Original Article / Özgün Araştırma

The Effect of Different Adhesive Resins, Composite Resins and Thermal Cycling on the Repair Bond Strength of Bulkfill Composite Resin

Bulkfill Kompozitlerin Tamir Bağlanma Dayanımı Üzerine Farklı Adeziv Rezinlerin, Kompozit Rezinlerin ve Termal Siklusun Etkisi

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Abstract

Objective: This study evaluated the influence of different adhesives, composites and thermal cycling on the repair bond strength of bulkfill composite.

Materials and Methods: A total of 54 bulkfill composite resin disks were obtained. The samples were stored in distilled water for 14 days and then the sample's surfaces were air-abraded with Al_2O_3 particles, etched with phosphoric acid, washed and dried. An adhesive was applied to the samples after the silane application. The samples were randomly divided into three main groups according to the type of adhesive resin used (a self-cured universal adhesive, a total-etch adhesive and a self-etch adhesive). After the adhesive application, four composite resin cylinders were placed on the sample surface using three different repair composites (bulkfill composite, microhybrid composite and nanohybrid composite). A total of 5000 thermal cycles were applied to half of the samples (n=12). A microshear bond strength test was performed using a universal tester. The data obtained were analyzed using Mann-Whitney U and Kruskal-Wallis tests.

Results: Of the repair composites, bulkfill composite tended to show the highest bond strength. There was no significant difference between the microhybrid and the nanohybrid composite groups ($p>0.05$). Generally, the adhesives did not significantly affect the repair bond strength.

Conclusion: The use of bulkfill composite to repair bulkfill composite provides more efficient repair bond strength. The tested adhesives can be used safely to repair bulkfill composite. The repair bond strength was not negatively affected after 5000 thermal cycles.

Keywords
Bulkfill composite, composite repair, microshear bond strength, self-cured adhesive

Anahtar Kelimeler
Bulkfill kompozit, kompozit tamir, mikroshear bağlanma dayanımı, adezivler

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Öz

Amaç: Bu çalışmada bulkfill kompozit rezinlerin tamiri üzerine farklı adezivlerin, kompozitlerin ve termal siklusun etkisinin değerlendirilmesi amaçlanmıştır.

Gereç ve Yöntemler: Bu çalışmada 54 adet bulkfill kompozit rezin disk hazırlanmıştır. Örnekler 14 gün boyunca 37 °C'de distüle suda tutulmuştur ve daha sonra örnek yüzeyleri Al_2O_3 partikülleri ile 10 sn kumlanmıştır, ardından fosforik asit ile dağlanmış, yıkanmış ve kurutulmuştur. Silan uygulamasından sonra numunelerin yüzeylerine adeziv rezin uygulanmıştır. Örnekler, kullanılacak adezive göre rastgele 3 ana gruba ayrılmıştır (bir self-cure üniversal adeziv, bir total-etch adeziv ve bir self-etch adeziv). Adeziv uygulaması sonrası, numune yüzeyine üç farklı tamir kompoziti (bulkfill kompozit, mikro hibrit kompozit ve nanohibrit kompozit) kullanılarak dörder adet kompozit silindir yerleştirilmiştir. Örneklerin yarısı 5000 termal döngüye tabi tutulmuştur (n=12). Mikromakaslama bağlanma dayanımı testi, evrensel bir test makinesi kullanılarak gerçekleştirilmiştir. Veriler Mann-Whitney U ve Kruskal-Wallis testleri kullanılarak istatistiksel olarak analiz edilmiştir.

Bulgular: Tamir için kullanılan kompozit rezinler arasında bulkfill kompozit rezinler daha yüksek bağlanma dayanım değerlerine sahipti. Mikrohibrit ve nanohibrit kompozit grupları arasında anlamlı bir fark yoktu (p>0,05). Genel olarak, adeziv rezinler bağlanma dayanımını istatistiksel olarak anlamlı derecede etkilemedi.

Sonuç: Bulkfill kompozit rezinlerin tamirinde bulkfill kompozit rezin kullanımı daha verimli tamir bağlanma dayanımı sağlar. Test edilen adezivler, bulkfill kompozit rezinleri tamir etmek için güvenle kullanılabilir. Beş bin termal siklus tamir bağlanma dayanımını olumsuz etkilemedi.

Introduction

Composite resins (CR) are commonly used restorative materials in dental applications due to advantages such as aesthetic and adhesive characteristics of them, and they permit the use of a minimal invasive approach in restorative dentistry by preserving sound tooth structure (1). However, some problems such as microleakage, discoloration, wear, chipping or fracture of the restoration may occur depending on the degredation of the CR caused by various conditions such as pH and temperature changes in the oral environment, diet, and other factors (2,3). If the defects are minor, repairing of the restoration is a more appropriate approach because it is a protective, fast and simple approach.

The success of the repair of CR restorations depends on some factors, including the characteristics of the surface, the wettability of the adhesive resins, and the chemical compound of the CR (4). A durable adhesion between the aged restoration and the repair CR is essential for a successful repair procedure. In fact, adhesion to aged CR restorations can be quite challenging because of water absorption over time, and the reduction in the number of accessible C=C bonds that will react with the new CR (5).

Hybrid and especially microhybrid CRs can be used in both front and back teeth by successfully combining mechanical with aesthetic properties. Nanohybrid CRs offer advantages such as durability, low polymerization shrinkage, good polishability, ease of use, and superior aesthetic (6,7). In recent years, bulkfill CR that can be placed into a cavity with greater increments have been marketed. This class of CR helps to eliminate features such as marginal fractures associated with polymerization stress, and they have a high fluidity and can easily penetrate in hard to access cavities (8). The interaction between these different CR should be well known in order to select the most appropriate repair technics.

The role of adhesive resin is to improve the wettability of the surfaces which have been mechanically treated and silanized (9). Universal adhesives (UA) were designed to be used in both direct and indirect restorative applications, including bonding to different substrates such as CRs, dental ceramics and alloys, and they could be used in all three application modes (etch-and-rinse, self-etch or selective-etch modes) (10). These adhesives would allow bonding to various surfaces without a priming agent such as silanes, or other surface primers which are dedicated and have to be separately placed. Recently, manufacturers have introduced different types of UA. The UA used in our study is a self-cured adhesive system in two-component form and it has been developed in order to be fully compatible with CRs in all three curing modes (light-cured, self-cured and dual-cured). Moreover, the manufacturer claims that it improves the adhesion of polymerizable resin materials to indirect restorative materials. However, to the best of our knowledge, there has been no study on the effect of self-cured adhesives on the repair bond strength (RBS) of bulkfill CRs.

Although there are many studies related to the repair of CRs in the literature, there is no consensus on which materials (adhesive resins and CR) are most appropriate for a successful repair process. Therefore, the present study aimed to investigate the early and late RBS of a bulkfill CR using different CR and different dental adhesive, using microshear bond strength test method. The hypotheses tested are as follows: 1) There is no difference in the RBSs of the tested CRs. 2) There is no difference in RBS with regard to the tested dental adhesives. 3) There is no difference between the RBS of the tested materials, with and without thermal cycling.

Materials and Methods

Preparation of the Samples

The materials used in this study, their compositions and batch numbers have been given in Table 1. In this study, fifty four composite discs (8 mm x 2 mm) were obtained using a bulkfill CR (Filtek Bulk Fill Posterior, 3M ESPE, MN, USA). The CR were packed into the teflon mold between two glass plates as bulk and polymerized for 20 s with an LED device (VALO Cordless; Ultradent Products, UT, USA, 1000 mW/cm^2). Thereafter, the samples were embedded in autopolymerized acrylic resin by using PVC rings with their surface exposed. The surfaces of the samples were ground respectively with 400-grit and 600-grit sanding paper under water cooling and stored in distilled water at 37 °C for 14 days (6). The surfaces of the samples were air abraded for 10 s with aluminum oxide (Al_2O_3) particles (50-µm) 10 mm from the sample surface under a pressure of 4 bar and then they were etched with phosphoric acid for 30 s, washed for 60 s, and finally dried for 60 s. A silane agent (Ultradent Silane, Ultradent, South Jordan, USA) was applied and 60 s was waited and the samples treated mechanically and chemically were then randomly divided into 3 main groups, each containing eighteen CR discs according to the dental adhesive applied (7):

Group 1: Tokuyama Universal Bond (Tokuyama Dental, Vicenza, Italy; TU; a self-cured universal adhesive resin), Group 2: Clearfil S3 Bond (Kuraray, Noritake, Japan; CS3; a self-etch adhesive resin), Group 3: Adper Single Bond 2 (3M ESPE, MN, USA; SB2; a total-etch adhesive resin).

The samples in each adhesive group were then deployed into three subgroups, each with six composite resin discs according to the repair composite used:

Group a: Filtek Bulkfill (FBF) Posterior (3M ESPE, MN, USA; FB; a bulkfill CR), Group b: Charisma Smart Composite (Heraeus Kulzer GmbH, Hanau, Germany; CSC; a microhybrid CR), Group c: Filtek Z550 (3M ESPE, MN, USA; FZ; a nanohybrid CR)

TU was prepared by mixing the double component in equal amounts and then applied to the sample surface. Mild air was then applied until the solvent evaporated and any curing was not applied. TU was used in self-cure mode. CS3 and SB2 were applied to the the sample surface for 10 s, and a uniform adhesive film was made using a mild air flow before being polymerized for 10 s with LED.

Table 1. Materials, compositions and batch numbers

Materials	Compositions
Tokuyama Universal Bond Tokuyama Dental, Vicenza, Italy Batch 004	A) Phosphoric acid monomer (3D-SR), Bisphenol A di(2-hydroxy propoxy) dimethacrylate (Bis-GMA), Triethylene glycol dimethacrylate (TEGDMA), 2-Hydroxyethyl methacrylate (HEMA), MTU-6 (thiouracil monomer), Acetone B) γ-MPTES, Borate, Peroxide, Acetone, Isopropyl alcohol, Water
Clearfil S3 Bond Kuraray, Noritake, Japan Batch 6M0075	Bis-GMA, Sodium fluoride, 10 MDP, Colloidal silica, dl-Camphorquinone, Accelerators, Initiators, Hydrophilic aliphatic dimethacrylate, Hydrophobic aliphatic methacrylate, ethanol, and water
Adper Single Bond 2 3M ESPE, St Paul, MN, USA Batch N878242	Dimethacrylates, BisGMA, HEMA, a novel photoinitiator system, a methacrylate functional copolymer of polyacrylic and polyitaconic acids, ethanol, and water
Filtek Bulkfill Posterior 3M ESPE, St Paul, MN, USA Batch N853695	Urethane dimethacrylate (UDMA), Aromatic dimethacrylate (AUDMA), and 1,12-dodecane dimethacrylate, zirconia/silica and ytterbium trifluoride filler.
Charisma Smart Composite Heraeus Kulzer GmbH, Hanau, Germany Batch K010509	Barium Aluminum Fluoride glass, Bis-GMA, silicon dioxide
Filtek Z550 3M ESPE, St Paul, MN, USA Batch N887521	Bis-EMA, Bis-GMA, UDMA, TEGDMA, silica/zirconia (20 nm-3 µm, 81,8 vol%)
Ultradent Silane Ultradent, South Jordan, USA Batch BG3TD	MPS 5-15 wt %, pH 5,3 in Isopropanol

After the adhesive application, four CR cylinders were placed on the surface of each bulkfill CR disc using tygon tubes (1 mm x 1 mm) with repair composites. The CR used for repairing was polymerized with the same LED device for 20 s. The tygon tubes around the CR cylinders were carefully removed using a scalpel, and the samples were then kept in distilled water at 37 °C for 48 h. A total of 5000 thermal cycles (TC) (5-55 °C, a dwell time of 30 s) were performed to half of the samples in each group. The sample size was twelve in each group (n=12) (Figure 1). Figure 2 shows schematically how the samples were prepared.

Microshear Bond Strength Test

A microshear bond strength (μSBS) test was performed using a universal tester (Instron, Model 4444; Instron Corp., Canton, USA). A 0.25 mm thick

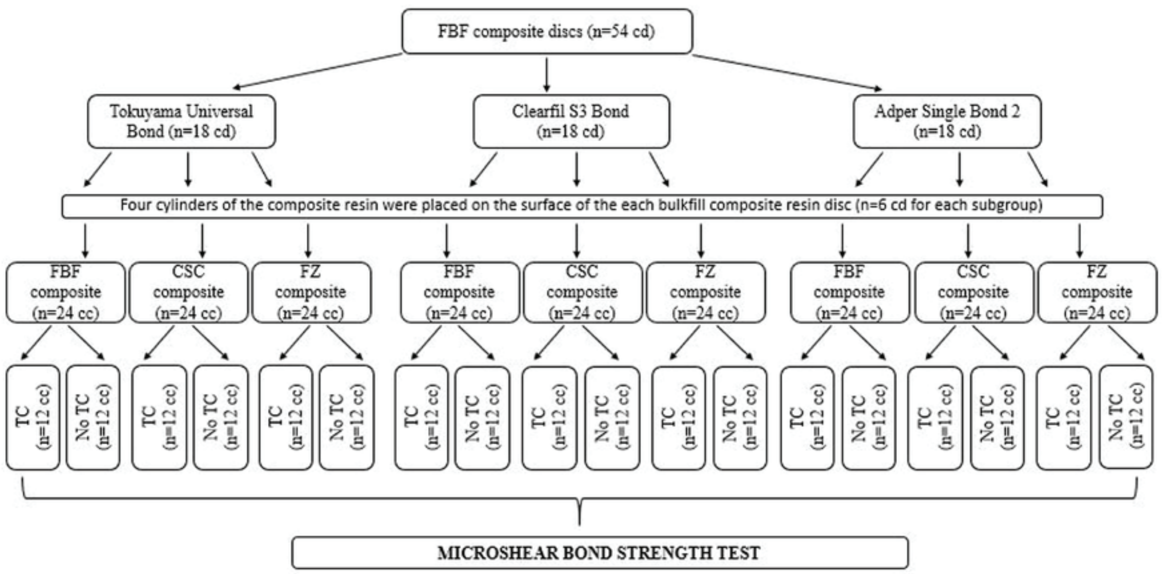

Figure 1. Study design and treatment groups

FBF: Filtek bulkfill, CSC: Charisma smart composite, FZ: Filtek Z55O, TC: Thermal cycling, cd: Composite discs, cc: Composite cylinders

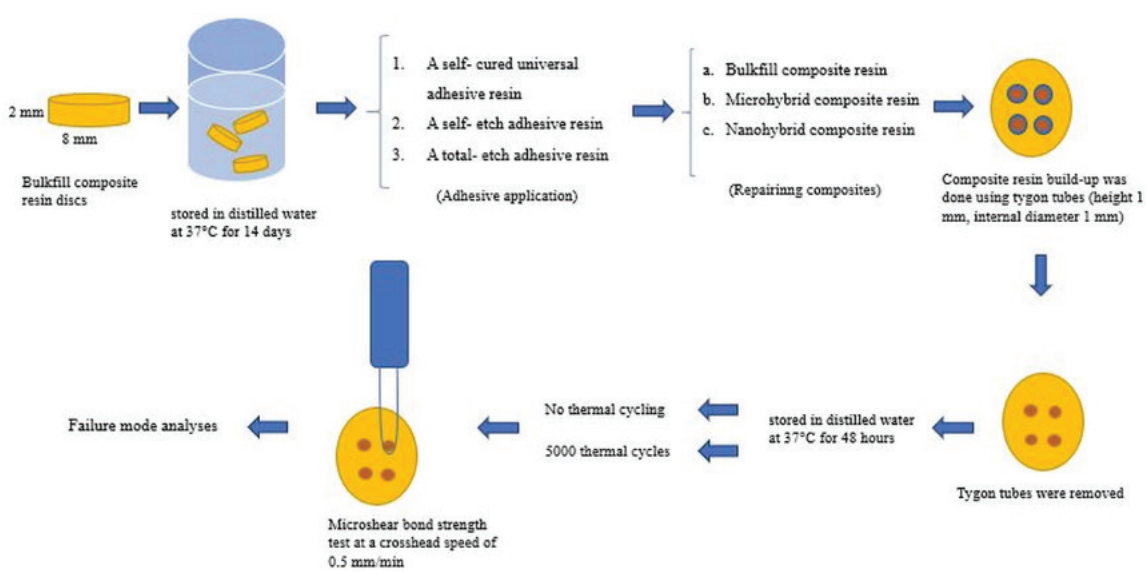

Figure 2. Shematic illustration of sample preparation and microshear bond strength test

wire loop which was placed around the CR cylinders contacting semicircularly were positioned at the bonding interface at a crosshead speed of 0.5 mm/min until failure occurred. µSBS test was applied to half of the samples without TC, while the other half of the samples were tested after the TC. The maximum force at failure was recorded in Newtons (N) and µSBS values were calculated as Megapascal (MPa) by dividing this force to the bonding area (mm^2).

The failure areas were analyzed under an operation microscope (Stemi 1000, Zeiss, Germany) at 50× magnification to determine the type of failure, which were classified as adhesive failure, cohesive failure or mixed failure (adhesive failure; fracture at the old CR-repair CR interface, cohesive failure; fracture in the old CR or repair CR, mixed failure; a combination of adhesive and cohesive failure).

Statistical Analysis

In this study, the SPSS 22 statistical package (IBM Inc, Chicago, IL, USA) were used for statistical tests. Descriptive statistics in the form of mean, standard deviation, median, frequency and ratio values were used with regard to the data. The distribution of variables was measured using the Kolmogorov

Table 2. The mean shear bond strength values (± SD), medians of the groups and statistically differences between the groups

Without TC	Tokuyama universal bond		Clearfil S3 bond		Single bond 2		p-value
	Mean ± SD	Median	Mean ± SD	Median	Mean ± SD	Median	
FBF	25.3±2.6	24.6	25.4±6.3	29.1^{X}	23±3.3*	22.7	0.21
CSC	20.3±5.2	19	19.3±6	19.6^{Y}	18.8±4.3	19	0.947
FZ	25.6±9.2	22.9	19.2±3.1	18.9^{Y}	20.7±6.4	19.8	0.249
p	0.064		0.035		0.073		
With TC	**Tokuyama Universal Bond**		**Clearfil S3 bond**		**Single bond 2**		**p-value**
	Mean ± SD	**Median**	**Mean ± SD**	**Median**	**Mean ± SD**	**Median**	
FBF	23.3±3.9	24.2^{A}	27.8±4.4	$27.8^{B,X}$	30.5±8.4*	$31.1^{B,X}$	0.013
CSC	22.1±7	21.6	24.8±8.3	$25.8^{X,Y}$	20.1±5.4	19.3^{Y}	0.353
FZ	25±7.2	26.8	19±3.2	18.6^{Y}	23.7±6.5	21.8^{Y}	0.06
p	0.345		0.003		0.01		

Different letters (X, Y) within columns indicate which groups have a statistically significant difference according to the type of composite resins (p<0.05). Different letters (A, B) within rows indicate which groups have a statistically significant difference according to the type of adhesive systems (p<0.05). Superscript "*" indicate the statistically difference between the groups with or without TC. SD: Standard deviation. TC: Thermal cycling, FBF: Filtek bulkfill, CSC: Charisma smart composite, FZ: Filtek Z55O

Table 3. Distribution of failure modes [n (%)]

Adhesive resins	Repair composite resins	Before TC			After TC		
		Adhesive	Cohesive	Mix	Adhesive	Cohesive	Mix
Tokuyama Universal bond	FBF	10 (83)	0 (0)	2 (17)	6 (50)	1(8)	5 (42)
	CSC	9 (75)	0 (0)	3 (25)	8 (67)	0 (0)	4 (33)
	FZ	9 (75)	0 (0)	3 (25)	8 (67)	0 (0)	4 (33)
Clearfil S3 bond	FBF	6 (50)	2 (17)	4 (33)	4 (33)	0 (0)	8 (67)
	CSC	5 (42)	2 (17)	5 (42)	6 (50)	0 (0)	6 (50)
	FZ	5 (42)	2 (17)	5 (42)	4 (33)	0 (0)	8 (67)
Single bond 2	FBF	12 (100)	0 (0)	0 (0)	10 (83)	0 (0)	2 (17)
	CSC	12 (100)	0 (0)	0 (0)	7 (58)	0 (0)	5 (42)
	FZ	12 (100)	0 (0)	0 (0)	8 (67)	0 (0)	4 (33)

FBF: Filtek bulkfill, CSC: Charisma smart composite, FZ: Filtek Z55O, TC: Thermal cycling

Simirnov test. Since the data distributions were not normal, non-parametric tests were used to determine the differences between the groups. Mann-Whitney U and Kruskal-Wallis tests were performed to detect any statistical differences between the variables, and to compare the groups.

Results

Table 2 gives the mean µSBS values of the samples. When the bond strengths of the groups without the TC were analyzed, no significant difference was found in terms of the adhesives used. Among the groups without TC, FBF showed higher µSBS when the repair composites were compared. Although FBF showed significantly higher µSBS than the other CR groups when used with CS3 ($p=0.035$), there was no statistically significant difference between the FZ repair composite group and the CSC repair composite group ($p>0.05$).

When the µSBSs of the groups with TC were examined, there was a statistically significant difference between the tested adhesives when FBF was used as the repair composite ($p<0.05$). However, there was no statistically significant difference between the adhesive resins which were used with other CR (FZ and CSC) ($p>0.05$). When TU was used as an adhesive, there was no significant difference between the CR ($p>0.05$). When CS3 was used as an adhesive, FBF showed the highest µSBS value. However, there was no statistically significant difference between the FBF and the CSC groups while there was a statistically significant difference between FBF and FZ groups ($p>0.05$). When SB2 was used as an adhesive, the FBF showed significantly higher µSBS than other CR groups ($p<0.05$). Furthermore, there was no significant difference between the FZ and the CSC groups ($p>0.05$).

When the RBS values of the groups before and after TC were compared, no statistically significant difference was observed except the SB2 + FBF group ($p=0.018$ for the SB2 + FBF group).

The fracture types of the samples are shown in Table 3. In our study, mostly the adhesive type failure was observed. This was followed by mixed and cohesive failures.

Discussion

Secondary caries, microleakage, discoloration, chipping and fracture are the most common reasons for failure of CR restorations. Recently, repairing of defective restorations has been recommended because repair has a limited risk of complications, and it reduces the loss of sound tooth structure when compared to total replacement. Furthermore, repair could decelerate the so-called restoration cycle, given that the replacement would lead to a greater scale of preparation (11).

Bulkfill CRs are very popular materials among clinicians as they offer ease of application, thereby eliminating time-consuming layering procedures. In literature, there is no study evaluating the effect of a silane containing self-cure adhesive in the repair of bulkfill composites. Therefore, in this study, the influences of thermal cycling, different CRs and adhesive resins on the RBS to a bulkfill CR were evaluated. The tested hypotheses, which suggest that there is no difference between the RBSs of different types of adhesives, and that thermal cycling does not influence the RBS of the bulkfill CR, were partially accepted. The null hypothesis which suggest that there is no difference between the RBSs of the tested CRs was rejected.

The use of convenient surface treatment methods, and the selection of the most suitable repair material and adhesive systems, are critical for successful repair. Different surface conditioning methods, including mechanical, chemical and physicochemical surface treatments, have been proposed in order to achieve a durable bonding between old and new CRs (12). Air abrasion with aluminum oxide is one of the most frequently-used mechanical roughening methods. In previous studies, it was found that air abrasion with Al_2O_3 (50-µm) significantly improved the RBS (9,13). In addition, the use of a silane agent during the repair of CR increases the wettability of the repair surface, and promotes chemical bonding by forming siloxane bonds between the silica-containing filler particles exposed on the surface to be repaired, and the resin matrix of the new resin layer (9,14). Due to the positive contributions mentioned above, the surfaces of the substrates were roughened with Al_2O_3 and a silane agent was applied in this study.

The adhesive system is another important factor in terms of improving the RBS between old and new CRs. The adhesive resins used in this study are in different generations, and contain different functional monomers and solvents. The SB2 is an etch-and-rinse adhesive which is water-ethanol disperse, contains both hydrophilic and hydrophobic resin monomers. When applied to a surface, monomer molecules orientate per the nature of the hydrophobic or hydrophilic surface, providing a good contact with the surface. The nature of SB2 creates a potential for adhesion on surfaces with different wetting properties (15). The CS3 is a self-etch adhesive which comprises 10-MDP (10-Methacryloyloxydecyl dihydrogen phosphate) and ethanol. 10-MDP, which is a functional monomer, can bond chemically to Ca^{+2} and make the bonding interface more resistant to degradation (16). The TU is a self-cured universal adhesive which contains an acidic three-dimensional self-reinforcing monomer (3D-SR), silane coupling agent (γ-MPTES), and acetone. The adhesive systems used in this study did not significantly affect the RBS of the tested groups. This may be due to the fact that they all contain different monomers all of which contribute to bond strength. Similarly, a previous study evaluated the influence of different adhesive systems (a self-etch adhesive, an etch-and-rinse adhesive and a universal adhesive) on the µSBS of repaired bulkfill CRs and it was found that the adhesive systems used did not significantly affect the RBS of the tested groups, and is therefore in consistent with the results of our study (17). Moreover, adhesive bonding to enamel is thought as the gold standard of bond strength between aged and fresh CRs (7). In literature, it was reported that a RBS between 15 and 30 MPa would be clinically acceptable, similar to CR to enamel bond strength (17). In the present study, the RBS values of all tested adhesive resins were within the acceptable range.

Bulkfill CRs have become increasingly popular among dental practitioners since they minimize some of the disadvantages of incremental layering, and decrease the application time (12). However, in the literature, there are a limited number of studies about the repair of aged bulkfill CRs with different types of CRs. In this *in vitro* study, this issue is also investigated, and the groups repaired with bulkfill CR showed higher µSBS than did the other CR groups. Our findings are in agreement with previous studies, indicating that the use of the same CR is more appropriate when it comes repairing CR (12,17,18). Moreover, Cuevas-Suárez et al. (19) investigated the effect of different surface treatments on the bond strength of bulkfill CRs repaired with bulkfill or conventional nanoparticle composites. They reported that using the same bulkfill CR in the repair process could improve the effectiveness of the procedure (19). In contrast to findings of our study, in a study investigating the ability of posterior CR to repair aged bulkfill CR, the authors reported that the resin composite repair type did not affect the bond strength, and that the aged bulkfill CR could be effectively repaired with posterior CR (20). In addition, they emphasized the importance of the use of proper repair protocol, by specifying that the combined use of 10% hydrofluoric acid (HF) etching and adhesive resin would provide efficient RBS when the aged bulkfill CR is to be repaired using conventional CR. This discrepancy between the studies can be explained by the different surface treatment strategies, and the different materials used. Intraoral use of HF may be inconvenient because HF contamination to the skin or mucosa may cause necrosis in the deeper layers of the tissue (21). In addition, a calcium fluoride (CaF_2) precipitate is formed when HF is in direct contact with dentin and enamel. This precipitate prevents the adhesive resin infiltration into dentin tubules and the adhesion of CR is adversely affected (22). Moreover, the effectiveness of HF used for composite repair has been shown to be related to some properties of the inorganic filler such as the percentage, size, and type (23). Therefore, the use of HF as a routine procedure for composite repair is not recommended, especially if the composition of the old CR is not exactly known (24).

Aging has a key role in evaluating the RBS of CRs. Thermocycling is one of the commonly used aging methods in *in vitro* studies and simulates the stress created by changing the environmental temperature at the interface between materials (25). In the present study, 5000 TCs were performed between 5 and 55 °C with a dwell time of 30 s and it was found that the composite RBS was not negatively affected. Our findings are consistent with the results of a previous study which reported the RBS of CR was not affected by the aging conditions (5000 TCs) (25). On the other hand, in the literature, there are studies that 5000 TCs significantly decrease the RBS of CR (3,4). Şişmanoğlu et al. (26) evaluated the influence of different universal adhesive resins and surface treatment methods on the RBS of bulkfill CRs, with and without TCs. They found that 5000 TCs significantly reduced the RBS with the exception of two adhesive group. They attributed this to the fact that these adhesives contained 10-MDP. In our study, 5000 TCs did not decrease the RBS in any groups, regardless of whether it contains 10-MDP. The difference between our results and those of these studies may be due to additional silane application, different ingredients and different chemical properties of the tested materials, and different testing conditions. However, it is estimated that 10000 TCs correspond to approximately one-year clinical functioning, when considering that thermocycling may occur 20-50 times a day (27). In this study, the samples were subjected to 5000 TCs which mimics a relatively short term of clinical function (approximately six-months). For this reason, thermal cycling may not adversely affect the RBS and it might be useful to perform additional studies with a larger number of cycles.

In the present study, a µSBS test method was preferred because it is considered an effective method for verifying the bond strength of materials, and it is a good representation of the forces clinically experienced by a restoration. Furthermore, the µSBS test has some advantages, including less rigorous sample preparation, and easier control of the bonding test area by means of tygon tubes (28).

This study was conducted in an *in vitro* environment without considering various factors such as saliva, dietary variables, and occlusal forces, and only CR samples were tested. In addition, the low number of TC is another limitation of our study. Therefore, further studies designed in *in vivo* and *in vitro* conditions are needed to confirm the results of this in vitro study.

Conclusion

Within the limitations of this study, it can be concluded that:

1. The use of bulkfill composite resin for repairing bulkfill composite resin would provide a more efficient RBS.

2. 5000 TCs (5 to 55 °C) did not negatively affect the composite repair bond strength.

3. All the tested adhesive systems can be used safely to repair bulkfill CRs.

However, additional studies with regard to bulkfill CR and self-cured adhesives should be performed.

Ethics

Ethics Committee Approval: In this study, ethics committee approval is not required because any material or tissue of human or animal is not used.

Informed Consent: This study does not require patient consent.

Peer-review: Externally and internally peer-reviewed.

Authorship Contributions

Surgical and Medical Practices: S.A., H.B., B.A., A.D., Concept: S.A., H.B., Design: S.A., Data Collection or Processing: S.A., H.B., B.A., Analysis or Interpretation: S.A., H.B., Literature Search: S.A., H.B., Writing: S.A., H.B., A.D.

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