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Effect of surface treatment on the repair bond strength of OMNICHROMA and Charisma Diamond ONE resin composites bonded to variable substrates

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ABSTRACT

Objectives: To compare repair bond strength of OMNICHROMA and Charisma Diamond ONE resin composites bonded to variable composite substrates. Also, to evaluate the influence of different surface treatments on repair bond strength.
Methods: A total of 80-disc shaped specimens was fabricated using two resin based composite materials; IPS Empress Direct Enamel and OptiShade (n = 40). Substrate discs were thermocycle 5000 cycles then each substrate material was subdivided based on the surface treatment into two groups; air particle abrasion (APA) and silicon carbide grinding (SiCr) both groups followed by phosphoric acid etching. All groups received a single bond universal adhesive application prior to repairing with composite, in a smaller disc shape. All specimens were thermocycled for 10,000 cycles prior to shear bond strength testing and subsequent failure analysis. Statistical analyses were conducted and the level of statistical significance was set at 0.05.
Results: The comparison of mean values (considering the combination of the two types of substrates, surface treatments and repairing materials) showed a highly statistically significant difference in the shear bond strength among the eight study groups ($p < 0.0001$). The highest value of mean shear bond strength was associated with OptiShade substrates repaired by Diamond ONE (38.6 ± 2.4). Meanwhile, the lowest value was recorded for the SiCr treated OptiShade group repaired by Diamond ONE (13.6 ± 2.3). The failure analysis revealed that cohesive mode of failure was the most predominant.
Conclusion: Omnichroma showed higher repair bond strength values with SiCr surface treatment. Meanwhile, Charisma Diamond ONE had better bond strength with APA. Surface pretreatment had a significant impact on the repair bond strength where APA groups had significantly higher values compared to SiCr groups. **Clinical Significance**: Within the limitation of the present study; APA is recommended as surface pretreatment for improved bond strength in restorative composite repairs.

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1. Introduction

Dental resin-based composite (RBC) is one of the most commonly used restorative material. However, similar to other materials RBC has a limited longevity with a mean annular failure rate of 2.2% [1]. Where, secondary caries and restorative fracture are the most common causes of restorative failures [2,3,4]. Management of defective restoration involve variable treatment options including the most conservative option of no further treatment, only follow-up or refurbishment. While repair and replacement are the more complex treatment options [5].

Repair is a minimally-invasive treatment modality of restorative correction that involve addition of a new restorative material to become in a clinically acceptable status [6]. Repair bond strength is affected by several factors including; compatibility between defective restoration (substrate) and repair restorative materials in term of chemical composition [7–10]. In addition to, aging modality, applied surface conditioning technique on the substrate [5,11,12], and usage of intermediate agents such as; silane, adhesive and/or flowable resin-based composites prior repairing material application [4,13]. Moreover, the used testing method for bond strength assessment, is among the factors shown to be significantly influencing the repair bond strength [14].

Although repair methodology is inconsistent in published literature, most studies agreed on the necessity of surface pretreatment and some recommended certain adhesive applications with or without silane. A study of Brendeke et al. showed higher repair bond strength values with silica coating and silanization in comparison with etching by phosphoric acid followed by adhesive application [11]. However, sandblasting using silica-coated particles followed by a silane coupling agent showed to have no advantage over common bonding systems [15].

Effectiveness of variable repair methods is material dependent. Hence, none of the common surface treatment techniques can be suggested as a universally applicable method for repair [16]. However, when the substrate material is unknown, Loomans et al. recommended phosphoric acid etching or sandblasting as surface pretreatment followed by bonding agent application using a combination of a silane and an adhesive [16].

Multiple resin composites are indicated for use as a restorative repair material. For most composite materials, proper shade selection is critical to ensure good shade matching with surrounding. However, shade matching can be very difficult due to polychromatic nature of teeth and unknown shade of the defective restoration in most clinical situations [17]. In an attempt to simplify the shade matching process, OMNICHROMA resin composite was introduced by Tokuyama Dental America Inc. This material is considered as a universal composite material available in only single shade that is claimed to match any surrounding tissue color once material is cured. Additionally, a new universal composite material (Charisma Diamond ONE) introduced by Kulzer Dental in single shade corresponding to the 16 VITA classical shades. Likewise, Charisma Diamond ONE resin composite is indicated for use as a repair restorative material. Although both OMNICHROMA and Charisma Diamond ONE resin composites are indicated for use as repair materials, to the authors' knowledge no published study evaluated the use of these new universal composites as repair materials for both direct and indirect defective restorations. Hence, the aim of this study was to compare repair bond strength of OMNICHROMA and Charisma Diamond ONE resin composites bonded to variable composite substrates. And to compare the influence of different surface treatments on their repair bond strength. The tested null hypotheses were; no significant difference in the repair bond strength of OMNICHROMA and Charisma Diamond ONE resin composites when bonded to variable composite substrates. Also, no significant difference in repair bond strength of OMINCROMA and Charisma Diamond ONE resin composites when bonded to variable composite substrates when different surface treatment are used.

Table 1
List and chemical compositions of the materials to be tested.

	Material	Manufacturer	Lot Number	Type	Chemical Composition
Substrate materials	Optishade	Kerr Corporation, USA	8,246,395	Nanohybrid	2,20 -ethylenedioxydiethyl dimethacrylate, poly (oxy-1,2 ethanediyl), α, α'- [(1 methylethylidene) di-4,1-phenylene] bis [ω- [(2- methyl-1-oxo-2-propen-1-yl) oxy]-, ytterbium fluoride
	IPS Empress Direct Enamel	Ivoclar Vivadent, Schaan, Liechtenstein	Z00TDL	Nanohybrid	Urethane dimethacrylate, ytterbium trifluoride, tricyclodocane dimethanol dimethacrylate, Bis-GMA.
Repairing materials	OMNICHROMA	Tokuyama, Yamaguchi, Japan	157S4	Nanohybrid	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	2-Propenoic acid, (octahydro-4,7-methano-1H-indene-5 -diyl) bis(methyleneiminocarbonyloxy-2,1-ethanediyl) ester, triethylen glycol dimethacrylate
Intermediate agent	Single Bond Universal Adhesive	3 M ESPE, Neuss, Germany	8,326,047	-	10-MDP phosphate monomer, Vitrebond, copolymer, HEMA, BISGMA, dimethacrylate resins, filler, silane, initiators, ethanol, water

2. Materials and methods

2.1. Study materials

Two resin based composite materials was used in this study for substrate specimen preparation including; OptiShade (Kerr Company, USA), Shade Medium and IPS Empress Direct Enamel (Ivoclar Vivadent, Schaan, Liechtenstein), Shade A2. Two universal resin based composite materials was used as repair restorative material for all substrates including; OMNICHROMA (Tokuyama, Yamaguchi, Japan) and Charisma Diamond ONE (Kulzer Dental, Wehrheim, Germany). The list and chemical compositions of the materials used in this study are shown in Table 1.

2.2. Substrate specimen preparation

A total of 80 specimens were fabricated using the aforementioned two resin based composite materials. Stainless-steel molds were used to fabricate disc shaped specimens of 10 mm diameter and 2 mm thickness. The composites were condensed incrementally in the molds using a clean plastic instrument. A Mylar strip (Hawe Stopstrip Straight, Kerr-Hawe, Bioggio, Switzerland) covered final composite increment and a 1 mm thick glass cover plate was placed perpendicular to the long axis of the cylindrical molds. Each increment was cured for 20 s using a Bluephase N light curing unit (Ivoclar Vivadent, Schaan, Liechtenstein, Switzerland; light output: 1500 mW/cm^2) positioned directly over the glass plate. The light intensity was monitored via a dental Bluephase radiometer (Ivoclar Vivadent, Schaan, Liechtenstein, Switzerland).

All specimens were stored in 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° and 55 °C with a dwell time of 15 s and transfer time of 10 s.

2.3. Surface treatments

For each aforementioned material groups, specimens were randomly assigned into two subgroups based on the surface treatment as shown in Fig. 1.

2.3.1. Group I: silicon carbide grinding followed by phosphoric acid etching (SiCr)

The specimens were ground using wet 240-, followed by 400-, and then 600-grit silicon carbide papers (Buehler, Lake Bluff, Illinois, USA) that was mounted in Automata Machine (Jeanwirtz, GMBH, West Germany) and a stop watch was utilized for 30s duration timing. Then specimens were rinsed for 10 s using a stream of oil-free compressed air/water from a syringe tip. Then an air syringe was used for 5 s to remove excess surface water.

Phosphoric acid gel N-Etch 37% (Ivoclar Vivadent, Schaan, Liechtenstein) was applied on the surface of resin composite specimens

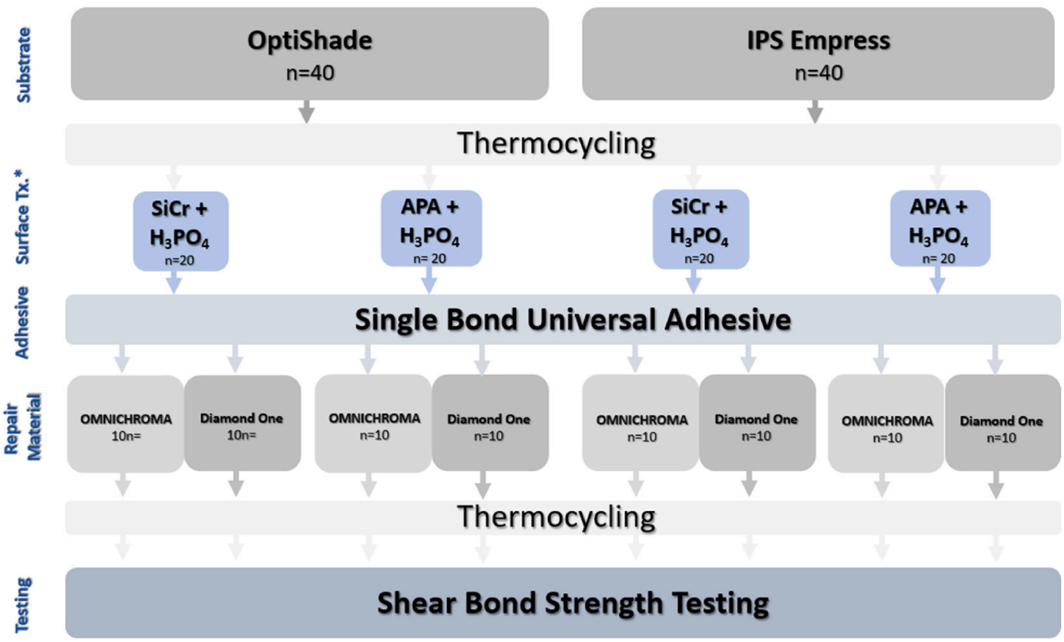

Fig. 1. Schematic representation of the study design. Substrate surface treatment include; SiCr: Silicon Carbide, APA: Air particles abrasion, H3PO4: Phosphoric acid etching. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

for 20 s. After that 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.

2.3.2. Group II: air particle abrasion followed by phosphoric acid etching (APA)

Composite specimens were air-abraded using an air spray of 50-μm aluminum oxide particles (Microetcher II, Danville Engineering; San Ramon, CA, USA) for 10 s from a distance of approximately 10 mm perpendicular to the specimen surface at a pressure of 60 psi. Then, specimens were rinsed for 10 s using a stream of oil-free compressed air/water from a syringe tip. Air syringe was used for 5 s to remove excess surface water. Similar to group I N-Etch 37% phosphoric acid gel (Ivoclar Vivadent, Schaan, Liechtenstein) was applied on the surface of resin composite specimens. And specimens were cleaned and air-dried similarly.

2.4. Adhesive and repair composite application

Single Bond Universal Adhesive (3 M ESPE, Neuss, Germany) was applied to all previously treated composite surfaces using disposable applicator. The adhesive was rubbed on the surface for 20 s then gently air dried for approximately 5 s until no movement is seen and the solvent evaporated completely. At that point, light curing was performed for 20 s using a Bluephase N light curing unit (Ivoclar Vivadent, Schaan, Liechtenstein, Switzerland) positioned 1 mm away from the surface.

Half of the specimens of each group received Omnichromatic resin composite (Omnichroma, Tokuyama, Yamaguchi, Japan) as a repair material. While the other half was repaired using Charisma Diamond ONE resin composite (Charisma Diamond ONE, Kulzer Dental, Wehrheim, Germany). Repair composites was condensed on top of the cured adhesive layer utilizing a clean plastic instrument and customized silicon mold to produce composite cylinder (measuring 2 mm in thickness and 5 mm in diameter). Lastly, light curing was performed for 20 s using Bluephase N light curing unit (Ivoclar Vivadent, Schaan, Liechtenstein, Switzerland) positioned 1 mm away from the surface. Specimens were cautiously taken out of the molds and checked for defects; defective specimens were excluded.

All specimens were stored in distilled water incubator at 37 °C for 1 week during which they were subjected to 10,000 cycles of thermal aging in thermocycling apparatus (Thermocycler 1100/1200, SD Mechatronik) between 5° and 55 °C with a dwell time of 15 s and transfer time of 10 s.

2.5. Shear bond strength testing

All specimens were shear tested using the Instron Universal Testing Machine (Instron 8500, Instron Corp, Norwood, MA, USA) at a cross-head speed of 0.5 mm/min. To fit the specimens to the mounting jig of the Instron machine, the substrate part of composite specimens were fixed in a plastic ring 2.5 cm in diameter by means of Orthoresin (DeguDent GmbH, Hanau, Germany). The peak force at which specimen failure occurred was recorded in megapascals (MPa).

For failure analysis, an optical microscope at 50 × magnification was used to examine all fractured composite specimens by each examiner independently. Furthermore, each examiner reanalyzes the specimens at least one week apart to confirm the 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). Selective specimens were examined using scanning electron microscope (SEM) (JSM, 6360LV, JEOL, Tokyo, Japan) and photomicrographs were taken at magnification of 20 × to 25 × .

2.6. Statistical analysis

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

3. Result

The mean SBS and standard deviation (SD) of maximum load (N) and shear bond strength (MPa) for all study groups are presented

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

Study Groups	Abbreviation	Substrate	Surface treatment	Repairing material	Maximum load (N)	Shear bond strength (MPa)
G1	**Op-SC-Om**	OptiShade	SiCr	Omnichroma	154.06 ± (9.22)	21.79 ± (1.30)
G2	**Op-APA-Om**	OptiShade	APA		174.60 ± (17.10)	24.70 ± (2.42)
G3	**Em-SC-Om**	IPS Empress Direct	SiCr		160.62 ± (10.11)	22.72 ± (1.43)
G4	**Em-APA-Om**	IPS Empress Direct	APA		182.39 ± (21.07)	25.80 ± (2.98)
G5	**Op-SC-DO**	OptiShade	SiCr	Charisma Diamond ONE	96.42 ± (16.14)	13.64 ± (2.28)
G6	**Op-APA-DO**	OptiShade	APA		272.62 ± (17.29)	38.57 ± (2.44)
G7	**Em-SC-DO**	IPS Empress Direct	SiCr		115.66 ± (16.87)	16.36 ± (2.38)
G8	**Em-APA-DO**	IPS Empress Direct	APA		202.24 ± (28.61)	28.61 ± (3.81)

in Table 2. The highest value of mean shear bond strength was associated with OptiShade substrates repaired by Charisma Diamond ONE after APA surface treatment (Op-APA-DO/G6) with a mean shear bond strength of 38.6 ± 2.4. Meanwhile, the lowest value was recorded for the OptiShade group repaired by Charisma Diamond ONE after SiCr surface treatment (Op–SC–DO/G5) with a mean shear bond strength of 13.6 ± 2.3. The comparison of maximum load and shear bond strength (SBS) using multivariate ANOVA (considering the combination of the two types of substrates, surface treatments and repairing materials seen in Table 2) showed a highly statistically significant difference in the mean values among the eight study groups with these three variables ($F = 93.714$, $p < 0.0001$).

Regarding the surface treatment, the post hoc test showed that for SiCr surface treated groups, OMNICHROMA had significantly higher mean values compared to Charisma Diamond ONE regardless of the substrate. Where the mean values of Op–SC–Om [G1; 21.79 ± (1.30)] are significantly higher than those of Op–SC–DO [G5; 13.64 ± (2.28)] p-value = 0.0001. In addition, those of Em–SC–Om groups [G3; 22.72 ± (1.43)] are significantly higher than Em–SC–DO groups [G7; 16.36 ± (2.38)] ($p < 0.0001$). However, the data revealed that among groups of the same repairing material, no statistical differences between the mean values of Op–SC–Om and Em–SC–Om groups [G1; 21.79 ± (1.30) and G3; 22.72 ± (1.43)] and between the mean values of Op–SC–DO and Em–SC–DO groups [G5; 13.64 ± (2.28) and G7; 16.36 ± (2.38)].

On the other side for APA treated groups, the post hoc test showed that the mean value of Op-APA-DO group [38.57 ± (2.44)] are significantly higher than those of the other tested groups ($p < 0.0001$). While, the mean values of Em-APA-DO group [28.61 ± (3.81)] was significantly higher than those of Op-APA-Om group ($p < 0.0001$) but, not significantly different compared to the mean values of Em-APA-Om group. Meanwhile, the mean values of the two Omnichroma repaired groups are not significantly different regardless of the substrate (Em-APA-Om group [G4; 25.80 ± (2.98)] Op-APA-Om group [G2; 24.70 ± (2.42)]).

Furthermore, the two groups of each variable were compared independently as shown in Table 3. The post hoc test indicated that the mean values of APA surface treated groups were significantly higher than the mean values of groups of SiCr surface treatment ($p < 0.0001$). While, comparison of the mean values between two substrate types (Optishade and IPS Empress direct) showed no statistically significant difference among groups. Also, the comparison between two types of repairing materials (Omnichroma and Charisma Diamond ONE) showed no statistically significant difference.

Intraclass correlation coefficient proved excellent intra- and inter-examiner reliability of 1.0 and 0.9 respectively. The distribution of failure modes is represented in Fig. 2 as a percentage of specimens for each study group. The failure analysis revealed that cohesive mode of failure was the most predominant in both substrate and repair. Where, the main mode of failure for most groups was cohesive failure in the substrates, followed by cohesive failure in the repairing materials being the main mode of failure in Op-APA-Om and Op–SC–DO groups (G2 and G5). Adhesive mode of failure was reported exclusively in Op–SC–Om and Em–SC–DO groups (G1 and G7) and being the main mode of failure for G1 only ($n = 5$). Meanwhile, mixed failure mode recorded for all groups excluding Op–SC–Om and Em-APA-DO groups (G1 and G8). A representative specimen for each mode of failure were analyzed using SEM as presented in Fig. 3(A-D).

4. Discussion

This study compared repair bond strength of OMNICHROMA and Charisma Diamond ONE resin composites bonded to variable composite substrates. And evaluated the influence of different surface treatments. The results of the current study revealed that there was no significant difference in the repair bond strength of OMNICHROMA and Charisma Diamond ONE resin composites when bonded to variable composite substrates. However, the surface treated groups using APA showed significantly higher mean values than groups treated using SiCr. Hence, the first null hypothesis was accepted while the second cannot be accepted.

Shear bond testing method was used to compare repair bond strength among study groups, since it is one of the most commonly used testing methods that is known for being reliable and easy [18]. In-vitro shear loading was described to be clinically relevant due to varied stresses production (compressive, tensile in addition to shear) hence better representing masticatory loads [19]. Moreover, the tested specimens were aged by thermal cycling to represent the clinical sittings. The adhesion of repairing composite layer might be

Table 3
Comparison of the mean values between two types of each variable.

Outcome Variable	Type of Substrate		Mean Difference	t-value	*P*-value
	Optishade	IPS Empress Direct			
Maximum load	174.42 (65.99)	165.23 (37.70)	9.19	0.765	0.447
Shear bond strength	24.67 (9.33)	23.37 (5.33)	1.30	0.765	0.447
Outcome Variable	Type of Surface treatment		Mean Difference	t-value	p-value
	Silicon Carbide	Air Particle Abrasion			
Maximum load	131.69 (29.95)	207.96 (44.04)	−76.27	−9.06	<0.0001
Sheer bond strength	18.63 (4.24)	29.42 (6.23)	−10.79	−9.06	<0.0001
Outcome Variable	Type of repairing material		Mean Difference	t-value	*P*-value
	OMNICHROMA	Charisma Diamond ONE			
Maximum load	167.92 (18.47)	171.74 (73.97)	−3.82	−0.32	0.752
Shear bond strength	23.75 (2.61)	24.29 (10.46)	−0.54	−0.32	0.752

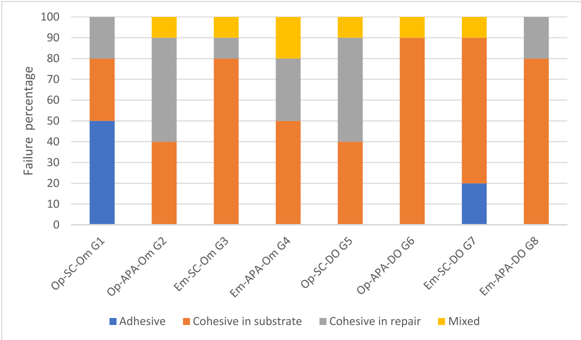

Fig. 2. Diagrammatic representation of the failure modes for all the tested specimens.

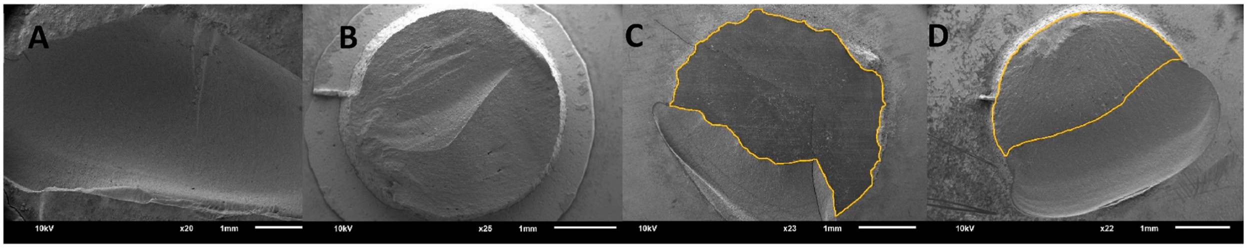

Fig. 3. Micrographs of the representative specimens for each mode of failure; cohesive in substrate(A), cohesive in repair(B), adhesive(C), and mixed(D) using scanning electron microscope (SEM) at a magnification of 20 × to 25 × .

significantly impacted by temperature fluctuations. And recurrent expansion-contraction stresses that occurred in substrate composite materials in addition to changes in the material's properties [18].

Repair methodology is inconsistent in published literature, however most studies agreed on the necessity of surface pretreatment and some recommend certain adhesive applications with or without silane. Cavalcanti et al. demonstrated that air abrasion using aluminum oxide in association with application of self-etching adhesive system is the only technique capable to provide repair bond strength similar to the cohesive composite strength [20].

The present study showed significantly higher bond strength values for groups that surface treated by APA. In accordance with this finding, KUŞDEMIR et al. reported an enhanced repair bond strength when substrate surface physically conditioned by air abrasion with Al_2O_3 particles [21]. Similarly, several studies demonstrated that air abrasion is more effective compared to surface roughening as surface pre-treatment [15,22–24]. Air abrasion has been proven to produce composite surfaces that are more micro-retentive than those produced by diamond burs, hence associated with higher bond strengths [23–25]. Although abrasion can be obtained either by silica coating or aluminum oxide, the Al_2O_3 is preferred and more commonly used to improve the repair bond strength [24,26]. Moreover, the utilized 50 μm particle size in addition to the 10 s of abrasion are similar to other repair testing studies [15,23,24,26]. However, Dieckmann et al. compared surface pre-treatments using aluminium oxide and bur abrasion for a nanohybrid composite repair. They reported that both mechanical surface treatments appear to be equally effective for both aged and freshly repaired RBC restorations. Moreover, they showed a significantly low mean bond strength values of 1.1 MPa, for specimens with no surface roughening [27].

Compatibility between defective restoration (substrate) and repair restorative materials is among other factors that have been reported to influence the repair bond strength [14]. Özcan et al. showed that composite repair using dissimilar substrate and repairing materials did not reduce the repair bond strength. This finding is clinically relevant when the underlying substrate composite is unknown [28]. Similarly, the present study showed no significant difference in the repair bond strength values among the substrate and repair materials when both evaluated independently. Nevertheless, Yu et al. concluded that an improved repair bond strength might be produced when an identical types of aged and freshly added resin composites are used, however employing the same resin composite to repair the aged resin is not mandatory [29]. In accordance with their findings, a systematic review and meta-analysis by Al Rabiah et al. highlighted the impact of RBC compatibility on repair. Their included studies presented that best outcomes were obtained when similar substrate and repair materials were used [30].

In many clinical settings, the brand and/or type of the defective restorative material cannot be identified [31]. Although numerous resin composites are indicated for use as a restorative repair material, the recently marketed universal shade-less composites can be considered as a practical option since no shade matching step is required. However, there is no published data tested these composites as repairing materials to compare the results. From the analyses it can be inferred that, the values of maximum load and shear bond strength changed with the effect of type of surface treatment in combination with type of substrate and repairing materials.

The failure analyses in the present study showed that cohesive failure was the predominant failure mode in the majority of tested specimens. This mode of failure represents the high bond strength values, which indicate that the strength of adhesive interface is higher than the cohesive strengths of the tested resin composites. Furthermore, if the repair failed cohesively in the composite substrates, it could be assumed that the tested repair protocol is suitable to withstand occlusal loads [32]. In agreement with these results of Burrer et al. that revealed mostly cohesive failure of their experimental nanohybrid composite specimens [33]. Also, this could be due to the applied shear testing method which has been criticized for higher tendency to produce cohesive mode of failure [34]. However, Burrer et al. applied a micro-tensile testing method and had similar mode of failure [33]. While cohesive failure in the repairing material was mostly recorded for Omnichroma repaired groups. This could be attributed to the lower mechanical properties of the Omnichroma compared to Charisma Diamond ONE which has been reported in a recent study by Ilie. Where he showed that Omnichroma has the lowest mechanical properties compared to other tested universal chromatic RBCs [35]. The enhanced mechanical strength of Charisma Diamond ONE, according to their manufacturer, is due to higher degree of conversion and increased crosslinked reactivity. Comparison with results of other studies is not possible due to variations in the methodological designs and utilized testing method. Moreover, adhesive mode of failure was recorded for groups were the substrate treated by SiCr. This represents their lower shear bond strength (exclusively Op–SC–Om and Em–SC–DO groups [G1: 21.79 $\pm$ (1.30)and G7: 16.36 $\pm$ (2.38)]) which could be attributed to the absence of surface irregularities leading to lower micromechanical retention possibility.

The limitations of the present study include; the use of one type of intermediate agents (universal adhesive) for all experimental specimens. Another limitation is that Optishade, Omnichroma, and Charisma Diamond ONE resin composites are recently introduced hence imitated published research are available for comparison. And the use of nanohybrid types of composites only hence future research to compare variable composite formulations are suggested. Additionally, the use of one aging modality and static testing method is not fully representative of the clinical settings. Therefore, future research using variable aging modalities and/or fatigue testing are advised. Further research is required to evaluate other repair methodologies for shade-less RBC and the shade matching capabilities in repairing variable shades and types of composite substrates.

5. Conclusions

Within the limitations of the present study, the repair bond strength of OMNICHROMA and Charisma Diamond ONE resin composites are comparable to each other and depends on the applied surface treatment. Where, Omnichroma showed higher bond strength values with SiCr surface treatment. Meanwhile, Charisma Diamond ONE had better bond strength with APA. Hence, both tested restorative materials could be used for repairing defective composite restorations, especially when the shade and/or material of the defective restoration is unknown. Air abrasion surface treatment using Al_2O_3 particles of 50 μm are recommended to enhance repair bond strength.

Authorship contribution statement

AlFulwah AlOtaibi and Prof. Nadia Taher: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Data availability

All data used to support the findings of this study will be included in the submitted documents, any additional data are available from the corresponding author upon request.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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