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Repair Bond Strength of Two Shadeless Resin Composites Bonded to Various CAD-CAM Substrates with Different Surface Treatments

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Abstract: This study compared the repair bond strength values of two single-shade composite resins bonded to different computer-aided design and computer-aided manufacturing (CAD-CAM) substrates with different surface treatments. A total of 80 slice-shaped specimens were fabricated using two CAD-CAM materials: Lava Ultimate and VitaEnamic. The substrates were thermocycled and then, based on the surface treatment, each substrate material was subdivided into four groups: the air abrasion group (APA), the hydrofluoric-acid-etched group (HF) and two silicon carbide ground groups (SiCr). All of the groups received silane followed by Single Bond Universal Adhesive application prior to being repaired with a resin composite of a smaller disc shape. All the specimens were thermocycled prior to shear bond strength testing and subsequent failure analyses. Statistical analyses were conducted, and the level of statistical significance was set at 0.05. A comparison of the mean values showed a highly statistically significant difference among the eight groups. The highest value of mean shear bond strength was associated with Lava Ultimate substrates repaired using the Charisma Diamond ONE composite after APA surface treatment (36.7 ± 1.99). Meanwhile, the lowest value was recorded for the Vita Enamic group repaired using the OMNICHROMA composite after SiCr surface treatment (17.8 ± 1.6). The failure analysis revealed that cohesive failure in the substrate was the most predominant. Within the limitations of this study, Charisma Diamond ONE showed better bond strength values compared to Omnichroma. Meanwhile, APA is recommended for improved bond strength in repairs of Lava Ultimate restorations.

Keywords: CAD-CAM; repair; surface treatment; shadeless resin composites; OMNICHROMA; Charisma Diamond ONE; bond strength

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1. Introduction

Computer-aided design/computer-aided manufacturing (CAD/CAM) dental materials have evolved and are widely used, including both ceramics and composites [1]. Indirect composite blocks (ICs) are an alternative to conventional ceramics and composites [1,2]. There are two types of these blocks: polymer-infiltrated ceramic network (PICN) materials (such as Vita Enamic) and ICs with dispersed fillers (ICDFs) (such as 3M Lava Ultimate Restorative, GC Cerasmart and Shofu Block HC) [2–4].

One of the main advantages of ICs is that they have closer elasticity moduli to that of dentin. Hence, their abilities to absorb masticatory loads are better than those of ceramics [5]. Also, they can be milled to thicknesses as thin as 0.2–0.5 mm, which means they might be easier to mill and repair if restorative failure occurs [2]. However, indirect restorations are still prone to fractures in the challenging oral environment. Fractures could occur due to trauma, parafunctional habits, inadequate occlusal contact and/or defects of the internal material [6,7].

Intra-oral restorative repair is one of the recommended treatment options as it is a minimally invasive protocol which can be used to prevent the disadvantages of total

replacement [8]. Repair can be defined as a conservative treatment approach involving restorative correction that involves the addition of a new restorative material to make the composite clinically acceptable again [9].

Although multiple repair systems are commercially available, the repair methodology in the published literature is inconsistent. Most studies agree on the necessity of surface pretreatment, and some recommend certain adhesive applications with or without silane. A systematic review and meta-analysis by Yu et al., conducted in 2020, showed that a combination of mechanical and chemical surface treatments produced the highest bond strength values in indirect composite repair. They recommended hydrofluoric acid etching followed by the application of a universal primer for PICN substrate materials. Meanwhile, for ICDF substrates, micromechanical retention was suggested as the best approach for the optimization of the repair bond strength. For retention to be achieved, it is advisable to use airborne-particle abrasion or tribochemical silica airborne-particle abrasion followed by a silane coupling agent [9–11].

Silane application improves the surface wetting of bonding agents; hence, it is expected to infiltrate more easily into surface irregularities created by roughening pretreatments. A silane-coated substrate surface is more reactive to the methacrylate group of the repair resin material [12]. In repair procedures, the application of a universal adhesive alone showed promising results. However, surface pretreatment followed by universal adhesive application is advised for aged CAD/CAM restorations [11].

Shade matching can be very difficult due to the polychromatic nature of teeth. It can become more challenging in the presence of an existing defective restoration with an unknown shade [13]. To simplify this procedure, universal shadeless composites were introduced to the market. Recently, the OMNICHROMA resin composite was produced by Tokuyama Dental America Inc.(Yamaguchi, Japan), and Charisma Diamond ONE was produced by Kulzer Dental (Wehrheim, Germany). The manufacturers claimed that these composites will match any surrounding tooth color.

Several studies evaluated the repair bond strengths of variable indirect restorative materials using different resin-based composite (RBC) repair materials. However, studies assessing surface treatments and the intraoral repair of resin ceramics are sparse [14–17]. The results of these studies are inconsistent, and multiple limitations regarding their methodological designs have been reported. However, the manufacturers of the shadeless resin composites reported that both are suitable for use as repairing materials. Meanwhile, to the best of the authors' knowledge, no published study has evaluated the use of these new universal composites as repair materials for both direct and indirect defective restorations. Hence, the purpose of the present study was to compare the repair bond strength values of OMNICHROMA and Charisma Diamond ONE resin composites bonded to hybrid CAD/CAM substrates. The purpose was also to compare the influence of different surface treatments on the repair bond strengths of two shadeless resin composites bonded to hybrid CAD/CAM substrates. The tested null hypotheses were that there would be no significant difference in the repair bond strengths of the two shadeless resin composites when bonded to hybrid CAD/CAM substrates. Also, there would be no significant difference in the repair bond strengths of the two shadeless resin composites when bonded to hybrid CAD/CAM substrates when different surface treatments were used.

2. Materials and Methods

2.1. Study Materials

Two hybrid ceramic restorative materials were used in this study for substrate specimen preparation:

1. Lava Ultimate (3M ESPE, St. Paul, MN, USA).
2. VitaEnamic (Vita Zahnfabrik, Bad Säckingen, Germany).

Two shadeless resin-based composites (OMNICHROMA and Charisma Diamond ONE) were used as the repairing restorative materials. Monobond N (Ivoclar Vivadent, Schaan, Liechtenstein) and Single Bond Universal Adhesive (3M ESPE, Neuss, Germany)

were used as the intermediate agents. The manufacturers and chemical compositions of the materials used in the present study are shown in Table 1.

Table 1. List and chemical compositions of the materials used.

Material	Manufacturer	Lot. Number	Type	Chemical Composition
Vita Enamic	Vita Zahnfabrik, Bad Säckingen, Germany	43410	PICN ICs CAD/CAM	86 wt% feldspar ceramic; 14 wt% polymer
Lava Ultimate	3M ESPE, St. Paul, MN, USA	NA38845	ICDFs CAD/CAM	80 wt% nanoceramic; 20 wt% resin.
Monobond N	Ivoclar Vivadent, Schaan, Liechtenstein, Switzerland	8246395	Silane	Alcohol solution of silane methacrylate, phosphoric acid methacrylate, and sulphide methacrylate
Single Bond Universal Adhesive	3M ESPE, Neuss, Germany	8326047	Bonding agent	10-MDP phosphate monomer; Vitrebond; copolymer; HEMA; BISGMA; dimethacrylate resins; filler; silane; initiators; ethanol; water.
OMNICHROMA	Tokuyama, Yamaguchi, Japan	157S4	Nanofilled RBC	2-Propenoic Acid; 2-Methyl-; 7;7;9(Or 7;9;9)-Trimethyl-4;13-Dioxo-3;14 Dioxa-5;12-Diazahexadecane-1;16-Diyl Ester; 2 Propenoic Acid; 2-Methyl-; 1;2-Ethanediylbis(Oxy-2;1-Ethanediyl) Ester; 2;6-Di-T-Butyl-4 Methylphenol; Bicyclo[2.2.1]Heptane-2;3 Dione; 1;7;7-Trimethyl-; (±)-Phenol; 4-Methoxy
Charisma Diamond ONE	Kulzer Dental, Wehrheim, Germany	K010022	Nanohybrid RBC	2-Propenoic acid; (octahydro-4;7-methano1H-indene-5-diyl) bis(methyleneiminocarbonyloxy-2;1-ethanediyl) ester; triethylen glycol dimethacrylate

2.2. Substrate Specimen Preparation

Eighty ceramic slices with 2 mm thicknesses were obtained from 14 mm × 12 mm × 18 mm CAD/CAM blocks (n = 40 per CAD/CAM material) using a low-speed diamond saw (IsoMet 1000; Buehler Ltd., Lake Bluff, IL, USA) under water cooling. The ceramic slices were mounted in a polyvinylchloride (PVS) cylinder using Orthoresin (DeguDent GmbH, Hanau, Germany). Then, the specimens were polished under water cooling, utilizing 400-, 600- and 1000-grit silicon carbide abrasive papers (Buehler, Lake Bluff, IL, USA) mounted in an Automata Machine (Jeanwirtz, GMBH, Dusseldorf, Germany), and a stopwatch was utilized to time durations of 30 s to standardize the time.

All the specimens were stored in a distilled water incubator at 37 °C for 24 h; then, they were subjected to 5000 cycles of thermal aging in thermocycling apparatus (Thermocycler 1100/1200, SD Mechatronik) between 5°C and 55 °C, with a dwell time of 15 s and a transfer time of 10 s.

2.3. Surface Treatments

The specimens of each CAD/CAM restorative material were randomly divided into two groups (n = 20/ group) based on the surface treatment (Figure 1).

The Lava Ultimate (3M ESPE, St. Paul, MN) specimens received one of the following surface treatments:

- Group I: Air particle abrasion

The Lava Ultimate specimens were sandblasted using an air spray of 50 µm aluminum oxide particles (Microetcher II, Danville Engineering; San Ramon, CA, USA) at a pressure of 30 psi. Sandblasting was conducted for 10 s until the bonding surface looked dull. The surface was cleaned with alcohol and then dried with an oil-free, moisture-free air stream.

- Group II: Silicon carbide grinding

The specimens were ground using wet 240-, followed by 400-, and then 600-grit silicon carbide papers that were mounted in an Automata Machine, and a stopwatch was utilized to time durations of 30s, similar to previous studies [17,18]. Then, the specimens were rinsed for 10 s using a stream of oil-free compressed air/water from a syringe tip. An air syringe was used for 5 s to remove excess surface water.

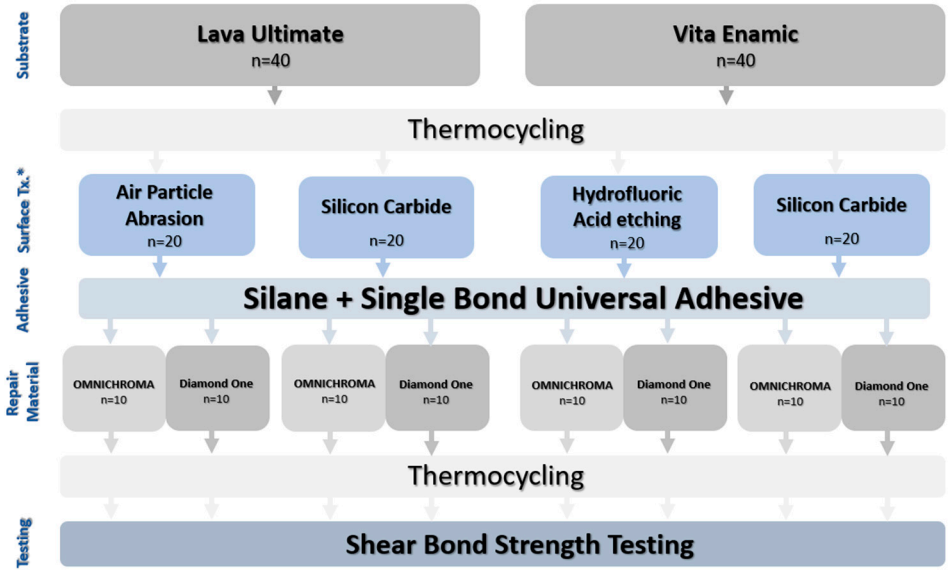


Figure 1. Schematic representation of the study design.

The Vita Enamic (Vita Zahnfabrik, Bad Säckingen, Germany) specimens were subjected to one of the following surface treatments:

- Group III: Hydrofluoric acid etching

Based on the manufacturers' instructions, a hydrofluoric acid gel (HF; 9% Ultradent Porcelain Etch; Ultradent Product Inc., South Jordan, UT) was applied to the surfaces of aged Vita Enamic specimens for 60 s. Then, the specimens were rinsed for 10 s using a stream of oil-free compressed air/water spray. An air syringe was used for 10 s to remove excess surface water.

- Group IV: Silicon carbide grinding

In this group, the surfaces were treated similarly to those in group II.

2.4. Adhesive and Repair Composite Application

The specimens in each surface treatment group received a silane application (Monobond N, Ivoclar Vivadent, Schaan, Liechtenstein) prior to the application of the adhesive. Monobond N was applied to the ceramic surfaces using a microbrush and allowed to react for 60 s. The surfaces were then dried with oil-free air.

Subsequently, Single Bond Universal Adhesive was applied to ceramic surfaces using a disposable applicator. The adhesive was rubbed on the surface for 20 s. Then, it was allowed to gently air dry for approximately 5 s until no movement could be seen and the solvent had evaporated completely. At that point, light curing was performed for 10 s, using an LED curing unit (Elipar S10 LED Curing Light, 3 M ESPE, St Paul, MN, USA) positioned 1 mm away from the surface.

Half of the specimens in each group received the Omnichroma resin composite as a repair material. Meanwhile, the other half were repaired with the Charisma Diamond ONE resin composite. The repair composites were condensed on top of the cured adhesive layers using a clean plastic instrument and customized silicon molds to produce composite cylinders (2 mm in thickness and 5 mm in diameter). Lastly, light curing was performed for

10 s, as recommended by the manufacturer, using a Bluephase N light curing unit (Ivoclar Vivadent, Schaan, Liechtenstein, Switzerland; light output: 1500 mW/cm^2) positioned 1 mm away from the surface. Afterward, the specimens were cautiously taken out of the molds and checked for defects; defective specimens were excluded.

All the specimens were stored in a distilled water incubator at 37 °C for one week, during which, they were subjected to 10,000 cycles of thermal aging in a thermocycling apparatus (Thermocycler 1100/1200, SD Mechatronik) between 5° and 55 °C with a dwell time of 15 s and a transfer time of 10 s.

2.5. Shear Bond Strength Testing

All the specimens were shear tested using an Instron Universal Testing Machine (Instron 8500, Instron Corp, Norwood, MA, USA) at a cross-head speed of 0.5 mm/min. The acrylic resin molds with embedded ceramic plates were fixed in a jig, as shown in Figure 2. Then, force was applied perpendicular to the adhesive interface until bond failure occurred. The peak force at which the specimen failed was recorded in megapascals (MPa).



Figure 2. An image of a prepared specimen fixed in the jig for shear bond testing.

For failure analysis, an optical microscope at 50× magnification was independently used by each examiner to examine all fractured composite specimens. Moreover, each examiner reanalyzed the specimens twice at least one week apart to confirm intra-examiner reliability. The failure modes were classified as "adhesive" (at the interface between the composite substrate and repair), "cohesive" (failure of the composite resin) or "mixed" (a combination of adhesive/cohesive failure). Selected specimens were examined using a scanning electron microscope (SEM) (JSM, 6360LV, JEOL, Tokyo, Japan), and photomicrographs were taken at a magnification of 46× to 51×.

2.6. Statistical Analysis

Data were analyzed using SPSS software version 26.0 (IBM Inc., Armonk, NY, USA). A one-way analysis of variance (ANOVA) was used to identify statistically significant differences among the study groups. Tukey's multiple comparison test and Student's *t*-test for independent samples were used to compare the differences among subgroups. The intraclass correlation coefficient was used to analyze intra- and inter-examiner reliability. The level of statistical significance was set at 0.05.

3. Results

The values of the mean shear bond strength (SBS), the standard deviation (SD) of maximum load (N) and the shear bond strength (MPa) for all study groups are presented in Table 2. The highest mean shear bond strength value was recorded for the Lava Ultimate substrates repaired using the Charisma Diamond ONE composite after APA surface treatment (LU-APA-DO/G6), with a mean shear bond strength of 36.7 ± 1.99. Meanwhile, the

lowest value was recorded for the Vita Enamic group repaired using the OMNICHROMA composite after the SiCr surface treatment (VE-SC-Om/G3), with a mean shear bond strength of 17.8 ± 1.6.

Table 2. Mean values of maximum load and shear bond strength in the study groups.

Study Group	Abbreviation	Substrate	Surface Treatment	Repairing Material	Maximum Load (N)	Shear Bond Strength (MPa)
G1	LU-SC-Om	Lava Ultimate	SiCr	Omnichroma	149.74 ± 19.29	21.81 ± 2.73
G2	LU-APA-Om	Lava Ultimate	APA		254.74 ± 18.85	36.04 ± 2.67
G3	VE-SC-Om	Vita Enamic	SiCr		125.85 ± 11.35	17.09 ± 1.61
G4	VE-HF-Om	Vita Enamic	HF		177.57 ± 11.34	25.12 ± 1.60
G5	LU-SC-DO	Lava Ultimate	SiCr	Charisma Diamond ONE	194.83 ± 10.49	27.56 ± 1.48
G6	LU-APA-DO	Lava Ultimate	APA		259.44 ± 14.07	36.70 ± 1.99
G7	VE-SC-DO	Vita Enamic	SiCr		235.73 ± 13.42	33.35 ± 1.89
G8	VE-HF-DO	Vita Enamic	HF		237.86 ± 16.04	33.65 ± 2.27

A comparison of the maximum load and shear bond strength (SBS) using a one-way ANOVA showed a highly statistically significant difference in the mean values among the eight study groups ($p < 0.0001$) considering the three variables (the combination of the two types of substrates, surface treatments and repairing materials, as seen in Table 2).

Regarding the repairing material, the independent *t*-test indicated that the mean values in the groups repaired using Charisma Diamond ONE were significantly higher than the mean values in the groups repaired with OMNICHROMA ($p < 0.0001$). The two groups were compared independently, as shown in Table 3.

Table 3. Comparison of the mean values between two types of surface treatments and repairing materials.

Variable	N	Shear Bond Strength M (SD)	*p*-Value	95% Confidence Interval	
				Lower Bound	Upper Bound
LU-SiCr	20	24.37± 3.91	0.000	22.54	26.20
LU-APA	20	36.37 ± 2.32		35.29	37.45
VE-SiCr	20	25.58 ± 8.16	0.075	21.76	29.39
VE-HF	20	29.39 ± 4.78		27.15	31.62
OM	40	25.04 ± 7.27	0.000	22.71	27.36
DO	40	32.82 ± 3.83		31.59	34.04

Based on the surface treatments recommended by the substrates' manufacturers, multiple comparisons tests (MCTs) for APA-treated groups revealed no statistical differences regardless of the repairing materials. The mean values in the LU-APA-Om group (G2: 36.0 ± (2.7)) were not significantly different to those in the LU-APA-DO group (G6: 36.7 ± (1.99)). On the other hand, in the hydrofluoric-acid-etched groups, the mean values in the VE-HF-DO group (G8: 33.6 ± (2.3)) were significantly higher than those in the VE-HF-Om group (G4: 25.1 ± (1.6)) ($p < 0.0001$).

In the silicon-carbide-treated groups, MCTs showed that the mean values in the Charisma Diamond ONE groups were significantly higher compared to those in the groups repaired using Omnichroma, regardless of the substrate. The mean values in the LU-SC-DO group (G5: 27.6 ± (1.5)) were significantly higher than those in the LU-SC-Om group (G1: 21.2 ± (2.7)) ($p = 0.0001$). Also, the values in the VE-SC-DO group (G7: 33.3 ± (1.9)) were significantly higher than those in the VE-SC-Om group (G3: 17.8 ± (1.6)) ($p = 0.0001$). Among groups in which the same repairing material was used, the data revealed no statistical differences between the mean values in the Omnichroma-repaired groups (the LU-SC-Om and VE-SC-Om groups (G1: 21.2 ± (2.7) and G3: 17.8 ± (1.6))). Meanwhile, the mean values in the VE-SC-DO groups (G7: 33.3 ± (1.9)) were significantly higher than those in the LU-SC-DO group (G5: 13.64 ± (2.28)).

The intraclass correlation coefficient provided excellent intra- and inter-examiner reliability values of 1.0 and 0.9, respectively. The distribution of failure modes is represented in Figure 3 as a percentage of specimens for each study group. The failure analysis revealed that cohesive failure in the substrate was the predominant mode of failure. The main mode of failure in the APA-treated Lava Ultimate substrates and VitaEnamic SiCr groups was cohesive failure in the substrates (LU-APA-DO-G3: n = 10; LU-APA-Om-G7: n = 10; VE-SC-DO-G2: n = 8; VE-SC-Om-G6: n = 5). The adhesive mode of failure was predominant in the SiCr-treated Lava Ultimate substrates and the VitaEnamic HF-etched groups (LU-SC-DO-G1: n = 10; LU-SC-Om-G5: n = 7; VE-HF-DO-G4: n = 4; VE-HF-Om-G8: n = 6). Cohesive failure in the repairing material was only recorded in the Omnichroma-repaired group and, was exclusively recorded in the LU-SC-Om group (G1: n = 2). Meanwhile, in the groups repaired using Chrisma Diamond ONE, no cohesive failures in the repairing material were observed. Meanwhile, the mixed failure mode was recorded in all VitaEnamic groups (VE-SC-DO-G2: n = 2; VE-HF-DO-G4: n = 3; VE-SC-Om-G6: n = 3; and VE-HF-Om-G8: n = 4) in addition to one SiCr-treated Lava Ultimate group (LU-SC-Om-G5: n = 1). A representative specimen for each mode of failure was analyzed using SEM, as presented in Figure 4.

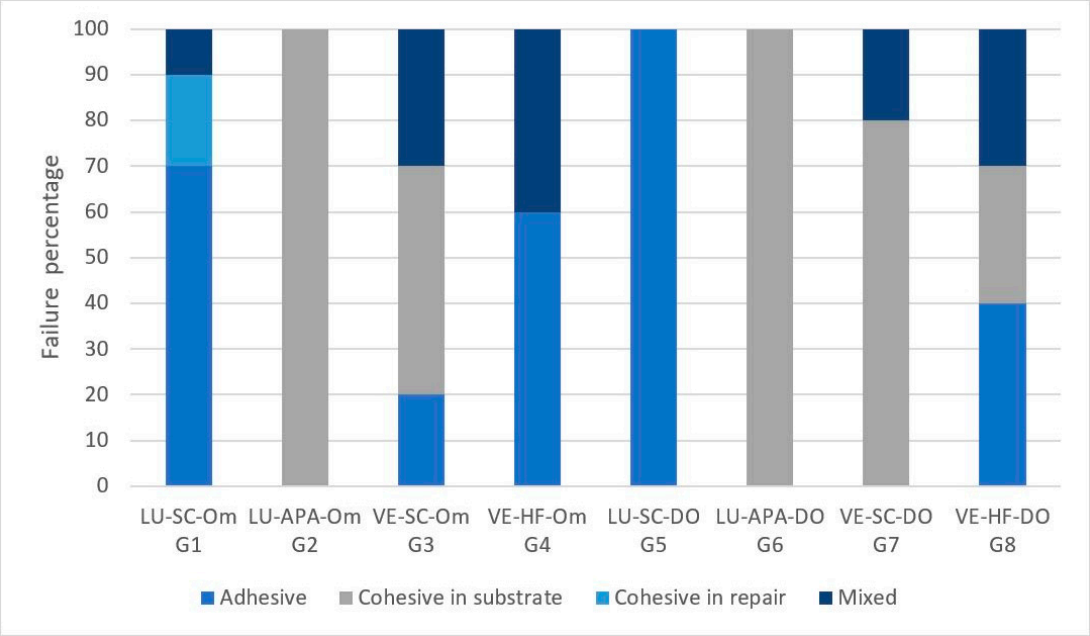


Figure 3. Diagrammatic representation of the failure modes for all the tested specimens.

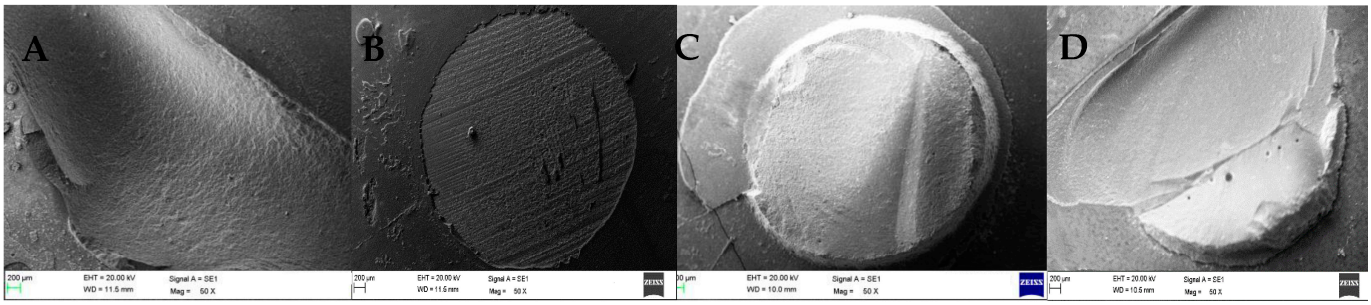


Figure 4. Micrographs of the representative specimens for each mode of failure; cohesive in substrate (**A**), adhesive (**B**), cohesive in repair (**C**) and mixed (**D**), using scanning electron microscopy (SEM) at an average magnification of 50×.

4. Discussion

The current research compared the repair bond strength values of two shadeless resin composites bonded to variable CAD-CAM substrates. Also, it evaluated the influences of different surface treatments. The results of the current study revealed that the groups repaired with Charisma Diamond ONE had significantly higher repair bond strength values than the groups repaired with Omnichroma resin composites. Moreover, for Lava Ultimate substrates, the groups that were surface-treated using APA exhibited significantly higher mean values than the groups treated using SiCr. However, for the Vita Enamic substrates, there were no significant differences in the mean values of the groups treated using either HF or SiCr. Therefore, the first null hypothesis cannot be accepted, while the second hypothesis is partially accepted.

Based on the repairing composite materials, the current study showed significantly higher mean values for groups repaired using Charisma Diamond ONE compared to the groups repaired using Omnichroma. This could have been due to the differences in the chemical compositions of these RBCs. Although both are Bis-GMA-free and contain UDMA and TEGDMA in their monomer structures, Charisma Diamond ONE also includes a tricyclodecane (TCD) monomer. This is a highly reactive monomer with low viscosity, designed to reduce polymerization shrinkage and stresses [19]. Also, Frauscher and Ilie showed that it is more resistant to hydrolytic degradation compared to TEGDMA and Bis-GMA monomers [20]. Moreover, differences in the filler load, shape and particle size are also involved: Charisma Diamond ONE contains prepolymerized filler particles. Nanofillers of lower proportion are present in Omnichroma [21].

Based on the surface treatments for the Lava Ultimate (LU) substrates, the present study showed that the APA-treated groups had significantly higher repair bond strength values (LU-APA-Om (G2: 36.0 ± (2.7)) and LU-APA-DO (G6: 36.7 ± (1.99))) compared to the SiCr-treated groups (LU-SC-Om (G1: 21.2 ± (2.7)) and LU-SC-DO (G5: 13.64 ± (2.28))). The improved bond strength of the APA groups could be attributed to the increased surface roughening, surface energy and surface wettability, which led to improved microinterlocking [9]. This result is in accordance with the manufacturers' instructions in which APA using Al_2O_3 with a particle size of 50 μm is recommended for bonding LU materials. The results of Sismanoglu et al. also reported significantly higher bond strength values when LU was treated via APA compared to other surface treatments [10]. Moreover, several studies confirmed that air abrasion is more effective as a surface pretreatment for LU restorative materials [22–25]. Similarly, a recent systematic review and meta-analysis considered the use of alumina air abrasion followed by a universal adhesive to be the best bonding approach for indirect composite blocks.

On the other hand, for the VE substrates, the data in the current study showed that the HF-treated groups had non-significantly higher repair bond strength values compared to the SiCr-treated groups. HF acid etching creates a microretentive surface by dissolving the glassy phase of the PICN material. Meanwhile, the polymer phase is unchanged, forming a honeycomb structure and promoting micromechanical retention [2]. However, this non-significant difference could have been attributed to the increased adhesion affinity to silane due to the high silicon dioxide (SiO2) composition in VE. Similarly, El-Damanhoury et al. and Alnafaiy et al. showed that there was no significant difference between VE groups treated using either hydrofluoric acid etching or a self-etching ceramic primer. However, both studies used a lower concentration of HF etchant (5% and 4.8%) compared to the present study (9% HF) [26,27]. Madani et al. compared bond strengths after etching with 5% and 9.5% HF acid, and they showed non-significantly lower values associated with the 5% acid concentration. It should be noted that the ceramic substrate tested had a different composition [28]. A recently published systematic review and meta-analysis showed that the highest bonding values for VE are obtained when chemical acid etching is used and then a universal primer is applied. This surface treatment is in accordance with the manufacturer's bonding instructions [9]. The hazardous effect of HF acid must be considered; in 1998, it was classified as an unsafe chemical in nondental disciplines

due to its toxicity [29]. Therefore, the intraoral application of HF acid etchants should be performed with caution and proper tissue isolation.

Defective restorations are frequently encountered in which fractures are one of the most common causes of CAD-CAM restoration failure [30]. Meanwhile, the repairability of indirect composite blocks is one of their main advantages compared with ceramics [31]. The repair methodology is inconsistent in the published literature, but most studies agree on the necessity of surface pretreatment, and some recommend certain adhesive applications with or without silane [32].

In repair procedures, the application of a universal adhesive alone showed promising results, but surface pretreatment followed by universal adhesive application is recommended for aged CAD/CAM restorations [10]. Silane application improves the surface wetting of bonding agents; hence, it is expected to infiltrate more easily into surface irregularities created by roughening pretreatments. Silane-coated substrate surfaces are more reactive to the methacrylate group in repair resin materials [11]. Silanes are chemical compounds composed of two main functional groups: silanol and organo-functional groups. The silanol bonds to the silica of the composite filler, while the organo-functional group co-polymerizes with methacrylate of the bonding agent [33–35].

Numerous resin composites have been indicated for use as restorative repair materials. The recently marketed universal shadeless composites can be considered practical options as no shade-matching step is required in their use. This is in addition to the fact that the brand and/or type of defective restorative material cannot be identified in many clinical settings [36]. However, no studies testing these composites as repairing materials have been published to compare the present results with. From the analyses, it can be inferred that the values of maximum load and shear bond strength changed with the effect of the applied surface treatment in combination with the type of substrate and repairing materials used.

Repair bond strength was evaluated using the shear bond testing method, as it is one of the most commonly used testing methods that is known for its simplicity and reliability [37]. In vitro shear loading was described to more accurately represent masticatory loads because it produces a variety of stresses (compressive and tensile, in addition to shear) and is therefore clinically relevant [38]. However, using a microtensile bond strength (μTBS) testing method is more reliable. This methodology may lead to inaccurate bond strength measurement due to an increased likelihood of pretest failures and issues regarding uneven stress distribution [39,40]. It is noteworthy that shear bond strength seems to produce higher values compared to TBS [41]. Therefore, the absolute findings obtained using different testing methods should not be compared directly [42].

Furthermore, to represent clinical sittings, the tested specimens were aged via thermal cycling. The adhesion of a repairing composite layer might be significantly impacted by temperature fluctuations. This is in addition to recurrent expansion–contraction stresses that occur in composite and resin matrix ceramic materials, as well as changes in the material's properties [43,44]. The impact of storage and aging conditions on four CAD-CAM materials (Vita Enamic, Lava Ultimate, Vitablocs Mark II and IPS e.max CAD) were evaluated by Porto et al. They showed that Vita Enamic exhibited flexural strength and modulus characteristics that are comparable to ceramics. Meanwhile, Lava Ultimate was similar to a direct composite in terms of its water absorption and reduction in flexural strength [45].

The failure analyses in the current study showed that cohesive failure in the substrates followed by the adhesive failure mode were predominant in the majority of the specimens tested. In agreement with this finding, Burrer et al. revealed a mostly cohesive mode of failure in their experimental nanohybrid composite specimens [46]. Also, this could have been due to the shear testing method used, which has been criticized for its higher tendency to produce cohesive modes of failure [47]. Nevertheless, Burrer et al. used a microtensile testing method and found a similar mode of failure [47]. The adhesive mode of failure was recorded for groups with low mean values (the LU-SC-Om (G1:10), LU-SC-Do (G5:7), VE-HF-Om (G4:4) and VE-HF-Om (G8:6) groups), which represents their lower values of shear bond strength (G1: 21.81 ± (2.73), G5: 27.56 ± (1.48), G4: 25.12 ± (1.60) and

G8: 33.65 ± (2.27)). Meanwhile, cohesive failure in the repair was exclusively recorded in SiCr-treated Lava Ultimate repaired using Omnichroma (n = 2). This can be attributed to the lower mechanical properties of the repairing composite. A recent study by Ilie showed that Omnichroma has the lowest mechanical properties compared to other universal chromatic RBCs tested [22].

The limitations of the present study include the limited number of published studies available for comparison. This is because the Omnichroma and Charisma Diamond ONE resin composites were recently introduced, and to the best of the authors' knowledge, the present study is the first to evaluate their use as repairing materials. Another limitation is our use of one type of intermediate agent (silane followed by universal adhesive) for all the experimental specimens. Therefore, it is suggested that future research comparing variable composite formulations and intermediate agents should be carried out. Also, the use of one aging modality and static testing method was not expected to accurately reflect clinical settings. Hence, future research using variable aging modalities and/or fatigue testing is advised. Further research is required to evaluate other repair methodologies for shadeless RBC and the shade-matching capabilities in the repair of different shades of different substrate materials.

5. Conclusions

Within the limitations of the present study, it can be concluded that both shadeless resin composite materials tested could be used to repair defective restorations, especially when the shade and/or material of the defective restoration is unknown. However, Charisma Diamond ONE showed better repair bond strength values compared to Omnichroma with the tested substrates. An air abrasion surface treatment using Al_2O_3 particles of 50 µm is recommended to enhance the repair bond strength of Lava Ultimate when using both single-shade resin composites.

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