

# Comparison of Shear Bond Strength of Three Generations of Resin Bonding Agents and Glass Ionomer to Dentin

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## Abstract

**Background and Aim:** Due to specific properties of dentin, such as tubular structure and intrinsic moisture, bond to dentin is more difficult than to enamel. The purpose of this study was to compare the shear bond strength (SBS) of composite resin to dentin using three different types of resin bonding agents and a glass ionomer-based adhesive.

**Materials and Methods:** In this in vitro study, 72 premolar teeth without caries or restorations were selected and randomly divided into six groups of 12. The first group (I) was chosen as the control group and received no preparation of dentin surface. The remaining groups received application of Single Bond (group II), OptiBond XTR (group III), All-in-One (group IV) and GC Fuji Bond LC adhesive as pre-cure (group V) and co-cure (group VI) on dentin surface, respectively. The samples were stored for two weeks in water at room temperature and then their SBS was measured using Zwick universal testing machine with a crosshead speed of 1mm/min. Statistical data were analyzed using One-way ANOVA and Tamhane's T2 test.

**Results:** The group bonded with OptiBond XTR had the maximum SBS ( $24.05 \pm 9.43$  MPa) while the control group showed minimum SBS ( $0.68 \pm 0.32$  MPa). SBS of composite resin to dentin in groups V and VI bonded with GC Fuji Bond LC adhesive was significantly lower than that in groups bonded with resin bonding agents ( $p < 0.05$ ).

**Conclusion:** Based on the results, application of GC Fuji Bond LC glass ionomer adhesive is not recommended to bond composite to dentin.

**Key Words:** Dentin bonding agent, Fuji bond LC, Glass ionomer, Composite resin

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## Introduction

Dental science has undergone significant advances in the past decade in terms of adhesive restorations [1].

In 1995, Bounocore evaluated chemical treatment of enamel with acidic solutions to change the enamel surface and enhance the bond to resin [1, 2]. Considering dentin characteristics such as tubular structure and moisture, bond to dentin is more difficult than to enamel. This has resulted in advances in resin bonding agents [3]. To confer resistance to bonding agents against

polymerization shrinkage stresses, different generations of bonding agents with high bond strengths have been produced [4-6]. Considering the fact that dentin is a moist tissue containing intratubular fluids, glass ionomer cements are more compatible with dentin compared to hydrophobic composite resins [7,8]. The main mechanism of bonding of these cements is the ionic affinity between the carboxyl groups of the cement and the calcium ions in the enamel and dentin [9].

GI cements are aqueous-based materials formed by an acidic reaction between poly polyalkenoic acid

and fluoroaluminosilicate glass [10]. However, since they are fragile, attempts have been made to enhance their physical properties and decrease their moisture sensitivity by addition of water-soluble resin to produce resin modified GI cements [11].

According to elastic bonding theory, adequately thick and relatively elastic unfilled or semi-filled adhesive resin can absorb and neutralize polymerization shrinkage stresses via elastic elongation. Thus, gap formation at tooth-restoration interface is prevented and bond strength increases. Therefore, for composite resin bond to tooth, resin modified GI adhesives such as GC Fuji Bond LC were introduced. GC Fuji Bond LC has a film thickness in-between that of resin bonding agents and conventional GI adhesives and is relatively elastic [12]. Elasticity of light cure GC Fuji Bond LC compensates for the composite resin shrinkage and neutralizes occlusal forces without bond failure. Use of this material as an adhesive provides long-term seal, protects the pulp and decreases pressure. Also, GI adhesive provides adequate bond between dentin and composite resin. This material is durable, releases high amounts of fluoride, induces tooth remineralization, provides chemical bonds and has low technical sensitivity [13-16].

Only a few studies have assessed the efficacy of GI adhesives for composite bond to dentin. Thus, this study aimed to compare the SBS of composite to dentin using three different resin bonding agents and a GI adhesive (GC Fuji Bond LC).

## Materials and Methods

This experimental study was conducted on 72 sound premolar teeth without fracture, structural anomalies, caries, or previous restorations. These teeth had been extracted for orthodontic purposes. Enamel of the buccal surface of the teeth was removed along the long axis using a cylindrical diamond bur (Diatech Coltene/Whaledent, Altstätten, Switzerland) and high-speed handpiece under water and air spray. Exposed dentin surfaces were ground using 600 grit silicon carbide abrasive papers (3M ESPE, St. Paul, MN, USA). Thus, dentin thickness decreased to 1 mm and middle dentin was exposed. To ensure dentin exposure and absence of enamel, the bonding surface was

evaluated under a light microscope (Olympus Optical Co, Tokyo, Japan) at 20X magnification. Selected teeth were randomly divided into 6 groups of 12 based on similar studies [17-20]:

Group 1. was the control group and received no dentin surface preparation.

Group 2. Dentin surface was etched with 37.5% phosphoric acid gel (Gel etchant, Kerr Italia SpA, Scafati, Italy) for 15 seconds followed by 15 seconds of rinsing and 15 seconds of air-drying with gentle air spray. A 5<sup>th</sup> generation bonding agent (OptiBond Solo, Kerr Italia, SpA) was applied to dentin surface for 15 seconds. The solvent was evaporated by gentle air spray and light curing was done with an LED light-curing unit (Demetron A.2, Kerr Italia, SpA) with an intensity of 1000mW/cm<sup>2</sup> and 1mm distance from the dentin surface for 10 seconds.

Group 3. In this group, 6<sup>th</sup> generation bonding primer (OptiBond XTR, Kerr Italia, SpA) was applied to the dentin surface for 20 seconds and then adhesive was applied for 15 seconds and cured for 10 seconds.

Group 4. In this group, a 7<sup>th</sup> generation bonding agent (OptiBond All in One, Kerr Italia SpA) was applied to dentin surface in two steps. Each coat was applied for 20 seconds followed by 10 seconds of curing.

Group 5. One scoop of GI powder was mixed with 2 drops of liquid (GC Fuji Bond LC, GC Corporation, Tokyo, Japan) for 10 seconds and applied to dentin surface and pre-cured.

Group 6. In this group, GC Fuji Bond LC powder and liquid (GC Corporation) were mixed as in group 5 and applied to dentin surface as a thin coat but was not cured. In this group, GI as the bonding agent was co-cured with composite resin.

Immediately after applying the bonding agents to dentin surfaces, a clear plastic tube with an internal diameter of 3mm and height of 2mm was filled with Point 4 microhybrid composite (Kerr Italia SpA. A3 Body Shade) and placed on the dentin surface and cured for 10 seconds. Excess composite was removed by a scalpel and the composite was cured for 40 seconds from all dimensions. After curing of composite resin, plastic tube was carefully removed by a scalpel.

A composite resin rod remained on the dentin surface. All phases of study were conducted at

room temperature according to the manufacturer's instructions. After preparation, to prevent dehydration and cracking of specimens, they remained hydrated during the experiment. Specimens were stored in distilled water at room temperature for 2 weeks [18].

To measure SBS, a universal testing machine (Zwick GmbH Co, Ulm, Germany) was used at a cross-head speed of 1mm/min. Load at failure was recorded and the bond strength was calculated by dividing the load applied to the composite resin cylinder by the cross section of specimens.

Normal distribution of data was confirmed using Kolmogorov Smirnov test ( $p>0.05$ ).

Equality of variances was approved by Levene's test ( $p=0.001$ ). Thus, one-way ANOVA and Tamhane's T2 test were applied for comparison of groups.  $p<0.05$  was considered significant.

## Results

One-way ANOVA showed that the SBS of composite resin to dentin was significantly different in the understudy groups ( $p=0.001$ ). The mean SBS of composite to dentin in the groups is shown in Table 1. Based on the results, the highest SBS of composite resin to dentin ( $24.05\pm9.43$  MPa) was seen in group 3 using OptiBond XTR resin bonding agent (Kerr Italia SpA). The control group with no dentin preparation showed the lowest SBS ( $0.68\pm0.32$  MPa). Tamhane's T2 showed that except for groups 5 and 6 ( $p=0.892$ ), the pairwise difference in SBS among understudy groups was significant ( $p<0.05$ ) (Table 2).

The results showed that the SBS of composite resin to dentin in groups 5 and 6 using pre-cured and co-cured GI adhesive (GC Fuji Bond LC, GC Corporation) was significantly lower than that of groups bonded with resin bonding agents (groups 2, 3 and 4) ( $p<0.05$ ).

## Discussion

Clinical Heterogeneous nature of dentin complicates the process of bonding. Sound mineralized dentin enables the infiltration of large amounts of monomers into its structure. Thus, dentin must be suitably etched to create channels in between collagen fibrils for penetration of monomer into demineralized dentin [21].

**Table 1.** The mean, standard deviation, minimum and maximum SBS (MPa) of composite to dentin in the understudy groups

Groups	Mean $\pm$ SD	Maximum-Minimum
Control	0/68 $\pm$ 0/32	0/21-1/01
Single Bond	8/99 $\pm$ 4/49	4/52-15/28
OptiBond XTR	24/05 $\pm$ 9/43	1/40-38/20
All in One	14/81 $\pm$ 4/55	8/40-22/60
GC Fuji BOND. co-cure	2/06 $\pm$ 1/41	1/00-5/20
GC Fuji BOND. pre-cure	3/04 $\pm$ 1/44	1/00-5/60

After etching of dentin, it is important to maintain the spaces in-between demineralized collagen fibrils created following the removal of HA crystals. Such undermined demineralized collagen matrix can easily collapse and decrease the interfibrillar space and consequently, resin monomers can no longer penetrate into dentin structure. Thus, maintaining the integrity of demineralized collagen structure is important [22]. This study aimed to compare the SBS of three different resin bonding agents (5<sup>th</sup>, 6<sup>th</sup> and 7<sup>th</sup> generation resin bonding agents) and a GI adhesive (GC Fuji Bond LC) and showed that the SBS of composite to dentin among the understudy groups was significantly different. In this study, shear load was used to assess the bond strength because the shear forces are the most common type responsible for bond failure in the clinical setting. Also, shear bond strength test can be performed easily and rapidly. Although the control of force application to the interface of the two materials is difficult [23]. Also, in the current study, all specimens were immersed in distilled water at room temperature for 2 weeks to allow completion of polymerization and prevent dehydration.

The obtained results showed that GC Fuji Bond LC provided significantly lower bond strength to dentin compared to resin bonding agents and of the understudy resin bonding agents, OptiBond XTR provided the highest SBS. At present, 5<sup>th</sup> generation bonding agents require rinsing after etching. Thus, excess moisture must be thoroughly

**Table 2.** Inter-group comparison of mean SBS using Tamhane's T2 test

Groups	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6
<b>Control</b>	-	0/001	0/001	0/001	0/011	0/02
<b>Single Bond</b>	0/001	-	0/001	0/23	0/001	0/001
<b>Opti Bond XTR</b>	0/001	0/001	-	0/001	0/001	0/001
<b>All in One</b>	0/001	0/23	0/001	-	0-001	0/001
<b>GC Fuji BOND. co-cure</b>	0/011	0/001	0/001	0/001	-	0/89
<b>GC Fuji BOND. pre-cure</b>	0/02	0/001	0/001	0/001	0/89	-

eliminated while preventing over-drying of collagen fibrils. Despite adequate care, the collagen structure may remain over-hydrated or over-dried. Another important parameter affecting the bond is the polymerization shrinkage of composite resin resulting in separation of resin from the hybrid layer [12]. A gap-free interface is often seen when a particle filled, thick adhesive resin is applied beneath the composite restoration and this suggests the elastic bonding theory [24, 25]. In this situation, an unfilled or semi-filled thick elastic adhesive resin layer can prevent microleakage due to polymerization shrinkage and prevent resin separation due to elastic elongation of this layer [12]. Powell et al. showed that use of resin modified GI liner in bilayer technique minimized stiffness and prolonged the clinical service of adhesive layer and restoration [26]. GC Fuji Bond LC as a GI-based adhesive was recently introduced as an alternative to conventional adhesive resins [19].

Similar to our study, Tulunoglu et al. compared the microleakage of 4<sup>th</sup>, 5<sup>th</sup> and 6<sup>th</sup> generation resin bonding agents and GC Fuji Bond LC GI in bond to dentin and reported that 6<sup>th</sup> generation resin bonding agent (Clearfil Liner Bond) showed the lowest microleakage [27]. Also, evaluation of bonded surfaces under an electron microscope revealed that application of GI adhesive to dentin surfaces caused no resin tags [20]. However, in contrast to our study, Neelimia et al. stated that 5<sup>th</sup> generation resin bonding agent (Single Bond) provided the highest bond strength and the 6<sup>th</sup> generation resin bonding agent (Adhes) was not significantly different from GC Fuji Bond LC in this regard [18]. Satish et al. evaluated the microleakage of 5<sup>th</sup> generation (Single Bond) and

6<sup>th</sup> generation (Prompt L-Pop) adhesives and Fuji Bond LC and reported that Prompt L-Pop had the highest degree of microleakage while GC Fuji Bond LC had the best performance [19]. The probable reason was reported to be the low acidity (0.4-0.8) of Prompt L-Pop. Van Meerbeek claimed that acidic monomers are strong and can demineralize dentin to a great depth. However, resin may not be able to penetrate well into deep areas. On the other hand, strong acids denature and destruct the collagen fibers [25].

The mechanism of bonding of a GI adhesive to dentin is via chemical and micromechanical bonds. A partial demineralization of dentin caused by poly acrylic acid creates microporosities shallower than one micrometer. Thus, penetration of resin monomers creates a thin hybrid layer and forms ionic bonds between the poly acrylic acid and the residual hydroxyapatite crystals in the network of collagen fibrils in the hybrid layer [28, 29].

This adhesion mechanism is similar to the mechanism of adhesion of self-etch resin bonding agents with mild acidity. The only difference is that the molecular weight of the carboxyl-based monomer present in GI is much greater than the molecular weight of acidic monomers present in self-etch resin bonding agents. Thus, the GI monomers have less penetration and subsequently, shorter resin tags are formed resulting in a weaker bond and greater microleakage [22]. On the other hand, the commonly used self-etch adhesives (both 6<sup>th</sup> and 7<sup>th</sup> generations) are divided into three groups in terms of acidity: mild, moderate and strong. Strong self-etch adhesives have a pH of  $\leq 1$  and as stated earlier, they can cause extensive demineralization as in total etch technique while resin cannot penetrate all the way into the

demineralized dentin [22]. It has been confirmed that such strong acidity significantly decreases the bond strength of these adhesives to dentin [30-32]. However, mild self-etch adhesives have a pH of approximately 2 and cause one micrometer deep demineralization in dentin and result in the formation of a relatively thin hybrid layer [31, 33]. A new series of self-etch adhesives were recently introduced into the market and Opti Bond XTR, used in the current study, is one of them. They have a pH of approximately 1.5 and are classified as moderate acidity self-etch adhesives. They have the advantages of both mild and strong self-etch adhesives and create a hybrid layer with adequate thickness. This layer, with relative demineralization at the base of the hybrid layer, serves as a mild self-etch adhesive and enables formation of chemical bonds [22]. This may explain the higher bond strength of Opti Bond XTR in this study in contrast to previous studies. Also, the results of the current study showed that GC Fuji Bond LC showed no significant difference in SBS in two forms of pre-cure and co-cure and this result is in accord with the findings of Tulunoglu et al [27].

## Conclusion

Based on the results of this study and properties of dentin, application of GC Fuji Bond LAC for composite bond to dentin is not recommended. Also, among resin bonding agents, Opti Bond XTR self-etch resin bonding agent is more suitable for composite resin bond to dentin compared to other understudy bonding agents

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