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# Comparison of shear bond strength of light-cured resin-modified glass ionomer and moist insensitive primer on contaminated enamel

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**Abstract.** Despite rapid developments in adhesive technology, contamination of bonding surfaces remains a major problem. The aim of this study was to evaluate the influence of contamination on shear bond strength of two adhesive systems: resin-modified glass ionomer cement (Fuji Ortho LC; GC America Corp) and Moist Insensitive Primer (Transbond MIP, 3M Unitek) combination with Transbond XT (light-activated), under different enamel conditions. Metal brackets were bonded to the buccal surfaces of 42 human premolars. The total sample was divided into 6 groups (n = 7 teeth) and brackets were bonded with one of the 2 adhesives under 3 enamel surface conditions: (1) dry (2) saliva-contaminated (3) saliva and blood-contaminated. The shear bond strength was tested using Universal Strength Tester Autograph Shimadzu Corp. There was no significant difference in the shear bond strength between dry, saliva, and saliva-blood contamination bonded with MIP combined Transbond XT. There were significant differences in the shear bond strengths between dry and saliva -blood contaminated enamel bonded with Fuji Ortho LC. In conclusion, Fuji Ortho LC is not recommended for clinical bonding application under saliva-blood contaminated enamel conditions.

## 1. Introduction

Orthodontists and oral surgeons often collaborate in the exposure and orthodontic treatment of unerupted ectopic teeth, since it is difficult to work under ideal conditions [1,2]. In this situation, the treatment options are either exposure of the tooth only or exposure of the tooth and direct bonding of attachment for orthodontic traction. Delaying the bonding procedure until healing occurs will reduce the risk of blood contamination and moisture. However, the soft tissues that cover the tooth must be excised or repositioned to expose the crown, which will cause an undesirable situation, a poor gingival margin. Another option is removing the mucosa to expose the impacted teeth. In this situation, the only strategy is to bond the attachment at the time of operation. However, saliva and blood contamination can result in failure of the attachment bonding procedures [3]. The new orthodontic cements, adhesive resins, and resin-cement hybrid offer improved physical properties and clinical advantages but there are indications and contra-indications for each material.

Glass Ionomer Cement (GIC) began to be used widely in the field of restorative dentistry due to its ability to release fluoride, adherence to the tooth structure, and biocompatibility. However, this material also has some shortcomings, such as long hardening time, sensitivity to moisture during the initial hardening, and rough surfaces which will reduce the mechanical resistance. Resin-modified glass ionomer cement (RMGIC) was developed to overcome the problem of sensitivity to moisture and increase the strength during hardening while maintaining the clinical advantages of conventional glass ionomer that include a chemical bond to enamel, adhesion in a wet field, and fluoride release [4-6]. The addition of 10 % - 20 % resin monomers to the GIC result in accelerated hardening, through polymerization of the monomer. However, either light or chemical activators are required. RMGIC is adhesive cement with improved physical properties and a hydrogel phase that is more stable than GIC. Although the amount of resin monomer added to a solution of polyalkenoic acid is very limited, the polymerization of the resin monomers accelerates the initial hardening of RMGIC without significantly interfering the acid-base setting reaction, and the release of fluoride or the attachment of carboxyl groups to metal and tooth surfaces. In addition to the chemical bonding of RMGIC, resin monomers penetrate surface irregularities to produce a micromechanical interlock (bond) after polymerization. Not only is there the advantage of operator-controlling setting, light-activated polymerization also proceeds significantly faster than acid-base (cement forming) reactions, resulting in improved early physical properties, especially fracture resistance. However, despite the favorable characteristics of such materials, the bond strength in contaminated enamel still has to be tested and proven [5,6].

The conventional method for bonding orthodontic attachments to the enamel surface requires three different agents: acid etchant, liquid primer, and adhesive resins [7,8]. Bonding with the use of conventional materials require a dry tooth surface to get adequate bonding strength to withstand the orthodontic force and the load of chewing. However, various clinical conditions do not permit ideal isolation for common orthodontic bonding adhesive use and protocols. To address this, some manufacturer have introduced hydrophilic bonding material and suggested that it may be possible to obtain successful orthodontic bonding to a contaminated enamel surface with this material. New hydrophilic enamel primers for orthodontic treatment use have been formulated with alcohol and/or acetone as ingredients to displace moisture from contaminated enamel [3,9,10]. This formulated differently as reflected in the manufacturers' protocols for use and may play a role in the successful bonding to a contaminated enamel surface. This primer is called Moist Insensitive Primer, commercially available as Transbond MIP (3M Unitek Dental Products, Monrovia, Calif.). The manufacturer recommends that this primer can be used on both wet and dry enamel surfaces and combined with a resin adhesive that is activated either chemically or light. MIP is chemically identical to containing ethanol dentin bonding materials (Single Bond; 3M, St. Paul, Minn.). In this study, bracket bonding was conducted by using Transbond XT adhesive resin. The composition of Transbond XT, Transbond Moist Insensitive Primer, and Fuji Ortho LC is shown in Table 1 [4,11,12].

**Table 1**. Composition Transbond XT (paste) and TMIP.

| Adhesives | Composition | % by Wt |
|---|---|---|
| Transbond | Paste : | |
| XT | Silane-treated quartz | |
| | Bisphenol A diglycidyl ether dimethacylate | 70-80 |
| | Bisphenol A bis(2-hydrocyethyl ether) dimethacylate | 10-20 |
| | Dichlorodimethylsilane reaction product with silica | 5-10 |
| | | <2 |
| | Ethyl alcohol | 30-40 |
| TMIP | Bisphenol A diglycidyl ether dimethacylate | 10-30 |
| | 2-Hydroxyethyl metacrylate (HEMA) | 10-30 |
| | 2-Hydroxy-1,3-dimethacryloxypropane | 7-13 |
| | Copolimer itaconic and acrylic acid | 7-13 |
| | Diurethane dimethacrylate | 3-7 |
| | Water | 3-7 |

Although literature has been published regarding the bond strengths of RMGIC and MIP, to our knowledge there is no reported study yet available about the effect of the mixture of saliva and blood contamination on these adhesive systems.

## 2. Materials and method

This research was a laboratory experiment using 42 extracted maxillary premolar teeth. The criteria for tooth selection included intact buccal enamel and no caries. The teeth were cleaned and then polished with pumice, then embedded in a resin block. The teeth were divided into 3 groups (A, B, C) each group consisting of two sub-groups, each sub-group consisting of 7 teeth. The bonding procedure was done as follows:

### *2.1. Group A: Non-contaminated enamel*

A1: The tooth was cleaned, then dentin conditioner was applied for 30 seconds, then blotted away with a cotton pellet. Next the capsule containing Fuji Ortho LC was triturated for 10 seconds, bonding material was applied to the bracket base, the bracket was bonded to buccal surface 4 mm from the occlusal. Excess adhesive was carefully removed from the tooth using a scaler. The tooth was immersed in artificial saliva for 24 hours, then the shear bond strength was measured.

A2: The tooth was cleaned, then etched with 37 % phosphoric acid for 30 seconds, rinsed with water for 15 seconds, blown dry with air, MIP was then applied to the teeth and bracket base, Transbond XT paste was applied to the bracket base. The bracket was bonded to buccal surface 4 mm from the occlusal. Excess adhesive was carefully removed from the tooth using a scaler. The tooth was immersed in artificial saliva for 24 hours, then the shear bond strength was measured.

### *2.2. Group B: Saliva-contaminated enamel*

B1: The tooth was cleaned, then dentin conditioner was applied for 30 seconds, blotted away with a cotton pellet. Next, artificial saliva was applied to the tooth’s surface, the capsule containing Fuji Ortho LC was triturated for 10 seconds, bonding material was applied to the bracket base, and the bracket was bonded to buccal surface 4 mm from the occlusal. Excess adhesive was carefully removed from the tooth using a scaler. The tooth was immersed in artificial saliva for 24 hours, then the shear bond strength was measured.

B2: The tooth was cleaned, then etched with 37 % phosphoric acid for 30 seconds, rinsed with water for 15 seconds, and blown dry with air then artificial saliva was applied to the etched enamel, MIP was applied to the teeth and bracket base, and Transbond XT paste was applied to the bracket base. The bracket was bonded to the buccal surface 4 mm from the occlusal. Excess adhesive was carefully removed from the tooth using a scaler. The tooth was immersed in artificial saliva for 24 hours, then the shear bond strength was measured.

### *2.3. Group C: Saliva + blood-contaminated enamel*

C1: The tooth was cleaned, then dentin conditioner was applied for 30 seconds, blotted away with cotton pellet. Artificial saliva + fresh human blood was applied to the tooth’s surface, the capsule containing Fuji Ortho LC was triturated for 10 seconds, and bonding material was applied to the bracket base. The bracket was bonded to the buccal surface 4 mm from the occlusal Excess adhesive was carefully removed from the tooth using a scaler. The tooth was immersed in artificial saliva for 24 hours, then the shear bond strength brackets was measured.

C2: The tooth was cleaned, then etched with 37 % phosphoric acid for 30 seconds, rinsed with water for 15 seconds, and blown dry with air. Artificial saliva + fresh human blood was applied to the etched enamel, MIP was applied to the teeth and the bracket base, and Transbond XT paste was applied to the bracket base. The bracket was bonded to the buccal surface 4 mm from the occlusal. Excess adhesive was carefully removed from the tooth using a scaler. The tooth was immersed in artificial saliva for 24 hours, then the shear bond strength was measured.

The shear bond strength measurements were carried out in the Laboratory of Department of Chemical Engineering, ITB (Bandung Institute of Technology). The instrument used was the Universal Strength Tester Autograph Shimadzu Corp. set at a speed of1mm/minute. Measurements were taken after the sample had been immersed in artificial saliva for 24 hours. The embedded tooth and the adhesively fixed bracket were positioned in the testing apparatus. Shear bond strength measurement begins by providing a tensile load 0 kgf and continued until shear tested to failure.

The results obtained from Autograph were converted to MPa by using the following formula in equation (1).

$$Bond\ strength\ (mPa) = \frac{Forces\ (Newtons)}{Surface\ area\ of\ brackets\ (mm^2)}\ (1)$$

To determine statistical differences, a Student-Newman-Keuls test was performed. The means and standard deviations were calculated. The level of significance was set at α = 0.05.

## 3. Results and discussion

The mean of shear bond strength of Fuji Ortho LC adhesive material and Transbond MIP in dry enamel, saliva-contaminated and saliva + blood contaminated enamel shown in table 2. The results of the ANOVA showed that under dry conditions, the bond strengths of all adhesives systems were comparable. Under saliva contamination, both Fuji Ortho LC and MIP showed acceptable and comparable bond strengths; however, the bond strength displayed by Fuji Ortho LC on saliva+ blood contamination was not adequate. (Figure 1)

There are significant differences of shear bond strength on the different enamel conditions ($p<0.05$). When the two adhesives systems were compared, nor significant differences on shear bond strength and enamel conditions ($p>0.05$).Descriptive statistics for shear bond strength are given in Table 3.

**Table 2**. Mean shear bond strength of Fuji Ortho LC adhesive material and Transbond MIP in dry enamel, saliva-contaminated and saliva + blood contaminated enamel.

| Adhesives | Dry | Saliva | Saliva + blood |
|---|---|---|---|
| Fuji Orto LC | 12.79 | 13.05 | 6.76 |
| | 10.08 | 9.56 | 4.51 |
| | 8.08 | 8.18 | 8.95 |
| | 10 | 8.96 | 5.36 |
| | 8.96 | 9.52 | 6.125 |
| | 11.9 | 9.87 | 5.11 |
| | 13.78 | 7.66 | 4.32 |
| Transbond MIP | 4.95 | 5.42 | 4.32 |
| | 4.79 | 5.7 | 8.23 |
| | 11.44 | 6.5 | 14.91 |
| | 12.375 | 11.15 | 4.3 |
| | 9.875 | 11.46 | 9.97 |
| | 4.32 | 10.44 | 7.13 |
| | 12.5 | 6.5 | 5.34 |

The highest shear bond strengths produce on dry enamel either with Fuji Ortho LC and Transbond MIP. There are reductions in shear bond strength for all contaminated enamel groups. Fuji Ortho LC revealed a distinctive and significant decrease in shear bond strength after saliva + blood contamination. For Transbond MIP no significant differences in shear bond strength values were detected between dry and contaminated enamel. For Fuji Ortho LC there is significant differences between dry enamel and saliva+blood contaminated enamel.

In saliva-contaminated enamel there are reductions in shear bond strength for Fuji Ortho LC and Transbond MIP. The lowest shear bond strength value found in saliva + blood contamination for Fuji Ortho LC, even below than clinically required for adhesive bonding (6Mpa).

**Table 3.** The shear bond strength of FOLC and Transbond MIP under different enamel conditions.

| | Interaction | Statistic | | | | |
|---|---|---|---|---|---|---|
| | | Mean | Median | Std. Deviation | Min | Max |
| Shear bond strength | Fuji Ortho LC-Dry | 10.7986 | 10.0800 | 2.08138 | 8.08 | 13.78 |
| | Transbond MIP-Dry | 8.6071 | 9.8750 | 3.77069 | 4.32 | 12.50 |
| | Fuji Ortho LC-Saliva | 9.5429 | 9.5200 | 1.73926 | 7.66 | 13.05 |
| | Transbond MIP-Saliva | 8.1671 | 6.5000 | 2.71104 | 5.42 | 11.46 |
| | Fuji Ortho LC-Saliva and blood | 5.8764 | 5.3600 | 1.60380 | 4.32 | 8.95 |
| | Transbond MIP-Saliva Transbond Transbond MIP-Saliva and blood | 7.7429 | 7.1300 | 3.79218 | 4.30 | 14.91 |

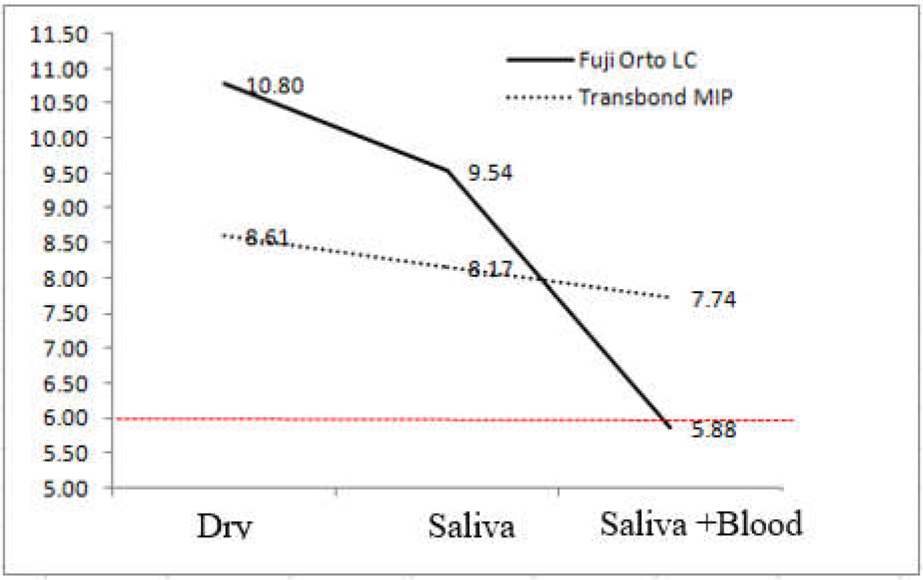


**Figure 1.** Mean shear bond strength of Fuji Ortho LC and Transbond MIP under 3 testing conditions (dry, saliva contamination, and saliva + blood contamination).

The most common contaminant of enamel during bonding procedures are saliva and blood. Contamination causes plugging of porosities caused by acid etching and a reduction in surface energy [13]. Whereas saliva occurs in all bonding situations, blood is mainly a problem on operation procedure to expose the impacted teeth. Saliva consists mostly of water (99.4%), with 0.6% solids. The solid is composed of macromolecules like proteins, glycoprotein sugars and amylase, inorganic particles like urea, amino acids, fatty acids and free glucose [14]. It seems that within seconds, an organic smear layer is formed, covering the etched porous surface [10]. It has been reported that the minimum bond strength of 6–8 Mpa was adequate for most clinical orthodontic needs [7].

Our study showed differences in the bonding characteristics of the 2 adhesives systems on contaminated surfaces. In this study, the shear bond strength of the group tested ranged from 5.88 to 10.80 Mpa. The Fuji Ortho LC is light-cured resin-modified glass ionomer cements and formulated to bond orthodontic brackets in wet environment. This eliminates the need to maintain the teeth in a completely dry condition during the bonding procedure. This cement not only provides enamel bonding but also have a mechanism for releasing and reloading fluoride so that the white lesions around the orthodontic brackets and bands can be reduced. In addition, this material facilitates the debonding procedures without injuring the enamel surface [15]. The result of this study indicate that the Fuji Ortho LC adhesive when used on dry and saliva-contaminated enamel, has an adequate bond strength: 10.80 Mpa and 9.54 Mpa respectively. Fuji Ortho LC had the best results in a humid environment whether by saliva contamination or water. The effective bond produced by Fuji Ortho LC in the presence of water could have three plausible explanations: (1) The cementing agent may be able to displace a sufficient amount of water so that the chemical bonding between the Fuji Ortho LC and the calcium in the tooth is not impeded [2]. The water present is simply incorporated into the cement because water is the carrier for the acidic component in this reaction.□3□ Another explanation might be the presence of HEMA as a major constituent of the resin component in Fuji Ortho LC; this water-soluble hydrophilic monomer is an essential ingredient to inducing wetting and penetration.

In contrast to the contamination with saliva tolerated by Fuji Ortho LC, contamination with blood led to highly decreased bonding forces. It seems that high amounts of organic substances impede the binding between the primer and adhesive. Fuji Ortho LC showed significantly lower values for the saliva + blood contamination group (5.88 Mpa). This is in agreement with previous reports [1,3,10,11,14,16]

Previous studies that evaluated the effect of blood contamination on the bond strengths of light-cured composites showed a significant reduction in bond strength values [3,9,11]. To address this, manufacturer have introduced hydrophilic bonding material, suggesting the possibility of obtaining successful orthodontic bonding to a moisture-contaminated enamel surface. A different behavior was observed in the present study with Transbond MIP. There is no significant difference on the shear bond strength of Transbond MIP on 3 conditions of enamel. For saliva + blood contaminated enamel, the hydrophilic primer showed the shear bond strength value higher than Fuji Ortho LC. It seems that ethanol, which is responsible for humidity tolerance, and addition HEMA can enhance the adhesive strength on saliva-contaminated and saliva + blood contaminated enamel [4,12]. By applying a layer of Transbond MIP to acid-conditioned enamel, in addition to micromechanical retention, a reversible hydrolytic bond mechanism can be established by breaking and reforming of carboxylate salt complexes formed between the ionized carboxyl groups of the methacrylate functionalized-polyalkenoic acid copolymer and residual enamel calcium. These results agree with other study and contrary to some studies [2-4,9]. This difference might be explained by the use of anticoagulant in blood on experiment material.

In conclusion, there are significant differences of shear bond strengths on different enamel conditions. Statistically there is no significant difference between the shear bond strength between Light-Cured Resin-Modified Glass Ionomer Cement and Moist Insensitive Primer. The shear bond strength generated by Light-Cured Resin-Modified Glass Ionomer Cement and Moist Insensitive Primer on contaminated enamel surface lower than uncontaminated enamel. Light-Cured Resin-Modified Glass Ionomer Cement and Moist Insensitive Primer on blood + saliva-contaminated enamel produced the lowest shear bond strength. Using of light-cured resin-modified glass ionomer on blood + saliva-contaminated enamel is not recommended because it produces the shear bond strength lower than required for orthodontic application.

## 4. Conclusion

There was no significant difference in the shear bond strength between dry, saliva, and saliva-blood contamination bonded with Moist Insensitive Primer combined Transbond XT. There were significant differences in the shear bond strengths between dry and saliva -blood contaminated enamel bonded with Fuji Ortho LC. In conclusion, Fuji Ortho LC is not recommended for clinical bonding application under saliva-blood contaminated enamel conditions.

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