

Original Article

Effect of Caries Removal Methods on the Shear Bond Strength of Resin and Glass Ionomer Adhesives to Primary Dentin

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Abstract

Statement of Problem: There is no enough published data about the shear bond strength of resin modified glass ionomer adhesives on caries-affected primary tooth dentin excavated using minimally invasive systems.

Objectives: To evaluate the shear bond strength of 2 different adhesives (one resin modified glass ionomer and one resin) using two caries removal techniques on healthy and caries-affected primary dentin.

Materials and Methods: Two caries removal methods including mechanical (handpiece) and chemomechanical (Carisolv) techniques and two types of adhesives including one resin adhesive (Clearfil SE Bond; CSEB, Kuraray) and one resin-modified glass ionomer adhesive (Riva Bond LC; RBLC, SDI) were used in this study. Ten extracted healthy primary teeth were used for the control group. The teeth were sectioned bucco-lingually and mesio-distally in order to obtain four specimens from each tooth. Thirty suitable specimens were selected as the “control” and randomly divided into two groups of “sound dentin” based on the type of the adhesive used. Sixty extracted caries affected teeth were used for the carious group; sectioned as mentioned above and sixty suitable specimens were selected as the “treatment”. Then the specimens were arbitrarily divided into four groups based on caries removal techniques and the type of adhesive used (n = 15). After bonding with either CSEB or RBLC, the specimens were restored with a resin composite by means of PVC tubes and subjected to the shear bond strength test. The data was analyzed using ANOVA and Tukey’s test.

Results: The specimens in Carisolv group bonded with CSEB (11.68 ± 3.1) showed a statistically significant higher mean bond strength followed by those in handpiece group bonded with CSEB (9.4 ± 2.7), which exhibited higher mean values than those groups with RBLC ($p < 0.05$). Shear bond strength values for Clearfil SE Bond was not significantly higher than Riva Bond LC when used in sound dentin.

Conclusions: The lowest shear bond strengths for both adhesives were observed on caries-free dentin.

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Introduction

The management of dental caries has changed significantly from G.V. Black's "extension for prevention" concept to "prevention of extension" due to the advances in tooth coloured restorative materials and adhesive dentistry, along with a better understanding of the potential for re-mineralization of the tooth structure. The purpose of a conservative approach is to prevent the progress of a 'cavitated' carious lesion using minimal removal of the hard structure of the tooth so as to preserve the tooth integrity and pulp vitality, promote the healing of the remaining dentino-pulpal complex, and eliminate a more extensive restoration [1].

Conventional caries removal using rotary instruments often results in the removal of most of the caries-affected dentin leading to excessive loss of the tooth structure [2]. This method also increases the thermal effect and pressure to the pulp [3]; that may be a greater problem in the primary teeth due to their large pulps and open dentin tubules. The frequent need for local anesthesia [4] and unpleasant vibrations felt by patients [5] may increase anxiety and fear of dental procedures. Thus, to reduce some of the factors, the application of the chemomechanical caries removal (CMCR) method [6], based on the non-invasive technique activity of a solution of monochloroaminobutyric acid (MAB) marketed as GK101E, was introduced in the late 1970s [7]. The action of MAB involves disruption of collagen in the carious dentin, thus facilitating its removal.

In addition to removing the infected tissue, CMCR can maintain the healthy tooth structure and prevent pulpal irritation and patient discomfort [8,9]. In the 1980s, a new CMCR solution was developed by adding sodium chloride, glycine, 5% sodium hydroxide and aminobutyric acid, named Caridex. More recently a newer system, Carisolv (Mediteam Dental AB, Savedalen, Sweden), was introduced to supersede the Caridex system.

There is an indication of different bond strengths between the primary and permanent tooth dentin. Hosoya *et al.* [10] investigated the bond strengths of three dentin bonding systems to the sound permanent and primary dentin, reporting that the bond strengths to primary dentin were significantly lower than those to permanent dentin. They also reported that the influence of Carisolv on resin adhesion to both primary and permanent dentin differed between the type of adhesive systems used, which may

be due to the adhesive's composition as well as the way they adhere to the tooth structure. Besides the considerable interest in aesthetic restorative materials, many bonding systems have been developed in order to provide high strength bonding to the dentin, ensuring the longevity of the restoration and preventing the marginal leakage and secondary caries [11,12].

Clearfil SE Bond (CSEB) is one of the most popular and extensively researched 2-step self-etching priming systems currently available. Koyuturk *et al.* [13] reported higher shear bond strength for CSEB than Prompt L-Pop (3M/ESPE), one-step resin based adhesive, to both caries-affected and sound dentin. A retention rate of 93% clinical success in cervical restorations bonded with CSEB over a period of 2 years was reported 2% better than a single bottle system [14] while another study revealed almost 100% retention rate in the 5 year follow up [15].

Riva Bond LC (RBLC) is a recent commercially available light-cured resin-modified glass ionomer (RM-GI) adhesive used in the placement of direct resin composite restorations. Based on the manufacturer's claim, the continuous release of fluoride, short setting time, adhesion properties and the ability to compensate for the volumetric polymerization shrinkage of resin restorative make this material a useful adhesive in numerous situations where other resin-based systems may not be well suited.

A recent study [16] investigated the microtensile bond strength of three RM-GI adhesives to the dentin, reporting that Riva Bond LC showed comparable bond strength with Fuji Bond LC, and both adhesives showed significantly higher microtensile bond strength than Ketac N100 primer. The authors concluded that forming a typical ion exchange layer between the RM-GI adhesives and dentin might be a key factor for creating a strong bond.

Little is known about the shear bond strength of resin-modified glass ionomer adhesives on caries-affected primary tooth dentin that has been excavated using minimally invasive systems [9,17]. The objectives of the present study were to: 1) compare the shear bond strengths of a two-step self-etching priming resin adhesive with a RM-GI adhesive to sound and caries-affected primary dentin; and 2) examine the influence of two caries removal techniques on the shear bond strength of the two adhesives to the caries-affected primary dentin. The null hypotheses are: 1) there is no difference between

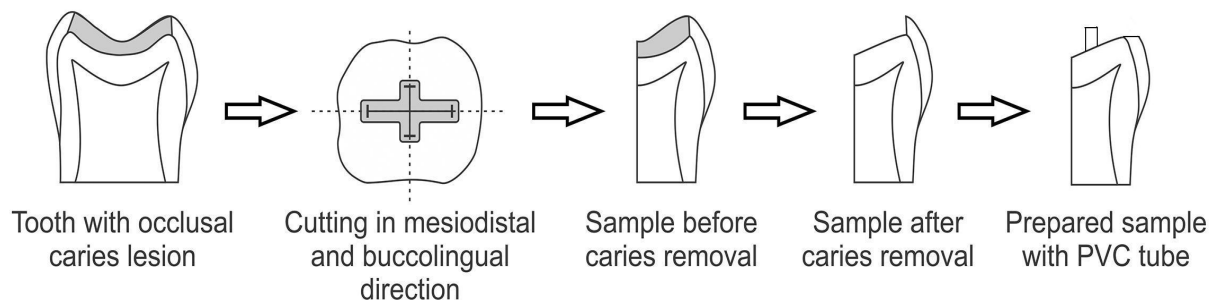


Figure 1: Schematic draw of the specimen preparation

the shear bond strength of two adhesives to sound and caries-affected dentin, and 2) the method of caries removal does not affect the shear bond strength of the adhesives to the caries-affected dentin.

Materials and Methods

The approval of Ethics Committee for using extracted teeth was obtained from Shiraz Dental School, Shiraz University of Medical Sciences (Application # 4521).

Sample size calculation

Overall, 70 freshly extracted teeth were collected from pediatric clinics including 10 non-carious and 60 carious primary molars with occlusal caries. The teeth were stored in normal saline at room temperature immediately after extraction, disinfected and cleaned with an ultrasonic scaler, and then stored in 0.1% chloramine T solution at 4°C until needed.

All the teeth were sectioned as explained below and the most suitable specimens were selected. The non-carious specimens were selected as the “control group” and randomly divided into two groups of 15 based on the type of adhesive used. The carious specimens were considered as the “treatment group” and arbitrarily divided into four groups, each

containing 15 specimens, based on caries removal techniques and the type of adhesive used (Table 1). The sample sizes were calculated according to the previous similar studies at the level of $\alpha = 0.05$ and based on bilateral power 80, 15 specimens for each group were indicated ($N = 4 \times 15 = 60$).

Tooth preparation for carious tooth group

The teeth selected for the study exhibited cavitated occlusal caries lesions that occupied less than half the depth of the coronal dentin. The roots were removed by diamond disk and sectioned beneath the occlusal lesion parallel to the occlusal surface. Each section was then cut bucco-lingually and mesio-distally in order to obtain four specimens (Figure 1). The most suitable specimens were selected; this included at least 2 mm dentin thickness between the tooth surface to the pulp and was at least 1.4 mm wide, being equal to the PVC tube diameter used in the bond test.

The selected 60 specimens were divided into two groups; in group one, caries was removed using Carisolv multimix gel (Mediateam Dental AB, Save-dalen, Sweden) and hand instruments in accordance with the manufacturer’s instructions (Table 2). In the second group, caries was removed using new round steel burs (sizes 3 and 5) in a slow-speed hand piece. Caries removal continued until the sound den-

Table 1: Division of Specimens					
Group 1 (n = 15)	Group 2 (n = 15)	Group 3 (n = 15)	Group 4 (n = 15)	Group 5 (n = 15)	Group 6 (n = 15)
Sound dentin bonded with CSEB	Sound dentin bonded with RBLC	Caries removed by Carisolv and bonded with CSEB	Caries removed by Carisolv and bonded with RBLC	Caries removed by hand piece and bonded with CSEB	Caries removed by hand piece and bonded with RBLC

tin (hard tissue) was reached, using a blunt dental explorer.

Tooth preparation for the control group

The crowns were sectioned parallel to the occlusal plane to provide a mid-coronal zone of the dentin, and each sample was then segmented vertically, as mentioned above, into 4 specimens. Overall, 30 specimens were selected from the 10 teeth and randomly divided into two groups, based on the type of adhesive used (n = 15).

For all specimens, both enamel and dentin were reduced to the same level as the excavated caries lesion of the specimen. Only the specimens that had a surface of at least 1.4 mm in width were used,

consisting of caries-affected dentin for placement of a PVC tube. Flattened specimens were mounted by placing the flattened tooth surface onto a glass slab and holding the specimen in place with sticky wax (Ainsworth, Marrickville, NSW, Australia). A plastic ring with internal diameter of 15 mm was placed over the tooth samples, and filled with Type IV dental stone (GC FUJIROCK EP, Tokyo, Japan). In each group, specimens were divided into two subgroups based on the adhesive used. After bonding with either CSEB or RBLC, according to the manufacturer's instructions (Table 2), a PVC tube (Microtube Extensions, Sydney, NSW, Australia) with an internal diameter of 1.4 mm was placed on the bonded dentin surface. The tube was filled

Table 2: The study groups, materials and methods of application

Material	Manufacturer	LOT Number	Application
Riva Bond LC	SDI, Bays water, Vic, Australia	R60911	Samples were treated by Riva conditioner (37% Phosphoric acid for 5s, then capsule was activated, mixed using (Ultimate 2 amalgamator, SDI, Vic, Australia) for 10 s, pierced the metal foil with an applicator, applied by micro brush and cured for 20 seconds.
Clearfil SE Bond	Kuraray Medical Inc., Okayama, Japan	01039A	A layer of primer was applied, dried with a light jet of air, adhesive was applied and the excess was removed with a light jet of air then light cured for 20 seconds
Carisolv	Mediteam Dental AB, Sweden	12-03	The Carisolv gel was mixed using twin multi mix syringe dispenser and applied to the carious lesions using a cotton pellet. After 30 seconds the soft dentin was excavated using the number 2 hand instrument. When the gel was contaminated with debris, after application, it was removed with a cotton pellet and the fresh gel was applied. The procedure was continued until the gel was clear and the surface of the dentin was hard when scraped with a blunt dental explorer. The remaining gel was washed off, using a wet cotton pellet.
TPH3	Dentsply international Inc, USA	1109241	The PVC tube was filled with resin composite using a plastic instrument then cured for 40 seconds

with hybrid resin composite (Table 2) and light-cured according to the manufacturers' recommended exposure times using an LED curing light with a wavelength range of 440-480 nm at an output of 1500 mW/cm² (Radii plus LED, SDI, Bayswater, Vic, Australia). After curing, the tube was removed using a No. 11 scalpel blade leaving a cylinder of resin composite with 2 mm height attached to the dentin. The finished specimens were transferred to distilled deionized water and stored at 37°C for 24 hours in the incubator.

The mounted and bonded specimens were loaded parallel to the interface using a thin edge blade at a crosshead speed of 1mm/min on the universal testing machine (Zwick/Roll Z020, Zwick GmbH & Co, Germany). Shear bond strength was calculated using the following formula:

$$\text{Shear Bond Strength (MPa)} = \frac{\text{Shear Force (N)}}{\text{Cross - Sectional area (mm}^2\text{)}}$$

The collected data were analyzed by adapting the SPSS package, version 18 (SPSS Inc., Chicago, IL, USA). Two-way analysis of variance (ANO-

significant differences for shear bond strengths of all groups. The results of two-way ANOVA did not show a statistically significant association between the caries excavation methods and adhesive type ($p = 0.853$). However, when the interaction terms were ignored and the main effects of the methods were fitted to each material, strong significant differences were observed. For each bonding system, there were statistically significant differences between the caries removal methods ($p < 0.001$). The difference between the two bonding systems used was not significant for Carisolv excavation method; yet, it was significant for the group treated by a hand piece ($p < 0.001$). For CSEB, the difference between Carisolv treated group and handpiece treated group was not significant ($p = 0.15$). The results of Mann-Whitney test showed no significant differences between the sound dentin bonded with RBLC and CSEB ($p = 0.873$).

Discussion

There are conflicting reports on the shear bond strength of resin adhesives to the dentin after using

Table 3: Mean values and standard deviations for shear bond strength, MPa (± SD) of bonding systems in the control and treatment groups (n = 15)

Bonding	Method	Sound Dentin (Control Group)	Handpiece (Treatment Group)	Carisolv (Treatment Group)
Clearfil SE Bond		^A 6.7 ± 1.2	^{A,b} 9.4 ± 2.7	^{A,b} 11.7 ± 3.1
Riva Bond LC		^A 6.2 ± 0.9	^{B,b} 6.1 ± 1.4	^{A,c} 9.1 ± 2.5

Means with the different upper-case letter in each column were significantly different ($p < 0.05$).

Means with the different lower-case letter in each row were significantly different.

VA) was used to evaluate the interaction between the caries excavation method (Carisolv or bur) and adhesive type (CSEB or RBLC) in the treatment groups. Differences between the two adhesives were assessed using one-way ANOVA and Tukey's test for each bonding system in terms of two substrates, namely the excavation methods (Carisolv or bur) at a statistical significance level of 5%. For the control group, the shear bond strength of CSEB and RBLC to sound dentin was assessed using Mann-Whitney test.

Results

Table 3 shows the means, standard deviations and

conventional or chemomechanical caries removal techniques for permanent or primary dentin [1,17-22]. Whether this is due to the effect of the caries removal methods, bonding to the caries-affected dentin, the type of the dentin, different orientations of dentinal tubules at various intra-tooth locations, or the nature and composition of primary dentin is unknown.

According to the results of the present study, the null hypothesis was rejected. There were significant differences in the shear bond strength of the two adhesives to sound and caries-affected dentin with lower bond strength to sound dentin. A possible reason for the lower bond strength to the sound dentin could be due to the higher depth of the dentin in the

treatment groups (caries-affected dentin) compared to that of the control group. Caries-affected dentin is partially demineralized and due to mineral loss, the carious inter-tubular dentin had a higher degree of porosity than the sound inter-tubular dentin [23]. The porous nature of the inter-tubular dentin leads to thicker hybrid layers in the caries-affected dentin compared to the sound dentin, which allows for simpler diffusion of acidic conditioners and adhesive monomers [23].

This finding is in agreement with the results reported by Koyuturki *et al.* [13]. In this study, higher bond strengths of adhesives such as CSEB, Prompt-L-Pop (PLP) and Optibond Solo Plus [(OSP); Kerr corporation, USA] Self-Etch to the sound dentin were determined compared to the caries-affected dentin with a lower bond strength of other agents such as AQ Bond, and Tyrian SPE to the sound dentin. The authors suggest that the strength of adhesion to the dentin depends on two factors, the type of adhesive system used and type of the dentin.

On the other hand, Peumans *et al.* found that all adhesives showed reduced adhesion to caries-affected dentin than normal dentin after Carisolv treatment [15]. The low mineral content of the affected dentin was mentioned as the main cause for these differences, which results in fewer ionic bonds and decreased shear bond strength [15]. Another study evaluating microtensile bond strength of Single Bond to healthy dentin compared to the caries-affected dentin using Carisolv reported significantly higher mean bond strength values to the healthy dentin [24]. The lower bond strength of the caries-affected dentin can be attributed to the presence of altered dentin rather than the chemomechanical method used for the removal.

The present findings indicated significantly higher bond strength for Carisolv than bur excavation for both bonding agents on the primary caries-affected dentin. This finding is in contrast with the results reported in other studies [1,9], in which using a bur showed a higher value of shear bond strength than Carisolv after using CSEB on the primary caries-affected dentin. The differences could be due to incomplete removal of caries by Carisolv gel on those studies [1,9]; this might have interfered with bonding efficiency. Another possible reason could be the high pH level of Carisolv, which neutralizes acids in the adhesive and reduces the shear bond strength [1] by reducing demineralization of the tooth. Regarding the effectiveness of chemo-

mechanical caries removal methods in the primary teeth, Flückiger *et al.* [25] reported that there was no significant difference between the teeth prepared by Carisolv or a bur in terms of residual caries and dentin microhardness.

Investigating the effect of applying Carisolv on shear bond strength of different adhesive systems, Erhardt *et al.* [26] reported that Carisolv did not interfere with adhesion to the dentin. It has been demonstrated that Carisolv neither attacks the collagen fibrils nor damages the pulp tissue in the sound dentin [23]. In their study on the reaction of sound and demineralized dentin to Carisolv, Dammaschke *et al.* [23] reported that Carisolv brought about destruction of the cellular component of the odontoblastic processes but did not attack the healthy collagen fibrils. They speculated that the organic component of the dentin is protected by mineral crystals and is not attacked by the constituents of Carisolv. On the other hand, during the caries removal and cutting procedures using a bur, collagen fibrils are shown to be removed mechanically. In a study conducted by Banerjee *et al.* [27] comparing five different methods of caries removal, it was demonstrated that the affected dentin remained intact when Carisolv was used and there was no significant difference in working time using either Carisolv or a bur.

Other researchers [28] used Carisolv gel in comparison with rotary instruments, using two single-component adhesive systems; they reported much higher shear bond strengths for the Carisolv groups, which is in agreement with the results of the present study for CSEB and RBLC.

In the present study, the method of caries removal affected the bonding characteristics of the adhesives used; the two types of adhesives reacted differently with two different caries removal methods; this is in agreement with the findings of other studies [9,10,19].

In general, CSEB performed better than RBLC. For RBLC, the differences of shear bond strength between the two methods of caries removal were statistically significant with the highest value for Carisolv, while there were no significant differences for CSEB. The weaker bonding of RBLC, compared with CSEB, is in agreement with a previous report that compared the microtensile bond strength of the resin adhesives and glass ionomer cements to permanent dentin [17]. The authors reported a significant difference between the bond strength of CSEB

and GIC with the lowest value for the conventional GIC [17]. Another reason for showing lower bond and time was the conditioner used in the present study. Treating the dentin with 37% phosphoric acid for five seconds, as used in the present study, is only suggested by the manufacturer of RBLC. It has been speculated that phosphoric acid etching dissolves the mineral of the tooth structure quickly and easily; hence, it is not recommended as an ideal method for promoting ionic bonding to the mineral component of the tooth structure [29].

A limitation of this study was the lack of micro-mechanical evaluation of the bonded interface which could verify the efficacy of the adhesion examined in this study and help better understand their clinical performance and durability.

Conclusions

Within the limitation of this *in vitro* study, there was a statistically significant difference between the caries removal techniques for each bonding system and between the two bonding systems used for each excavation method. Although RBLC appears to be a comparable material with CSEB in terms of bond strength after using Carisolv, its bond strength after using steel slow-speed burs was lower than that of CSEB.

Conflict of interest

Authors declare that there is no conflict of interest in this study.

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