Mean ± SD
A	U	11.86 ± 0.93^a
	V	19.86 ± 2.52^b
L	U	6.30 ± 0.77^a
	V	9.69 ± 1.69^b
C	U	12.31 ± 1.74^a
	V	12.54 ± 2.19^a

a,b: Significant differences between adhesive systems within 1 pretreatment ($p < 0.05$). C: control group, no treatment; B: sandblasting; L: Er:YAG laser irradiation,U: universal bond; V: visiolink.



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Box plot representing mean shear bond strength

DISCUSSION

This in vitro study evaluated the effects of surface pretreatments and adhesive systems on bond strength of veneering composite to

PEEK. The results showed that sandblasting increased the SBS significantly; however, 1.5 W (150 mJ) Er:YAG laser irradiation had no effect on resin bonding to PEEK. Both adhesive systems had a significant effect on veneering bonding to PEEK. Pretreatments increased the effect of Visio.link, but did not affect the bonding effectiveness of Scotchbond universal adhesive. The SBS values of conditioned laser pretreatments were significantly lower than other pretreatments.

CONCLUSION

Within the limitations of this in vitro study, sandblasting demonstrated the highest SBS values among the pretreatments applied to PEEK while 1.5 W (150 mJ) Er:YAG laser pretreatment of PEEK surface did not influence the bonding effectiveness of veneering resin.

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