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Evaluation of Shear Bond Strength of Compomer Repaired with Different Protocols

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Research Article

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ABSTRACT

Objectives: This study aimed to comparatively assess the bond strengths of the repaired compomer samples using different repair protocols under in-vitro conditions.

Materials and Methods: 60 compomer specimens were prepared with the dimensions of 10×2.5×2 mm^3 using metal moulds. The prepared samples were thermocycled for 5000 cycles, between 5-55 °C with 30 seconds dwell time. Samples were then randomly assigned to 3 different repair protocol groups as universal adhesive (Group 1 - Prime&Bond® Universal), 2 step total etch system (Group 2 - 35% Scotchbond Universal OF Acid+Prime&-Bond® Universal) and silane coupling agent (Group 3 - Monobond Plus+Prime&Bond® Universal). For each group, the specimens were re-placed in a 20×2.5×2 mm^3 mould and repair surface was subjected to the relevant repair protocol. Compomer restorative was placed to the remaining area of the moulds, polymerised and finished. Shear bond strength testing was performed using a universal testing machine. Obtained data were analyzed with Anova and Tukey's HSD tests. The significance level was set at $p < 0.05$.

Results: Samples in Group 3 presented higher repair bond strength values with a statistically significant difference compared to Group 1 and Group 2 (p=0.000 and p = 0.005, respectively). However, no statistical significant difference was found between Group 1 and Group 2 (p = 0.639).

Conclusions: The use of silane in the repair of compomer restorations can be recommended as an alternative to traditional repair methods.

***Keywords*:** Compomers, dental restoration repair, silanes.

Farklı Protokollerle Onarılan Kompomerlerin Makaslama Bağlanma Dayanımının Değerlendirilmesi

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ÖZ

Amaç: Bu çalışmanın amacı, farklı onarım protokolleri kullanılarak onarılan kompomer örneklerinin bağlanma dayanımlarını in-vitro koşullar altında karşılaştırmalı olarak değerlendirilmesidir.

Gereç ve Yöntemler: 60 kompomer örneği 10×2.5×2 mm^3 boyutlarındaki metal kalıplar kullanılarak hazırlanmıştır. Hazırlanan örnekler 5-55 °C arasındaki banyoda 30 saniye bekleme süresi ile 5000 döngü olacak şekilde ısıl işleme tabi tutulmuştur. Örnekler daha sonra universal adeziv (Grup 1 - Prime&Bond® Universal), 2 aşamalı total etch sistem (Grup 2 - %35 Scotchbond Universal OF Acid+Prime&- Bond® Universal) ve silan bağlayıcı ajan (Grup 3 - Monobond Plus+Prime&Bond® Universal) olmak üzere 3 farklı onarım protokolü grubuna rastgele atanmıştır. Her grup için örnekler 20×2.5×2 mm^3'lük kalıplara yeniden yerleştirilmiş ve onarım yüzeyi ilgili onarım protokolüne tabi tutulmuştur. Kompomer materyali kalıpların kalan alanlarına yerleştirilmiş, polimerize edilmiş ve bitirme işlemleri yapılmıştır. Makaslama bağlanma dayanımı testi üniversal test cihazı kullanılarak yapılmıştır. Elde edilen veriler Anova ve Tukey's HSD testleri ile analiz edilmiştir. Anlamlılık düzeyi $p < 0,05$ olarak belirlenmiştir.

Bulgular: Grup 3'teki örnekler, Grup 1 ve Grup 2'ye kıyasla istatistiksel olarak anlamlı bir farkla daha yüksek onarım bağlanma dayanımı değerleri sunmuştur (sırasıyla p = 0,000 ve p = 0,005). Ancak, Grup 1 ve Grup 2 arasında istatistiksel anlamlı bir farklılık bulunmamıştır (p = 0,639).

Sonuçlar: Kompomer restorasyonların onarımında silan kullanımı geleneksel onarım yöntemlerine alternatif olarak önerilebilir.

Anahtar Kelimeler: Dental restorasyon onarımı, kompomerler, silanlar.

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Introduction

Minimal Intervention Dentistry (MID) is a treatment philosophy that focuses on keeping teeth functional for as long as possible. Although it is often associated with managing dental caries, MID extends to various areas of dentistry and encourages the early diagnosis of caries, supports remineralisation efforts and promotes minimally invasive procedures.[1] A core principle of MID is to prioritise repairing existing restorations rather than replacing them entirely — an

especially important approach in both paediatric and adult dental care.[1-3] In line with this, clinical decisions about restoration replacement should be carefully evaluated. For instance, when a restoration exhibits a radiolucent area yet exhibits no signs or symptoms affecting the pulp, complete replacement may not be necessary, as regular monitoring could be a more suitable alternative.[2-4] When treatment is required, preserving healthy tooth structure is essential in order to protect pulpal health, reduce costs and minimise the overall burden on the patient. Therefore, whenever possible, repairs should be favoured over full restoration replacements.[1-4]

Historically, restorations were often replaced even when defects were minor, based on the belief that these flaws could compromise the entire restoration. However, removing an existing restoration can lead to the loss of underlying base materials and enlarge the cavity, thereby increasing the risk of failure.[5-8] Recently, clinical practice has shifted towards repairing restorations that are only partially defective, in accordance with minimally interventional dentistry (MID) principles.[5-8] This trend is supported by advancements in adhesive technologies, which make it feasible to repair resin-based restoratives in daily practice. Unlike total replacement, repair techniques preserve the original size of the restoration, avoid the removal of unnecessary enamel and dentin, and limit further pulpal damage.[9,10]

Several materials and techniques have been proposed to improve the success of repairing resin-based restorations. One of the main issues during repair is ensuring reliable adhesion between the aged restoration and the new material.[7,10,11] Over time, resin restorations undergo changes due to factors such as saliva, chewing forces and temperature shifts, which make strong bonding more challenging.[7,10,11] Recently, silane coupling agents have attracted attention as an alternative to more conventional options such as universal adhesives and flowable composites.[10,12-14] Silanes form chemical bonds with the resin and filler particles of the restorative material. Their methacrylate groups interact with adhesives, while their silanol groups bond with the silica or alumina present on treated surfaces.[15]

Most studies evaluating the performance of silane agents in restorative repair have focused on composite materials. However, there is little information available on their effectiveness in repairing compomers, particularly in paediatric dentistry. To address this knowledge gap, the present study aimed to evaluate the shear bond strength of compomer restorations repaired using different protocols in-vitro. The null hypothesis (H_o) was that there would be no statistically significant difference in bond strength between the tested repair techniques.

Materials and Methods

Study Design

This study was an in-vitro laboratory analysis planned to comparatively analyse the shear bond strength after repairing of compomer specimens with different repair protocols. Also, the current research was conducted by complying with CRIS Guidelines to strengthen the quality of this in-vitro experiment.[16]

Sample Size Calculation

In order to evaluate the size of the difference between the groups, the effect size was calculated and the eta square (η^2) value was reported. The effect size obtained as a result of ANalysis Of VAriance (ANOVA) analysis was 9.745 and the sample size was found to be n = 60 according to the calculated $\eta^2 = 0.255$ value. The $\eta^2 = 0.255$ value calculated according to the ANOVA result shows a 'high level' effect size according to Cohen's classification. This finding supports that statistical differences may also be clinically/practically significant.

Sample Preparation

30 compomer specimens were prepared with the dimensions of 20×2.5×2 mm^3 using metal moulds. Initially, an isolant material (Isolant Cms, Dentsply) was applied to the surfaces between the restorative material and the metal mould to easily separate two surfaces from each other. Subsequently, Dyract XP (Dentsply DeTrey GmbH, Konstanz, Germany) was applied in bulk mass and the transparent glass plate was placed over the compomer mass to obtain smooth standard surfaces. Compomer restorative material was light cured for 20 s (3M ESPE, Elipar S10 1790 mW/cm^2). Then, the samples were polished and finished using diamond burs (Meisinger, Diamond Dud FG, 831S, extra fine, with yellow tape, size: 016) and discs to be applied from coarse grain to fine grain respectively (Sof-Lex® Finishing and Polishing Discs, 3M ESPE, St. Paul, MN, USA). After polymerisation and finishing & polishing procedures, the prepared samples were cut in half with a high-speed diamond blade (Microcut 201, Metkon Instruments Inc., Bursa, Turkey) to obtain 60 compomer samples in the dimensions of 10×2.5×2 mm^3. Thus, an area of 2.5×2 mm^2 was prepared to simulate the repair surface.

Artificial Aging

Following the preparation of compomer samples, the specimens were subjected to thermocycling by using a thermal cycler (SD Mechatronik GMBH, Feldkirchen, Westerham, Germany) for 5000 cycles, between 5-55 °C, with a 30 s dwell time. After that, repair protocols were performed to aged specimens.

Repair Processes

Thermocycled 60 compomer samples were then randomly and equally assigned to three different repair protocol groups (n = 20). 3 experimental repair protocols, as universal adhesive, total etch system and silane coupling agent, were included in the study procedure. Afterwards, each of the three protocols was applied to the samples assigned to the relevant group within the application details given below.

Group 1 - Universal Adhesive (Prime&Bond® Universal Adhesive): The specimens (in the size of 10×2.5×2 mm^3) were placed to one side of the master mould (in the size of 20×2.5×2 mm^3) and repair surface was subjected to universal adhesive repair protocol. Prime&Bond® Universal Adhesive was applied to the repair surface and slightly agitated for 20 s (2.5×2 mm^2) and the excess solvent was removed for 5 s. Universal adhesive was light cured for 10 s by using a light curing device. Subsequently, compomer restorative material was placed to the other side of the master mould and then was cured for 20 s using

a curing light. Finally the repaired surface was and finished and polished.

Group 2 - 2 Step Total Etch System (35% Scotchbond Universal Orthophosphoric Acid + Prime&Bond® Universal Adhesive): The specimens (in the size of 10×2.5×2 mm^3) were placed to one side of the master mould (in the size of 20×2.5×2 mm^3) and repair surface was subjected to universal adhesive repair protocol. 35% Scotchbond Universal Orthophosphoric Acid was applied to the repair surface for 15 s, rinsed with water for 15 s and air dry gently. Then, Prime&Bond® Universal Adhesive was applied to the repair surface for 20 s (2.5×2 mm^2) and the excess solvent was removed by gently drying with clean, dry air from a dental syringe for 5 s. Universal adhesive was cured for 10 s using a curing light. Subsequently, compomer restorative material was placed to the other side of the master mould and then was cured for 20 s using a curing light. Finally the repaired surface was and finished and polished.

Group 3 - Silane Coupling Agent (Monobond Plus + Prime&Bond® Universal Adhesive**):** The specimens (in the size of 10×2.5×2 mm^3) were placed to one side of the master mould (in the size of 20×2.5×2 mm^3) and repair surface was subjected to universal adhesive repair protocol. Monobond Plus (Ivoclar Vivadent, Schaan, Liechtenstein) was applied to the repair surface for 60 s and an air jet was used to evaporate the solvent. Then, Prime&Bond® Universal Adhesive was applied to the repair surface for 20 s (2.5×2 mm^2) and the excess solvent was removed for 5 s. Universal adhesive was light cured for 10 s by using a light curing device. Subsequently, compomer restorative material was placed to the other side of the master mould and then was cured for 20 s using a curing light. Finally the repaired surface was and finished and polished.

Bond Strength Testing

Shear bond strength values were calculated by using a universal testing machine (Lloyd Instruments Ltd. Hampshire, United Kingdom) with a crosshead speed of 1 mm/min. Max load at the failure was calculated in Newton unit (N). Calculated value was divided by surface area (adhesion surface) (in mm^2 unit) to calculate the shear bond strength in megapascal unit (MPa) for each specimen included.

Statistical Analysis

All statistical analyses were performed using IBM SPSS Statistics 22.0 (IBM Corp., Armonk, NY, USA). The normality of data distributions was assessed for each group using the Shapiro–Wilk test, and the assumption of normality was confirmed ($p > 0.05$ for all groups). The homogeneity of variances was evaluated using Levene's test, which also yielded non-significant results ($p > 0.05$), confirming that the variances were homogeneous across groups. To compare Maximum Load (N) values among three independent groups, a one-way analysis of variance (ANOVA) was conducted. When a statistically significant main effect was observed, Tukey's Honestly Significant Difference (HSD) test was employed for post-hoc pairwise comparisons. Tukey HSD is an appropriate method when equal variances are assumed and provides strong control over the Type I error rate. For all statistical tests, $p < 0.05$ was considered statistically significant.

Results

Table 1 showed the repair shear bond strength values. According to the results obtained, the highest repair shear bond strength was observed in Group 3 (138.37 ± 38.69), followed by Group 2 (99.80 ± 33.52) and Group 1 (89.18 ± 38.79). Accordingly, the application of Silane Coupling Agent + Universal Adhesive provided the best bond strength value in compomer repair process, while the application of universal adhesive alone provided the lowest bond strength value. In statistical anaylsis, a statistically significant difference was found between the groups in terms of shear bond strength ($p = 0.000$) (Table 1). Post-hoc tests were performed to determine which 2 groups lead the statistical difference (Table 2).

Accordingly, the shear bond strength values in the samples applied with silane coupling agent showed higher shear bond strength values with statistically significant difference compared to the samples treated with universal adhesive and 2-stage total etch system ($p = 0.000$ and $p = 0.005$, respectively) (Table 2). However, there was no statistically significant difference between the universal adhesive and 2-stage total etch system ($p = 0.639$) (Table 2).

Table 1. Statistical comparison between different repair protocols in terms of the shear bond strength

Repair Protocols	n	Mean	Median	Minimum	Maximum	Standard Deviation (SD)	Anova	
							F	p
Group 1 (Universal Adhesive)	20	89.18	82.27	16.84	158.82	38.79	9.745	**0.000***
Group 2 (2 Step Total Etch System)	20	99.80	90.64	36.88	179.08	33.52		
Group 3 (Silane Coupling Agent + Universal Adhesive)	20	138.37	136.65	85.89	214.78	38.69		

**bold p value stated the statistical significance*

Table 2. Post-hoc comparisons between different repair protocols

Multiple Comparisons (Tukey's HSD Post Hoc)						
Repair Protocols		Mean Difference (I-J)	Standard Deviation (SD)	p	95% Confidence Interval	
					Lower Bound	Upper Bound
Group 1 (Universal Adhesive)	Group 2 (2 Step Total Etch System)	-10.63	11.73	0.639	-38.8	17.6
Group 1 (Universal Adhesive)	Group 3 (Silane Coupling Agent + Universal Adhesive)	-49.19	11.73	**0.000***	-77.4	-21.0
Group 2 (2 Step Total Etch System)	Group 3 (Silane Coupling Agent + Universal Adhesive)	-38.57	11.73	**0.005***	-66.8	-10.3

**bold p values stated the statistical significance*

Discussion

The main objective of this study was to comparatively evaluate the bond strengths of repaired compomer samples using different repair protocols in-vitro. According to the obtained findings in the current work, the null hypothesis was rejected since the statistical significance difference was found among the repair protocols included. Within the framework of MID, repair of restorative materials rather than complete replacement of restorative materials in either primary or permanent teeth is a clinically more desirable approach since the tooth is exposed to minimal intervention.[5-8] In this context, the repair of compomer restoratives, which are frequently used in pedodontics, with traditional methods or newly developed techniques has not been studied as frequently as dental composites. This study focussed on the repair of compomers and how bond strength, an indicator of adhesion, is affected as a result of repair. Therefore, these objectives point to the clinical significance of the study, and the results of the study have implications that may include clinical recommendations.

Repair of restorations offers some advantages over total restoration replacement, as they require less chair time and cost. Moreover, repair process preserves sound tooth tissues and reduce the risk of pulp irritation. They also comply with the minimal interventional dentistry concept by extending the life of restorations.[17-19] On the other hand, for a successful and acceptable restoration repair, it is necessary to perform procedures with sufficient mechanical strength and adhesion. In this context, mechanical roughening of the substrate surface of the resin restorative material for micromechanical retention is important to achieve the desired level of repair bond strength.[19,20] Indeed, it has been reported that pre-treating the surface of the resin material aged in the oral environment with diamond burs, sandblasting with aluminium oxide or silica coating increases the repair bond strength by increasing the adhesive surface.[7,19]

Recently, it has been shown in the previous studies that silane coupling agents also showed successful effects in the repair of resin materials.[7,8,13] In their study, Staxrud and Dahl[21] reported that silanising components were important in dental composite technology as coupling materials, with the authors emphasising that the use of silane coupling agents in combination with adhesive (bonding) materials has been investigated in recent years. However, a review of the current dentistry literature reveals that many previous studies examining the effects of silane on the bond strength of restorations have included composite-based materials in their methodology. Consequently, due to the lack of sufficient evidence on the effects of silane coupling agents on the repair process of compomers, in this study, it was planned to include compomer material, given its high frequency use in paediatric dentistry.

The higher bond strength observed in the silane group may be due to micromechanical and chemical interactions. Silane coupling agents can enhance adhesion by promoting chemical bonding between the filler particles of compomer and the methacrylate groups of adhesive resin.[15] Silanol groups of silan coupling agents can react with the inorganic components of compomer resin (e.g. silica or glass fillers), creating a durable siloxane network. Furthermore, micromechanical interlocking may be improved as the application of silane can penetrate and adapt to micro-irregularities on the surface of the aged compomer, particularly after thermocycling.[12,14] These dual bonding mechanisms could account for the superior bond strength of the repaired samples treated with silane.

Sandblasting can also be preferred before the application of the silane coupling agent on the substrate surface. Sandblasting is applied to remove the resin mass that has degraded on the superficial surface of the resin restorative material that has aged in the oral environment. Moreover, sandblasting is also preferred to provide a larger surface area, which is necessary to achieve an increased bond strength.[7,22] However, since compomer material was included to the current study, compomer samples were not sandblasted before silane coupling agent application to avoid simulating prolonged chair time in the paediatric dental patient group.

According to obtained results, repair bond strength was the highest after the use of silane, followed by the 2-stage total etch system. Samples repaired with only the

universal adhesive showed the lowest repair bond strength values. Similar to the current results, Mendes et al.[14] reported that additional silane application steps could increase the repair bond strength of the resin composite materials. Moreover, Leelaponglit et al.[23] stated that an additional silane agent used prior to the single bond universal adhesive use has the highest shear bond strength. On the other hand, there were also controversial findings in the literature regarding the use of silane application to increase the repair bond strength of dental composites. Jusué-Esparza et al.[24] emphasized that the use of a silane coupling agent before the adhesive application does not significantly affect the process of adhesion to an aged resin material. Similarly, Gajski et al.[25] reported in their study that in the repair of fresh or aged composite material, the silane-containing universal adhesive was not superior to the adhesive without the silane application.

In a review of the dental literature, the effects of silane coupling agents or silane-containing adhesive systems on the repair process of resin materials have mostly been focused on dental composite resins. Also, to our knowledge, quite limited data were found that studied the repair bond strength of silane application in the repair of compomers. In this context, Samimi et al.[26] investigated the repairability of compomers with different methods of surface conditioning and the authors were reported that all groups in their study were treated with silane application. According to the mentioned study results, sandblasting with alumina could be the best approach for ideal surface preparation method in the repair process of compomer materials. However, apart from the study mentioned in the literature, there was no other previous study focusing on silane application in the repair processes of compomer materials, revealing the necessity of investigating this subject.

This study had several strengths and limitations. Since the repair of resin restorative materials is so important within the MID concept, the inclusion of two materials, such as compomer and silane coupling agent, which have not been investigated in most previous studies, was a strength aspect of this study. In addition, although carried out under in vitro conditions, the artificial ageing of the compomer material to be repaired to mimic intraoral temperature changes and the use of two adhesive application methods commonly used in paediatric dentistry, with the exception of the experimental study group (silane application), point to the strengths of this research. The fact that this study was conducted under in-vitro design and that the repaired compomer material was not applied to natural tooth cavities meant that the changes in the oral environment could not be totally simulated. Therefore, it was not possible to state clinical conclusions regarding the success of the repair protocols included in this research. On the other hand, although this study was conducted in a laboratory setting, the materials and techniques employed are similar to those commonly used in routine paediatric dental practice. Given the widespread clinical use of compomer restorations and the relevance of repair strategies to minimally invasive care principles, these findings could inform treatment decisions in similar situations. However, further validation through clinical trials is essential before firm conclusions can be drawn about their long-term effectiveness in patient care. Further and comprehensive clinical studies are required to overcome these limitations and confirm the obtained results of the current study.

Conclusions

The use of silane coupling agent in the repair of compomer restorations can be recommended as an alternative to traditional repair methods. Nevertheless, it is recommended that the results of the current study be confirmed by further and comprehensive studies.

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Not applicable

Conflicts of Interest Statement

The authors declare no competing interests.

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