Original Article

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INFLUENCE OF DIFFERENT SURFACE TREATMENTS ON THE BOND STRENGTH OF POLYETHERETHERKETONE CROWNS LUTED TO DENTIN

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ABSTRACT:

Statement problem: Polyetheretherketone (PEEK) is a suitable material for using in dentistry as a fixed prosthesis; however the retention of this material is still controversial.

Purpose: This study is purposed to evaluate the tensile bond strength between PEEK crowns and human dentin after different methods of surface treatments.

Materials and methods: Forty human molar teeth were prepared with a standard dimensions. Polyetheretherketone (BioHPP, Bredent, Germany) crowns were fabricated and the specimens were divided according to the surface treatment method into 5 groups (n=8) as follows: gp (Aa) air abrasion with aluminum oxide particles (Rocatec Pre,particle size 110 microns, 3M ESPE , seefeld Germany), gp (AP) Piranha acid etching following air abrasion with aluminum oxide particles, gp (Si) Tribochemical treatment with silica coated particles (Rocatec plus, particle size 110 microns, 3M ESPE , seefeld Germany) gp (SP) Piranha acid etching after tribochemical treatment and gp (C) no surface treatment. The groups were then conditioned with an adhesive system (visio.link, Bredent Gmbh & Co. KG) and luted to the prepared dentin abutments using self-adhesive resin cement (G-Cem, GC, Tokyo, Japan). After water storage (48 hours) and thermocycling (7000 cycles, 5˚C/55˚C), the tensile bond strength of the crowns was determined with a pull-off testThe data were analyzed with 1-way ANOVA.

Results: Crowns that were untreated showed the lowest tensile bond strength results (8.49±0.66 MPa). The highest values were found in the groups (AP and SP) which were treated with piranha acid etching after alumina particles or silica particles air abrasion (12.03±2.4 MPa and 12.5±2.3 MP respictively).

Conclusions: The tensile bond strength of the tested PEEK crowns to dentin was improved after treatment with airborne-particle abrasion in combination with piranha acid etching.

Keywords: PolyEtherEtherKetone, Crowns, Surface treatment, Air abrasion, Piranha solution, Thermocycling, Tensile bond strength.

INTRODUCTION:

Dental Esthetics is devoted to restoring and enhancing the natural beauty of patient smile using conservative, state-of-the-art procedures that will result in beautiful, long lasting smiles. Restorations should also exhibit good mechanical characteristics. The mechanical characters mean that the material should have High compressive and flexural strength, to be durable with high fracture toughness, high wear resistance and abrasion resistance, dimensionally stable during set and over time, Bio-mimetic and exhibits mechanical properties similar to tooth structure, and to be highly polishable.[1]

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Poly ether ether ketone (PEEK) is a high performance polymer which is chemically consists of an aromatic molecular backbone chain that is connected with ether and ketone functional groups.[i] It is a poly-cyclic semi-crystalline thermoplastic material that was produced by a group of scientists from England in 1978. After a short period of time, in 1980s, PEEK was introduced as a material for industrial applications as turbine blades and aircrafts. By the late ninetieths, PEEK was categorized as a high-performance thermoplastic candidate of high importance for replacing the metallic implant components, especially in traumatic applications and orthopedics. At first, PEEK was used in vertebral surgeries as a material of the inter-body fusion cage. After the emergence of carbon-fiber reinforced Polyetheretherketone (CF/PEEK), this new composite material was used in fixation of fractures and femoral prosthesis in replacement of artificial hip joints. Since the last few years, PEEK and and CF/PEEK have attracted interests from material scientists, orthopedists and lately, dental researchers. [2]

PEEK properties are similar to dentin and enamel. Thus, it has superiority over metal alloys and ceramic restorations. CAD-CAM milled PEEK fixed prostheses' possess resistance to fracture (up to 2300N). It has higher resistance than lithium disilicate ceramic (900N) or zirconia (950-1300N).[3]

It has modulus of elasticity of (3– 4 GPa) which is another beneficial property as it is close to human cancellous bone (1.3-7.8 GPa).[2] PEEK can be modified easily by incorporation of other materials. For example; incorporation of carbon fibers can increase the elastic modulus up to 18 GPa. The modulus of carbon-reinforced PEEK is also comparable to those of cortical bone and dentin (12-20 GPa), so the polymer could exhibit lesser stress shielding when compared to titanium which used as an implant material. Moreover, tensile properties of PEEK are also analogous to those of bone, enamel and dentin.[2,3] PEEK has a hydrophobic, chemical inert surface and poor wetting capabilities which are blamed to be responsible of its weak bonds with the resins.[2] Multiple studies tried to increase its wettability and surface roughness in order to improve its bond strength with other materials.

Air abrasion with and without silica coating creates wettable surface, while etching with sulfuric acid creates rough and chemically processed surface. Uhrenbacher et al.[2] investigated the modification of the surface strength of PEEK crowns adhesively bonded to dentin abutments. The highest values were found for the airborne-particle abrasion and sulfuric etched groups. The results of Hallmann et al.[2]

research show that abraded PEEK surface with 50 µm alumina particles followed by etching with piranha solution lead to the highest tensile bond strength values. Li Zhou et al[2] also studied the effect of different surface treatment methods on the shear bond strength of PEEK specimens and found that air abrasion significantly increased shear bond strength values compared to the control group. They also studied the effect of thermo-cycling 5˚C-55˚C for 5000 and 10000 cycles and found that the specimens with 10000 cycles showed significantly lower shear bond strength values than that with 5000 cycles.

This study simulated oral conditions through preparation of human molar abutment rather than geometric synthetic specimens, thermocycling of the specimens for 7000 cycles 5˚C-55˚C which is approximately equivalent to 2.5 years of intra oral environment[ii], and evaluating the retention strength of the crowns by pull-off test which is done by exerting axial forces over the crowns till dislodgement .

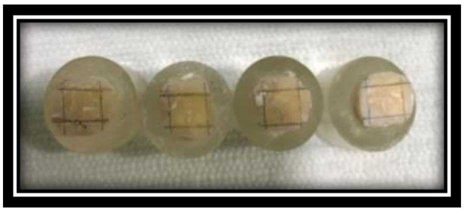
The study also evaluated the effect of air abrasion, tribochemical treatment and combination of mechanical and chemical treatment. The null hypotheses stated that the surface treatment factor of PEEK crowns had no effect on the tensile bond strength values.

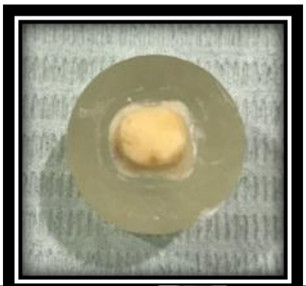
MATERIALS AND METHODS:

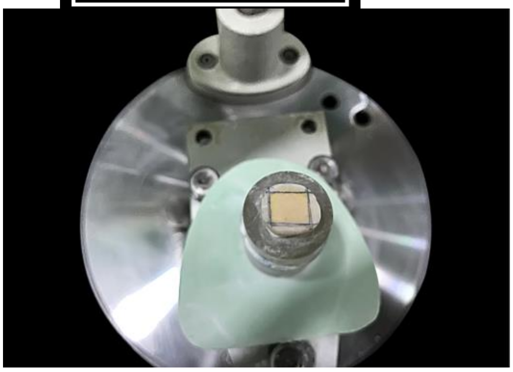
Forty extracted caries free human molars were collected, cleaned, scaled and polished with rubber burs. Retention elements with an average diameter of approximately 2 mm were drilled into the roots. The teeth were centralized in epoxy resin blocks till the height of 1 mm below the cemento-enamel junction.

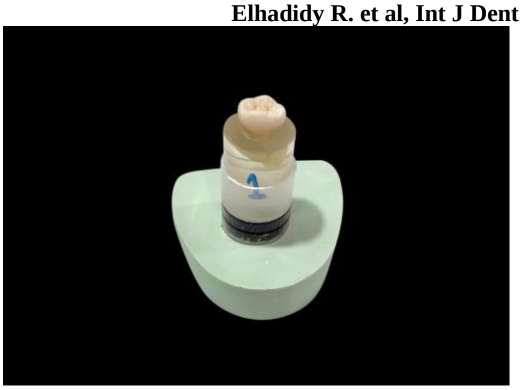
A

stone base was fabricated to provide a fixed centralized position of the specimen during tooth preparation.

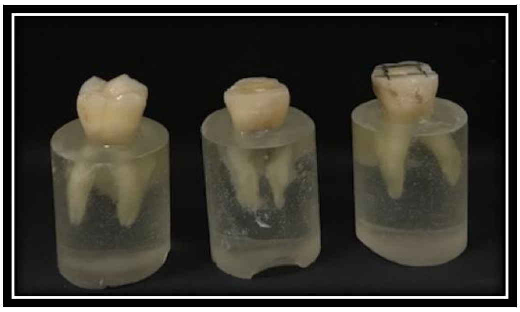




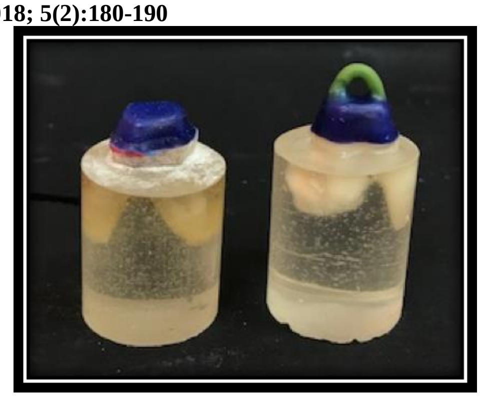




Teeth preparation was made in a paralellometer (surveyor, Marathon 103) with a low speed straight hand piece and an external cooling system. The abutments were reduced to a height of 4 mm with a cutting wheel abrasive stone. The surface area of the tooth structure was standardized to an oval shape with major axis of 7.5 mm and minor axis of 6.5 mm and a taper of 6 degrees, sharp edges were rounded and line angles were smoothened.



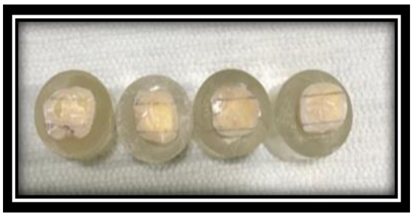
A non-anatomical wax pattern was made and a ring of wax was attached to the occlusal aspect. The minimum thickness of the wax pattern at the axial walls was 1mm and at the occlusal surface and the ring diameter was approximately 1.5 mm following the PEEK manufacturer's instructions (BioHPP, Bredent, Germany)



PEEK crowns were hot pressed (BioHPP granulat, Bredent Germany) in for 2 press machine. Crowns were finished and polished then, ultrasonically cleaned in distilled water.

The crowns were devided into five groups according to their pretreatments:

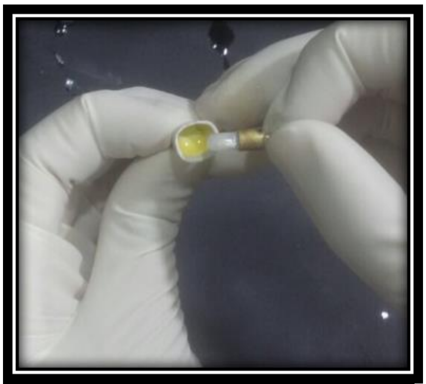
Group (Aa)

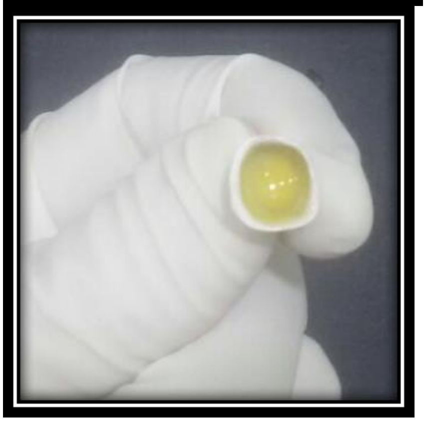


Airborne-particle abrasion with aluminum oxide size 110 microns particles for 15 seconds with the nozzle of the sandblaster away from the crown surface by approximately 1 cm (Rocatec Pre),

Group (AP)

Same as group A and then chemical treatment of the sandblasted surface by Piranha solution (10 parts of 98% sulfuric acid: 3 parts of hydrogen peroxide 30%) for 30 seconds and then washed thoroughly with distilled water for another 30 seconds.





Group (Si)

Fitting surfaces were tribochemically treated by the following steps:

The surfaces were air abraded using 110 micron alumina particles (rocatec pre for 15 seconds.

Then, the surfaces ware silicatised using 110 microns silica coated alumina particles for 15 seconds (Rocatec plus).

Group (SP) Tribochemical silica coating of the fitting surfaces of PEEK crowns same as Group C but then Piranha acid etching was done for 30 seconds.

Group (C)

Control Group

No surface treatment was done to this group.

Immediately after surface treatments, crowns were ultrasonically cleaned in distilled water ultra-sonic bath.

visio.link was applied in thin layer with a bond brush and a light cure device was used to complete the light polymerization process for 90 seconds (wavelength range 370 nm–400 nm).

The crowns then were luted to the dentin abutments with self-adhesive resin cement (G-Cem) with a seating weight of 5 Kilograms[iii].

The specimens then were stored in water for three days at room temperature and thermocycled for 7000 cycles (between 5˚C and 55 ˚C with a dwell time of 20 seconds in each water bath**)**.

For retention strength measurements, crown pull-off test was done using a universal testing machine (Instron) at a crosshead speed of 5 mm/min until debonding. The maximum force needed for debonding was recorded, while the surface area was calculated mathematically with the given standard dimensions. The bond strength was calculated from the equation:- Bond = F/A

RESULTS:

Data were fed to the computer and analyzed using IBM SPSS software package version 20.0. Quantitative data were described using mean, standard deviation for parametric data after testing normality using Kolmogrov-Smirnov test and Shapiro-Wilk test. All tests were 2-tailed with significance of the obtained results at the 5% level. **Student t** test was used to compare between two studied subgroups and **One Way ANOVA test** to compare between more than two studied groups with Post hoc LSD **f**or pairwise comparison between groups.

Tensile bond strength values were significantly increased after all methods of surface treatment of PEEK crowns in comparison with the un-treated group. The groups (AP and SP) that were treated with the combination between alumina particles air abrasion then piranha solution and silicated alumina particles then Piranha solution (12.3±2.4, 12.5±2.3 MPa respectively) showed significant difference in bond strength values in comparison with the control group C (8.49±0.66 MPa) .

Table (1): Comparison of bond strength between studied subgroups A, AP, Si, SP & C

	Aa	**AP**	**Si**	**SP**	**C**	**Test of significance**
Bond strength (MPa) Mean ± SD	10.35±1.3	12.03±2.4	10.3±1.2	12.5±2.3	8.49±0.66	F=3.5 P=0.03*
Post Hoc LSD		P=0.18	P=0.96 P1=0.17	P=0.09 P1=0.7 P2=0.08	P=0.14 P1=0.01* P2=0.15 P3=0.004*	

F: One way ANOVA test

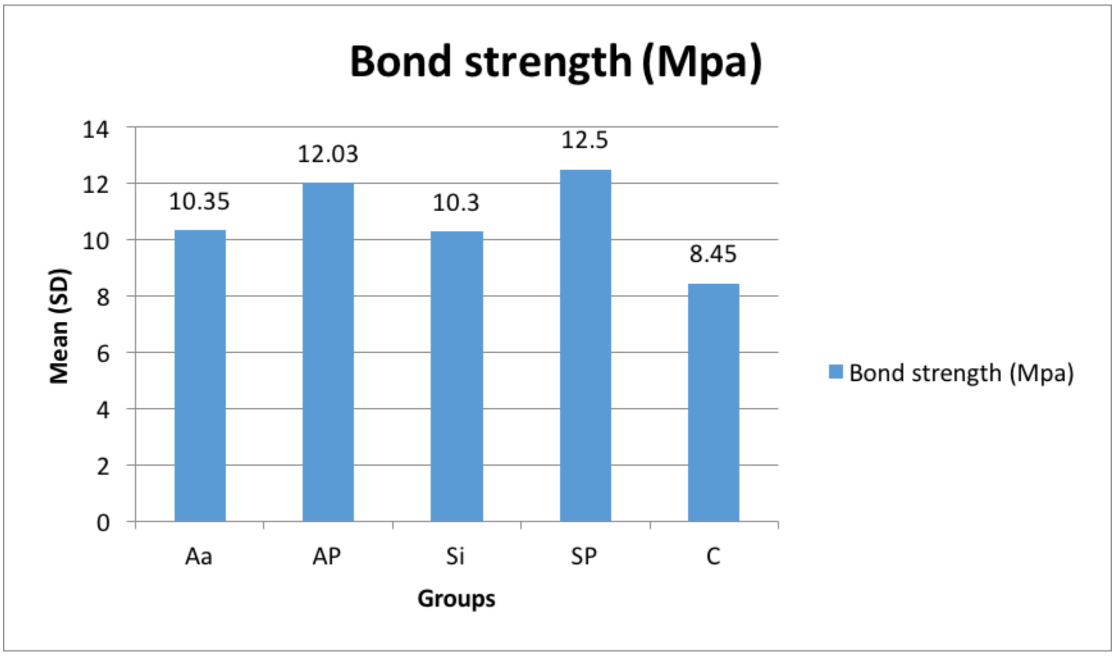
*P: Probability *Statistically significant (P<0.05)*

P: Significant difference between groups and group Aa,

P1: Significant difference between groups and group AP,

P2: Significant difference between groups and group Si,

P3: Significant difference between groups and group SP



DISCUSSION:

The null hypothesis of this study, which stated that different methods of surface treatment of PEEK crowns have no effect on the tensile bond strength values, was rejected.

Silica coating of the PEEK surfaces improved the tensile bond strength values when used either solely or in combination with piranha chemical treatment.

The mechanism of this process is: When the grains of the silica particles hit the air abraded surface of PEEK, very high impulses of energy are transferred into the surface (at the microscopic level). The affected PEEK surfaces are excited and a triboplasma is formed. The silicon dioxide particles are impregnated and fused into the hit surface forming islands of silica which are responsible of increasing bond strength with adhesive system[4]. These results are in disagreement with Helmann et al[14] who demonstrated the low values of tribochemical treatment of PEEK surfaces as the silica particles are attached to the surface loosely and after piranha etching they are washed away. The difference in the results between the two studies might be because the previous study used a particle size of 30 micron (cojet system) while in this study a 110 micron particle size (Rocatec plus) was used which caused more surface roughness and more impregnation of silica particles within PEEK surfaces which withstand the washing effect of acid etching.

Micromechanical surface treatment of the specimens using alumina particles (Rocatec pre, size 110 microns) enhanced the bond strength compared to un treated groups. The reason of this improvement was due to increasing the micro roughness of the surface which means increasing the effective surface area needed for bonding with the adhesive resin cement. The increased micro roughness also causes an improvement in the mechanical anchorage and penetration of the adhesive within the polymer surface. Also, The presence of fibers in the carbon fiber reinforced PEEK has a significant impact on the results of the air abrasion process. Ourahmoune R et al[4] , found that after air abrasion under the same surface treatment conditions, the composites had an increased roughness level than the unreinforced matrices. It was also found that the particle size of the sandblasting material is directly proportional to the surface roughness and wettability of the PEEK surface. All these findings confirmed that air abrasion process used in this study was the cause of the positive influence of the bond strength among the sandblasted groups. The results of current study were in agreement with those of Schmidlin PR et al[4] , Stawarczyc B et al[3], Stawarczyk et al [4] and sproesser O et al[5].

This study also showed that the chemical treatment after air abrasion enhanced the tensile bond strength as compared to the air abrasion without the chemical treatment. This may be attributed to the improvement of the micro roughness of PEEK surface in combination with increasing the functional groups after chemical treatment, which is responsible for a better crosslinking of polymers.[14] The established crosslinking, due to the reaction of functional groups of etched PEEK and adhesive also enhances the diffusion of adhesive resins inside the polymer layers, which increases bond strength values.

Moreover, using sulfuric acid and hydrogen peroxide mixture (Piranha solution) has a dual effect in the chemical activation of PEEK surface[4], While the atomic oxygen released during the reaction of hydrogen peroxide with sulfuric acid react with benzene ring as well. This process leads to the oxidation of PEEK polymer surface, increasing its surface polarity, opening of the aromatic ring and thus, producing more functional groups that are able to react with adhesive resins these results are in agreement with Hallmann L [14] et al while the results are in contrast to the results of Stawarczyk B et al.[18] This disagreement may be due to this previous study used another concentration of sulfuric acid and hydrogen peroxide which led to non-significant difference in the values before and after the application of piranha solution.

Methyl Metha acrylate monomers existed in Visio.link adhesive bond cause the PEEK surface to swell, pentaerythritol triacrylate (PETIA) and the dimethacrylate monomers provide 2 carboxyl groups to connect with the composite resins as binding sites.[13] This effect was explained in the study of Kern M and lehmann F [4] who investigated the tensile bond strength of a provisional resin restoration to PEEK after different methods of surface treatments and conditioning with different adhesive systems.

They found that the highest values were obtained (14.5 _2.6 MPa) for adhesive systems that contain Methyl methacrylate.

CONCLUSION:

Within the limitations of this study, airborne-particle abrasion and silica coating in combination with piranha acid etching of PEEK crowns is recommended before luting PEEK crowns to dentin.

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