Research Title:

Po.5

Effect of Different Surface Pre-treatments and Veneering Techniques on Shear Bond Strength of PEEK Coping Single Crowns: In Vitro Study.

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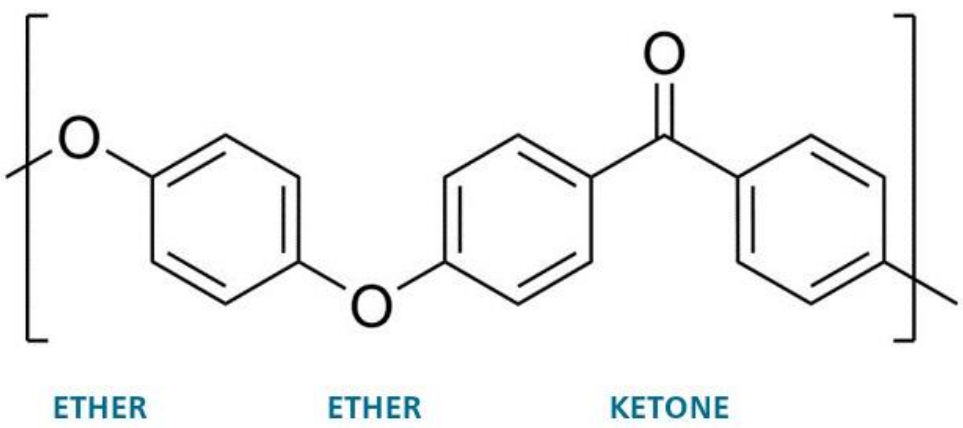
Statement of The Problem:

Using PEEK as a coping material seems promising and can gain popularity in the field of fixed prosthodontics. However, insufficient information is available about the use PEEK as a coping material veneered with ceramics.

Introduction

What Is PEEK ?

Polyetheretherketone (PEEK) is a high-temperature polymer of the family of polyaryletherketone. It is a semicrystalline thermoplastic consisting of an aromatic backbone molecular chain, interconnected by ketone and ether functional groups.



Chemical structure of PEEK.

(Stawarczyk et al., 2015).

Why PEEK?

- In clinical practice, clinicians may encounter failures with metallic restorations caused by the migration of metal ions within the prosthetic in the oral cavity.
- PEEK is a bio HPP - High Performance Polymer - belongs to the group of high-performance thermoplastic polymers, easy to use and prepare, which generally behaves as a physiologically inert material.

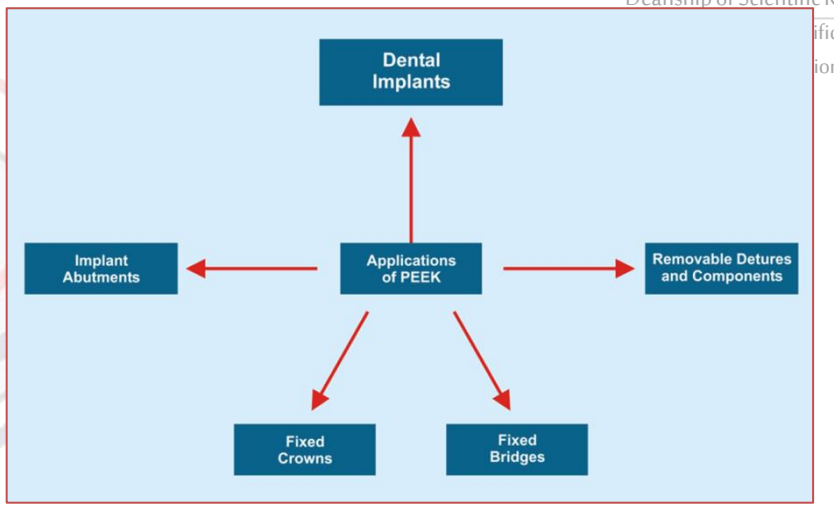
(Toni et al., 2015)

Applications of PEEK?

- PEEK is used in various medical applications for more than 20 years specially in orthopedics because of its excellent chemical, mechanical, and thermal properties, expressed by its high strength combined with adequate milling and grinding properties. Such as: Artificial hip, fingers, joints and heart valve replacements, etc.

- In dentistry, PEEK is used for interim abutments, implant-supported bars, clamp material, and dental implants.

(Najeeb et al., 2016).



Clinical applications of PEEK.

PEEK Maxillary Obturator Prosthesis.

Introduction:

Properties of PEEK?

The modulus of carbon-reinforced PEEK is also comparable to those of cortical bone and dentin so the polymer could exhibit **lesser stress shielding** when compared to titanium which used as an implant material (Table 1).

Moreover, tensile properties of PEEK are also analogous to those of bone, enamel and dentin making it a **suitable restorative material** as far as the mechanical properties are concerned.

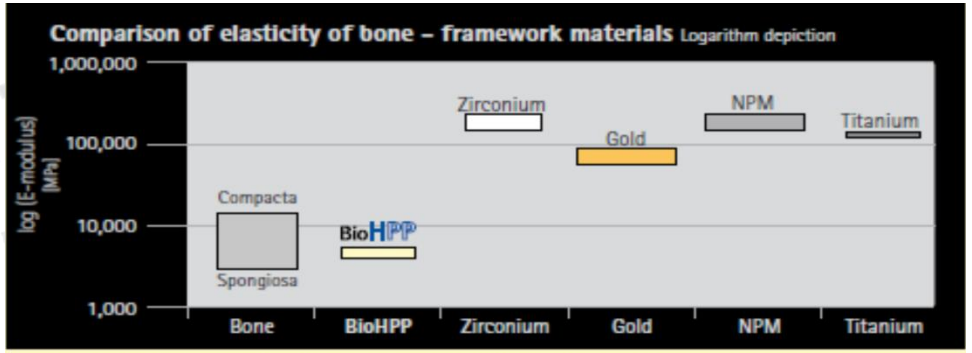
(Toni et al., 2015, Najeeb et al., 2016).

Table 1 – The tensile strength and elastic moduli of PEEK, CFR-PEEK, PMMA and mineralized human tissues.

Material	Tensile strength (MPa)	Young's modulus (GPa)	References
PEEK	80	3–4	[11]
CFR-PEEK	120	18	[11]
Cortical bone	104–121	14	[9,13]
PMMA	48–76	3–5	[14,15]
Dentin	104	15	[8,10]
Enamel	47.5	40–83	[7,8,12]
Titanium	954–976	102–110	[16]

PEEK, polyetheretherketone; CFR-PEEK, carbon-reinforced polyetheretherketone; PMMA, polymethylemethacrylate.

Similarity of the modulus of elasticity of PEEK to Bone, Dentin and Enamel.



In contrast to the framework materials previously used, BioHPP has an elasticity that is suited to the bone. Ceramics and NPM are approximately 20 x as rigid as bone, and gold and titanium are 10 x as rigid as bone. This similarity to bone has a beneficial effect, especially in wide-span framework structures.

Comparison of the elasticity of different framework materials compared to bone.

Cont. Properties of PEEK:

- Easy processing, milling and polishing.
- Good dimensional stability at high temperature.
- Chemically stable to nearly all organic and inorganic chemicals.
- Shows resistance to radiation damage and compatibility with many reinforcing agents like glass or carbon fibers.

(Toni et al., 2015, Najeeb et al., 2016).

Objective:

To evaluate the shear bond strength values of PEEK copings that are surface treated and veneered with different materials and techniques in both artificial aging and non-aging conditions.

Hypothesis:

- **First Null Hypothesis: There's No difference in shear bond strength of PEEK copings that are surface treated with five different surface pre-treatments methods.**

H0: μ1= μ2 = μ3 = μ4 = μ5

H1: There's at least one of the means is different from the others.

- **Second Null Hypothesis: There's No significant difference in shear bond strength between different veneering ceramic materials and techniques.**

H0: μ1= μ2 = μ3

H1: There's at least one of the means is different from the others.

- **Third Null Hypothesis: There's No difference in shear bond strength value among the aging and non-aging groups.**

H0: μ1 = μ2

H1: There's at least one of the means is different from the others.

Literature Review:

Literature Review:

- PEEK blanks have a grayish-brown or pearl-white opaque color and are unsuitable for the fabrication full contour monolithic esthetic dental restorations, especially for the anterior region. Thus, additional veneering is required to obtain satisfactory esthetics. Primarily, through achieving durable bonding to ensure an adequate functional outcome and long-term stability.

(Stawarczyk et al., 2015).

Cont. Literature Review:

- A considerable number of published articles have studied PEEK copings that were veneered with composite resins after applying different surface pre-treatments and several other studies have investigated the bonding of PEEK to dentin after preforming several surface pre-treatments.

(Stawarczyk et al., 2015, Najeeb et al., 2016, Stawarczyk et al., 2014, Kern and Lehmann, 2012, Uhrenbacher et al., 2014, Stawarczyk et al., 2013).

Cont. Literature Review:

- Articles investigated treating PEEK surface before veneering with composite resins reported that chemical etching of PEEK increased the surface free energy and surface roughness; *however*, it did not clearly improve the bond strength to the veneering resin and bonding was only achieved when additional adhesive materials were applied.
- Air-abraded PEEK did not result in any adhesion unless when a multifunctional methacrylates containing resin varnish was applied on the air-abraded PEEK surfaces.

(Kern and Lehmann, 2012)

Cont. Literature Review:

- Porcelain and ceramics exhibit more biocompatibility , color stability and superior aesthetics when compared to composite resins which makes them a perfect veneering materials.

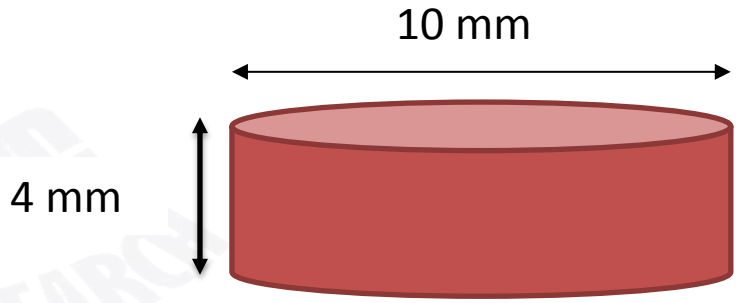
- However, the literature had no published articles studied the use of porcelain and ceramics as a veneering material over PEEK copings.

Methodology

1- Specimen Preparation and Surface Treatment.

(Smile PEEK, Onesto Scavino, Italia)

(Opera System Pro-Expert 5 milling machine)



1- Specimen preparation and surface treatment

n= 18

N= 90 PEEK Disks (10*4mm)

No treatment

Sandblasting with alumina. Mean particle size of 50 µm

Sandblasting with alumina. Mean particle size of 110 µm

Acid-etching with sulfuric acid (98%) for 1 min

Acid-etching with sulfuric acid (98%) for 1 min with silane coupling agent

2- Veneering Materials and Techniques:

N= 90 Ceramic Disks (10*4mm)

n= 6

Feldspathic porcelain

(Vita)

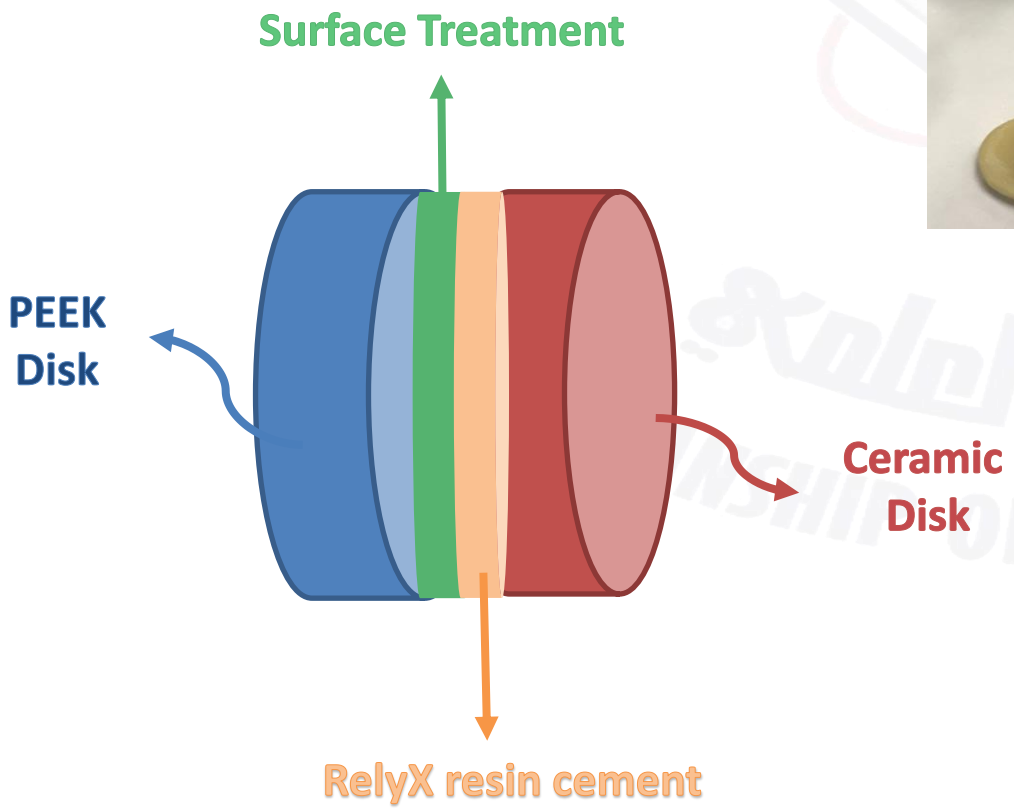
Lithium disilicate ceramic ingot

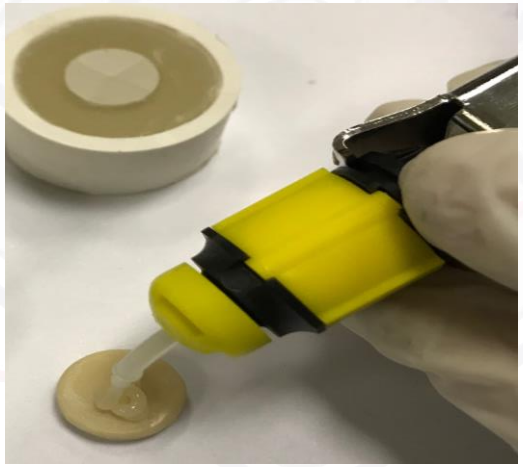
(E- max Pressed)

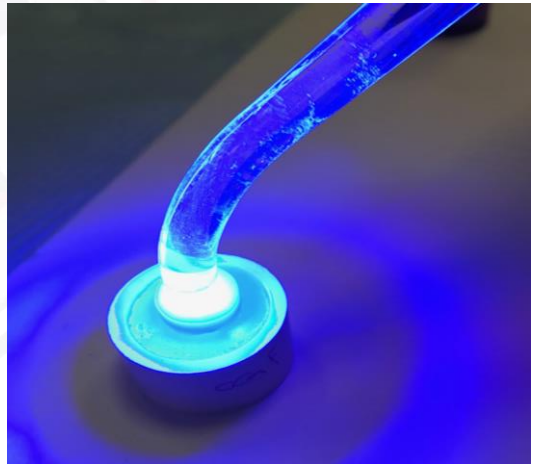
Leucite glass ceramic ingot

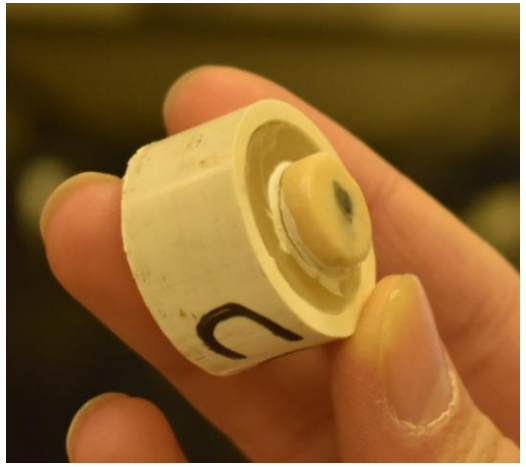
(IPS Empress)

3- Bonding procedure:



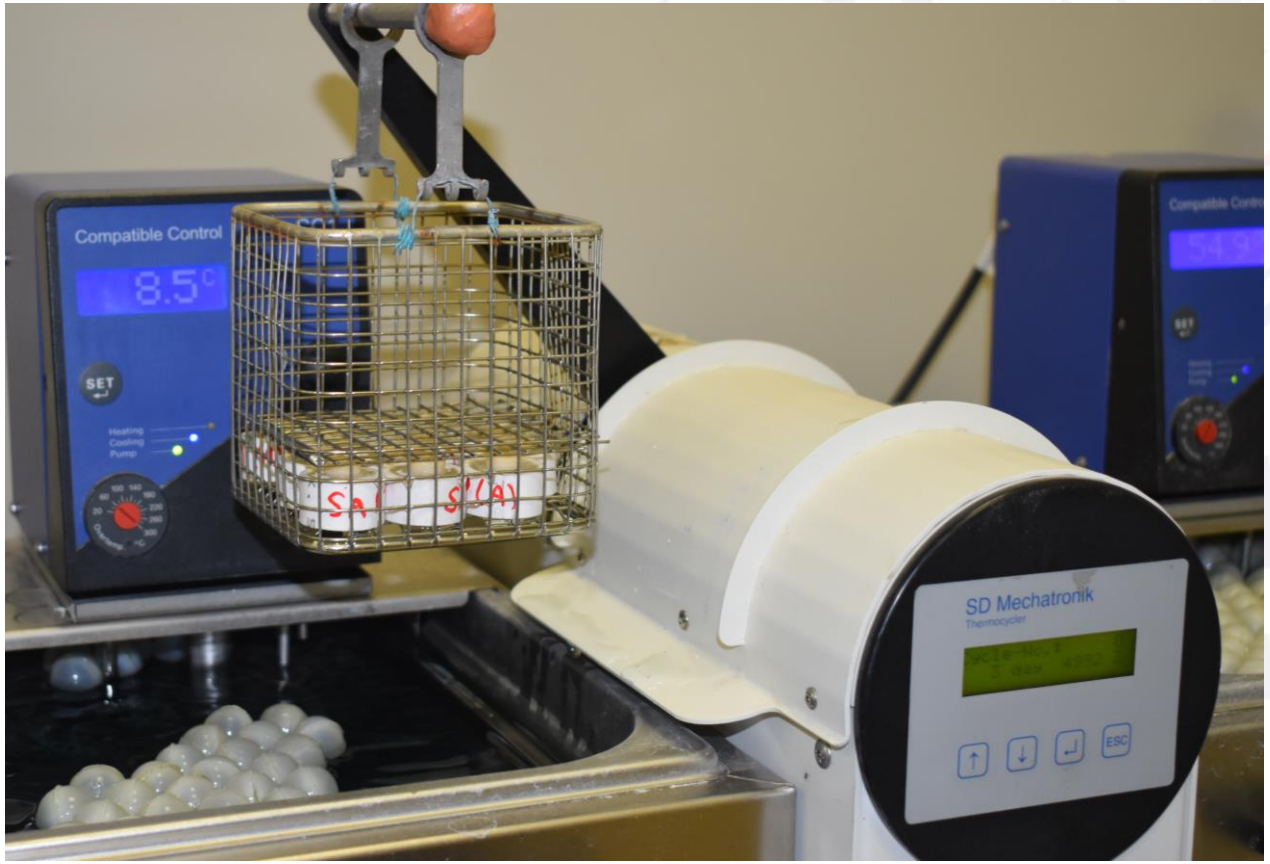






(Relyx Unicem Aplicap, 3M ESPE)

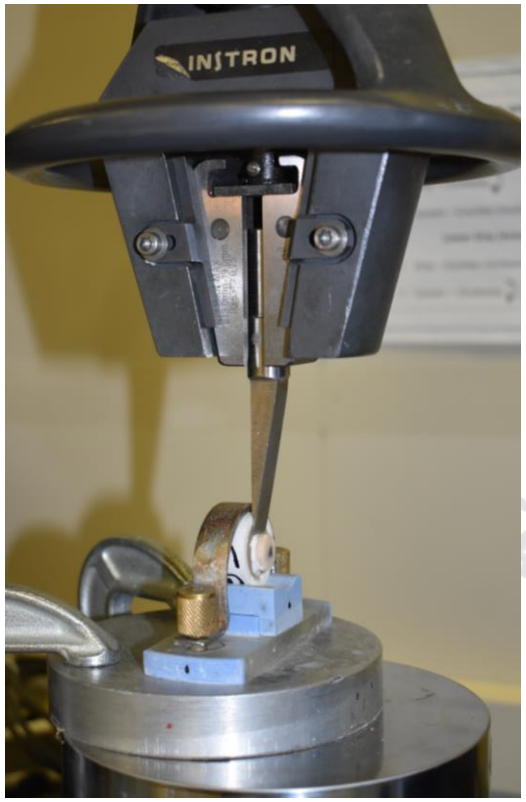
4- Artificial Aging:

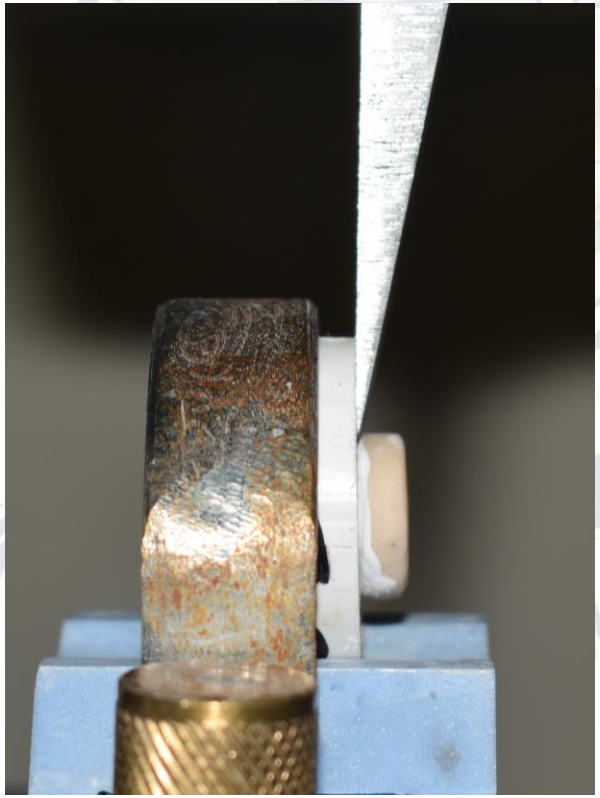


Artificial aging by exposure to
5000 cycles (1min/cyc)

Thermocycling Machine
(SD Mechatronik Thermocyler)

5- Measurement of shear bond strength:





- All specimens were loaded compressively in a universal testing machine **(Instron).**
- The load was applied with a cross-head speed **of 2mm / min.** by placing a knife edged blade directly parallel to the adhesive interface between PEEK and ceramic.
- The maximum load before debonding was measured and shear bond strength was then determined.

Statistical Analysis

- Descriptive analysis
- One-way Anova, Three-way Anova and Post-hoc test
- Independent T-test.
- A value of $P < 0.05$ is considered to indicate statistical significance.
- Statistical analyses were conducted with SPSS Statistics version 22.

Results

Results:

PEEK group treated with acid-etching (98% sulfuric acid and silane coupling agent) and bonded with E-max ingot porcelain in non-aged condition had **the highest** mean shear bond strength.

(10.03 ± 0.61 MPa)

Results:

Values of shear bond strength test for different groups among aging and non-aging condition in Megapascal (MPa):

Surface treatment	Aging	Feldspathic porcelain M.V±S.D	P-value	E-max Ingot porcelain M.V±S.D	P-value	Empress Ingot porcelain M.V±S.D	P-value
No Treatment	Non-A A	3.62 ±2.56 3.61±0.84	0.994	4.55±2.2 2.09±0.17	0.124	3.83±0.32 5.11±0.38	0.01*
Sandblasting with alumina (mean particle size of 50 µm)	Non-A A	5.95±2.8 5.84±1.74	0.955	5.71±3.2 5.00±0.64	0.725	3.39±0.39 3.84±0.39	0.234
Sandblasting with alumina (mean particle size of 110 µm)	Non-A A	3.66±1.3 4.71±1.58	0.424	3.10±0.24 3.63±0.56	0.212	4.17±0.31 5.78±1.06	0.066
Acid-etching with 98% sulfuric acid	Non-A A	1.92±0.54 3.43±0.90	0.067	5.64±0.37 7.49±3.86	0.456	5.16 ±0.06 4.96±0.06	0.015*
Acid-etching with 98% sulfuric acid with Monobond	Non-A A	8.86±0.75 7.47±0.84	0.101	10.03±.0.61 8.32±0.86	0.048*	7.71±0.45 7.89±0.62	0.703

Non-A , Non-aged group; A, Aged group; M.V, Mean value; S.D, Standard deviation; P-value **Significant at level 0.05

Results:

PEEK treated with **Acid-etching 98% sulfuric acid with silane coupling agent** showed a *significant difference* compared with the control group "No treatment" when bonded to all types of ceramics.

Results:

In non-aged group: PEEK treated with Acid-etching 98% sulfuric acid with silane coupling agent showed a **higher SBS** compared with the group of Acid-etching 98% sulfuric acid when bonded to all types of ceramics.

However, E-max ingot was the only ceramic type that had *no significant difference in aged group.*

Discussion

- The effective bonding to **PEEK** is a prerequisite for its use in dentistry as a prosthetic material.

- **After the shear test in the present study,** veneering ceramic were separated from the PEEK surface for every specimen group. Thus, it could be observed that the bond strength between PEEK and the veneering ceramic was weaker than the cohesive strength of the veneering ceramic.
- **In other words,** the weakest link was the interface between the PEEK and the veneering ceramics.

(Fischer et al., 2008, Schmidlin et al., 2010)

- During firing of **zirconia** copings, a strong chemical bond is established between the veneering ceramics and the polished zirconia surfaces as observed in a previous study.

- As **PEEK** being an inert material with high chemical resistance and low surface energy, bonding can't be achieved on its polished untreated surface.

- **Surface roughness** was shown to enhance the adhesive techniques and therefore different surface treatments were applied to increase the surface roughness and bonding area.

(Fischer et al., 2008, Schmidlin et al., 2010)

Comparison:

Zirconia + Ceramics	PEEK + Resin Composites	PEEK + Ceramics
In a different study that investigated the SBS of zirconia veneered with different ceramics the shear strength ranged from **23.5 ±3.4 MPa to 33.0 ± 6.8 MPa** without explicit correlation to the respective surface treatment and in another similar study reported a value of **36.2 MPa.**	In contrast, studies reported the shear bond strength of PEEK veneered with composite resins after different surface modifications reported a maximum SBS of **27.1± 3.1 MPa** and the lowest value was **5.4 ± 2.6 Mpa** and most of the failures were adhesive failures.	In our study, treated PEEK surfaces veneered with ceramics showed a maximum SBS of **10.03 ± 0.61 MPa** and the lowest value was **1.92 ± 0.54 MPa** with most of the failures were adhesive failures.

(Fischer et al., 2008, Rosentritt et al., 2015)

- Schmidlin et al. found that the **highest bond strength value** out different surface treatments when the PEEK was chemically pre-treated with 98% sulfuric acid.
- They also investigated the failure mode, the highest percentage of **cohesive failure** could be observed when PEEK was chemically surface treated with 98% sulfuric acid.
- Moreover, Stawarczyk et al. reported that PEEK specimens which were acid etched with 98% sulfuric acid for 1 min revealed the **highest SBS value up to 19.73 Mpa.**
- **Current study** elicits similar results, as the highest bond strength value was found in PEEK specimens that were treated with 98% sulfuric acid with silane coupling agent.

(Schmidlin et al., 2010, Stawarczyk et al., 2013)

Conclusion:

- **98% sulfuric acid with saline coupling agent** treatment improved the bond strength of PEEK with resin cement RelyX™ unicem. Therefore, the null hypothesis was rejected.

- **IPS E-Max Press Ingot** seemed suitable to bond to PEEK material. However, the use of 98% sulfuric acid is not clinically viable for the corrosive performance and considered toxic for dental office use. Thus, **Bonding of Porcelain to PEEK is not applicable** and more effective surface treatments of PEEK and favorable adhesives may be explored in future experimental studies.

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Questions?!

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