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REPAIR STRENGTH AND BOND FAILURE OF AGED CAD/CAM HYBRID CERAMIC AFTER DIFFERENT SURFACE TREATMENTS

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ABSTRACT

Objective: investigating the effect of surface treatments on the repair of aged CAD/CAM hybrid ceramic by composite resin utilizing MSBS test.

Methods: (Shofu HC) Hybrid ceramic and Nano-hybrid composite resin (Tertric N-Ceram Ivoclar Vivadent) were used. CAD/CAM blocks were divided into four groups, Control group, Sand-blasting group, Bur grinding group, HF etching group. Composite resin was packed into holes of a rubber base cylinder mold made from heavy body rubber base impression material to accomdate the composite micro tubes prepared for the microshear test. Half of the specimens were tested right after 24 hrs on the universal testing machine and the other half were stored in artificial saliva at 37°C for 6months then thermo-cycled for 5000 cycles. MSBS and fractographic analysis were used to evaluate the failure mode.

Results: MSBS values were the highest at the sand-blasting groups and the lowest values were recorded in the control group. Aging caused decline in bond strength

Conclusion: Surface treatments had positive effect on bond strength but Aging had a detrimental effect.

KEYWORDS: Repair, CAD/CAM Hybrid Ceramics, Surface treatments, Microshear bond strength, Thermo-cycling .

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INTRODUCTION

Due to patients' growing demand for esthetics, the use of CAD/CAM ceramic restorations, including veneers, crowns, inlays, and onlays, has become more prevalent recently.[2, 10] Conversely, clinical ceramic restorations are most liable to fractures and chipping. All-ceramic restorations are known to fracture owing to intraceramic weaknesses, trauma and parafunctional habits.[16] When considering the following aspects, such as replacement expense, more tooth structure loss, and further damage to the tooth, replacing a failed restoration may not always be the best achievable line of treatment.[13]

Intraoral repair is a minimally aggressive technique that involves adding a restorative material to a restoration, either with or without preceding preparation.[11] On the other hand, restoring cracked ceramic restorations presents a difficult clinical condition. There is currently very little information available regarding the clinical performance of restored restorations.[17]

There is a variety of repair protocols to improve the efficiency, longevity, and esthetics of ceramic restorations like airborne particle abrasion with aluminum oxide, airborne particle abrasion with silica coating , and acid etching (e.g., hydrofluoric acid, acidulated phosphate fluoride, and phosphoric acid) On the other hand, viewpoints differ over which repair method is the most effective in ensuring a positive clinical result.[5]

Ceramic blocks are very good in terms of esthetics, mechanical qualities, chemical stability, and biocompatibility but they are often fragile and stiff.[18] Interpenetrating phase composites are a type of hybrid ceramic material that has been infiltrated with a polymer and exhibits features similar to those of tooth structure. The advantageous qualities of composites and ceramics are combined in this structure. In addition, the material exhibits great flexibility, low stiffness, brittleness, and hardness, as well as fracture toughness.[14]

In restorative dentistry, dental ceramic fracture remains the main issue as different repair protocols still have their limitations as the risk of surface roughness, the potential for impaired bond strength, worries about the repair's long-term endurance, difficulties matching colors precisely, and the potential for surface imperfections.[19]

Thus, the aim of the present laboratory study was to assess the microshear bond strength of CAD/CAM hybrid ceramic that had been restored by direct resin composite restoration with and without surface pre- treatments.

MATERIALS AND METHODS

In this study, two restorative materials were investigated: Hybrid ceramic blocks (Shofu HC) and Nanohybrid resin composite (Tetric N Ceram). **Table 1** lists all of the materials utilized in this study along with their manufacturers and compositions.

TABLE (1) Materials Used in The Study

Material	Specification	Manufacturer	Batch #S	Chemical Composition
Shofu HC Hard	Resin Nanoceramic	Shofu Dental GmbH, Ratingen, Germany	0819919	Silica powder, micro fumed silica, zirconium silicate fillers 61% by weight. UDMA, TEGDMA.
Porcelain Etchant	Hydrofluoric acid-etch	Bisco, Schaumburg, Illiinois, USA	2400000483	9.5% hydrofluoric acid gel.
Porcelain Primer	Pre-hydrolyzed silane primer	Bisco, Schaumburg, Illiinois, USA	2300111902	Silane with methacrylate (1-10%), acetone (30-70%) and ethanol(30-70%).
Tetric N-Ceram resin composite	Nanohybrid resin composite	IvoclarVivadent, Schaan, Liechtenstein	Z03KBY	Dimethacrylates (19-20 wt. %). The fillers contain barium glass, ytterbium trifluoride, mixed oxide and copolymers (80-81 wt. %).
Single Bond Universal	Universal Adhesive	Tetric N-Bond Ivoclar Vivadent, Schaan, Liechtenstein	Z03WDZ	Methacrylates, ethanol, water, highly dispersed silicon dioxide, initiators and stabilizers.

*Abbreviations: **UDMA**:Urethane dimethacrylate,**TEGDMA**: Triethylene glycol dimethacrylate*

Methods:

Specimens grouping and preparation:

Eight Shofu hybrid ceramic blocks (10 mm x 12 mm x 16 mm) were randomly divided into four groups (each group had two blocks) based on the type of surface pre-treatment that was applied to each block surface. Each group was then further divided into two sub-groups based on the aging protocols resulting in immediate group and delayed group.

The specimens were divided as follows based on the kind of surface pre-treatment , The pretreatments were caried out by one operator to the ceramic surfaces before composite resin application

- First group (control group): No treatment was given.
- Second group (sandblasting): The specimens were subjected to 20 seconds of 50 μm Al2O3 (Ney; Blastmate II, Yucaipa, CA) sandblasting at a pressure of 2 bar. The specimens were positioned within a specially designed holder that positioned the nozzle 10 mm away from the surface at a straight angle. Following a distilled water wash, the specimens were allowed to air dry.
- Third group (bur-grinding): Using a high-speed rotary tool and water cooling for four seconds, the surface was roughened with a green-banded diamond fissure bur.
- Fourth group (hydrofluoric acid and silane application): 9.5% hydrofluoric acid was used to etch the surface for 90s and usage of a water spray to clean for 60s. After that, the surface was cleaned for five minutes with an ultrasonic cleaner, let to air dry. With a fine microbrush, the silane coupling agent was evenly applied and left to sit for 60s.

Using a silicon-based impression medium, a rubber base cylinder with a diameter of 2.5 cm, 2mm thickness at the edges, and 1 mm thickness at the ceramic rectangle region was produced. In order to facilitate the creation of composite micro-tubes, a depression was made on the inside surface of the silicon base cylinder to fit each ceramic rectangle. Based on the diameter of each rectangle, marks were evenly dispersed at the silicon base cylinders' depressions. Next, a 1 mm diameter cylindrical bur was used to drill these markings, producing holes with a diameter of 1 mm and a spacing of 2 mm between each hole and the next, forming a mold that would hold the composite micro tubes for the microshear test.

The universal adhesive was applied to the ceramic blocks' surfaces and light cured. The previously made rubber base cylinders were readjusted over their blocks and finally the resin composite material was condensed and light cured for 20-30s into the holes to create the composite micro tubes. Nine composite micro tubes (n=9) were present on each ceramic block surface. Every specimen was prepared using the same process.

Half of the ceramic/composite blocks were evaluated immediately, while the other half underwent artificial aging protocols to mimic a long-term service

Firstly the specimens were stored in artificial saliva at 37°C for 6 months at incubator after that the specimens were subjected to thermocycling for 5000 cycles with transfer period 15s and dwell time 30s and temperature changes ±0.5 °C.

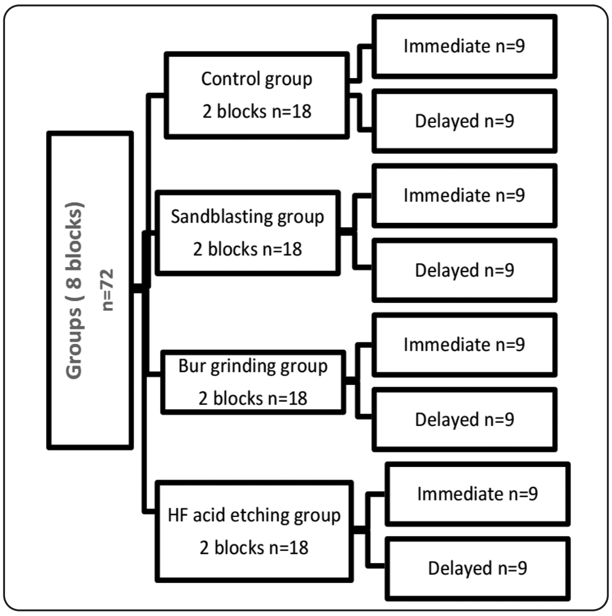

Fig. (1) Diagram that schematically displays the study groups and study design

Microshear bond strength test:

A Universal Testing Machine (Bluehill Universal, Instron, Norwood, USA) was used to assess the microshear bond strength of half of each group's specimens after a 24-hour period. Nevertheless, after storage, the remaining half was examined. Every block was positioned on the lower jig of the machine. At the ceramic-composite interface level, a stainless steel wire was wrapped around the resin composite micro-tube and attached to the upper moving arm of the testing apparatus. Each cylinder specimen was subjected to a shear force of 0.5mm/min cross head speed until failure occurred. The load of failure was then recorded in MPa, and the force required to produce debonding was divided by the bonded area of the specimens to reflect the MPa bond strength values.

Fractographic Analysis

From each group, one specimen was chosen at random and prepared for scan electron microscope (SEM) (JSM6510LV, JEOL, Japan) **Figure 2** at x1000 magnification .The following failure modes were categorized: Adhesive failure (interface between CAD/CAM hybrid ceramic blocks and resin composite restoration) In addition, there was mixed failure.

Fig. (2) Scanning electron microscope (JSM-6510LV, JEOL, Japan).

Statistical Analysis

Data were coded and tabulated with the help of Microsoft Excel 2016. The statistical package for social science (SPSS 22, SPSS Inc, Chicago, Illinois, USA) was used to analyze the data.

RESULTS

Microshear Bond Strength Test Results

The test used was a parametric two-way ANOVA. Surface treatment and time had a substantial impact on MSBS, according to the results of the two-way ANOVA test ($p<0.05$). Furthermore, the surface treatment * time interaction between the two components was not statistically significant ($p>0.05$).

The results showed that surface treatments significantly increased the MSBS of the materials in comparison to the control groups with no surface treatments. The MSBS mean values of the control group: Immediate (7.68±2.28) MPa, Delayed group (0.00±0.00) MPa showed significant difference compared to all other test groups ($p<0.05$) with the lowest mean values. The MSBS mean values of the sandblasting groups: Immediate (28.04±4.93) MPa, Delayed (19.47±3.71) MPa showed significant difference in comparison to the all other test groups ($p<0.05$) with highest mean values. The MSBS mean value of the bur group: Immediate (21.16±6.74) MPa, Delayed (13.91±2.14) MPa showed significant difference in comparison to all other test groups ($p<0.05$). The MSBS mean value of hydrofluoric acid groups: Immediate (22.03±4.32) MPa, Delayed (13.74±3.16) MPa showed significant difference in comparison to the all other test groups

Failure Mode Analysis

All specimen groups with different surface treatment processes had a dominance of mixed failure(A), with the exception of the control groups, which demonstrated adhesive failure (B), according to the results of the mode of failure analysis. **Figure 3**

TABLE (2) Results of Two-way ANOVA test of MSBS means among test groups

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	4988.162a	7	712.595	46.745	.000
Intercept	17868.533	1	17868.533	1172.135	.000
ST	3847.547	3	1282.516	84.130	.000
Time	1135.857	1	1135.857	74.510	.000
ST * Time	4.758	3	1.586	.104	.957
Error	975.643	64	15.244		
Total	23832.339	72			
Corrected Total	5963.806	71			

a. R Squared = .836 (Adjusted R Squared = .819) ***Abbreviations:* ST: *Surface treatment***

TABLE (3) Mean and Standard Deviation (SD) Values of MSBS test among the test groups

Groups	**N**	**Mean**	**Standard Deviation**
Immediate Control	9	7.68	2.28
Delayed Control	9	0.00	0.00
Immediate Sandblasting	9	28.04	4.93
Delayed Sandblasting	9	19.47	3.71
Immediate Bur	9	21.16	6.74
Delayed Bur	9	13.91	2.14
Immediate HF	9	22.03	4.32
Delayed HF	9	13.74	3.16
Total	72	15.75	9.17

Abbreviations : **HF**:Hydroflouric acid

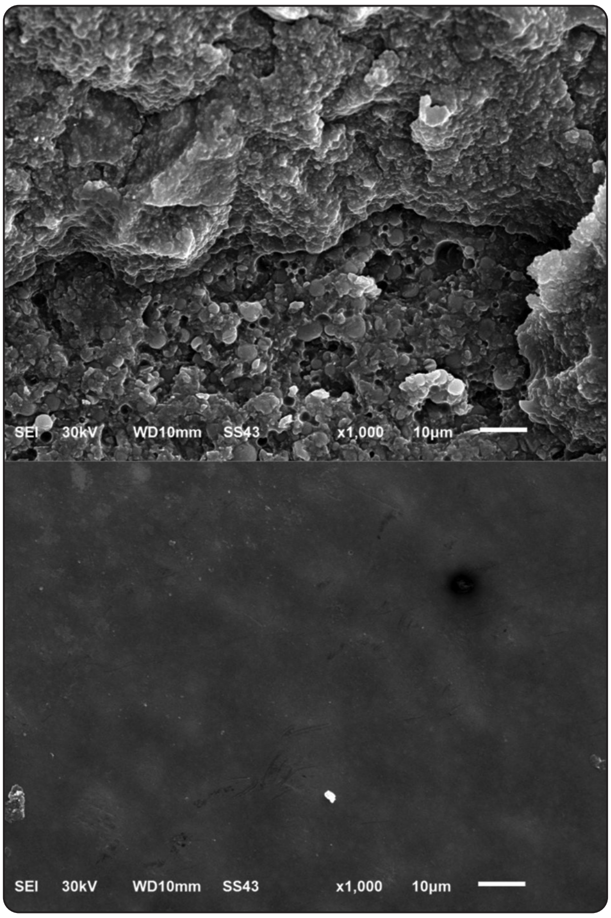

Fig. (3) Microographs showed mode of failure by scan electron microscope (A) mixed failure (B) adhesive failure.

DISCUSSION

This study looked into the intraoral reparability of CAD/CAM hybrid ceramic materials, which combine the advantages of ceramics and composites, because it is widely acknowledged that intraoral repair is a less invasive and economical technique .The primary factor in assessing the restorative materials' ability for repair is mechanical interlocking so the material surface received many different kinds of surface treatments.

The bond strength can be increased by sandblasting (50 μm Al2O3) to provide a wide surface area that will increase wettability and micro-retentive structure for micromechanical luting of the bonding material.[15] Because it is a simple and affordable way to provide the ceramic surface an abrasive treatment, grinding with a green banded diamond bur is used as a mechanical treatment to strengthen the binding between repair resin composite and ceramics. These procedures were created to guarantee a consistent surface treatment and to stop cracks and fractures.[20] The baseline for this study is the control group, which received no surface treatment, and the etching with HF acid to generate a roughened surface in acid-sensitive polymers and ceramics. During intraoral ceramic restoration repair, these methods are frequently used for surface treatments.[8]

It is stated that the universal adhesive system used in this study has a special chemistry that includes MDP in addition to other ingredients and enables the adhesive to bond chemically to glass ceramic surfaces without the need for an additional ceramic primer.[21] Rubber base impression material was used to create molds for resin composite micro-tubes, as this material did not stick to the composite. This preserves the micro-tubes' structural integrity while making it simple to remove the molds. The resin composite was chosen for direct restorations, such as anterior and posterior, as well as intraoral repairs of damaged crowns and bridges, due to its unique filler technology, which guarantees low shrinkage stress and quick esthetic results. Its strong bond strength and adaptability for intraoral repair of damaged restorations are the reasons it was selected for this study in agreement with Kalra *et al.*[12]

Microshear bond strength testing was done in the study to prevent cohesive fracture of several samples and to make it easier to prepare the specimens. It assumed that the microshear test is straightforward and simple to conduct. However, because of the uneven stress distribution in the bond area, this method's reliability is called into question.[6]

In the oral cavity, dental restorations are subjected to a range of temperatures. The normal temperature of the mouth cavity is between 35 to 37°C, although diet and drink can alter this. Due to variances in filler and matrix thermal expansion, temperature changes can cause mechanical stresses, cracking, and spreading in materials containing resin.[4] In an oral environment that is both humid and thermally active, restorations typically fail as they age. Planning restoration repairs should consider restoration aging.[7] By simulating intraoral temperature fluctuations, thermal cycling an accelerated artificial aging method for dental materials stimulates thermal strain on the bonding surface through the action of liquids and temperature changes.[3]

Nevertheless, in this investigation, the control group's specimens failed during thermal cycling, demonstrating the influence of the stress and alterations brought about by thermal cycling on the repaired surfaces of restorative materials. The pretest failures were all in the untreated control groups, according to an analysis of the failures. Bond strength in thermal aging is affected by a number of elements, the most significant of which being cycle count, dwell duration, and temperature settings.[1]

CAD/CAM hybrid ceramic materials, however, have no consensus regarding the repair method that produces a good clinical result.[5, 9, 22]

CONCLUSIONS

Based on the limitations of this investigation, the following conclusions could be stated:

1. Surface treatments had positive effect on the microshear repair bond strength.
2. Aging had a detrimental effect of the bond durability.

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