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Comparative analysis of bond strength of lithium disilicate to polyetheretherketone surface treated with sandblasted alumina, piranha solution and visio.link solution– An invitro study

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Abstract

Introduction: PEEK is an innovative dental biomaterial used in a variety of dental applications including implant abutments, single crowns, removable partial denture frameworks, fixed partial denture frameworks, and frameworks for implant-supported fixed complete dentures. Several surface treatments are being employed to improve PEEK's bonding properties to other materials. Further studies are required to evaluate the bond between PEEK and other dental materials.

Lithium disilicate has caught the interest of many dentists due to its unusual physical properties, excellent aesthetic attributes, ability to conform to adhesive cementation protocols, and adjustable production technique. As a result, its use in dentistry has expanded dramatically.

Aim: To compare the shear bond strength of lithium disilicate to PEEK surface treated with sandblasted alumina particles, piranha solution and visio.link solution.

Materials and Method: 60 PEEK discs were mounted on acrylic blocks and divided into three groups. All the samples were sandblasted with alumina particles using a pen blaster. Group 1 did not receive any further treatment. PEEK samples from Group 2 were surface treated with piranha solution for 60 seconds. PEEK samples from Group 3 were surface treated with visio.link solution and light cured for 2 minutes. The PEEK samples were then bonded with 60 lithium di silicate discs using dual cure resin cement. In a universal testing machine, the bondedsamples were evaluated for shear bond strength until debonding occurred. The shear bond strength (MPa) of the groups was calculated.

Results: The mean shear bond strength of group 1 was 571.93±329.01. The mean shear bond strength of group 2 was 1521.47±790.39. The mean shear bond strength of group 3 was 4441.91±1361.75.

Conclusion: The shear bond strength of lithium di silicate bonded to PEEK surface treated with visio.link solution was the highest followed by lithium di silicate bonded to PEEK surface treated with piranha solution. The shear bond strength of lithium di silicate bonded to PEEK surface treated with sandblasted alumina particles was found to be the least.

Keywords: Shear bond strength, Lithium di silicate, PEEK, Sandblasted alumina, Piranha solution, Visio.link solution

Introduction

Polyetheretherketone (PEEK) is a high-temperature, semicrystalline thermoplastic polymer. For many years, it has been employed in medical procedures like spinal implants and joint replacements. Due to its biomechanical characteristics, PEEK has become more widely employed in dentistry.[26]

By using nucleophilic substitution, polyketones, commonly known as PEEK, are created from aromatic dihalides and bisphenolate salts. By using the Williamson ether synthesis, the bisphenolate salt is produced in-situ from bisphenol and either additional sodium or additional alkali metal carbonate or hydroxide. PEEK is a thermoplastic semi-crystal with good mechanical qualities. [2]

PEEK can be easily worked and has good mechanical strength, heat resistance, and chemical resistance. Its structure involves an ether or ketone bond connecting the benzene ring to the other rings. PEEK is utilised commercially in parts for vehicles, aircraft, and semiconductors that operate in challenging settings and need to be resistant to heat and chemicals. Considering that PEEK is radiolucent, it can be used with imaging techniques like computed tomography, magnetic resonance imaging, and radiography. [20]

It has long been employed in medical procedures including spinal implants and joint replacements. PEEK is being used more frequently in dentistry in part due to its biomechanical qualities, which include acceptable strength, low solubility and water absorption, good wear characteristics, low biofilm formation, high biocompatibility and chemical inertness, non-allergenicity, adequate polishability, an elasticity modulus comparable to bone, and tensile properties comparable to those of bone, enamel, and dentin. [26]

The ability of PEEK to be manufactured without the addition of any additives that would compromise its biocompatibility qualities makes it a highly advantageous material for use in the medical and dentistry fields. Because PEEK is compatible with reinforcing materials (such glass and carbon fibres), its mechanical properties can be increased. Dental based polymers offer a fresh option for a brand-new line of metal- and ceramic-free crowns, bridges, and implants that can be used for patients who are allergic to titanium. Due to its closely white, tooth-like tint that closely resembles that of natural teeth, it gives adequate aesthetics. It is a great biomaterial for short term uses, including healing caps and temporary abutments. Stress

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shielding, osteolysis, and implant loosening may be prevented by flexural modulus resembling that of cortical bone. [4]

One of the most significant characteristics of adhesive bonding is long-term durability. It depends on a variety of variables, including humidity levels, peak stress levels, and hostile settings. The substrates and adhesive engage in a complicated interplay. When the adhesive penetrates deeply into the substrate and releases the majority of its energy, a strong connection is formed. When the substrate and adhesive both contain reactive groups, a strong binding can be produced. A key element of adhesion is the substrate's roughness.

By increasing surface contact by up to 10, it enhances the mechanical anchoring of the adhesive. The roughness of the surface is increased by air abrasion, which is frequently utilised in clinical practise. The bond characteristics and fatigue resistance are determined by the surface preparation. Less deterioration is likely to occur with physical links.[4]

Due to its resonance-stabilized chemical structure and delocalized higher-orbital electrons, PEEK is chemically inert. PEEK should therefore receive surface treatments to improve wettability before an adhesive bonding agent is used to generate a micromechanical bond. [26]

Physical techniques like plasmas, UV light, laser and wet chemical procedures have both been investigated to enhance the adhesive characteristics of PEEK. All of these techniques need a lot of space, expensive equipment, and investments, making them impractical for the majority of clinical settings. Hence simple and effective methods must be investigated and used to enhance the adhesive properties of PEEK.[4]

Lithium disilicate a glass ceramic, provides superior aesthetic and optical qualities when compared to zirconia.The characteristics of lithium disilicate demonstrate that it has a flexural strength of more than 350 MPa, making it a suitable material for implant restoration.For the creation of full-contour monolithic lithium disilicate restorations, CAD/CAM technology is ideally used.To increase the surface area and strengthen the bond between the materials, different surface treatments can be used. Air abrasion is the most popular surface modification method, often used in conjunction with plasma modification or acid etching.[31]

When opposed to titanium, newer materials like PEEK abutments have better aesthetics, however there is little study on the bonding of these materials to lithium disilicate.

Hence, this study was taken up to evaluate the effect of different surface treatments on the bond strength between PEEK and lithium di silicate.

Aim

To compare the shear bond strength of lithium disilicate to PEEK surface treated with sandblasted alumina particles, piranha solution and visio.link solution.

Methodology

A total number of 60 discs of Lithium di silicate and 60 discs of PEEK were used. Lithium disilicate specimens were sectioned from a cylindrical block, each specimen measuring 10mm in diameter and 2mm in thickness. Cylindrical PEEK specimens were sectioned from a block with each specimen having a diameter of 10mm and thickness of 2mm.

The PEEK specimens were mounted onto acrylic blocks and divided into 3 groups:

Group 1(n=20)

PEEK surface treated with sandblasted alumina particles

Group 2(n=20)

PEEK surface treated with sandblasted alumina particles and piranha solution

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Group 3(n=20)

PEEK surface treated with sandblasted alumina particles and visio.link solution

Surface treatment

All the PEEK samples were air abraded using a pen blaster with alumina particles of 110 microns at an angulation of 45º on all sides followed by cleaning the samples using distilled water. Group 1 received no further surface treatment. Group 2 PEEK samples were acid etched with piranha solution [khariwal laboratory] {H_2SO_4: H_2O_2 3:1} for 60 seconds. Group 3 PEEKsamples were surface treated with Visio.link primer [bredent]. The primer was applied using a microtip applicator and was light cured for 2 mins [woodpecker]. All the sample surfaces were cleaned using 70%isopropyl alcohol before the bonding procedure was done to clean any residues that were left on the surfaces following treatment.

Lithium disilicate discs were treated with 10% hydrofluoric acid [angelus] for 60 seconds and cleaned with distilled water before bonding them to PEEK using a resin cement [GC G-CEM ONE].

Bonding procedure:

G CEM ONE[GC] dual cure resin cement was used to cement the lithium disilicate discs to the PEEK discs. Following manufactures instruction the surface of PEEK discs were cleaned using isopropyl alcohol and dried. A primer that was provided with the resin cement was applied to the PEEK surface and air dried. The resin cement was dispensed onto mixing pad and mixed for 30 seconds and placed onto the PEEK surface and a lithium disilicate disc was placed onto it and constant finger pressure was applied by a single clinician and initial cure was done using LED light curing unit [wood pecker] for 2 seconds and excess cement was removed using a probe and cured for 60 seconds. The same procedure was followed for all the samples.

All the samples were stored in distilled water for 24 hours and the bond strength was tested using universal testing machine [Mecmesin Multi Test 10-i] at a cross head speed of 1mm/sec until debonding.

Results

Data was subjected to Normalcy test (Shapiro Wilk test). Data showed normal distribution Hence parametric tests (ANOVA with post-hoc Bonferroni) was applied for bond strength.

The Shapiro–Wilk test is more appropriate method for small sample sizes (<50 samples) although it can also be handling on larger sample size while Kolmogorov–Smirnov test is used for n ≥50. For both of the above tests, null hypothesis states that data are taken from normal distributed population. If the p value of the Shapiro-Wilk Test is greater than 0.05, the data is normal. If it is below 0.05, the data significantly deviate from a normal distribution.

Tests of Normality						
Groups	Kolmogorov Smirnov[a]			Shapiro-Wilk		
	Statistic	Df	p value	Statistic	df	p value
Group 1	.152	20	.200*	.934	20	.181
Group 2	.209	20	.023	.908	20	.059
Group 3	.138	20	.200*	.925	20	.122

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Table 1: Comparison of the bond strength among the groups using Anova

Groups	N	Minimum	Maximum	Mean	S.D	p value
Group 1	20	100.64	1170.70	571.93	329.01	0.001*
Group 2	20	462.42	3017.83	1521.47	790.39	
Group 3	20	2629.29	7066.24	4441.91	1361.75	

*significant

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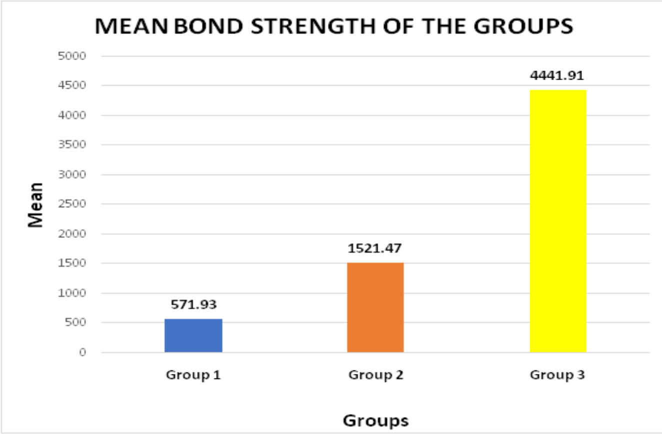

Table 2: Inter-Group Comparison Using Post-Hoc Bonferroni Test

	Mean Difference	p value
Group 1 Vs Group 2	-949.53	.006
Group 1 Vs Group 3	-3869.98	0.001*
Group 2 Vs Group 3	-2920.44	0.001*

*significant

Discussion

PEEK is a biocompatible engineering thermoplastic with distinctive material characteristics that make it appealing for use in dentistry. Even though PEEK has a long history of use its potential use as a dental restorative material has received minimal attention in industrial and medicinal applications. There has been little research on PEEK's adherence to teeth or its endurance after applying various surface-treatment techniques. As a result, adhesion guidelines for PEEK’s use in dentistry are still being developed. PEEK must successfully bind to another surface in order to be used as a prosthetic material in dentistry.

Enough surface roughness is typically necessary to increase the bonding strength of plastic dental materials. Similar to this, PEEK’s surface needs to be sufficiently roughened to ensure effective mechanical retention throughout the bonding process. However, due to PEEK’s strength and hardness, only a few surface roughening techniques can be used with success.

In dentistry, sandblasting is a straightforward, frequently used surface treatment technique. It is well known that sandblasting can alter surfaces and strengthen shear bonds.It has been applied in clinical settings to clean dental materials and increase their surface roughness. Sandblasting improves surface roughness, adds a new layer to the surface, and encourages micromechanical interaction between the dental adhesive-treated surface and the surface. Previous research has demonstrated that when surface morphology is enhanced using sandblasting, bonding strength is significantly increased.

In earlier studies, 98% concentrated sulfuric acid was used to treat the PEEK surface, resulting in a highly porous surface that was permeable to adhesives. The strength of the relationship was thereby increased.For the surface treatment of dental PEEK, highly corrosive solutions like piranha solution (sulfuric acid with hydrogen peroxide) and 98% sulfuric acid have been tested in other in vitro experiments. Because PEEK is an apolar, inert polymer with great chemical resistance and low surface energy, these solutions are necessary. However, due to its severe corrosiveness, the use of 98% sulfuric acid is not therapeutically feasible.[20]

Piranha solution, also known as peroxymonosulfuric acid (H_2SO_5) in chemistry, is composed of sulfuric acid (H_2SO_4) and hydrogen peroxide acid (H_2O_2). It possesses significant oxidising effects, boosts surface polarity, and breaks the aromatic ring, increasing the amount of functional groups that can form bonds.[8]

In addition to increasing the amount of functional groups, treating PEEK surfaces with piranha solution improves the surface’s micro-roughness. Only the carbonyl and ether groups on the PEEK surface were attacked by sulfuric acid when it was used as the sole

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treatment. In the instance of piranha solution, the benzene ring was affected by the atomic oxygen generated during the interaction of hydrogen peroxide with sulfuric acid. This causes the PEEK polymer to oxidise, which increases surface polarity, opens aromatic rings, and establishes more functional groups that can interact with adhesive. Additionally, the created crosslinking increased the diffusion of adhesive inside the etched PEEK by reacting with adhesive's functional groups, resulting in an improvement of the bond strength.[4]

In general, methyl methacrylate (MMA) monomer-based adhesive solutions demonstrated durable tensile bond characteristics (7.6-69 MPa) even after ageing. [12]

Visio.link, is a MMA based primer solution which contains pentaerythritol triacrylate (PETIA) in solution, methyl methacrylate (MMA) monomers, and extra dimethacrylates. It is a coupling agent used to increase the bond strength between two materials. Various studies have been conducting to evaluate the effect of PEEK surface treated with visio.link solution. The results showed a better bonding potential when PEEK was surface treated with visio.link solution. The chemical composition of the agent was shown to play an important role. It is probable that PETIA dissolves the PEEK surface, MMA monomers enlarge the dissolved surface, and dimethacrylate monomers create the link by acting as binding sites for two methyl groups.[8]

Lithium disilicate reinforced glass ceramic, one of a variety of commercially available ceramic systems, has drawn a lot of attention over the past ten years due to its physical characteristics, excellent aesthetic features, ability to adhere to adhesive cementation protocols, and flexible fabrication process (either lost-wax technique or, more recently, CAD/CAM manufacturing).

Monolithic full-contour anatomical crowns that could later be crystallised and characterised for customising were made possible by the creation of several precrystallized ceramic CAD/CAM blocks of various translucencies. The flexural strength of monolithic crowns is 360 MPa as opposed to the 90 MPa provided by the veneering ceramic in veneered zirconia crowns.

In comparison to any other ceramic layered system, lithium disilicate reinforced glass-ceramic monolithic crowns have shown to be superior in terms of flexural strength and fatigue resistance (independent of employing metal or zirconia as an infrastructure). Consequently, their application in dentistry has greatly expanded.[9]

This study was taken up to compare the shear bond strength of lithium disilicate to PEEK surface treated with sandblasted alumina particles, piranha solution and visio.link solution.

Cylindrical specimens were prepared from lithium di silicate and PEEK blocks. All the PEEK specimens were mounted onto acrylic blocks and sandblasted with a pen blaster at an angle of 45º using 110 µm alumina particles. The first group received no further treatment. The second group of PEEK samples were acid etched with piranha solution [khariwal laboratory] {H_2SO_4: H_2O_2 3:1} for 60 seconds. The third group of PEEK samples were surface treated with Visio.link primer. The primer was applied using a microtip applicator and was light cured for 2 mins. All the sample surfaces were cleaned using 70%isopropyl alcohol before the bonding procedure was done to clean any residues that were left on the surfaces following treatment.

Lithium disilicate discs were treated with 10% hydrofluoric acid [angelus] for 60 seconds and cleaned with distilled water before bonding them to PEEK using resin cement [GC G-CEM ONE].G CEM ONEdual cure

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resin cement was used to cement the lithium disilicate discs to the PEEK discs. Following manufactures instruction the surface of PEEK discs were cleaned using isopropyl alcohol and dried. A primer that was provided with the resin cement was applied to the PEEK surface and air dried. The resin cement was dispensed onto mixing pad and mixed for 30 seconds and placed onto the PEEK surface and a lithium disilicate disc was placed onto it and constant finger pressure was applied by a single clinician and initial cure was done using LED light curing unit for 2 seconds and excess cement was removed using a probe and cured for 60 seconds. The same procedure was followed for all the samples.

All the samples were stored in distilled water for 24 hours and the bond strength was tested using universal testing machine [Mecmesin Multi Test 10-i] at a cross head speed of 1mm/sec until debonding.

Results showed highest shear bond strength of lithium disilicate bonded to PEEK specimens surface treated with visio.link primer, followed by lithium disilicate bonded to PEEK specimens surface treated with piranha solution, followed by lithium disilicate bonded to PEEK specimens surface treated with sandblasted alumina particles. All the results obtained were statistically significant. Thus, it can be concluded within the limitations of this study that visio.link solution and piranha solution increase the shear bond strength between PEEK and lithium disilicate and hence successfully enhance the adhesion between them.

Conclusion

PEEK is a novel dental biomaterial that is used in a wide range of dental applications, such as implant abutments, single crowns, endocrowns, telescopic secondary crowns, removable partial denture frameworks, fixed partial denture frameworks, and frameworks for implant-supported fixed complete dentures. To enhance PEEK's bonding capabilities to other materials, several surface treatments are being used.

Due to its unique physical characteristics, great aesthetic qualities, ability to adhere to adhesive cementation protocols, and adaptable production technique, lithium disilicate has attracted a lot of interest. As a result, its application in dentistry has significantly increased over the past ten years.

Within the limitations of this study, it can be concluded that

- The shear bond strength between lithium disilicate and PEEK improved when PEEK was surface treated with sandblasted alumina particles.
- The shear bond strength between lithium disilicate and PEEK improved when PEEK was surface treated with piranha solution.
- The shear bond strength between lithium disilicate and PEEK improved when PEEK was surface treated with visio.link solution.
- On comparing the shear bond strength between lithium disilicate and PEEK surface treated with sandblasted alumina particles, piranha solution and visio.link solution, the samples surface treated with visio.link solution showed highest shear bond strength followed by samples surface treated with piranha solution followed by samples surface treated with sandblasted alumina particles.

Annexure

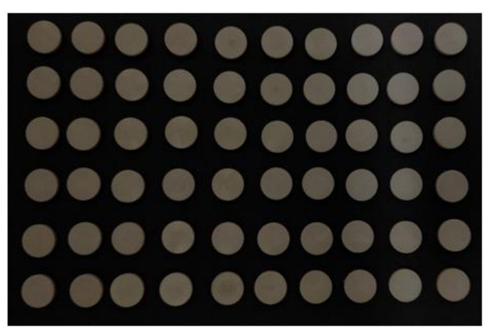

Figure 1: 60 Peek Discs

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Figure 2: Peek Discs Measuring 10 mm Diameter and 2mm Thickness

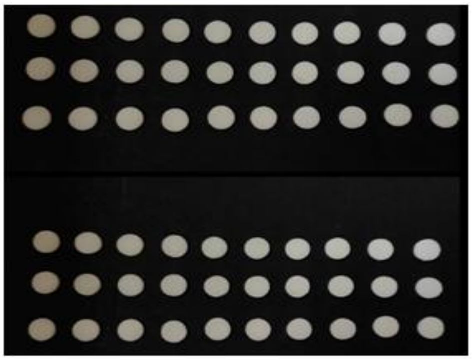

Figure 3: 60 Lithium Di Silicate Discs

Figure 4: Lithium DI silicate discs measuring 10mm in diameter and 2mm in thickness

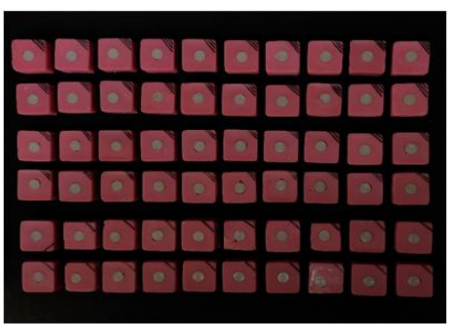

Figure 5: Peek discs mounted on acrylic blocks

Figure 6: Sandblasting of peek discs using pen blaster with alumina particles

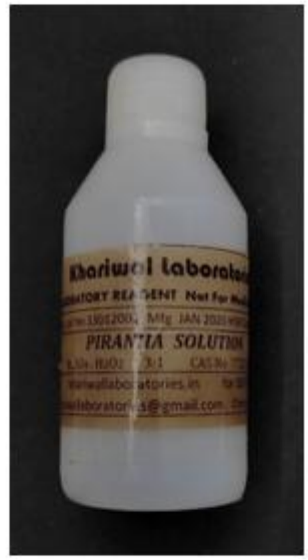

Figure 7: Piranha solution [khariwal laboratories]

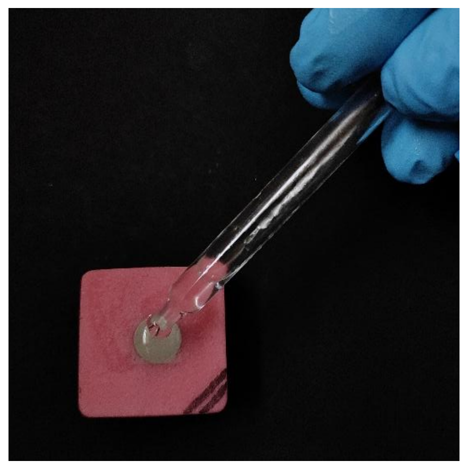

Figure 8: Acid Etching of Peek Samples Using Piranha Solution

Figure 9: visio.link solution [bredent]

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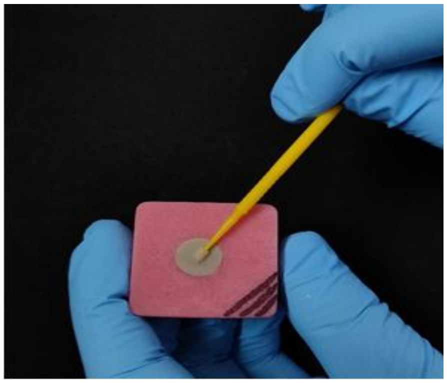

Figure 10: Application of visio.link solution using microtip applicator

Figure 11: Light Curing Unit [Woodpecker]

Figure 12: Light curing of visio.link solution using light curing unit

Figure 13: Alcohol swabs [70% isopropyl alcohol]

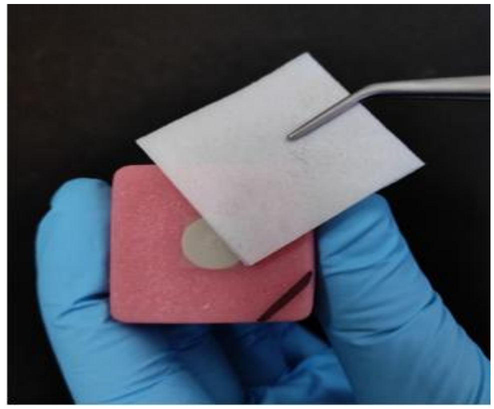

Figure 14: Cleaning the samples using 70% isopropyl alcohol swabs

Figure 15:10% Hydrofluoric Acid (Angelus)

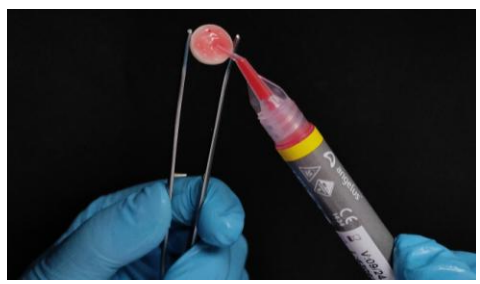

Figure 16: Porcelain Etching Using 10% Hydrofluoric Acid

Figure 17: G-CEM One Dual Cure Resin Cement [GC]

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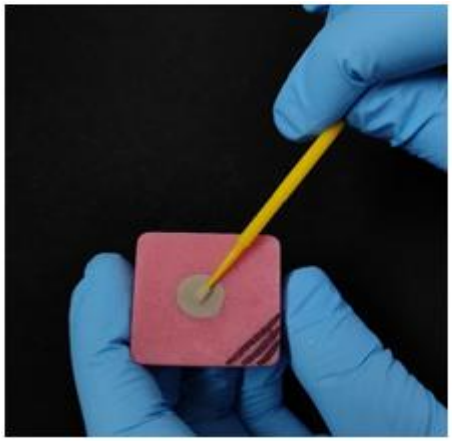

Figure 18: Application of Resin Cement Primer Using Microtip Applicator

Figure 19: Manipulation of resin cement according to manufacturer's instruction

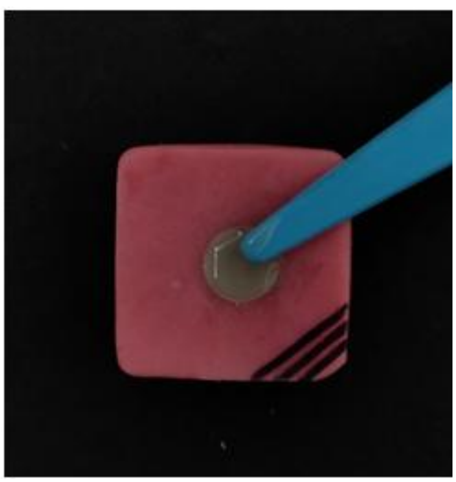

Figure 20: Cement dispensed on the surface of peek samples

Figure 21: Lithium Di Silicate Discs Placed Over the Peek Samples

Figure 22: Light curing of the resin cement using light curing unit [Woodpecker]

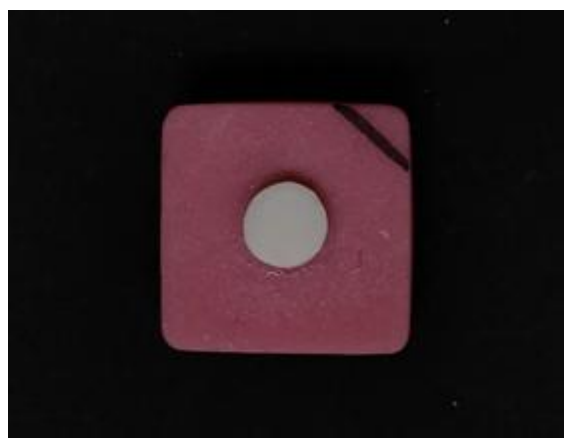

Figure 23: Lithium Di Silicate Bonded To Peek Discs

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Figure 24: Universal testing machine [mecmesin multi test 10-i]

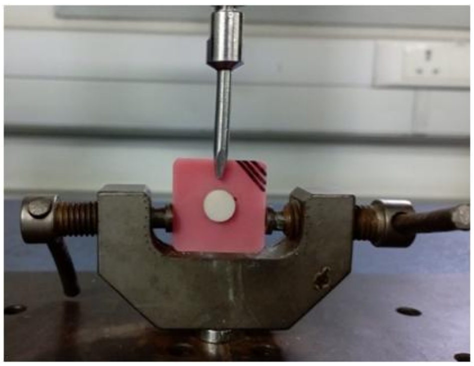

Figure 25: Samples Loaded Onto the Universal Testing Machine

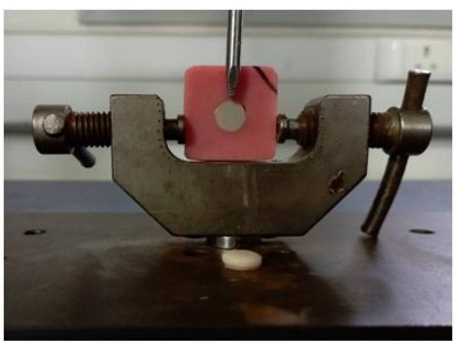

Figure 26: Load Applied Till Debonding Occurs

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