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Shear Bond Strength of Resin Nanoceramic Repairing with Various Single-Shade Resin Composites

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Abstract

Objective: This study aimed to compare the shear bond strength (SBS) values of resin nanoceramics repaired with 3 different single-shade resin composites.

Methods: Resin nanoceramic Cerasmart blocks were sliced, and rectangular-shaped specimens (14 × 12 × 1 mm; N = 40) were obtained. Based on the resin composites (Omnichroma, Charisma Diamond, and Vittra APS UNIQUE) and control group (Ceram. X sphereTEC one), the specimens were split into three experimental groups. The repair procedure was performed after the surface treatments. Shear bond strength values were measured at 2 different times, and failure modes were determined.

Results: "Main effect" is a statistical term that describes the effect of the composite independent of the groups. The main effect of time was statistically significant with regard to the SBS mean values ($P < .001$), as revealed by the 2-way analysis of variance test. Adhesive failure was the most common failure mode, with failure mode values for each composite and time.

Conclusion: Despite a limited number of studies comparing the SBS of various resin composites to resin nanoceramic, key findings suggest: that the SBS of resin composites is influenced by their structural compositions and monomer types, impacting mechanical properties over time; SBS and failure mode are affected by the adhesive type, technique, composition, and substrate surface treatment; and there exists an inverse relationship between time and bond strength, with SBS decreasing over time.

Keywords: Adhesives, ceramics, composite resins

INTRODUCTION

With plenty of advances in digital dental technology, alternatives for chairside computer-aided design and computer-aided manufacturing (CAD/CAM) materials have rapidly increased in the dental field, including ceramics, resin ceramics, and resin composites. Nowadays, prosthodontics have become more interested in ceramics, particularly resin ceramics such as nanoceramics, which are defined by the presence of nanoceramic particles bound in the resin matrix, and hybrid ceramics, which consist of a finely organized ceramic network strengthened by an acrylate polymer network. Glass ceramics and feldspathic ceramics are additional materials that are suitable with digital dental equipment. Since their introduction, they have frequently been clinically validated and were created before resin ceramics.[1]

Ceramic materials outperform resin composites in terms of their esthetic appeal, biocompatibility, durability, mechanical characteristics, and color resistance. In contrast, ceramics have a higher structural brittleness or breakage risk. Conversely, resin composites are easier to finish, polish, and repair. Various ceramic block forms, including feldspathic, reinforced glass, zirconia, and others, as well as newer CAD/CAM block types like resin ceramic hybrid materials, have been introduced. One such material is the resin nanoceramic Cerasmart (GC), which comprises 71% silica and barium glass nanoparticles. These materials combine the benefits of both ceramics and resin composites, including color stability and durability of ceramics

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as well as minimal abrasion and strong flexural properties. Notwithstanding these benefits, CAD/CAM materials are susceptible to mechanical fracture because of poor connectivity, poor occlusal alignment, internal stresses, parafunctional habits, and material porosity during manufacturing. Since replacing the restoration completely would require more preparation and result in the loss of more healthy tooth tissue; it would not be a practical alternative. To preserve the sound dental structure and get quicker results at a lesser cost, direct repair application utilizing resin composite offers a more appropriate and practical treatment.[2]

Resin composite has been a treatment of choice for dentists and is applicable in a variety of clinical situations due to its esthetic appeal and reliability. Currently, the clinical interest is going toward simplicity and short treatment time. Newly established single-shade universal resin composites were a turning point since they were advertised as having 1 shade that could replicate any tooth color. The incorporation of universal shade resin composites removes the requirement for careful color-matching procedure and layering, hence reducing technique sensitivity and chair time. Also, physicians do not need to keep track of the expiration dates of various composite shades, and the restorations may even change color in response to whitening or staining of the teeth, preventing the need for replacement of preexisting restorations.[3]

Finding an ideal bond strength between these composites and CAD/CAM materials without experiencing persistent adhesive issues has proven to be the key challenge in repairing CAD/CAM materials. It is essential to maintain strong bonding despite chewing forces and intraoral circumstances for a prolonged amount of time. The manufacturer's instructions state that this process entails providing the proper surface preparation, using adhesive systems, and then applying a light-polymerized resin composite.[1]

This study aims to evaluate and compare the shear bond strength (SBS) of different single-shade resin composites (Omnichroma, Charisma Diamond One, and Vita APS UNIQUE) to nanohybrid ceramic, specifically in the context of repairing resin nanoceramic with resin composite. The chosen single-shade resin composites will be compared to a conventional resin composite (Ceram. X sphereTEC one). Additionally, the study seeks to assess the impact of restoration aging on SBS by measuring it at 2 different time intervals—1 day and 1 month after the repair.

The null hypotheses of this study are as follows:

- There is no significant difference between all resin composites in SBS to ceramics.
- There is no significant difference in SBS between all resin composites at different time intervals (1 day and 1 month).

MATERIAL AND METHODS

Since this study exclusively involves nonhuman or inanimate materials, Ethics Committee approval is not required. The materials used in the current study have been listed in Table 1. Computer aided design/computer aided manufacturing (Cerasmart, GC Dental Products, Leuven, Belgium) nanoceramic blocks were used in this study. Three different types of single-shade resin composites (Omnichroma, Charisma Diamond One, and Vita APS UNIQUE) and 1 conventional resin composite (Ceram. X sphereTEC one)

Table 1. The Composition of Materials Used in the Study.

Material	Manufacturer	Type	Shade	Matrix	Filler Continent
Omnichroma	Tokuyama, Japan	Nanohybrid resin composite	Universal	TEGDMA UDMA	Uniform sized supra-nano spherical filler (260 nm spherical SiO_2-ZrO_2) and Composite filler
Charisma Diamond One	Kulzer, Germany	Nanohybrid resin composite	Universal	UDMA TCD-DI-HEA TEGDMA	B_2O_3-F-Al_2O_3-SiO_2, silica, TiO2, fluorescent pigments, metallic oxide pigments, organic pigments, 5-20 μm
Vittra APS Unique	FGM, Brazil	Nanohybrid resin composite	Universal	TEGDMA UDMA	Zirconia charge, silica (200 nm)
Ceram.X sphereTEC one	Dentsply Sirona, Germany	Nanohybrid resin composite	A2	Bis-EMA TEGDMA	Agglomerated non barium glass, ytterbium fluoride
G-Premio	GC, Tokyo, Japan	Universal Adhesive		Acetone, water, MDP: Methacryloyloxydecyl dihydrogen phosphate 4-MET: 4-methacryloxyethyl trimellitic acid MDTP: Methacryloyloxydecyl dihydrogen thiophosphate	Silicon dioxide

B_2O_3-F-Al2O3-SiO_2, boro-fluoro-aluminosilicate; Bis-EMA, bisphenol A diglycidyl methacrylate ethoxylated; SiO_2, silicon dioxide; TCD-DI-HEA, 2-propenoicacid; (octahydro-4,7-methano-1H-indene-5-diyl) bis (methyleneiminocarbonyloxy-2,1-ethanediyl) ester; TiO_2, titanium dioxide; TEGDMA, triethylene glycol dimethacrylate; UDMA, urethane dimethacrylate; ZrO_2, zirconium dioxide.*The data were provided by the manufacturers

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composition are listed in Table 1. The CAD/CAM materials were prepared with a low-speed diamond saw (IsoMet 1000, Buehler Ltd., Lake Bluff, Ill, USA) under running water. Forty rectangular specimens (14 × 12 × 1 mm) were obtained from Cerasmart blocks. Specimens underwent a standardized surface morphology preparation, involving the use of 600-, 800-, 1000-, and 1200-grit silicon carbide papers in wet conditions for 120 seconds. Subsequently, ultrasonic cleaning in distilled water for 10 seconds was performed to eliminate any potential contamination. Following this, specimens were embedded in self-cure acrylic resin (IMICRYL, Turkiye) using a specially crafted cylindrical Teflon mold measuring 20 × 20 mm. The obtained specimens per material were divided into 4 groups according to the material to be used. Each specimen underwent treatment following the guidelines outlined in the GC REPAIR KIT Technique guide, specifically designed for intra-oral repair of indirect restorations crafted from materials such as glass-ceramics, zirconia, alumina, and hybrid ceramics (e.g., Cerasmart), with no impact on the tooth structure. The specimens were then split into four groups based on the kind of composite that will be used, as previously mentioned.

G1: received Omnichroma (OMN; Tokuyama Dental, Tokyo, Japan).
G2: received Vittra APS Unique (VIT, FGM, Joinville, Brazil).
G3: received Charisma Diamond One (CHA, Kulzer GmbH, Hanau, Germany)
G4: received Ceram.X sphereTEC one, A2 (Dentsply Sirona, Germany)

Every ceramic specimen received 2 composite sticks that were applied by a Teflon mold with 2 mm length and 1.5 mm width. The composite was applied incrementally with a 1 mm increment inside the appliance tube and light cured by a qualified light curing unit Light Emitting Diode (D-Light Pro, GC Corporation, Japan) with the power of 1400 mW/cm^2 for 20 seconds. After placing the restorations, all specimens were stored in distilled water at 37°C in an oven (Memmert UN 110, Schwabach, Germany) for 24 hours before the SBS test to ensure that polymerization of the resin composite was completely achieved. The SBS was evaluated after 1 day and a month. The specimens were set up in the mounting jigs of the testing apparatus (Bisco Shear Bond Tester; Bisco, Schaumburg, Ill, USA), and the loading device was positioned to contact the bonded specimen at the composite and ceramic interface, thereby supporting the application of a force parallel to the bonded surface as shown in Figure 1. The specimen failed after being subjected to a shear load applied at a crosshead speed of 0.5 mm/min.

Failure Mode
After the SBS test was completed, a stereomicroscope (SZX-ILLB100, Olympus Optical Co. Ltd., Tokyo, Japan) with a 10× magnification was used to analyze the failure mode. The following terms have been used to characterize the failure modes: Failures where resin composite has been entirely

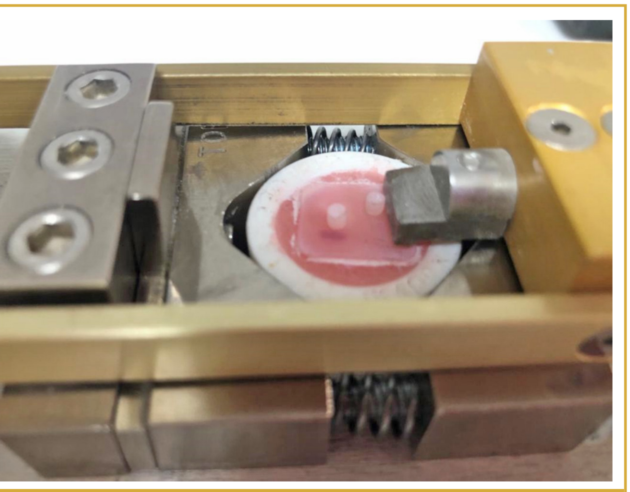

Figure 1. The shear bond strength measurement by (Bisco Shear Bond Tester; Bisco, Schaumburg, Ill, USA).

removed from the ceramic surface have been referred to as adhesive failures. Cohesive failures are those in which the fracture line can be seen on the resin composite. Surfaces with both types of failure have been referred to as mixed failure.[4]

Statistical Analysis
Data were analyzed with IBM Statistical Package for Social Science Statistics software for Windows, version 23.0. Conformity to normal distribution was evaluated with skewness and kurtosis values. A 2-way analysis of variance was used to compare the composite and time-normally distributed SBS values. Fisher's exact test and Pearson chi-square test were used to compare failure mode values for each composite and time. Analysis results were presented as frequency (percentage) for categorical variables and as mean ± SD for quantitative variables.

RESULTS

The SBS values (in MPa) were obtained due to repairing CAD/CAM nanoceramic (Cerasmart, GC Dental Products, Leuven, Belgium) with different types of single-shade resin composites by GC REPAIR KIT Technique guide, and the statistical comparison results are given in Table 2. The main effect of time was found to be statistically significant on the SBS mean values ($P < .001$) as revealed by the 2-way analysis of variance test. While the average SBS value obtained on the first day was,[5] the value obtained in the first month was.[6,7]

Shear bond strength measurement after 1 day: there was no statistically significant difference between the distribution of failure mode values according to the composites ($P = .358$). Omnichroma had the highest bond strength (20.57 ± 7.58) followed by Vittra APS UNIQUE (18.86 ± 7.37), Charisma Diamond One (18.66 ± 6.43), and Ceram. X sphereTEC one

Table 2. Comparison of Composite Shear Bond Strength Values Over Time

	TS	DF	MS	F	*P*	η^2
Time	492.03	1	492.032	15.89	**<.001**	0.181
Composite	70.66	3	23.554	0.76	.520	0.031
Time*Composite	29.75	3	9.916	0.32	.811	0.013

DF, degrees of freedom; *F*, 2-way analysis of variance test statistics; MS, mean of squares; TS, sum of squares. R^2 = 20.99%; adjusted R^2 = 13.31%; η^2 = partial eta square.

Table 3. Distribution of Failure Mode Values According to Composites at Each Time

		Composite						
Time		Omni chroma	Vittra APS Unique	Charisma Diamond One	Ceram.X Sphere TEC one	Total	Test St	*P**
One day	Failure mode							
	M	2 (20)	2 (20)	3 (30)	0 (0)	7 (17.5)	0.349	.358
	A	8 (80)	8 (80)	7 (70)	10 (100)	33 (82.5)		
One month	Failure mode							
	M	1 (10)	2 (20)	0 (0)	0 (0)	3 (7.5)	0.265	.185
	A	9 (90)	8 (80)	10 (100)	10 (100)	37 (92.5)		

*Pearson Chi-square test; frequency (percent).

(18.43 ± 4.94). The percentage rate of adhesive failure was 80%, 80%, 70%, and 100% for Omnichroma composite, Vittra APS UNIQUE composite, Charisma Diamond One composite, and control (Ceram. X sphereTEC one), respectively.

Shear bond strength measurement after 1 month: there was no statistically significant difference between the distribution of failure mode values according to the composites (*P* = .185). The Charisma Diamond One had the highest bond strength (15.49 ± 4.49) followed by Omnichroma (14.97 ± 3.12), Vittra Aps UNIQUE (14.24 ± 5.67), and Ceram. X sphereTEC one (11.98 ± 2.87). The percentage rate of those with adhesive failure was 90%, 80%, 100%, and 100% for Omnichroma composite, Vittra APS UNIQUE composite, Charisma Diamond One composite, and control (Ceram. X sphereTEC one), respectively. The failure mode distribution after 1 day and after 1 month for different composite types was explained in Table 3. This means that after 1 day the failure mode for all composite materials was mostly adhesive failure.

In the Omnichroma composite: There was no statistically significant difference between the distribution of failure mode values by time (*P* = 1.000). While the rate of those with adhesive failure was 80% after 1 day, this rate was 90% after 1 month.

In the Vittra APS UNIQUE composite, there was no statistically significant difference between the distribution of failure mode values by time (*P* = 1.000). While the rate of those with adhesive failure was 80% after 1 day, this rate was still 80% after 1 month.

In Charisma Diamond One composite, there was no statistically significant difference between the distribution of failure

Table 4. Distribution of Failure Mode Values According to Time in Each Composite

		Time				
Composite		1 day	1 month	Total	Test St	*P**
Omnichroma	Failure mode					
	M	2 (20)	1 (10)	3 (15)	-	1.000
	A	8 (80)	9 (90)	17 (85)		
Vittra APS UNIQUE	Failure mode					
	M	2 (20)	2 (20)	4 (20)	-	1.000
	A	8 (80)	8 (80)	16 (80)		
Charisma Diamond One	Failure mode					
	M	3 (30)	0 (0)	3 (15)	-	.211
	A	7 (70)	10 (100)	17 (85)		
Ceram.X sphereTEC one	Failure mode					
	A	10 (100)	10 (100)	20 (100)	-	-

*Fisher's exact test; frequency (percent).

mode values according to time (P = .211). While the rate of those with adhesive failure was 70% after 1 day, this rate was 100% after 1 month.

In the control (Ceram. X sphereTEC one) group, only adhesive failure was seen. The failure mode distribution in each resin composite after 1 day and after 1 month has been explained in Table 4. In Omnichroma, the failure mode after 1 day and after 1 month was adhesive failure.

DISCUSSION

A wide variety of factors, including insufficient connectivity, improper occlusal alignment, internal pressures, parafunctional habits, and porosity during production, can lead to CAD/CAM materials breaking or chipping. Since it would require more preparation and more healthy dental tissue loss, replacing the restoration completely would not be a conservative and practical solution. To preserve the sound dental structure, and to preserve time and cost, direct repair by resin composite offers a more appropriate treatment option. The main obstacle in repairing CAD/CAM materials has been achieving the optimal bond strength between these composites and CAD/CAM materials without encountering persistent adhesive difficulties. Strong bonding had to be maintained for an extended period regardless of intraoral conditions and chewing forces. The repairing protocol for each material has been stated by the manufacturer.[4] Therefore, the surface treatment of the resin nanoceramic has been done accordingly.

The different types of single-shade resin composites repairing resin nanoceramic have the same effectiveness in terms of SBS over time (after 1 day and after 1 month), so there is no significant difference in SBS of all types of resin composites to ceramic (P = .520). Thus, the first null hypothesis that there is no significant difference between all resin composites in SBS to ceramic was accepted.

In contrast, there was a significant difference in SBS over time, as the bond strength reduced after 1 month compared to the bond strength after 1 day. Thus, the second null hypothesis that there is no significant difference in SBS between all resin composites at different time intervals (1 day and 1 month) was rejected.

The effectiveness of composite bonding to ceramic depends on a variety of factors, including the type of resin composite used, the type of ceramic, and the application method of the repair system.[2]

In the current study, there were 4 different types of resin composites. It is anticipated that structural compositions are the reason for the diminishing SBS values of resin composite over time. The materials' composition may be responsible for the bond's gradual deterioration, given that composite matrices vary in monomer continents, and each of them has distinct features as mentioned in Araújo et al and Elfakhri et al, studies.[8,9] The SBS after 1 day showed no statistical difference between materials: Omnichroma, Vittra APS UNIQUE (18.86 ± 7.37), Charisma Diamond One (18.66 ± 6.43), and Ceram. X sphereTEC one (18.43 ± 4.94). Clinically, it has been noted that the bonding value should be at least 20 MPa when considering the optimal bonding value, as stated by Gul and Altınok-Uygun.[2] So, in our study, the decreased bonding strength over time was statistically significant (P < .001), which could be due to composite composition.

The water absorption over time leads to hydrolytic degradation, polymerization shrinkage due to a low degree of conversion, and high viscosity of monomer that reduces the cross-linking ability of the monomer to form a polymer chain. In the current study, the SBS after 1 month showed that there is no significant difference between materials after 1 month, although the Charisma Diamond One had the highest bond strength (15.49 ± 4.49) followed by Omnichroma (14.97 ± 3.12), Vittra Aps UNIQUE (14.24 ± 5.67), and Ceram. X sphereTEC One (11.98 ± 2.87). The difference could be due to the addition of a TCD-DI-HEA monomer that could improve the mechanical properties of the composite. The close readings for Omnichroma and Vittra UNIQUE are explained by having the same monomer continents. The surface of the broken ceramic should be prepared mechanically, chemically, or both to correct surface imperfections. This can be accomplished using techniques including hydrofluoric acid etching and airborne-particle abrasion (APA), as demonstrated in the study by Atala and Yegin.[6] In the current study, the initial bur treatment was used to standardize the ceramic surfaces. In repairing lithium disilicate CAD/CAM ceramic blocks, Erdemir et al[10] found that hydrofluoric acid etching and grinding with a high-speed fine diamond bur produced significantly higher surface roughness than the other pretreatment groups. Kilinc et al[1] discovered that the type of material, surface treatment, and their interactions were significant in SBS. For all the materials subjected to the assessment, laser irradiation might be an alternative option for surface preparation than air abrasion. In contrast to air abrasion and laser irradiation, non-aged Cerasmart combined with HF application demonstrated reduced SBS values, according to a previous study. Oz et al[7] after researching the most effective method in repairing hybrid CAD/CAM blocks concluded that the highest SBS was achieved by Er, Cr: Yttrium Scandium Gallium Garnet laser at 3 W followed by Er, Cr: YSGG laser at 2 W, sandblasting, hydrofluoric acid treatment, phosphoric acid treatment. Also, Duzyol et al,[11] study found that bond strength in resin nanoceramic roughened with bur was significantly higher than the other subgroups, which supports that using bur in pretreatment has a positive effect on bond strength in this study. So, to increase bonding potential, surface could be prepared with laser or air abrasion as well.

Thus, the way of creating irregularities could affect the bonding strength of different materials. Atala and Yegin's study showed that the utilization of various types of universal bonding agents had an impact on bonding strength. The research investigated the ability of universal bonding agents to adhere resin composite to diverse ceramic materials in accordance with the manufacturer's recommendations.[6] With the exclusion of Premio Bond and Tokuyama Universal Bond, it was hypothesized that surfaces treated with APA and hydrofluoric acid would weaken the connection due to a reduction in mechanical retention. Even yet, it is not possible to argue that the approach itself causes an increase in bond strength because the Tokuyama Universal Bond group's bond strength was relatively higher than that of many other groups. It may be concluded that increasing bond strength was not a direct result of hydrofluoric acid etching. Due to the presence of functional monomers, which are crucial for adhesion, the universal bonding adhesion is not only reliant on mechanical retention. Premio Bond's superior bonding ability to hybrid ceramics may be attributed to the hydrophilic dimethacrylate monomer, a useful functional molecule that offers more stable bonding to the surfaces of resin composite and hybrid ceramic surfaces.

Additionally, the bonding to silica-containing hybrid ceramics and Vitablocs Mark II is significantly affected by the fumed silica content of the Optibond XTR universal bond. Cerasmart and Vita Enamic, which include more resin, have stronger bonds because of Prime&Bond's multifunctional acrylate functional group. The maximum bond strength is found in the Tokuyama Universal Bond because:

1. It's Tokuyama Universal Bond 10-MDP, which is considered an acidic monomer that is prone to premature hydrolysis, which will interfere with the interaction between silane and ceramics.
2. The impact of the viscous monomer Bis-GMA on silane has been addressed through the addition of TEGDMA and HEMA monomers, enhancing surface wettability and bond strength.

All-Bond Universal agent has higher bond strength than Cerasmart, which could be due to:

1. extra application of silane and
2. mechanical bonding created by APA and hydrofluoric acid etching.

Depending on these findings, it is not possible to conclude that the application of a separate layer of silane and adhesive provides higher bond strength.[6]

The bonding material used in this study, G-Premio, which is a universal adhesive system and offers application flexibility with bonding potential to glass-rich (through silane application) and glass-poor zirconia (via 10-MDP) ceramics for indirect tooth-restoration indications, was also related to the deterioration of the composite bonding over time. However, the silane or HEMA monomers that increase their bonding potential and decrease their susceptibility to hydrolytic deterioration are absent from the G-Premio bonding agent.

The universal bonding effect over time in this study could be related to:

1. A thin film of less than 10 μm allows oxygen to prevent the polymerization of the adhesive layer across a significant amount of its depth. Inadequate polymerization could encourage water sorption and decrease its capacity to withstand stress by polymerization shrinkage placed on the bonding interface.
2. 10-MDP's esters, which connect the hydrophobic spacer to the methacrylate and phosphate functional groups at both ends of the functional monomer, are susceptible to hydrolytic dissolution.[12]
3. HEMA is a hydrophilic monomer that is soluble in water, acetone, and ethanol. This monomer improves stability by holding hydrophilic and hydrophobic monomers in the solution. The bonding agents that contain HEMA in their composition present higher bonding strength than others, as it improves the effect of hydrophobic viscous Bis-GMA monomer, which is one important part of chemical bonding, and increases the wettability of the bonding agent.
4. Silane in bonding agents: silane application increases the surface wettability of the ceramic by its bifunctional molecules. Clearfil Quick Universal and Tokuyama Universal Bond both contain silane coupling agents, but the Clearfil Quick Universal has the lowest bond strength among all types of ceramics.[6]

An acceptable bond strength in ceramics is achieved by all universal adhesive systems. While different types of universal adhesives affect the bond strength between resin composite and ceramics, the most suitable bonding agent must be selected for each ceramic type to increase bond strength.

The influence of the substrate on bond strength was previously believed to be connected to optimal interaction between the resin composite and substrate (ceramic). In the research conducted by Demirel and Baltacioglu,[5] the SBS of several universal adhesive methods used to repair hybrid (CAD-CAM) restorative materials using resin composite was examined. Different bond strengths were demonstrated by the hybrid block types and block type-adhesive treatment combinations examined in this investigation. According to their inorganic composition, hybrid ceramic materials can currently be divided into several subfamilies, including resin nanoceramics (such as Lava Ultimate and Cerasmart), glass ceramics in a resin interpenetrating matrix (such as Vita Enamic), and zirconia-silica ceramics in a resin interpenetrating matrix (such as Shofu block HC). When used with the Clearfil Universal and All Bond adhesive protocols, Cerasmart blocks are superior to Vita Enamic blocks in terms of repair performance. When used with the Clearfil Universal adhesive protocol, Cerasmart blocks are superior to Shofu Block HC blocks. These variations may be influenced by the surface microstructure of these hybrid blocks.[5]

CONCLUSION

The limitation of this in vitro study was that the performed test only sheared bond strength which does not simulate any other stresses clinically. The use of bonding agent and pretreatment method was standard, while different methods and agents could have different outcomes. Although limited studies are comparing the SBS of different types of resin composites to resin nanoceramic, we conclude that:

1. The SBS of the resin composites can be affected by its structural compositions. Thus, the type of the monomers will affect the mechanical properties over time. There are limited studies that relate the SBS of resin composites to their monomer composition.
2. The SBS and failure mode depend on the adhesive type, technique, composition, and surface treatment of the substrate. Even though the manufacturer's instructions have been followed for nanoceramic repair, the surface treatment may affect the bond strength in addition to the bonding agent.
3. Time and bond strength are conversely related, as SBS decreases with time.

Ethics Committee Approval: Since this study exclusively involves nonhuman or inanimate materials, Ethics Committee approval is not required.

Informed Consent: N/A.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept – A.D.; M.R; I.E.P; Design – A.D.; M.R; I.E.P; Supervision – A.D.; M.R; Resources – A.D; Materials – A.D.; Data Collection and/or Processing – A.D.; Analysis and/or Interpretation – M.R; I.E.P; Literature Search – M.R; I.E.P; Writing Manuscript – A.D.; M.R; I.E.P; Critical Review – A.D.

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