



Evaluation of Microshear Bond Strength of Light and Chemically-Cured Composite Resins to Light-Cured Glass-Ionomer Using Various Bonding Systems

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Abstract

Background: This study was conducted to compare the microshear bond strength (MSBS) of chemically-cured and light cured composite to resin-modified glass-ionomer (RMGI) based on different types of adhesive systems.

Methods: Thirty-two discs of Vitrebond RMGI were prepared and randomly divided into 8 groups. Four cylinders of composite resin were placed on each RMGI sample. Z250 composite was bonded to the RMGI discs with Single-Bond, Clearfil SE-Bond, and Clearfil S3-Bond adhesive agent in groups 1, 2 and 3, respectively. Group 4 was considered to be the control group without any adhesive. In groups 5-8, the procedures were the same as those in groups 1-4, except that a chemically-cured composite (Master Dent) was used. All the samples were kept at 37°C for 24 hours and tested for MSBS by a mechanical testing machine at a strain rate of 0.5 mm/min. Failure mode was assessed under a stereomicroscope. Data analysis was carried out by two-way ANOVA, independent t test, one-way ANOVA and Tukey honestly significant difference test.

Results: Application of a bonding agent significantly increased MSBS ($P=0.0001$). MSBS was significantly higher in samples with light cured composite resin compared to the chemically-cured composite ($P=0.0001$).

Conclusions: Application of an adhesive system significantly increased the MSBS of composite resins to RMGI. The bond strength of composite resin to RMGI could vary depending on the type of the composite resin and the adhesive system.

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Background

Application of glass-ionomer has increased due to its advantages, including biocompatibility, adhesion to tooth hard tissues, release of fluoride, etc (1-3). Initial conventional glass-ionomer cements had some disadvantages which limited their use (2,3). Polymerizable functional groups were added to their structure yielding resin-modified glass-ionomer cements (RMGICs) so that the clinical application and physical and chemical properties of conventional glass-ionomer cements were enhanced (4).

Despite great advances in the bonding of composite resins to dentin in recent years, microleakage at restoration margins remains challenging. Use of glass-ionomer cements as base materials beneath composite resin restorations (sandwich or laminate technique) has been advocated as an effective method to reduce microleakage at restoration margins (5,6).

Highlights

- ▶ Application of a bonding agent significantly increased MSBS of RMGI and composite
- ▶ The self etch adhesives have the best performance between all other systems.
- ▶ MSBS was significantly higher in RMGI with light cured composite compared to chemically-cured composite.

The sandwich technique reduces the effect of polymerization shrinkage by decreasing the volume of composite resin needed (6,7). In addition, considering its modulus of elasticity, glass-ionomer can serve as a stress-absorbing layer between the composite resin layer and tooth structure and can decrease restoration microleakage by compensating the effects of polymerization shrinkage (5,6).

Previous studies concluded that the major reasons for

the failure of such restorations are caries and improper bond between glass-ionomer and composite resin (8). Some studies have shown that using glass-ionomer in the sandwich technique leads to a significantly lower bond strength to composite resin in comparison with the use of glass-ionomer (9).

In spite of the extensive use of laminate technique in proximal restorations, only one study has evaluated the bond of glass-ionomers to composite resins, bonded with different adhesive systems (10). During the past years, there have been great changes in compositions and application techniques of resin-based bonding agents; evaluation of the reaction between glass-ionomer and bonding systems, especially newer, commercially available self-etch systems, might help improve the quality and durability of the bond.

The bond of composite resin to both conventional glass ionomer and RMGIC can improve by using bonding agents that increase the wettability of glass-ionomer surface (11). In fact, resin-modified glass-ionomers (RMGIs) can also form chemical bonds to resin adhesive agents (10).

Over the past two decades, self-etch systems have presented with less time required to apply them, so that dental practitioners' interest in the application of acids as a separate etching step has declined (9,12). The compositions and application techniques of these bonding systems have undergone great changes during the past 10 years; however, the bond between composite resin and glass-ionomer by these adhesive systems is still unknown (10).

The aim of the present study was to determine the microshear bond strength (MSBS) of chemically-cured and light cured composites to RMGI using etch-and-rinse and also self-etch adhesive systems. The null hypothesis of this study is that there are no differences between use of etch-and-rinse and self-etch systems on shear bond strength of RMGI to self-cured and light cured composites.

Methods

This in vitro study was carried out on 32 RMGI (RMGI) discs that were randomly divided into 8 groups. Four cylinders of composite resin were placed on each RMGI sample. PVC molds 15 mm in diameter and 2 mm in thickness were used to prepare RMGI discs. The molds were filled with a light cured RMGI cement (Vitrebond, 3M ESPE, St. Paul, USA), which was mixed according to manufacturer's instructions (Table 1). The surface of the filled mold was covered with a glass slab and light cured with a Demi light curing unit (LED Light Curing system, Kerr Corp, Orange, CA, USA) according to the manufacturer's instructions. The light intensity was 800 mW/cm² as measured by a radiometer. Disc samples were randomly divided into 8 groups (n=4) and the following procedures were carried out:

Group 1: Disc surface was etched for 15 seconds with 37% phosphoric acid (3M ESPE Dental Products, St. Paul, MN 55 144, USA), rinsed for 15 seconds and dried for 5 seconds using an air syringe. Single Bond etch-and-rinse bonding agent (Single Bond, 3M ESPE, St. Paul, USA) was applied to sample surfaces and light cured according to the manufacturer's instructions. Four cylindrical plastic molds 0.8 mm in internal diameter and 2 mm in height) were placed on each disc surface, and Z250 light cured composite resin (3M ESPE, St. Paul, USA) was carefully placed inside the molds using a rounded tip periodontal probe and light cured for 40 seconds.

Group 2: The procedures were the same as those in group 1 except that Clearfil SE Bond self-etch primer (Kuraray Medical Inc., Okayama, Japan) was used as the adhesive system according to the manufacturer's instructions.

Group 3: The procedures were the same as those in group 1 except that Clearfil S3 Bond self-etch adhesive (Kuraray Medical Inc, Okayama, Japan) was used according to the manufacturer's instructions.

Group 4: No adhesive agent was applied between RMGIC and light cured composite resin.

The procedures in groups 5-8 were the same as those in groups 1-4 except that chemically-cured composite resin (Master Dent, NY, USA) was used instead of light cured composite resin.

The prepared samples were stored in distilled water at room temperature for 1 hour; then, the plastic cylinders were removed using a scalpel blade and the samples were stored at 37°C for 24 hours to simulate the oral conditions.

The samples were fixed on the mechanical jaw of Universal mechanical testing machine (SANTAM, SMT-20, Iran) for MSBS test and a thin (0.3 mm diameter) brass wire was placed around each resin cylinder in a way that the metallic loop was along the movement path of the load cell. A shearing force was applied at a strain rate of 0.5 mm/min until fracture occurred. Two-way ANOVA, independent *t*-test, one-way ANOVA and Tukey honestly significant difference (HSD) tests were used to analyze the data recorded in MPa at a significance level of <0.05. The adjusted *P* value for limiting the family error rate was considered 0.02 for Tukey test. Data analysis was conducted by the SPSS software version 18.

Modes of failure were assessed for all samples under a stereomicroscope (SZ240, Olympus, Tokyo, Japan) at 40× magnification and were classified as follows: A-Cohesive fracture: fracture within RMGI or composite resin; B-Adhesive fracture: fracture at composite resin-RMGI interface; and C-Mixed fracture.

Two samples were selected from each group for the morphologic evaluation of fractured surfaces under a scanning electron microscope at 50× magnification. Each sample was placed on the special holder of the equipment and gold-sputtered. The specimens were then evaluated morphologically at various magnifications under the

Table 1. Materials, Manufacturers, Composition

Product	Manufacturer	Composition	Application
Adper Single Bond Plus (etch-and-rinse adhesive)	3M ESPE, St Paul, MN, USA SDI Limited	BisGMA, 2-hydroxyethyl methacrylate (HEMA), dimethacrylates, silica nanofiller, ethanol, water, photoinitiator system, methacrylate functional copolymer of polyacrylic and polyitaconic acids; 37% phosphoric acid	After etching, apply a sufficient amount of the adhesive on the cavity surface by a microbrush for 20 seconds. This action was done in duplicate. Lightly air-dry for 5 seconds. Light cure for 10 seconds.
Clearfil SE Bond (two-step self-etch adhesive)	Kuraray Medical Inc, Tokyo, Japan	Primer: 10-methacryloyloxydecyl dihydrogen phosphate (MDP), HEMA, hydrophilic dimethacrylate, dl-camphorquinone, N,N-diethanol-ptoluidine, water bond: MDP, bis-phenol A diglycidylmethacrylate (Bis-GMA), HEMA, hydrophobic dimethacrylate, dlcamphorquinone, N,N-diethanol-p-toluidine, silanated colloidal silica	1. Priming for 20 seconds (no mixing required) 2. Bond apply and light cure for 10 seconds
Clearfil S3 Bond (all-in-one adhesive)	Kuraray Medical Inc, Tokyo, Japan	MDP, diglycidylmethacrylate, bis-GMA, HEMA, hydrophobic dimethacrylate, dl-camphorquinone, ethyl alcohol, water, silanated colloidal silica	Apply a sufficient amount of the adhesive on the surface by a microbrush for 20 seconds. Lightly air-dry for 5 seconds. Light cure for 10 seconds.
Vitremer (Resin modified glass ionomer)	3M Dental Products, St Paul, MN, USA	FAS, PMAA, HEMA	
Filtek Z-250 (FZ250) (Light cure)	3M ESPE, St. Paul, USA	Zirconia/silica BisGMA, UDMA, Bis-EMA	
Master-Dent Paste/Paste Composite (self cure)	Master Dent, NY, USA		

SEM (JSM 6060f; JEOL, Tokyo, Japan).

Results

The mean (standard deviation) values of MSBS are reported in Table 2. The highest MSBS was recorded in group 2 and the lowest MSBS in the control group.

Two-way ANOVA test showed that application of a bonding agent between composite resin and RMGI resulted in a significant increase in MSBS values ($P=0.001$).

According to statistical analysis, there is a significant interaction between the composite resin type and the adhesive system type ($P=0.001$); in other words, depending on the type of the composite resin and the

adhesive system applied, the MSBS of composites to RMGI were different. Therefore, independent t -test and one-way ANOVA was performed separately for each type of composites (Tables 3 and 4).

Independent t -test showed a significant difference between MSBS values of self-cure and light cure composites ($P<0.001$).

Paired comparison of the groups using Tukey's HSD test at <0.02 significance level confirmed that the differences in MSBS among the groups were significant except for Single Bond vs. Clearfil S3 Bond group ($P=0.117$) (Tables 5 and 6).

The one-way ANOVA revealed that the bonding agent systems had a significant influence on the MSBS to RMGI

Table 2. Means and Standard Deviations of Microshear Bond Strength Values (MPa) in the Study Groups

Composite Resin	Group	Bonding System Group	Mean	SD	Number of Samples
Chemically-cured	8	Without bonding	5.94	1.04	14
	5	Single Bond	8.74	1.49	14
	7	S3 Bond	9.67	2.97	14
	6	SE Bond	7.87	2.74	14
Light cured	4	Without bonding ^{ab}	5.46	1.34	14
	1	Single Bond ^a	14.45	2.78	14
	3	S3 Bond	16.23	2.06	14
	2	SE Bond ^b	23.49	1.83	14

Note: Different letters indicate significant difference (Tukey HSD test, $P<0.02$).

Table 3. ANOVA Test Results (Self-cure)

	Sum of squares	df	Mean square	F	P value
Between groups	106.131	3	35.377	7.831	0.000
Within groups	234.906	52	4.517		
Total	341.037	55	35.377		

Table 4. ANOVA Test Results (light cure)

	Sum of squares	df	Mean square	F	P value
Between groups	2307.72	3	769.240	179.935	0.000
Within groups	222.305	52	4.275		
Total	2530.02	55			

Table 5. Tukey Post Hoc Test (Self-cure)

Bonding (I)	Bonding (J)	Mean Difference (I-J)	Standard Error	P value
Control	Single bond	-2.80000*	0.8033	0.0054
Control	S3	-3.72857*	0.8033	0.0001
Control	SE bond	-1.9286	0.8033	.0895
Single bond	S3	-.9286	0.8033	.6570
Single bond	SE bond	.8714	0.8033	.7003
S3	SE bond	1.8000	0.8033	.1258

* The mean difference is significant ($P < 0.05$).

Table 6. Tukey Post Hoc Test (light cure)

Bonding (I)	Bonding (J)	Mean Difference (I-J)	Standard Error	P value
Control	Single bond	-8.98571*	0.78149	0.000
Control	S3	-10.76429*	0.78149	0.000
Control	SE bond	-18.02857*	0.78149	0.000
Single bond	S3	-1.77857	0.78149	0.117
Single bond	SE bond	-9.04286*	0.78149	0.000
S3	SE bond	-7.26429*	0.78149	0.000

* The mean difference is significant ($P < 0.05$).

($P < 0.001$).

Comparison of the mean values of MSBS between bonding systems using the Tukey's test, showed that the differences in bond strength among the groups were not statistically significant except for Single Bond and Clearfil S3 Bond groups vs. control group (respectively $P = 0.0054$, $P = 0.0001$).

The failure modes of each group are presented in Figure 1. The surface morphologies of some samples were evaluated under SEM (Figure 2A-2C).

Discussion

In the present study, applying dentin-bonding agents led to an increase in the bond strength between composite resin and glass-ionomer. Some studies have confirmed our results regarding the application of bonding agents (10-14). In addition, findings indicated that the type of the composite resin (self-cured vs. light cured) had a significant effect on MSBS to RMGI cement, with higher bond strength values obtained for light cure composites.

In light cure composite groups, self-etching systems

had higher bond strength to RMGI compared to etch-and-rinse system. It has been reported that application of self-etch systems causes higher bond strength between GI and light cure composite resin compared to etch-and-rinse systems, which is consistent with the results of the present study (13,15,16).

Etching the surface of RMGIC with 37% phosphoric acid compromises the surface layer by dissolving the fillers beneath the surface layer matrix of GI cement; therefore, the cohesive strength of RMGIC is reduced with decreasing the bond strength between composite resin and GI (16-18). In the study of Zhang et al, it was shown that there was no significant difference in bond strength with respect to the decrease in the etching duration (10).

Etching and rinsing reduce HEMA and functional methacrylate groups on the surface of RMGI. Therefore, eliminating the functional groups involved in chemical bonding can reduce RMGI's bond strength to composite resin (19). Etch-and-rinse systems need two separate steps of rinsing and drying; thus, over drying produces microcracks on surface of GI, which might significantly

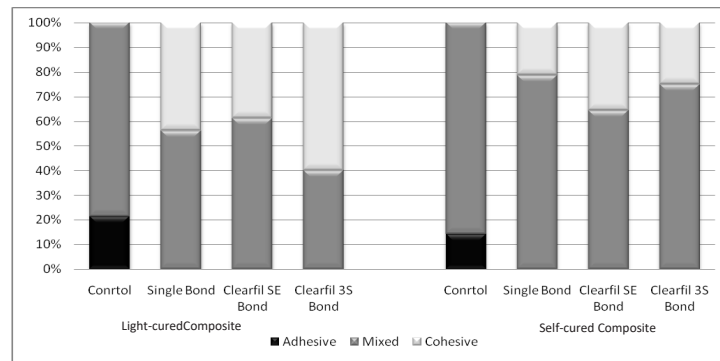


Figure 1. Frequency Percentages of the Fracture Patterns of Samples in the Groups Under Study.

decrease the bond strength. Additionally, self-etch bonding systems have potential to bond to the calcium and strontium in the glass-ionomer structure and exhibit a higher bond strength compared to etch-and-rinse bonding systems (10).

In the present study, we used two self-etch systems of SE Bond and S3 Bond to compare self-etch systems. SE Bond is a two-step self-etch primer without fluoride, containing acidic monomers (10-MDP) that dissolves the surface of RMGIC to produce a mildly etched RMGI surface (20). The pH reported for SE Bond and S3 Bond is 2 and 2.7, respectively. Due to its higher acidity, SE Bond primer

causes a more effective etching of the RMGI surface compared to S3 Bond, resulting in higher bond strength in light cure composite resin groups. Tukey's HSD test showed a higher bond strength between RMGI and light cured composite resin after the application of the self-etch primer system (Clearfil SE Bond) compared to other groups. One factor that is effective on bond strength is the viscosity of the bonding agent. According to the study of Mount et al, higher bond strength is achieved between composite resin and RMGIC with a decrease in the viscosity of the bonding agent because of the lower contact angle, leading to better wetting of the surface by the bonding agent (21). One previous study showed that self-etch adhesive systems (Clearfil SE Bond) yielded higher shear bond strength between glass ionomer and composite due to lower acidity compared to intermediate and strong self-etch adhesives (22). The primer of SE Bond system has a lower viscosity compared to S3 Bond, which can explain the higher bond strength of this adhesive to light cured composite resins.

In the light cure composite resin groups in which an adhesive system was applied on RMGI, the lowest bond strength was recorded for Single Bond adhesive system.

Because the majority of dental adhesive systems in the market are light cured, the present study investigated the effect of light cured adhesive agent on bond strength between RMGI and light and chemically-cured composites. The results showed bonding agent and the type of composite resin (light cured or self-cured) had a significant effect on MSBS of the samples. However, in the control groups, no significant difference was observed in the bond strength of RMGI between the chemically-cured and light cured composite resins. One of the factors that can be taken into account in this respect is the effect of the pH of these bonding agents on chemically-cured composite resins. It should be pointed out that the results of using SE Bond system in chemically-cured composite resin groups were reversed and SE Bond exhibited a lower bond strength compared to S3 Bond and Single Bond, with no statistically significant difference.

It has been shown that bonding agents with high acidic

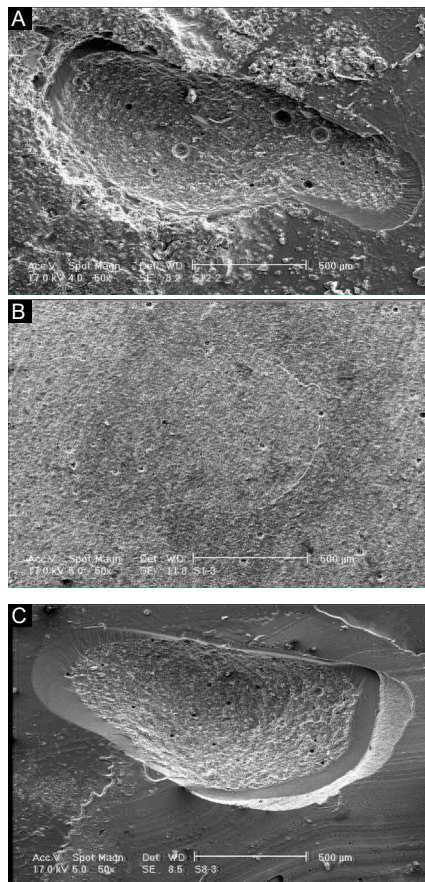


Figure 2. (A) Mixed fracture. (B) Adhesive fracture. (C) Cohesive fracture.

pH values can decrease bond strength to chemically-cured composite resins, and the presence of acidic monomers in the oxygen-inhibited layer results in the neutralization of the amine agent in the chemically-cured composite resins, and consequently a decrease in the rate of polymerization (23). Some studies have demonstrated a chemical incompatibility between the simplified dental adhesives and dual-cured and chemically-cured composite resins (24-27).

Although the acidity of the S3 Bond system (pH=2.7) is much higher than that of Single Bond system (pH=4.6), the results of the present study did not show any differences in bond strength between groups in which adhesive systems of S3 Bond and Single Bond were used to bond chemically-cured composite resin to light cured GI. It seems that the detrimental effect of acid etching on the surface of RMGI by 37% phosphoric acid for 15 seconds before the application of Single Bond adhesive is comparable to the adverse effects of incompatibility between the acidity of the self-etch bonding systems and chemically-cured composite resin. It is necessary to conduct further studies to investigate the use of dual-cured and chemically-cured bonding systems to create a bond between GI and chemically-cured and dual-cured composite resins so that these incompatibilities can be elucidated.

Based on the results of the present study, except for the control group in which adhesive and mixed fractures happened, in other groups the failures were of the cohesive and mixed types. Cohesive fractures were found to be noticeable especially in the self-etch adhesive groups. It has been suggested in some studies that cohesive fracture in the substrate can indicate a high bond strength (11); however, some others have reported no relationship between bond strength and fracture type (28,29). In the previous studies, most fractures of GICs and RMGICs have been considered to be of the cohesive type (30,31), which can be attributed to the physical and mechanical drawbacks of the tests used.

Based on the results of the present study, the interaction between composite resin type and the bonding system on the bond strength to RMGI was significant; in fact, depending on the type of the composite resin and the curing system used, the type of the bonding system and its application technique, the need for etching before application and the pH of the bonding system, different bond strength values between composite resin and RMGI can be obtained. Further studies needed because the bond between RMGI and composite resin is an important factor in restoration durability.

Conclusions

Given the limitations of the present study, it can be concluded that application of bonding systems results in an increase in MSBS between Vitrebond RMGIC and light cured and self-cured composite resins. The MSBS

of RMGIC to light cured composite resin by means of a bonding agent was significantly higher than that to self-cured composite resin. The bond strength of composite resin to RMGI could vary depending on the type of the composite resin and the adhesive system. It seems that the two-step self-etch primer results in the highest increase in the MSBS of light cured composite resin to RMGI.

Authors' Contribution

All authors have contributed to the concept and design of the study. MS contributed to the data collection. The statistical analyses and interpretation of data were carried out by SK, BA and MS. SK and MS drafted the manuscript. All the authors critically revised, read and approved the final manuscript.

Ethical Statement

The study was approved by the ethical committee of Hamadan University of Medical Sciences.

Conflict of Interest Disclosures

The authors declare that they have no conflict of interests.

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