Original Article

DOI: 10.14235/bas.galenos.2024.31644
Bezmialem Science 2025;13(1):45-50

In vitro Evaluation of Repair Bond Strength to Bulk-fill Composites Using Two Silane-Free Universal Adhesives, with and without Silane Application

Silan Uygulaması ile Birlikte ve Silan Uygulaması Olmadan Universal Adeziv Kullanarak Bulk-fill Kompozitlere Tamir Bağlantı Dayanımının *In vitro* Değerlendirilmesi

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ABSTRACT

Objective: To evaluate the effect of silane-free universal adhesives systems on the repair shear bond strength (SBS) of sonic-activated bulk-fill [SonicFill (SF) Kerr, USA] composite applying additional silane in the repair of bulk-fill composite.

Methods: Sonic-activated bulk-fill composite samples (n=40) were prepared using a teflon mold (6 mm x 4 mm) and polymerized. Then all samples were kept in an incubator to simulate the aging process at 37 °C for one month. Aged composite samples were embedded in acrylic resin. For the repair, the specimen surfaces were roughened with a diamond bur. They were divided into 2 groups (n=20) according to the adhesive system used and then into two subgroups (n=10) as additional silane was applied or unapplied.

Adhesive systems Ambar Universal Bond (AUB), (FGM, Brazil), G-Premio Bond (GPB) (GC, USA) and silane (G-Multi primer GC, Tokyo, Japan) were applied according to the manufacturer's instructions. Samples were subjected to a shear bond test in a universal testing device. For statistical analysis, one-way ANOVA test was performed ($p<0.05$).

Results: The highest SBS value was obtained in the silane-treated AUB group (21.88±6.4), while the lowest SBS value was obtained in the silane-treated GPB group (16.07±6.2). No statistically

ÖZ

Amaç: Silan içermeyen universal adeziv sistemlerinin, sonic enerji ile aktive edilmiş bulk-fill (SonicFill (SF), Kerr, ABD) kompozitinin tamirinde ilave silan uygulamasının tamir bağlanma dayanımı (TBD) üzerindeki etkisini değerlendirmektir.

Yöntemler: Sonic enerji ile aktive edilmiş bulk-fill kompozit örnekler (n=40) bir teflon kalıp (6 mm x 4 mm) kullanılarak hazırlandı ve polimerize edildi. Daha sonra tüm numuneler yaşlanma sürecini simüle etmek için bir inkübatörde 37 °C'de bir ay süreyle tutuldu. Yaşlandırılmış kompozit numuneler akrilik içerisine gömüldü. Tamir için numune yüzeyleri elmas frez ile pürüzlendirildi. Numuneler, kullanılan adeziv sistemine göre iki gruba (n=20) ayrıldı ve ardından ilave silan uygulanan ve uygulanmayan olarak iki alt gruba (n=10) ayrıldı. Ambar Universal Bond (AUB) (FGM, Brezilya), G-Premio Bond (GPB) (GC, ABD) ve silan (G-Multi Primer, GC, Tokyo, Japonya) üretici talimatlarına uygun olarak uygulandı. Örnekler universal bir test cihazında kesme bağlanma testine tabi tutuldu. İstatistiksel analiz için tek yönlü ANOVA testi kullanıldı ($p<0,05$).

Bulgular: En yüksek TBD değeri silan uygulanan AUB grubunda (21,88±6,4), en düşük TBD değeri silan uygulanan GBO grubunda

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Received: 09.12.2023
Accepted: 14.09.2024
Published date: 27.01.2025

Cite this article as: Aksoy A, Dönmez N. *In vitro* evaluation of repair bond strength to bulk-fill composites using two silane-free universal adhesives, with and without silane application. Bezmialem Science. 2025;13(1):45-50

ABSTRACT

significant difference was observed between all groups (p<0.05).

Conclusion: Additional silane application does not affect the SBS of universal adhesives on an SF composite material.

Keywords: Bulk-fill composite repair, sonic-activated bulk-fill composite, surface treatments, silane agent, universal adhesive

ÖZ

(16,07±6,2) elde edildi. Tüm gruplar arasında istatistiksel olarak anlamlı fark gözlenmedi (p<0,05).

Sonuç: İlave silan uygulaması, SF kompozit malzeme üzerindeki universal adezivlerin TBD'sini etkilememektedir.

Anahtar Sözcükler: Bulk-fill kompozit tamiri, sonic ile aktive bulk-fill kompozit, yüzey işlemleri, silan ajanı, universal adeziv

Introduction

In recent times, with the rise in both patients' and practitioners' aesthetic expectations, along with advancements in adhesive systems, composite resin has become increasingly common in restoring dental tissue losses (1-3). Especially for endodontically treated teeth and moderate substance loss, using the layering method for composite resin restoration can lead to gap formation between the resin layers due to the prolonged procedure.

Bulk-fill composites can be applied in a single layer up to a thickness of 4 mm, which reduces clinical procedure time, enhances comfort for both the patient and the clinician, and eliminates the risk of moisture contamination and gap formation associated with the layering technique, thereby providing more uniform restorations (4-6). Bulk-fill composites with high and low-viscosity formulations are currently available on the market. They employ various methods to increase the polymerization depth of each bulk-fill composite. These include enhancing the composite's translucency, utilizing specific polymerization modulators, or employing robust initiator systems (7). Generally, low-viscosity bulk-fillers have a low filler ratio to provide flowability; however, there is also a bulk-fill composite, which has a high filler ratio but increases its flowability with the effect of the sonic stimulator (SonicFill, Kerr, USA). This sonic-activated composite is one of the bulk-fill composites that can be used with an air-driven handpiece, which allows it to be applied to the cavity by reducing the viscosity of the composite with the effect of sonic vibration.

In clinical practice, the failure of composite restorations is a significant concern. Dentists may consider repairing these restorations since replacing the restoration can result in pulp exposure, weakened tooth structure, and loss of healthy tooth tissue (8). Repair is a minimally invasive procedure that preserves the tooth structure and extends the life of the restoration. It is also more cost-effective and significantly prolongs the lifespan of both the tooth and the restoration, making it a common choice over full restoration removal (9,10). Many methods are used for surface pretreatment of composite resin restorations before the repair process: mechanical roughening with diamond bur or air abrasion, mechanochemical roughening with sandblasting, chemical roughening with phosphoric acid, hydrofluoric acid or acidified phosphate fluoride (11,12).

Loomans and Özcan (13) stated that the effects of different repair techniques depended on the material, and none of the surface preparation methods were universally accepted.

"Universal" or "Multimode" adhesive systems have been introduced to the market to eliminate the disadvantages of one-step self-etch adhesive systems that provide clinical ease of use. Most acidic functional monomers contain 10-methacryloxydecyl dihydrogen phosphate (10-MDP) and silane. In addition to mechanical and chemical bonding in enamel and dentin, the most important advantage of universal adhesives is the variety of restorative procedures and adhesion strategies (14). The adhesive intermediate layer provides micromechanical retention by chemical bonding to the resin matrix and, if silane-containing, exposed filler particles and monomer penetration into the microporosities on the composite resin (15).

There is limited literature on studies evaluating the shear bond strength (SBS) in the repair of sonic energy-activated bulk-fill materials using both silane-containing and silane-free universal adhesives. The purpose of this study is to evaluate the repair bond strength (RBS) of two silane-free universal adhesive to a sonic-activated bulk-fill (SABF) composite resin after additional silane application. The null hypothesis of the study is that the additional application of silane in the repair of SABF composites would not affect the RBS of silane-free universal adhesives.

Methods

Forty SABF (SonicFill, Kerr USA) composite resin specimens (6 mm x 4 mm) were prepared using a teflon mold and polymerized for 40 seconds with a light emitting diode light device (Demi Ultra Capacitor, Kerr, USA, 450-470 nm wavelength). The prepared composite specimens were subjected to 10,000 cycles of thermocycling over the course of one month to simulate the aging process (16). 2 mm of the aged composite specimens were embedded in acrylic resin (İntegra, İstanbul, Türkiye). They were divided into 2 groups (n=20) according to the adhesive system used and then into two subgroups (n=10) as additional silane was applied or unapplied. The specimen surfaces were roughened with a green band diamond fissure bur (G&Z instruments Gmbh 6890 Lustenau/Austria) (17). Adhesive systems Ambar Universal Bond (AUB), (FGM, Brazil), G-Premio Bond (GPB) (GC, USA) and silane (G-Multi primer GC, Tokyo, Japan) were applied according to the manufacturer's instructions (18). The specimens were divided into four groups based on the type of bonding agent applied and the presence of a silane agent.

- Grup AUB

- Grup AUB + silane

- Grup GPB

- Grup GPB + silane (GPBS)

The main components of the materials used in this study are shown in the table below (Table 1). Specimens were subjected to a SBS test using a universal testing machine (Shimadzu AGS-X Universal, Tokyo, Japan) (crosshead speed: 1 mm/min) with a wedge-shaped tip aligned parallel to the longitudinal axis of the interproximal surfaces of the restorations until failure occurred. Failure modes were evaluated under a stereomicroscope. The obtained values were recorded as MPa.

Repair Procedures

A 2 mm x 2 mm silicone mold was used. Afterward applying the relevant surface treatments and adhesive procedures to the surface of the acrylic-embedded and aged bulk-fill composite specimen, a 2 mm restoration was performed with a bulk-fill (SonicFill, Kerr USA) composite using each specimen mold.

Statistical Analysis

In calculating the specimen size, the probability of type 1 error (α=0.05) and the power of the test (1-β) were considered 0.95. Using the G Power 3.1.9.2 program, it was calculated that the total specimen size should be at least 10. Therefore, the specimen size was determined as 10.

The data were analyzed using IBM statistical package for social sciences (SPSS) 26 Software for Windows. By performing the Shapiro-Wilks test, it was determined that the obtained data showed a normal distribution. Parametric tests were conducted among the groups for pairwise comparisons using ANOVA. The results were evaluated with a significance of $p<0.05$.

Failure Modes

After bond strength testing, the failure mode of all specimens was assessed under a light microscope at a magnification of x15 (Stemi 305, ZEISS, Germany) and classified into the following categories: Failures were classified as "adhesive" if the fracture occurred at the interface between the restorative material and the repair material. A "cohesive" failure was identified if the fracture occurred within either the restorative material or the repair material. If the fracture occurred both within the materials and at their interface, it was classified as a "mixed" failure.

Table 1. The main components of the materials used in this study

Materials	Manufacture	Batch no	Main components	Instructions for use
SonicFill 2	Kerr, Orange, CA, USA	8032275	Bis-GMA, TEGDMA, Bis-EMA, SiO2, glass, oxide	1. Activate SonicFill Handpiece by entirely depressing the foot pedal and filling the entire cavity (up to 5 mm). 2. After placement, press and sculpt, using a hand instrument to define the anatomy. 3. Light cure 40s 4. Finish and polish in the usual manner
Ambar Universal Bond	FGM,Joinville,SC, Brazil	230821	10-MDP, HEMA, UDMA, methacrylic monomers, photoinitiators, co-initiators, stabilizers, silica nanoparticles, and ethanol. pH= 2.6 - 3.0	1. Apply and rub for 20 s (repeat) 2. Air dry for 10 s 3. Light cure 10 s
G-Premio Bond	GC, Tokyo, Japonya	2208101	MDTP, 4-MET, MDP, acetone, photoinitiators, water, dimethacrylate monomers, silicon dioxide	1. Apply adhesive and leave undisturbed for 10 s 2. Dry thoroughly with maximum air pressure 3. Light cure for 10 s
G-Multi Primer (Silane)	GC, Tokyo, Japonya	2011111	Phosphoric ester monomer, Ethanol, Methacrylate monomer, γ-Methacryloxypropyl trimethoxysilane	1. Dispense one drop of G-Multi PRIMER into a dispensing dish 2. Apply a thin layer to the fractured surface of the restoration using a micro-tip applicator and dry with an oil-free air syringe 3. Continue the repair using a light-cured adhesive and a light-cured composite, referring to their respective manufacturer's instructions

Bis-GMA: Bisphenol A-glycidyl methacrylate, TEGDMA: Triethylene glycol dimethacrylate, Bis-EMA: Bisphenol A-diglycidyl methacrylate ethoxylated, 10-MDP: 10-Methacryloyloxydecyl dihydrogen phosphate, HEMA: 2-hydroxyethyl methacrylate, UDMA: Urethane dimethacrylate, MDTP: Methacryloyloxydecyl dihydrogen thiophosphate, 4-MET: 4-methacryloxyethyl trimellitic acid

Results

The descriptive statistics values of the SBS of the SABF composite material are shown in Table 2, 3. The highest SBS value was obtained in the AUB group (21.88±6.4 MPa) without silane application, while the lowest SBS value was obtained in the silane-treated GPBS group (16.07±6.2 MPa). No statistically significant difference was observed between all groups ($p<0.05$).

In the GPB group without silane application, only adhesive failures were observed. In other groups, adhesive failures were generally observed.

Discussion

It was determined that the application of additional silane to the repair process performed with two silane-free adhesives did not alter the RBS of the SABF composite. Thus, the null hypothesis was rejected. Composite resin restorations may deteriorate due to mechanical, thermal, and chemical stresses in the oral environment. In this respect, thermal cycling of bonded specimens is the one of the best method to mimic the aging of interfacial bonds. Additionally, the success of composite repair procedures depends on several factors, including surface properties, wettability of chemical bonding agents, and the chemical composition of composites (19-21). Surface roughness is very important for composite repair and the roughening process can be achieved mechanically with the diamond burs used for this purpose (19,22-24). Chemical bonding is also an ideal method for enhancing the bond strength of restored composite materials, apart from micromechanical interlocking (25). Silane agents chemically bond the fillers of the old composite resin to the organic resin matrix of the new composite resin (26,27). For this reason, the use of a silane coupling agent is recommended for composite resin repair (19).

An essential factor for the successful restoration of dental composite is to retain a strong bond with restorations (28). Regarding the repair of composite resins, consensus has not been reached on the optimal protocol or materials for surface preparation of existing and aged composite resin surfaces in clinical practice. In this study, as stated in the literature, roughening of the surface with a bur was used in the surface preparation for the repair process (17). The main factor influencing the RBS has been proposed to be the type of composite resin (29) and some research has indicated that the repair should be done with composite resin of the exact origin as the composite used to perform the original restoration (30).

In this study, the same composite material was used for repair according to the literature. The application of the same bulk-fill composite, which may be explained by the presence of similar monomers in its composition, is expected to increase the effectiveness of the repair procedure that allows adequate copolymerization of methacrylate groups from new and aged composite materials (31). There was no statistically significant difference between the two silane-free universal adhesives used in this study and the repair SBS obtained by applying additional silane.

Furthermore, the absence of any favorable effect of silane in universal adhesives can be clarified by its low stability in aqueous acidic adhesive solution, where the silanol groups formed by hydrolysis can undergo dihydroxylation and condensation to form an oligomer that cannot adhere to glass (32). While some studies (33,34) found no difference in RBS using silane-containing and silane-free universal adhesive, another study showed that previous silane application improved immediate RBS. Nevertheless, once the bottle is opened, the hydrolyzed silane solutions become less and less reactive and prevent optimal adhesion in the long run (26). Cuevas-Suárez et al. (35) claimed that pre-treatment with a silane coupling agent and application of a hydrophobic resin could increase the bond strength of bulk-fill restorations. Contrary to the findings of Cuevas-Suárez et al., (35) it was found that additional silane application did not affect the bond strength in this study. A major factor influencing the bond strength of repair is considered to be the type of resin (36) and some research has suggested that the repair be done with the same composite resin used to perform it (30). It has also been observed that using the same bulk-fill composites in the repair procedure can increase the system's effectiveness. We can explain this with the existence of similar monomers, which allows for the

Table 2. Descriptive statistics values of shear bond strength of sonic-activated bulk-fill composite material

Groups	Ambar Universal (mean ± SD)	G-Premio Bond (mean ± SD)	p-value
Silan +	19.45±10.9	16.07±6.2	0.433
Silan -	21.88±6.4	18.8±6.6	

SD: Standard deviation

Table 3. Failure mode analysis of fractured surfaces after SBS test for all tested groups (%)

	Ambar Universal		G-Premio	
	Silane (+)	Silane (-)	Silane (+)	Silane (-)
Adhesive failure	70	50	70	100
Cohesive failure	20	40	20	0
Mixed failure	10	10	10	0

same copolymerization between methacrylate groups in new and existing composite materials (31).

In this study, stereomicroscope observations indicated that the failure modes were predominantly adhesive. In addition to adhesive failures, cohesive failures in the restorative material were also observed, and the application of additional silane did not reduce the adhesive failure rate. This is consistent with our SBS test results.

In this regard, it is worth noting that when performing a composite restoration, it is essential for the operator to accurately document the type of material used so that the repair can provide adequate bond strength if needed. In this study, it was found that there was no statistically significant difference between the groups with additional silane application and the groups without silane application. Therefore, it can be concluded that applying silane may not be necessary for the repair process of the bulk-fill composite resin. The results of this study show that the bulk-fill composite can be repaired with the same bulk-fill composite without the need for additional silane application. Including silane in universal adhesives may have questionable importance in clinical practice. Silanes in acidic conditions can become unstable due to self-condensation. The reaction of silanol groups (37) causes bond degradation over time (31). Therefore, further studies are needed to evaluate other roughening methods and materials.

Study Limitations

This study was limited to the use of a single composite resin. Only two silane-free adhesive systems were evaluated in this study. The surface treatment was restricted to bur-roughening. The SBS test was limited by the negative characteristics and inhomogeneity of stress distribution at the bond interface.

Conclusion

When repairing a SABF composite material with the same bulk-fil material, it can be repaired with silane-free universal adhesives without the need for an additional silane application.

Ethics

Ethics Committee Approval: Ethics committee approval is not required.

Informed Consent: Informed consent is not required.

Footnotes

Authorship Contributions

Concept: N.D., Design: N.D., Data Collection or Processing: A.A., N.D., Analysis or Interpretation: A.A., N.D., Literature Search: A.A., N.D., Writing: A.A., N.D.

Conflict of Interest: No conflict of interest was declared by the authors.

Financial Disclosure: The authors declared that this study received no financial support.

References

1. Arıkan S. Posterior composite restorations. Cumhuriyet Univ Fac Dent J. 2005;8:63-70.
2. Duarte S Jr, Saad JR. Marginal adaptation of Class 2 adhesive restorations. Quintessence Int. 2008;39:413-8.
3. Kwon Y, Ferracane J, Lee IB. Effect of layering methods, composite type, and flowable liner on the polymerization shrinkage stress of light cured composites. Dent Mater. 2012;28:801-9.
4. El-Damanhoury H, Platt J. Polymerization shrinkage stress kinetics and related properties of bulk-fill resin composites. Oper Dent. 2014;39:374-82.
5. Lazarchik DA, Hammond BD, Sikes CL, Looney SW, Rueggeberg FA. Hardness comparison of bulk-filled/transtooth and incremental-filled/ occlusally irradiated composite resins. J Prosthet Dent. 2007;98:129-40.
6. El-Safty S, Silikas N, Watts DC. Creep deformation of restorative resin-composites intended for bulk-fill placement. Dent Mater. 2012;28:928-35.
7. Alrahlah A, Silikas N, Watts DC. Post-cure depth of cure of bulk fill dental resin-composites. Dent Mater. 2014;30:149-54.
8. Krejci I, Lieber CM, Lutz F. Time required to remove totally bonded tooth-colored posterior restorations and related tooth substance loss. Dent Mater. 1995;11:34-40.
9. "Fernández E, Martín J, Vildósola P, Oliveira Junior OB, Gordan V, Mjör IA, et al. Can repair increase the longevity of composite resins? Results of a 10-year clinical trial. J Dent. 2015;43:279-86".
10. Moncada G, Fernández E, Martín J, Arancibia C, Mjör IA, Gordan VV. Increasing the longevity of restorations by minimal intervention: a two-year clinical trial. Oper Dent. 2008;33:258-64.
11. Joulaei M, Bahari M, Ahmadi A, Savadi Oskoee S. Effect of different surface treatments on repair micro-shear bond strength of silicaand zirconia-filled composite resins. J Dent Res Dent Clin Dent Prospects. 2012;6:131-7.
12. Özcan M, Pekkan G. Effect of different adhesion strategies on bond strength of resin composite to composite-dentin complex. Oper Dent. 2013;38:63-72.
13. Loomans B, Özcan M. Intraoral repair of direct and indirect restorations: procedures and guideline. Oper Dent. 2016;41:68.
14. Munoz MA, Luque I, Hass V, Reis A, Loguercio AD, Bombarda NH. Immediate bonding properties of universal adhesives to dentine. J Dent 2013 41:404-41.
15. Tuğçe A, Can E. Universal adhesive systems. Turkiye Klinikleri J Dental Sci. 2019;26:496-503.
16. Fawzy AS, El-Askary FS, Amer MA. Effect of surface treatments on the tensile bond strength of repaired water-aged anterior restorative micro-fine hybrid resin composite. J Dent. 2008;36:969-76.
17. Chuenweravanich J, Kuphasuk W, Saikaew P, Sattabanasuk V. Bond durability of a repaired resin composite using a universal adhesive and different surface treatments. J Adhes Dent. 2022;24:67-76.
18. Özcan M, Pekkan G. Effect of different adhesion strategies on bond strength of resin composite to composite-dentin complex. Oper Dent. 2013;38:63-72.

19. Loomans BA, Cardoso MV, Roeters FJ, Opdam NJ, De Munck J, Huysmans MC, Van Meerbeek B. Is there one optimal repair technique for all composites? Dent Mater. 2011;27:701-9.

20. Ozcan M, Barbosa SH, Melo RM, Galhano GA, Bottino MA. Effect of surface conditioning methods on the microtensile bond strength of resin composite to composite after aging conditions. Dent Mater. 2007;23:1276-82.

21. Papacchini F, Dall'Oca S, Chieffi N, Goracci C, Sadek FT, Suh BI, et al. Composite-to-composite microtensile bond strength in the repair of a microfilled hybrid resin: effect of surface treatment and oxygen inhibition. J Adhes Dent. 2007;9:25-33.

22. Bonstein T, Garlapo D, Donarummo J Jr, Bush PJ. Evaluation of varied repair protocols applied to aged composite resin. J Adhes Dent. 2005;7:41-9.

23. da Costa TR, Serrano AM, Atman AP, Loguercio AD, Reis A. Durability of composite repair using different surface treatments. J Dent. 2012;40:513-21.

24. Rathke A, Tymina Y, Haller B. Effect of different surface treatments on the composite-composite repair bond strength. Clin Oral Investig. 2009;13:317-23.

25. Brosh T, Pilo R, Bichacho N, Blutstein R. Effect of combinations of surface treatments and bonding agents on the bond strength of repaired composites. J Prosthet Dent. 1997;77:122-6.

26. Lung CY, Matinlinna JP. Aspects of silane coupling agents and surface conditioning in dentistry: an overview. Dent Mater. 2012;28:467-77.

27. Matinlinna JP, Lassila LV, Ozcan M, Yli-Urpo A, Vallittu PK. An introduction to silanes and their clinical applications in dentistry. Int J Prosthodont. 2004;17:155-64.

28. Lima AF, Ferreira SF, Catelan A, Palialol AR, Gonçalves LS, Aguiar FH, et al. The effect of surface treatment and bonding procedures on the bond strength of silorane composite repairs. Acta Odontol Scand. 2014;72:71-5.

29. Spyrou M, Koliniotou-Koumpia E, Kouros P, Koulaouzidou E, Dionysopoulos P. The reparability of contemporary composite resins. Eur J Dent. 2014;8:353-9.

30. Blum IR, Lynch CD, Wilson NH. Factors influencing repair of dental restorations with resin composite. Clin Cosmet Investig Dent. 2014;6:81-7.

31. Li J. Effects of surface properties on bond strength between layers of newly cured dental composites. J Oral Rehabil. 1997;24:358-60.

32. Yoshihara K, Nagaoka N, Sonoda A, Maruo Y, Makita Y, Okihara T, et al. Effectiveness and stability of silane coupling agent incorporated in 'universal' adhesives. Dent Mater. 2016;32:1218-25.

33. Fornazari IA, Wille I, Meda EM, Brum RT, Souza EM. Effect of surface treatment, silane, and universal adhesive on microshear bond strength of nanofilled composite repairs. Oper Dent. 2017;42:367-74.

34. Michelotti G, Niedzwiecki M, Bidjan D, Dieckmann P, Deari S, Attin T, et al. Silane effect of universal adhesive on the composite-composite repair bond strength after different surface pretreatments. Polymers (Basel). 2020;12:950.

35. Cuevas-Suárez CE, Nakanishi L, Isolan CP, Ribeiro JS, Moreira AG, Piva E. Repair bond strength of bulk-fill resin composite: Effect of different adhesive protocols. Dent Mater J. 2020;39:236-41.

36. Spyrou M, Koliniotou-Koumpia E, Kouros P, Koulaouzidou E, Dionysopoulos P. The reparability of contemporary composite resins. Eur J Dent. 2014;8:353-9.

37. Stape THS, Tulkki O, Salim IA, Jamal KN, Mutluay MM, Tezvergil-Mutluay A. Composite repair: On the fatigue strength of universal adhesives. Dent Mater. 2022;38:231-41.