Original Article

Effect of Self-etching Adhesives on the Bond Strength of Glass-Ionomer Cements

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Abstract

Objective: Statement of Problem: Adequate bond strength between glass ionomer cements and composite resin is necessary for the success of the sandwich technique.
Purpose of Study: This study assessed the micro-shear bond strength of composite resin to glass-ionomer cements (GIC) using self-etch adhesives with different pH values.

Materials and Methods: One hundred specimens (6×4×2 mm) were made using Fuji II and Fuji II LC GICs and treated with different adhesives as follows: Group 1:Fuji II+ Adper Prompt L-Pop, Group-2: Fuji II+SE bond, Group-3: Fuji II + AdheSE, Group-4:Fuji II+ Protect bond, Group-5: Fuji II + Single bond, Group-6:Fuji II LC+ Adper Prompt L-Pop, Group-7: Fuji II LC+SE bond, Group-8:Fuji II LC+ AdheSE, Group-9: Fuji II LC+ Protect bond, and Group-10: Fuji II LC+ Single bond. Each group consisted of 10 specimens. A cylinder of Z100 composite resin was placed on each sample and light cured. After 24 hours of water storage (37˚C), the specimens were subjected to micro-shear bond strength tests (0.5 mm/min). Data were analyzed using two-way ANOVA and Tukey's test.

Results: The mean micro-shear bond strength of groups 1-10 was 11.66±1.79, 16.50±1.85, 18.47±1.77, 13.95±1.77, 15.27±1.49, 15.14±0.90, 20.03±1.19, 17.48±3.00, 16.24±1.98 and 16.03±1.49 MPa, respectively. There were significant differences between groups 1 and 7 ($P<0.05$). No significant difference was observed between other groups ($P>0.05$). Fuji II LC showed higher bond strength than Fuji II ($P<0.05$).

Conclusion: Type of self-etch adhesive had no significant effect on micro-shear bond strength of glass-ionomer to composite resin. Resin modified glass ionomer cement (RMGIC) exhibited higher bond strength than the conventional GIC.

Key words: Adhesives; Adper Prompt self-etch; Clearfil SE bond; Composite resins; Glass ionomer cements

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INTRODUCTION

Glass ionomer cements (GICs) have special properties, including chemical bonding to moist tooth structure, long-term fluoride release, low thermal expansion coefficient, optimal biocompatibility, hydrophilicity and anticariogenic activity. However, their application is associated with certain disadvantages such as inferior mechanical properties, low wear resistance, early moisture sensitivity, low

polishability, porous surface and low strength [1-2]. Composite resins are popular for their superior esthetic and physical properties; however, their use is associated with pulpal irritation and marginal microleakage especially at the cervical margins in some cases [3]. Use of glass ionomer cements in conjunction with composite resins, known as the sandwich technique, has been suggested as an effective method benefitting from the favorable properties of both materials in a single restoration [4]. In this process, the shortcomings of both materials are somehow eliminated.

Furthermore, chemical bonding to dentine and consequent micromechanical bonding to composite resin can be obtained when the GIC is used as a liner or base. The clinical advantages of this technique include pulpal protection, anticariogenic effect of fluoride release, reduced composite mass and consequently decreased polymerization shrinkage [5-6].

Adequate bond strength between the two materials is necessary for the success of sandwich technique. Adhesion of conventional glass ionomer to composite resin is completely micromechanical requiring microscopic pores on the glass ionomer surface for subsequent penetration of bonding resin; this can be achieved by acid etching of the glass ionomer surface with phosphoric acid together with the application of bonding resin [7].

Taggart and Pearson in 1991 showed that early etching of freshly set GICs decreased the mechanical properties and strength of the bond while delayed surface etching (24 hours after setting of the cement) improved the bond strength [8].

Hinoura and Suzuki in 1991 reported that bonding agents with lower pH dissolved the surface of the GIC and compromised the mechanical interlocking [9]. However, Taher and Ateyah demonstrated that etching of the surface of RMGIC did not improve the bond strength [10]. Self-etch bonding adhesives are composed of aqueous mixtures of acidic phosphoric esters and resin monomers [11].

These bonding agents contain acidic monomers, which are capable of simultaneous etching and priming; thus, the need for separate etching and washing is eliminated. All these decrease technique-sensitivity and improve the clinical efficacy of the simplified bonding procedures [12]. In other words, the main advantage of self-etching bonding adhesives is the elimination of separate procedures; consequently, the combination errors and post-operative tooth hypersensitivity will decrease [11, 13].

Self-etching products differ in pH values based on their acidic monomer or organic polymerizing acid contents and have been classified as mild, intermediate or strong with regards to their pH values: a pH of 1 or lower is considered strong, 2 or higher is considered mild and between 1 and 2 is considered intermediate. It has been shown that pH of self-etch bonding agents plays a critical role in the formation of a hybrid layer and resin tags [12-14].

Gopikrishna showed that the bond strength of composite to GIC was higher for self-etch adhesives applied to unset GIC, as compared to etch and rinse adhesives [15].

Arora assessed the role of self-etch adhesives in adhesion of composite resins to RMGIC. He found that application of self-etch adhesive between RMGIC and composite resin increases the shear bond strength of RMGIC to resin composite, as compared to the etch and rinse adhesives [16].

Kandaswamy showed that application of mild self-etch bonding agent over unset GIC improved the bond strength of GIC to composite resin, compared to the use of strong and intermediate self-etch bonding agents [17].

Etch and rinse adhesives have been repeatedly utilized in the sandwich technique and some studies have assessed their efficacy. However, to the best of our knowledge, there are few studies about the effect of self-etching adhesives with different pH values on the bond strength of GICs to composite resins [17].

Therefore, the purpose of the present study was to evaluate the micro-shear bond strength of composite resin to conventional and resin modified GICs after the use of self-etch bonding adhesives with different pH values.

MATERIALS AND METHODS

One hundred GIC specimens were fabricated in the molds with the dimensions of 6×4×2 mm. Half of the specimens (groups 1-5) were made of the conventional glass ionomers (Fuji II, GC International Corp., Tokyo, Japan) while RMGICs (Fuji II LC, GC International Corp, Tokyo, Japan) were used for the fabrication of the remaining specimens (groups 6-10). Table 1 lists the materials used in this study.

The specimens were prepared as follows:

Group 1: Fuji II conventional glass ionomer was mixed to fill the mold according to the manufacturer's instructions.

The mixed cement was placed in the molds, a Mylar strip was placed on its surface and a glass slide was also placed over the surface to obtain a smooth surface without porosity.

After setting, Adper Prompt L-Pop self-etch adhesive was applied to the GIC surface according to the manufacturers' directions. For this purpose, two liquid components were mixed and applied to the glass ionomer surfaces for 15 seconds using a special applicator tip.

The solvent was evaporated with gentle air stream and light curing was performed for 10 seconds.

Table 1. Materials evaluated in this study

Material	pH	Composition	Manufacturer	Lot
Fuji II		Powder: Fluoroaluminosilicate glass Liquid: acrylic acid, maleic acid, tartaric acid, water	GC International Corp., Tokyo, Japan	0702021
Fuji II LC		Powder: Fluoroaluminosilicate glass Liquid: acrylic acid, maleic acid, HEMA, water, comphorquinone	GC International Corp., Tokyo, Japan	0702141
Adper Prompt L-Pop	0.4	Red cushion: Methacrylic phosphates, bisGMA, Photo-initiator. Yellow cushion: Water, HEMA, Polyalkenoic acid polymer	3M ESPE, MN, USA	282227
Clearfil SE bond	1.9	Primer: water, MDP, HEMA, CQ, DET, hydrophilic DMA Bond: MDP, bisGMA, HEMA, hydrophilic DMA, CQ, DET, Silanized colloidal Silica	Kuraray, Tokyo, Japan	51405
Clearfil Protect bond	2	Primer: water, MDP, MDPB, HEMA, DET, hydrophilic DMA Bond: MDP, bis GMA, HEMA, hydrophilic DMA, CQ, DET, Silanized colloidal silica, surface-treated sodium fluoride	Kuraray, Tokyo, Japan	51128
AdheSE	1.4	Primer: acrylic ether phosphoric acid, bisacrylamide, water, CQ, stabilizers Bonding: BisGMA, GDMA, HEMA, fumed Silica, CQ, tertiary amine, stabilizers	Vivadent-Ivoclar	H 32401
Adper Single bond	4.6	Adhesive: dimethacrylate, HEMA, Polyalkenoic acid copolymer, 5nm saline treated colloidal silica, ethanol, water, photo-initiator	3M ESPE, MN, USA	20061128

Z100 composite resin (3M Dental Products Division, St Paul, Minn., USA) was applied to the standard Tygon tubes with an internal diameter of 0.7 mm and height of 1 mm and placed over the glass ionomer surfaces in a manner that the tubes were perpendicular to the surface and parallel to the horizontal axis. The composite resin was allowed to set after light curing for 40 seconds. The prepared specimens were stored in distilled water at 37°C for 24 hours.

A light-curing unit (Aria Lux, Fara Banafsh Teif Co., Tehran, Iran) was used to set the light-cure glass ionomer cement, adhesives and composite resin with an intensity of > 650 mW/cm^2.

Groups 2-5 were prepared in an identical procedure. Different bonding agents were used in each group as summarized in Table 2. The only difference was that:

To prepare groups 6 to 10 Fuji II LC RMGIC was used instead of Fuji II. Bonding agents were applied according to the protocol used for groups 1 to 5.

All specimens were mounted on micro-tensile tester (Bisco Inc., USA) using cyanoacrylate glue (Zapite, USA). The crosshead speed of the machine was 0.5 mm/ min. Micro-shear bond strength of specimens was calculated by dividing the load force at specimen fracture (in Newton) by its surface area (mm^2) and expressed in MPa. Data were analyzed using two-way ANOVA and Tukey's test. P-values <0.05 were considered statistically significant.

RESULTS

The minimum and maximum bond strength values were 11.66±1.79 MPa for Fuji II+L-Pop and 20.03±1.19 MPa for Fuji II LC+SE Bond, respectively. The mean values and standard deviations of micro-shear bond strength of 10 groups are presented in Table-2. The normal distribution of the data was tested by means of one sample Kolmogorov-Simonov test, which was approved with the least P-value of 0.369. Furthermore, the data were homogenous as shown by Levene's statistic (90 = 0.47).

Table 2. Micro-shear bond strength of studied groups

Group	Material	Mean (MPa)	SD	95% confidence interval		Minimum	Maximum
				Lower bound	Upper bound		
1	Fuji II+L-Pop	11.66	1.79	7.60	15.71	6.75	21.83
2	Fuji II+SE	16.50	1.85	12.29	20.70	8.05	24.43
3	Fuji II+ AdheSE	18.47	1.77	14.46	22.49	7.53	24.95
4	Fuji II+ Protect bond	13.95	1.50	10.53	17.36	8.05	20.01
5	Fuji II+ Single bond	15.27	1.49	11.89	18.65	7.01	21.31
6	Fuji II LC+L Pop	15.14	0.90	13.10	17.19	11.69	20.53
7	Fuji II LC+SE	20.03	1.19	17.33	22.73	13.77	24.95
8	Fuji II LC+ AdheSE	17.48	3.00	13.68	18.37	12.47	22.35
9	Fuji II LC+ protect bond	16.24	1.98	11.75	20.72	8.05	29.11
10	Fuji II LC+ Single bond	16.03	1.49	12.65	19.40	10.65	25.21

Therefore, two-way ANOVA was used to compare the micro-shear bond strength of different specimens.

Fuji II LC exhibited significantly higher bond strength in comparison with Fuji II. In other words, the type of GIC markedly affected the bond strength ($F_{1,90} = 4.78$, $P=0.031$). Furthermore, microshear bond strength was shown to be affected by the type of bonding agent ($F_{1,90} = 3.15$, $P=0.018$). Tukey's test revealed significant differences between groups one and seven (i.e., Fuji II+ L-Pop and Fuji II LC+ SE bond ($P=0.015$). No other significant differences were noted between the remaining groups ($P>0.05$). The interaction between the bonding agent and GICs was not significant ($F_{4,90} = 47$, $P=0.756$).

DISCUSSION

Applying GICs beneath the composite resins (sandwich technique) is a routine restorative technique benefitting from the favorable properties of both materials. Adequate bond strength between the GIC and the composite resin is necessary for the success of this technique [18]. The current study assessed the effect of application of different self-etch bonding agents on the bond strength of composite resin to conventional and resin-modified GICs.

The bonding systems used included a strong self-etch bonding agent (Adper Prompt L-Pop), a moderate self-etch bonding agent (AdheSE), a mild self-etch bonding system (Clearfil SE bond), a fluoridated mild self-etch bonding system (Clearfil Protect bond) and one etch and rinse bonding system (Adper Single bond) as the control, which are all highly popular bonding systems.

The obtained data regarding the micro-shear bond strength of different groups showed that Group 1 (Fuji II + Adper Prompt L-Pop) had the least strength values while Group 7 (Fuji II LC + Clearfil SE Bond) showed superior performance in comparison with other groups; the difference between these two groups was statistically significant. No other significant differences were noted.

Adper Prompt L-Pop is a strong self-etch bonding system while SE bond is a weak self-etch bonding agent. Kenshima et al. reported that strong self-etch adhesives (low pH) produced the lowest bond strength of resin to dentin [14]. Other investigations have reported that highly acidic self-etching adhesives contain higher solvent contents for promoting complete ionization of the acidic monomers. Thus, the adhesive layer after solvent evaporation will be quite thin, i.e. polymerization may be inadequate due to the formation of an air-inhibited layer. Consequently, unpolymerized acidic monomers will increase in this layer. All these factors compromise the polymerizing initiator system interfering with composite polymerization; thus, the bond strength of strong self-etching adhesives will be reduced [19].

Furthermore, the mechanism of action of strong self-etching adhesives is very similar to that of etch and rinse adhesives in which hydroxyapatite minerals are removed from the collagen surface layers following the application of adhesive to the teeth. This results in diminished chemical interactions between minerals, hydroxyapatite and functional monomers in turn [12]; thus, relying on mere micromechanical bonding in the absence of chemical bonding seems to lead to a lower bond strength, which is another factor that may contribute to the lower bond strength in strong self-etching adhesives. Hinoura et al. reported that low pH bonding agents mostly dissolve the GIC surface and increase micromechanical attachment [9]; this phenomenon was not observed in the current study.

According to Moli et al. Prompt L-Pop contains water as the solvent and solvent evaporation occurs slowly in these systems. Furthermore, the HEMA/water ratio increases when small amounts of solvent (water) are evaporated; the pressure of evaporation is lowered and the remaining water settles at the bond interface.

All these interfere with complete polymerization [20]. Incomplete polymerization of this bonding system may have also reduced its bond strength to GIC in the current study.

Clearfil SE Bond contains 10-methacryloxydecyl dihydrogen phosphate (10-MDP) as the functional monomer. This system is capable of producing very strong ionized bonds with calcium, which means monomers chemically interact with hydroxyapatite in the dentin and enamel in addition to micromechanical bonding. The rationale may be attributed to the higher bonding strength of the system [21]. This chemical interaction only occurs in mild self-etching adhesives as they cannot produce complete demineralization of the surface, having led to some hydroxyapatite crystals remaining on the collagen. Thus, chemical bonds with carboxylic acid-based monomers or phosphate will develop [21]. As GICs contain calcium, their chemical interaction with acid-etching functional monomers may also improve the bonding strength.

Van Meerbeek et al. (2003) stated that mild acidic self-etch bonding adhesives like SE bond are not capable of decalcifying the tooth structure effectively and the remaining hydroxyapatite crystals become involved in additional chemical bonding reactions. The presence of 10-MDP in these bonding systems results in chemical bonding with hydroxyapatite particles. MDP monomer was originally synthesized by Kuraray (Protect bond, SE bond). Its capability of forming strong ionic bonds with mineral ions like calcium may be partly attributed to its intense chemical adhesion to tooth structure [22]. Similarly, application of mild self-etch adhesive to GIC results in minimal flushing of ions. Consequently, remaining cations are available to make strong ionic bonds between the two materials [17].

Li et al. indicated higher shear bond strength of composite to RMGIC than conventional GIC; their findings were in agreement with the results of our study [23]. Different factors may be responsible for the increased shear bond strength of RMGICs in comparison with the conventional cements. For example, unpolymerized HEMA on the surfaces of the RMGICs increases the surface wettability of the bonding agent and can increase the bond strength when it polymerizes [24]. Also, unsaturated methacrylate groups on the polyacid chain of polymerized RMGIC may form strong covalent bonds with the resin bonding agent and improve adhesion at the interface of the two materials [25]. Last but not least, the higher cohesive strength of RMGIC might be responsible for the higher bond strength achieved [24].

CONCLUSION

Within the limitations of this study, type of self-etch bonding agents had no significant effect on micro-shear bond strength of GICs to composite resin. RMGIC exhibited higher bond strength than the conventional GIC.

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