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Effect of Different Micromechanical Roughening Methods on Bonding to Hybrid Ceramic

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ABSTRACT

Aim: To investigate the Shear bond strength of two resin cements to hybrid ceramic after different surface roughening methods.

Material and Methods: A total of 48 discs of hybrid ceramic (vita enamic) with the dimensions of 8 mm diameter and 3 mm thickness were used. The discs were divided into 6 groups (n= 8)according to different surfaces treatment and type of cement used set as G1: (E&P) with Monobond Etch & Prime,cemented with VITA ADIVA. G2: (E&P),cemented with Multilink Automix.G3: (SS) Sandblasting with 50 µm Al_2O_3 then silane application, cemented with VITA ADIVA. G4: (SS) Sandblasting with 50 µm Al_2O_3 then silane application, cemented with Multilink automix. G5: (SC) Silica Coating,Silane application and cemented with VITA ADIVA. G6: (SC)Silica Coating, Silane applicationand cemented with Multilink automix. All composite discs were bonded to ceramic discs, bonded specimens stored in water bath at 37°cfor 6 months. The shear bond strength was measured with a universal testing machine. Bond strength data was recorded and subjected to statistical analysis using SPSS V.25 with Two-Way ANOVA, Kruskal-Wallis test and Mann-Whitney Test.**Results:**There was significance difference between tested group 4 with group 3 and group 6 (P=0.015, P=0.035) respectively, based on interaction between surface treatment and cement used. However no significant difference between tested groups regarding to different surface treatment methods, as well as the type of cement used. **Conclusion:** 1. Sandblasting of CAD/CAM hybrid ceramic increased the bond strength of resin cement. 2. The combination of sandblasting and silane application was effectively increased the bond strength.

Keywords: Hybrid ceramics, Surface treatment, Ceramic primer, Resin cements, Bond strength.

I. INTRODUCTION

Digital dentistry has been recently introduced and has become a new challenge for dental practitioners. Computer-aided design/computer-aided manufacturing (CAD/CAM) technology is broadly used in daily dental practice due to its advantages such as its speed, ease of use, and quality of therapy.[1]

Our ultimate goal in dentistry is to create a beautiful pleasing smile. Advances in dental materials and new techniques in restorative dentistry have made this goal feasible. [2]

Dental ceramics display some physical properties similar to those of human enamel, whereas composite resins properties are more comparable to dentin characteristics.[3] There has been a need for a material that combines the advantages of ceramics with those of composites.[4] The recently introduced polymer-infiltrated-ceramic-network (PICN) or hybrid ceramic offers a combination of ceramic and polymer properties. [5]

PICN materials consist of a three-dimensional ceramic network which is infiltrated with a monomer mixture, offering a higher Weibull modulus and making the material less brittle than glass ceramics.[6] Due to their improved fracture toughness and reduced brittleness, hybrid ceramics and resin nanoceramics are in use today as an alternative to ceramics. [7] Vita Enamic is a polymerinfiltrated ceramic network (PICN) material composed of an 86 percent dominant network reinforced by a 14 percent acrylic polymer network, with both networks entirely permeating each other. [8]

MEP (Monobond Etch & Prime) is a revolutionary one-bottle method that replaces hydrofluoric acid with ammonium polyfluoride and silane. Despite its name, self-etching ceramic primer (SECP) should be washed with water after usage. This method streamlines the bonding process by etching and priming ceramics in one

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step while maintaining the ceramic's adhesive capabilities. (9)

In order to increase the bond strength between resin cement and prosthetic material, it is necessary to create a micromechanical locking and chemical connection. (10) For this purpose, it is tried to increase the bond strength between these two structures by applying some surface treatments to the restorations before the cementation process. There are many surface modifcation methods such as grinding, acid etching, sandblasting with aluminum oxide powder, tribochemical silica coating, laser, plasma spray, and application of silane bonding agents and adhesives. (11)

Sandblasting surface treatment, also called "air abrasion method", is a roughening method frequently used in prosthetic materials. Studies show that sandblasting is one of the most ideal surface treatments to increase the bond strength between restoration and resin. (12,13) Various methods such as silica coating are used to silanize the surfaces of prosthetic materials in order to clean the surfaces, create a retentive surface, and, above all, increase the silanability properties. Tribochemical silica coating is a method that can be used at chairside in the form of a specially modifed aluminum sandblasting method that covers the surfaces of the particles with silica. Covering the surface with silica provides chemical bonding, and sandblasting creates micromechanical bonding areas on the surface. Therefore, both chemical and mechanical bonding are achieved with the tribochemical silica coating. (14)

The silane coupling agent is a bifunctional molecule that enables it to link itself to inorganic (silicon oxide) and organic (methacrylate groups of the resin cement) substances.(15) This cementation process enhances the mechanical behavior and the clinical performance of all ceramic restorations by the penetration of the resin cement into the microporosities created by etching. (16)

Resin cements are typically used for adhesive cementation of all-ceramic restoration.(17)Resin cements are low viscosity composite materials with filler distribution and initiator content adjusted to allow for low film thickness and suitable working and setting time. Most of resin cements are radiopaque and release small amount of fluoride. The resin cements are classified according to curing mode as auto polymerized, light-polymerized and dualpolymerized.(18) Multi-step adhesive resin cements are time consuming, technique sensitive, and consequently may compromise bonding effectiveness. On other hand, self-adhesive resin cements are a luting agent with a very simple application procedure, combining the advantages of glass ionomer (adhesion, fluoride release) with mechanical properties of resin cements. They are indicated for cementation of cast alloy restorations, metal ceramic crowns and bridges, ceramics (except veneers) and indirect composite restorations. (19)

Studies have shown that the combination of surface treatments with adhesive systems increases bond strength. They stated that the reason for this is that the mechanical surface treatments reveal more functional groups to which the adhesive system components can be attached. (20,21)

Restorations in the oral cavity are subjected to different thermal and mechanical stresses resulting from intraoral masticatory forces. Different artificial aging procedures such as long-term water storage and thermal cycling can replicate the intraoral conditions. They are important to determine the durability of the bond obtained between resin cements and ceramics. (22)

Shear bond strength (SBS) is the most commonly used test to screen new adhesive formulations according to their bonding effectiveness. This test gains its high popularity in companies and research institutes since no further specimen processing is needed after the bonding procedure; thus, it is the easiest and fastest method. (23)

The present study was, therefore, carried out to evaluate the effects of different surface treatments on the Shear bond strength (SBS) of an indirect CAD/CAM hybrid ceramic (Vita Enamic) using two types of adhesive luting resin cement.

The null hypothesis of this in-vitro study was that bond strength to hybrid ceramic not influenced neither by different surface roughening and priming methodsnor types of resin cement , so the present studyaimedto evaluate the effect of different micromechanical roughening methods on bonding to hybrid ceramic

II. MATERIALS AND METHODS

1.Materials

Table 1: The materials used in the study

Materials	Product name	Main composition	Manufacturer	Lot number

Feldspar hybrid ceramic Polymer-infiltrated ceramic network (PICN)	Vita Enamic	Ceramic part (86 wt% / 75 vol %): Silicon dioxide SiO2, Aluminum oxide Al2O3, Sodium oxide Na2O, Potassium oxide K2O, Boron trioxide B2O3, Zirconia ZrO2, Calcium oxide KaO. Composition of the polymer part (14 wt % 25 vol%): UDMA (urethane dimethacrylate), TEGDMA (triethylene glycol dimethacrylate)	Vita, Zahnfabrik, Germany.	36660
Self-etching ceramic primer	Monobond Etch & Prime (ME&P)	Tetrabutyl ammonium dihydrogen trifuoride methacrylated phosphoric acid ester, trimethoxysilylpropyl methacrylate, alcohol, water.	Ivoclar Vivadent,	Z01RL2
50 µm Al_2O_3 for sandblasting	SHERA ALUMINIUM OXID 50 µm	99.7% aluminum oxide	SHERA WerkstoffTechnologie, Germany	1799872
30 µm Al_2O_3 Coated with silica	CoJet sandblasting		3M ESPE Germany	752900
Dual curing adhesive resin cement	Vita Adiva F-Cem	Methacrylates	Vita Zahnfabrik	E72001839
Adhesive resin cement	Multilink Automix	Dimethacrylate, 2-hydroxyethyl methacrylate (HEMA), barium glass, ytterbium trifluoride, spheroid mixed oxide	Ivoclar Vivadent,	Y51866
Light cure resin	master fill	Bisphenol A glicidimethecrylate; Urethane Ethlidimethecrylate; Inorganic filler; pigment and catalst	Biodinâmica, Ibipora,parana-brasil	87418
Silane containing bonding agent	Single Bond Universal adhesive, 3M ESPE Sil	10 Methacryloyloxydecyl dihydrogen phosphate, HEMA, silane, dimethacrylate resins, Vitrebond copolymer, filler, ethanol, water, initiators	3M ESPE, St.Paul, MN Germany	41453

2. Methods:

2.1. Preparation of hybrid ceramic discs

Fourty eight hybrid ceramic discs with the dimensions of 8mm diameter and 3mm thickness were wet milled from vita enamic (VE) block by using ceramill® Motion 3 CAD/CAM machine. Thickness and diameter of all discs were checked at different points of each disc and at the margin using a digital caliper. Untreated surface was marked by water proof blue pen to be easily identified from the treated surface of discs which were polished and finished by using Vita Enamic polishing set according to manufacture instructions. All samples were cleaned with 95% alchol for 3 min in ultrasonic cleaner after milling then dried and carefully holded with straight tweezer to keep the surfaces of the specimens untouched. All samples were divided into 6 groups according to their surface treatments andtype of used cements.Each group was wrapped in closed sterilization bags to be ready for surface roughning and cementation procedure.

2.2. Composite resin discs preparation

48 composite resin discs were constructed using resin pattern with central hollow (4mm

diameter and 3mm thickness).

The composite resin was applied into the central hollow in increment layers (1-2 mm) thickness, then carefully condensed. Each single-layer resin composite was light polymerized with light-curing apparatus (UniXS, Heraeus Kulzer, Wehrheim, Germany) for 40sec with an intensity of irradiation 130mW/cm^2 and at 5mm distance from different directions for each increament layer to fabricate the composite disc. All composite discs were cleaned with alcoholic swab and ultrasonic cleaner. Then each group was wrapped in closed sterilization bags to be ready for cementation procedure

2.3. Surface treatment of hybrid ceramics discs

• **Group I: Conditioning with Etch &Prime.**

Bonding surface was treated using self-etching ceramic primer (Monobond Etch & Prime, Ivoclar Vivadent) according to manufacture instructionapplied with a micro-brush for 1 or 2 min on the bonding surface (unmarked surface), then fully removed with a powerful jet of air/water spray for 30 sec, then dried with oil-free air for another 30 sec.

• **Group II: Sandblasting with 50 µm Al_2O_3&Silane application.**

The discs were sandblasted (Ney; Blastmate II, Yucaipa, CA) with 50 µm Al_2O_3 for 20 sec; 2 bar pressure was maintained for air abrasion. Discs were mounted in a right-angle holder where the distance between the nozzle and the surface was 10 mm. The samples were cleaned in distilled water, then air dried. Treated surfaces were received a coat of a silane containing bonding agent (Single Bond Universal adhesive, 3M ESPE), which was applied for 15 sec with gentle agitation using a fully saturated applicator and gently air thinned for 5 seconds to evaporate solvent. Prior to light curing for 20 sec

• **Group III: Silica coating &Silane application**

The hybrid ceramic discs were treated with 30 µmAl_2O_3modified with silica (CoJet Sand; 3M ESPE) by an airborne particle abrasion device (CoJet System) for 20 secat a pressure of 2 bar with a distance of 10 mm between the nozzle and the surface, the samples were rinsed with distilled water and silane was applied.The treated surfaces were received a coat of a silane containing bonding agent (Single Bond Universal adhesive, 3M ESPE), which was applied as same as in group II.

2.4. Bonding of composite resin discs to hybrid ceramic discs.

The bonding of composite resin discs and previously treated hybrid ceramics discs was performed using two types of adhesive resin cementsasDual- cure adhesive resin cement (VITA ADIVA F-CEM),&Self-curingadhesive resin cement, with light cure option (Multilink automix, Ivoclar Vivadent)

The resin cements were mixed and applied through the disposable automix tip on the bonding surface of the secured hybrid ceramics discs. The composite resin discs were bonded to the hybrid ceramics discs after cement application. The hybrid ceramics /composite discs assembly were subjected to a static load of (2 kg). Excess resin cement was removed with a micro brush then curing was done using (liteQ LD-107, MONITEX, Taiwan) from all directions for 20sec. The bonded specimens were kept for 5 minunder the static load.

Total number of all tested specimens was 6 groups according to different surface treatment & used type of cement.

- **Group 1:** (Monobond E&P+VITA ADIVA)
- **Group 2:** (Monobond E&P+ Multi link auto mix)
- **Group 3:** (SB50 µmAl_2O_3 + VITA ADIVA)
- **Group 4:** (SB50 µmAl_2O_3 + Multi link auto mix)
- **Group 5:** (CoJet sandblasting 30 µm Al_2O_3 + VITA ADIVA)
- **Group 6:** (CoJet sandblasting 30 µmAl_2O_3 + Multi link auto mix)

2.5. Artificial aging

The bonded specimens were stored in distilled water, dark environment at 37 ± 1 °C for 6 months followed by thermocycling for 10000 cycles using thermocycling device (SD MECHATRONIC THERMOCYCLER GERMANYEgypt) then air dried. Each thermal cycle composed of a 30 sec cold bath 5 ^{o} C followed by a 30 sec hot bath 55 ^{o} C with a Transfer time 10 sec. After artificial aging procedures the bonded specimens were subjected to shear bond strength test

2.6. Shear Bond Strength (SBS) Test

A total of 48 ceramic-resin composite specimens were placed inside the testing device, which was fixed in a universal testing machine (Instron model 3345 universal testing machine). Shear loading was applied at the interface between the cement and ceramic surface at a cross-speed of 1 mm/min fig (1) . The maximum debonding force (N) for each specimen was recorded and used in

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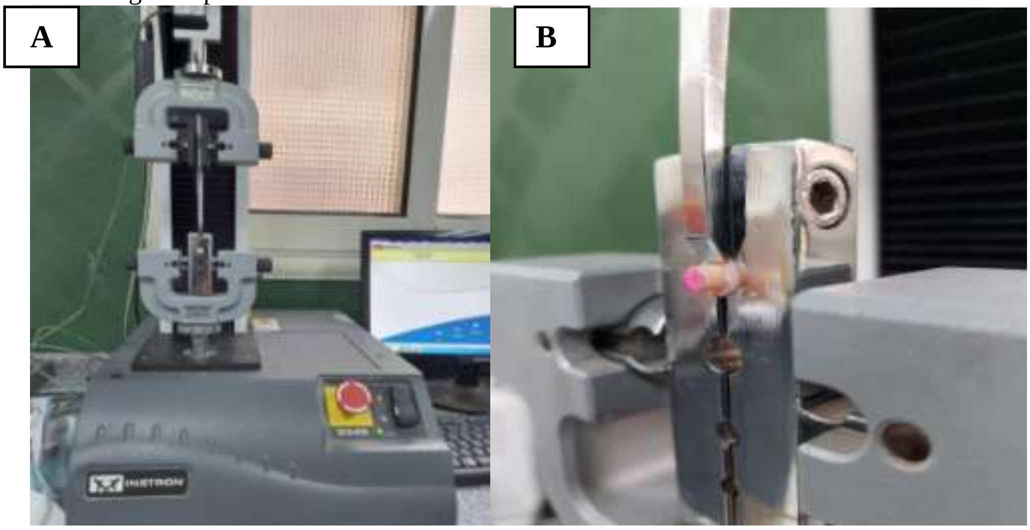
calculating the SBS value (in MPa).Data calculated and recorded using computer software BlueHill universal Instron England



Fig(1).
(A) Instron model 3345 universal testing machine
(B) Shear loading was applied at the interface between the cement and ceramic surfacee

2.7. Scanning Electron Microscope (SEM)

To evaluate surface characterization of vita enamic hybrid ceramic after debonding for mode of failure examination, two specimens from each group were analyzed by SEM. Each specimen was air dried, mounted on copper stubs, and then coated with a thin layer of gold (Sputter Coating Evaporator, SPI- Sputter Coater, USA) before being inspected with ascanning electron microscope (SEM) (JEOL.JSM.6510LV, Japan) at different magnifications (100x, 500x,1000x,2000x, 3000 x). [24]

Statistical Analysis Comparisons were made using the mean values of each specimen. The normality of the data was evaluated with kolmogorov smirnov test normality for groups. Data was analyzed with Two-Way ANOVA and Mann-Whitney Test tests comparing the means of each test groups at ($p \leq 0.05$), using SPSS Statistics 25 software (IBM Corpn., Armonk, NY, USA).

III. RESULTS

Table 2: The Medians, Means and Standard deviations (SD) of Shear bond strength values (MPa) for all tested groups are listed in

Groups	Median	mean	Stander. Deviation
G1	7.2	7.8± SD	4.03
G2	9.1	9.9± SD	3.6
G3	6.1	5.8± SD	3.1
G4	10.7	11.6± SD	3.9
G5	7.5	8.3± SD	2.5
G6	6.9	7.8± SD	3.3

3.1. Shear Bond Strength (SBS) results:
Statistical analysis kolmogorov smirnov test normality for groups

The sampling distribution of group 6 deviate from normal distribution, so non parametric test used as a conservative decision

a) Two-Way ANOVA

Tests of Between-Subjects Effects (variables interaction) It showed No significant differences in the values of shear bond strength as a result of applying different surface treatment methods, as well as no significant difference based on the type of cement used However, the interaction between different surface treatments and cement was significant in group 4 with group 3&6 (P=0.015, P=0.035) respectively.

Table 3: Two-way ANOVA test: influence of different variables on shear bond strength.

Dependent variable	**Shear Bond Strength**						
source	Type II sum of square	df	Mean Square	F	Sig	Noncent parameter	Observed Power
Model	3023.9	6	504	41.24	0.000	247.44	1.000
Surface Treatment	6.9	1	6.9	0.547	0.465	0.547	0.111
Luting cement	63.7	2	31.8	2.60	0.089	5.208	0.5
Surface Treatment* Luting cement	59.8	1	59.8	4.89	0.034	4.89	0.6
Error	403.3	33	12.2				
Total	3427.2	39					

The difference in the mean values showed significance when the p value ≤(0.05).*Indicate statistically significant difference

b) Mann-Whitney Test

It revealed that there was significance difference between group 4 with group 3 & group 6

Table 4: Mann-Whitney test for comparing between test groups.

groups	**G1**	**G2**	**G3**	**G4**	**G5**	**G6**
G1		0.5	0.3	0.08	0.7	0.8
G2			0.06	0.4	0.6	0.3
G3				0.015 *	0.27	0.3
G4					0.1	0.04 *
G5						0.6
G6						

Box Plots

Boxplot showing median shear bond strength of all tested groups

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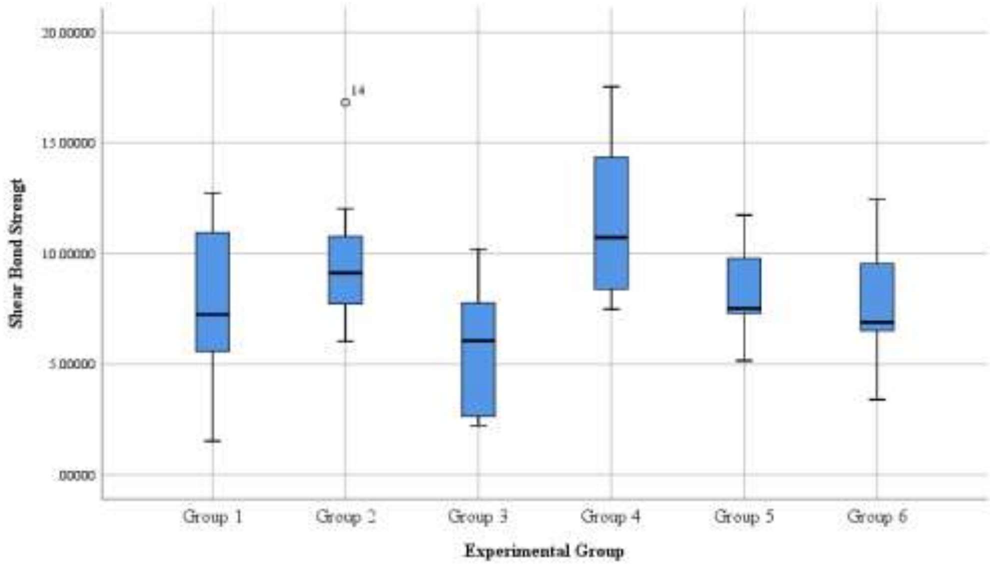
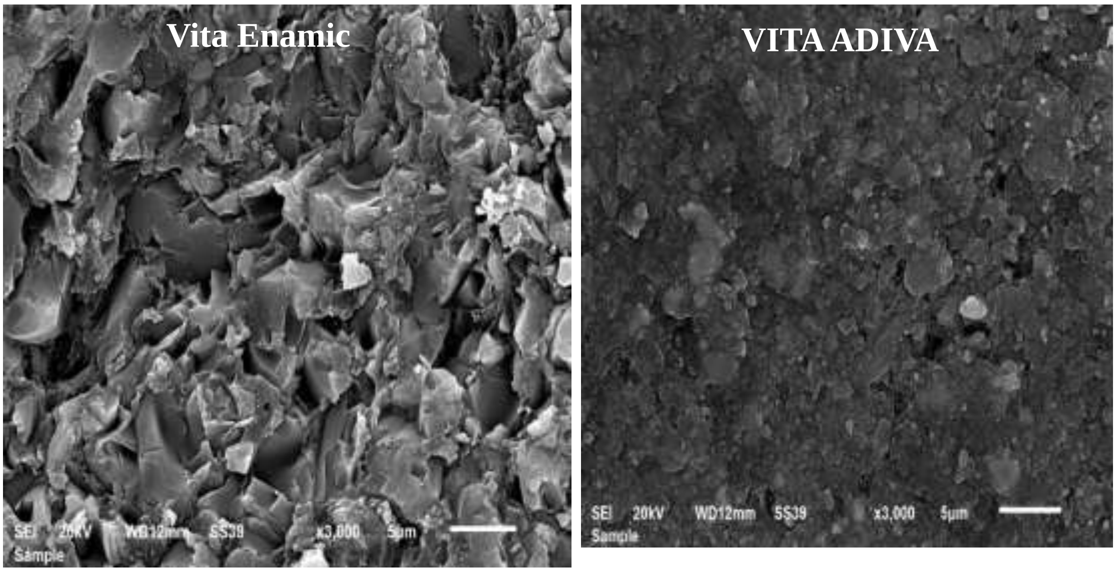


Fig. (3): Illustrates that the highest median shear stress at maximum load was among Group 4 (10.73),G2 (9.12) and G5 (7.52), then G1 (7.24), G6 (6.89), and the least was for groups 3G (6.06).

3.2.Scanning Electron Microscope (SEM):
SEM was used for investigation of surface characterization of ceramic discs as shown in Figure (4)
The failure resulted from the debonding procedure was classified as:

1- Adhesive: when the fracture occurred at the resin ceramic interface.
2- Cohesive: when the failure is at resin cement or composite or ceramic only.
3- Mixed: when a combination of adhesive and cohesive failures occurred.

A **B**



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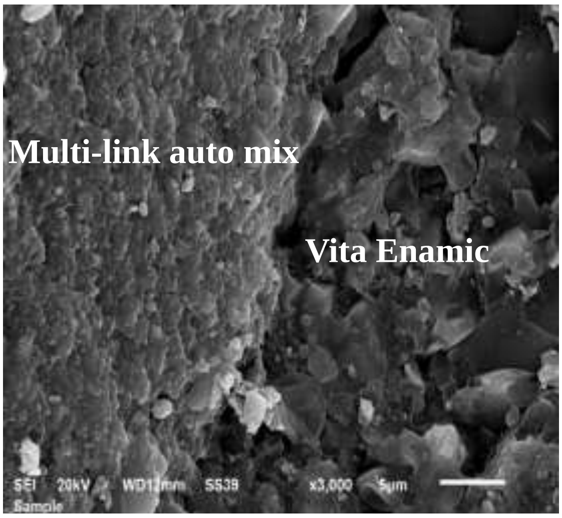

Fig. (4): Modes of failure where: (A) Adhesive failure. (B) Cohesive failure. (C) Mixed failure.

IV. DISCUSSION

This study aimed to assess the effect of different surface treatmentsuch as Monobond Etch and Prime (MEP),sandblastingwith 50 µm $Al_2O_3$and saline application, tribochemical coating and saline applicationonvita enamicand using two different types of cements. The null hypothesis was acceptedbecause the results of present study showed that surface treatment, and adhesive application had not a significant effect on the shear bond strength,butthere was a statistically significant differenceonly between group 4 with group 3 & group 6 (P=0.015& P=0.035) respectively. This difference was due to the interaction between different surface treatments and cements used.

There was no statistical difference in the SBSbetween tested groups, so similar bond strength can be expected if the materials are treated with the same surface treatment protocol. Therefore, the null hypothesis was accepted substantially. While the application of different surface treatments did not create a statistically significant difference on SBS, it created a significant difference on the interaction between different surface treatments and cements used. Similar results were reported in

Alp et al (2018).[25] where they applied two surface treatments, sandblasting and Cojet to Vita Enamic which is a polymer-infiltrated ceramic, Lava Ultimate from resin nanoceramics andCeraSmart which is a nanoparticle filled ceramic material.According to the results of their studies, no significant difference was found between sandblasting and Cojet groups, which are surface treatments in terms of roughness and SBS, and the results of our present study coincide with the results of this study. [25]

Barutcigil et al (2019).[26]applied Cojet, sandblasting, hydrofluoric acidadhesive, and laser to the Vita Enamic material and took the group that they did not apply surface treatment as the control group. They examined the surface roughness and shear bond strength. While they could not find a significant difference between the groups, they applied other surface treatments, they found the highest bond strength in the group they applied with adhesive, these results coincide with the results of the present study. Air-abrasion with aluminium oxide (Al_2O_3) particles leading to a higher micromechanical interlocking between the resin cement and the ceramic surface. [26]However, some authors believe that the irregularities may be shallow and insufficient to obtain a strong bonding compared with HF etching. [27]

The strength and stability of the bond between ceramic and resin cement determine the clinical outcome of a ceramic restoration. Self-adhesive resin cements combine the benefits of both adhesive and conventional luting agents, overcoming the multi-step adhesive resin cements luting procedure's complexity and technical sensitivity. [28]

Etch & Prime as a single-component ceramic primer, has been introduced to the market, as an alternative to hydrofluoric acid etching/silane coupling agent routine treatment. This product integrates the etching and silane priming treatments in a single step. It has been used to shorten the treatment time of the clinical steps by etching and silanating ceramic surfaces in one working step, free of the toxic HF acid, stable and retaining the original silanol activity after aging. [29]

The most frequently used treatment in the selected studies was sandblasting with 50 µm aluminum oxide particles (Al_2O_3) for resin-matrix ceramic, surface treatment is the most critical factor affecting the bond strength between the resin cement and the CAD-CAM material. [30]Sandblasting has been proposed as the preferred pretreatment for CAD-CAM hybrid ceramics with high ceramic content, such as Vita Enamic.[30]

Recently, it was advocated that sandblasting followed by a universal adhesive could also be used with effectiveness as pre-treatment.[31]**Rana Turunç-Oğuzman(2023)** [32]aimed to evaluate shear bond strength (SBS) between CAD/CAM blocks with different compositions following various surface treatments and bonding procedure. Specimens were prepared from Vita Enamic, CeraSmart, Tetric CAD and Vita Mark II CAD/CAM blocks and were subjected to thermocycling for 5000 cycles. Then, the specimens were allocated into 6 groups according to the surface treatment (n = 12): control (no surface treatment); hydrofluoric acid etching (HF); air-borne particle abrasion with aluminium-oxide; tribochemical silica coating; bur abrasion; and Monobond Etch and Prime application (MEP). Then, specimens were silanized and brackets were bonded with adhesive resin. After thermocycling, the SBS test was performed until failure.All groups, except the control, had reliable SBS values (above 6 MPa). Therefore, clinicians can use MEP, novel self-etching single-component ceramic primer, safely besides other surface treatments. [32]

Adhesiveresin cements are more frequently preferred in the cementation of prosthetic materials, as they have higher abrasion and fracture resistance and less solubility in oral fluids compared to conventional cements. [33]

Cement becomes more hydrophobic as chemical reactions in situ consume hydrophilic and acidic monomers. This is highly desirable in a fully and dual cured resin to minimize water sorption, hygroscopic expansion, and hydrolytic degradation. [34]

Self-adhesive resin cement with a lower pH-neutralizing capacity has higher residual hydrophilicity and higher hygroscopic expansion, water sorption and significant hygroscopic expansion stresses can result from the residual hydrophilicity during and after the setting reaction. Whenever a self-adhesive resin cement is a clinical option, cement with a strong neutralization reaction is recommended, resulting in lower hygroscopic expansion strain. [35]

The resin cement tested (VITA ADIVA) is composed of a dual-cure activation system to improve the chemical polymerisation of the resin cement, in an attempt to compensate for the absence of light. [36]

In contrast, Multilink Automix, a self-cured resin cement, consistently presents low microhardness values, which can be related to its reduced filler content. It is crucial to note that Multilink Automix is described by the manufacturer as a self-curing luting material with a light-curing option. However, several studies indicate that Multilink Automix behaves better when applied using the dual-curing mode instead of the self-curing mode. [37]

Thermocycling affected the shear bond strength of self-adhesive, self-etching resin cements, the most significant decreases in bond strength were observed for self-etching, self-adhesive cements when comparing samples that had not been thermocycled to those that had been artificially aged.[38]

Shade et al. (2014) **[39]** stated in their study that the bond strength is higher when polymerization is performed as dual cure. In the present study, a dual cure setting self-adhesive resin cement was used in accordance with the manufacturer's instructions. Some aging methods are used to imitate the environment in the mouth. [39]In the vitro studies, there are artifcial aging methods such as thermal cycling or keeping in water to evaluate bond strength, in order to provide conditions close to the clinical environment, samples were kept in distilled water at 37°cfor 6 months after the application of adhesive resin cement, then thermal cycling done as in similar studies. [40,41]

As reported by **Rosentritt et al. (2015)** **[42]** the roughening of the surface with surface treatment methods alone is not sufficient to ensure a stable bond strength between the resin cement and the treated ceramic surfacein the bonding procedure.

Artificial aging and thermocycling are two important factors that have been shown to decrease the bond strength in in vitro studies. [43]

Mehmet Uğur (2023) **[44]** approve that bond strength values decreased after thermal ageing in all groups. The decrease in bond strength was potentially due to hydrolysis of silicon-oxygen bonds at the ceramic-ceramic primer interface by water absorption **[44]** Some studies have shown that the water absorption increased with an increase in the ratio of TEGDMA and bis-GMA in the resin. It is possible that the presence of MDP and bis-GMA in the resin cements used in our study contributed to the acceleration of water absorption over time and affected the mechanical properties of resin cements after thermal ageing. **[45,46]**

Although there are many methods to measure bond strength extra orally, frequently used measurement methods are shear, tensile, and microtensile bond strength tests [47]. In the SBS test, a force is applied at a constant speed until a fracture occurs on the bonded surface of the bonding agent and the material. The bond strength value is calculated by dividing the maximum force obtained by the bond surface area. The SBS test is the most widely used bond test for evaluating the adhesion of dental materials, as it is relatively easy and quick to perform. [47,48] In this respect, SBS test was used to evaluate the bond strength in the present study. The most common causes of clinical failure of restorative materials are shear stress and problems with cement bonding. [49]

V. CONCLUSIONS

Within the limitations of this study, the following conclusions were drawn:

1. The Monobond Etch & Prime surface treatment for CAD/CAM ceramic discs increased the bond strength of resin cement.
2. Sandblasting to the CAD/CAM ceramic increased the bond strength of resin cement.
3. The combination of sandblasting & silane to the ceramic was effective to increase the bond strength of the resin cement.

It is recommended to work with different surface modifcation methods in addition to different resin cement. Since all samples were evaluated under in vitro conditions, they cannot fully reflect clinical conditions. In vivo studies are needed for more accurate clinical evaluation.

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