Journal of Conservative Dentistry

ISSN : 0972 - 0707 VOL : 9 No. 2 Apr - Jun 2006

An official Publication of
FEDERATION OF
OPERATIVE DENTISTRY
(INDIA)

Evaluation of the marginal sealing ability of a total etch adhesive in comparison with a self-etching adhesive and a resin modified glass ionomer adhesive

- An in-vitro fluorescent dye penetration test

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ABSTRACT

The purpose of this in-vitro study was to evaluate the marginal sealing ability of three adhesive systems on class V composite resin restorations. The adhesive systems that were employed in this study were Single bond (3M, total etch adhesive), Fuji bond LC (GC, glass ionomer based adhesive) Prompt L- Pop (3M, self etching adhesive).

Standardized class V cavity preparations were made at the CEJ of 45 maxillary premolars. Micro fill composite resin (Kulzer, Charisma) restoration was placed, light cured for 40 seconds, and polished. The surfaces around the restorations were coated with nail varnish, stained in Rhodamine-B fluorescent dye for 24 hours and longitudinally sectioned. Microleakage was evaluated with a fluorescent light microscope under 10X magnification.

The teeth were scored on a ranking system of 0-4, where '0' means no leakage and '4' means leakage along or up to axial wall. All the results were statistically analyzed.

The following conclusions were arrived that none of the bonding agents used in the study could completely prevent the microleakage and also among all the bonding agents tested, Prompt L- Pop exhibited the maximum microleakage at the composite dentin interface, followed by Single bond and Fuji bond LC.

Fuji bond LC exhibited the least microleakage compared to both Prompt L-Pop and Single bond, although there was no statistical difference with Single bond. Among all the groups tested Fuji bond LC performed better.

INTRODUCTION

Approximately 72% of restorations that replace existing restorations use composite resin[1]. This is due to increase in demand for esthetics, which in turn has led to development of composite materials with improved clinical properties.

Inspite of numerous advantages of composites, continuous ongoing research is focused on two areas, i.e. to improve the mechanical properties of the material and to achieve better bonding between the tooth and composite material. Polymerization shrinkage is a major drawback of composite material, which causes marginal gap between cavity wall and the restoration. This results in marginal staining, post operative sensitivity, secondary caries, and failure of the restoration[2].

Efforts have been made to develop new dentin bonding materials that can withstand the stresses induced by polymerization shrinkage. This has resulted in the evolution of bonding agents with higher bond strengths.

The problems with most currently used adhesive systems are more number of steps in their use, which can lead to clinical errors like moisture contamination and over dessication. Such errors can result in premature failure of an adhesive restoration. So in an attempt to simplify the clinical procedure certain manufacturers combined the etchant, primer, and bonding agent into 'One Bottle' adhesive[3]. Prompt L-Pop, a so-called Self-Etching adhesive has been introduced to minimize the potential errors and operating time.

According to 'Elastic Bonding Concept' sufficiently thick and relatively elastic unfilled or semi-filled adhesive resin may absorb polymerization shrinkage stress of composite material by elastic elongation, preventing the interface from detaching[4]. Because of similar reasons resin modified glass ionomer bonding agent was introduced. The efficiency of this material as a bonding agent will be assessed in this in-vitro study.

One of the techniques advocated for assessing microleakage is by using fluorescent light microscope. This technique offers several advantages over the other conventional tracers being employed[5]

1. More accurate evaluation of the microleakage
2. High-resolution imaging and direct viewing
3. Specimen dessication avoided

The objective of this in-vitro study is to evaluate the marginal sealing ability of a conventionally used bonding agent i.e. total etch adhesive (Single Bond) with resin modified glass ionomer bonding agent (Fuji Bond LC) and self-etch adhesive (Prompt L-Pop) by using fluorescent dye microscope.

MATERIALS AND METHODS

This study was done in the Department of Conservative Dentistry and Endodontics, Meenakshi Ammal Dental College in association with Department of Oral Pathology, Meenakshi Ammal Dental College.

Forty-five non-carious freshly extracted intact human maxillary premolars were collected and stored in deionized water with thymol at room temperature. The specimen teeth were utilized for the study within one month of extraction.

Preparation of samples

Standardized class V cavities were prepared in all teeth (3x3x2mm). The occlusal margin was in enamel and the gingival margin was in dentin cementum. The occlusal wall was beveled (45°) with a finishing bur. After preparation, the teeth were randomly assigned to 3 groups of 15 specimens each. The bonding agents used were

Table I
Bonding agents used

Group	Bonding agent
I, II, III	Single bond Fuji Bond LC Prompt L-Pop

All adhesives systems were used according to the manufactures recommendations

Table II
Adhesive systems used

Single bond (3M)	*Etching:* Apply for 15 seconds, rinse for 10 seconds, dry gently. *Bonding:* Brush two consecutive coats of priming resin, air-dry gently for 2-5seconds, light cure for 10 seconds.
Fuji Bond LC(GC)	Conditioning with 20% poly acrylic acid for 10 seconds, rinse for 5 seconds, dry gently, Fuji Bond LC mixed according to manufactures recommendations and applied with a brush, cured for 10 seconds.
Prompt-1-pop (3M)	Apply the mixture & rub the cavity for approximately for 15 seconds, air dry gently, light cure for 10seconds.

The preparations were restored with a Micro fill composite resin in increments. Each composite increment was cured for 40 seconds. The output of light unit was measured with a curing radiometer every five restorations ensure a constant value of at least 380 milliwatts/cm^2. The restorations were finished & polished according to manufacturer recommendations.

The samples were coated with nail varnish paint except for the restorations and 1mm rim of the tooth structure around the restorations. The specimens were placed in distilled water at 37°c for 48 hours. After 48hours the specimens were immersed in 50% alcoholic solution of 1% wt Rhodamine B Fluorescent dye for 24 hours. Following removal from the solution, the specimens were rinsed in tap water for 5min to remove excess dye. After rinsing, the specimens were stored in water for 24 hours. The specimens were sectioned buccolingually parallel to the long axis of the tooth, using slow speed diamond disk under copious water supply. The sectioned specimens were then analyzed under a fluorescent light microscope (Olympus BX40) under magnification 10x for evaluation of dye leakage by two investigators and scored using a rank order rating scale.

Rating system for scoring microleakage:

0 = No leakage
1 = Leakage into enamel or its equivalent depth on the cementum surface
2 = Leakage through enamel upto half of the cavity preparation
3 = Leakage overall half the depth of the cavity preparation without pulpal floor involvement
4 = Leakage to and along the pulpal floor.

The group exhibiting the highest rating was considered as having more microleakage. The results were statistically analyzed. Kruskal-Wallis one-way ANOVA was used to calculate the p-value. Mann-Whitney u-test was used to identify the significant groups at 5% level.

RESULTS

Table III

Mean and standard deviation and test of significance of mean values between different study groups

Group	Mean	S.D
Single bond	1.8	0.8
Fuji Bond LC	1.6	0.6
Prompt L-Pop	2.4	0.7

Kruskal-wallis one-way ANOVA was used to calculate the P-value.

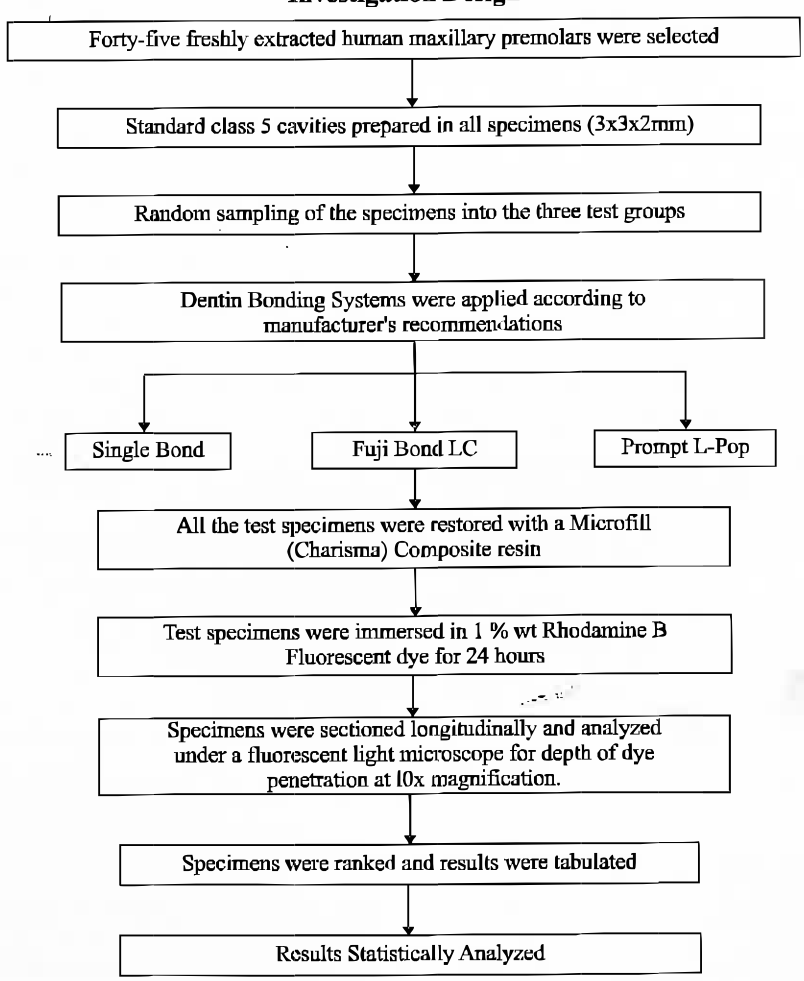
Mann-whitney u-test was used to identify the significant groups at 5% level.

Table IV

p-Value

Groups	P-value	Significant groups
I Vs II	1.8	Not Significant
I Vs III	1.6	Significant
II Vs III	2.4	Significant

Investigation Design



Lowest mean value is by Group II (1.6+0.6) followed by group I (1.8±0.8) and the highest mean is in-group III (2.4±0.7). Statistical analysis by Kruskal-wallis one-way ANOVA followed by Mann-Whitney u-Test showed that the mean value in-group II (1.6±0.6) is significantly lower than group III (2.4) ($p<0.05$) and also the mean value in-group I (1.8±0.8) is significantly lower than group III (2.4±0.7)($p<0.05$).

However, there is no significant difference in mean values between group I Vs. group II.

DISCUSSION

Microleakage with its resulting problems like marginal staining, postoperative sensitivity, secondary caries can be prevented by improving the adhesive bonding to enamel and dentin and by compensating the polymerization shrinkage stresses. The current research is focusing on these two avenues in order to improve the marginal sealing ability.

Bonding to enamel is a relatively simple process without major technical requirements and difficulties. However the task of adhering composite to dentin has remained a universal challenge, because unlike enamel which is a highly mineralized tissue composed of only 4% organic material, dentin contains 20% organic material & 10% water by weight[6]. This heterogeneous nature of dentin makes bonding always problematic & difficult.

Intact mineralized dentin does not permit much monomer diffusion through the tooth structure. Therefore dentin must be suitably conditioned or etched to create channels between collagen fibrils to allow monomers, which have good affinity to diffuse into the demineralized dentin[5].

After etching it is crucial to maintain the space between the demineralized collagen fibrils following the removal of the hydroxyapatite crystals. This demineralized unsupported collagen matrix can easily collapse causing a decrease in the interfibrillar spacing & loss of permeability to resin monomer[7]. Hence it is imperative to maintain the structural integrity of demineralized collagen.

Currently employed fifth generation bonding agents require rinsing after the completion of the etching process. This rinsing step has to be followed by careful removal of excess water without desiccating the collagen. Inspite of adequate operator care most of the times the collagen substrate might either become over wet or be over dried, in such over wet conditions excess water that was incompletely removed results in blister and globule formation at resin dentin interface[8,9]. Such interface deficiencies undoubtedly weaken the resin-dentin bond. On the other hand certain amount of water is recommended to avoid collapse of exposed collagen. Over drying of acid etched dentin surface is thought to induce surface tension stresses, causing the exposed collagen network to collapse, shrink and form a compact coagulate that is impermeable to resin[10,11].

In order to prevent such errors and to simplify the application procedure, self-etching & priming adhesives have been introduced. Self-etching priming adhesives utilize the acidic nature of the primer to demineralize the dentin and simultaneously facilitate the penetration of the resin adhesive[11,12]. This system does not require a separate etching, rinsing and drying steps. This eliminates the risk of over etching, over drying and incomplete resin infiltration[3].

The other major parameter affecting adhesion is the contraction of the restorative composite during the polymerization resulting in the detachment of the adhesive resin from the underlying hybrid layer[4]. Gap free intact surfaces were most frequently observed when a relatively thick layer of a separately polymerized and particle filled adhesive resin is present under polymerizing resin composite. These observations provide evidence for an elastic bonding concept[13,14] in which a sufficiently thick and relatively elastic unfilled or semi filled adhesive resin may absorb in part the polymerization shrinkage stresses of the composite material by elastic elongation thereby preventing the interface from detaching[4].

Powell et al[15] found that, the additional use of an intermediate resin -modified glass ionomer liner in so called 'sandwich' technique presently referred to as 'bilayered technique' minimizes the total stiffness of the restoration thereby increasing its longevity.

Fuji Bond LC, a glass ionomer adhesive has been recently introduced as an alternative to traditional resin adhesives. It is reasonable to presume that, due to similarity in film thickness between a resin and modified glass ionomer liner and resin modified glass ionoer bonding agent, the bonding is expected to be similar.

This present study was undertaken to evaluate the microleakage of three different adhesive systems namely

I.	Two step adhesive	Single bond (3M)
II.	Self etching adhesive	Prompt L Pop
III.	GIC based adhesive	Fuji Bond LC

Many techniques have been devised to test the sealing ability of the restorative materials both in vivo and in vitro. In vitro studies include the use of dyes, chemical tracers, radioactive isotopes, air pressure, bacteria, neutron activation analysis, scanning electron microscopy, and artificial caries techniques.

None of these above mentioned methods could be considered to be ideal for the detection of microleakage. Probably the most practical method that provides an acceptable degree of reliability is penetration by tracers like dyes, chemical and radio active isotopes[16]. Comparing with other methods, subjective evaluation, and destruction of the specimen are few limitations with use of tracers. However, tracers provide an effective in vitro method that allows fair comparison between different restorative techniques and materials[16].

The advantages of radioactive isotopes over dyes is that, they can be used to detect even minute amounts of leakage, but some of their disadvantages are[16]

1. Isotopes such as Ca have a high affinity for tooth and restorative material, this may be misleading.
2. A high-energy isotope produces more scatter on the film leading to an increase in apparent leakage.
3. Comparatively expensive and technique sensitive.

The use of dyes as tracers is one of the oldest and most common methods of detecting microleakage in vitro. Agents most frequently used for this purpose are Methylene blue, Indian ink, Crystal violet, Eosin, Basic Fuschin, Erythrosine, Fluoroscein, Rhodamine B. All these dyes are available in different concentrations and different particle sizes. It was found that different concentrations of dyes could vary in penetration time between 5min to 1hr17 that means as the concentration of dyes vary, the penetration time also varies.

To overcome this problem fluorescent dyes are found to be useful as tracers because they are detectable in dilute concentrations, inexpensive, and being nontoxic, can be used safely. Fluorescent

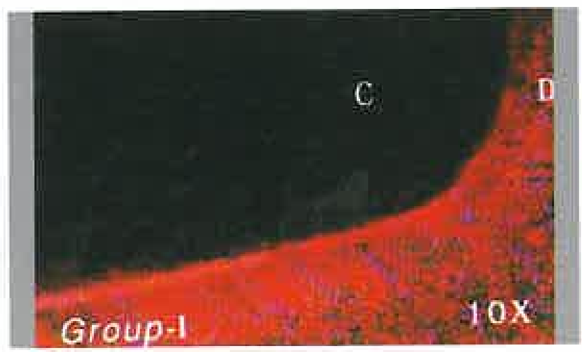


Fig 1:

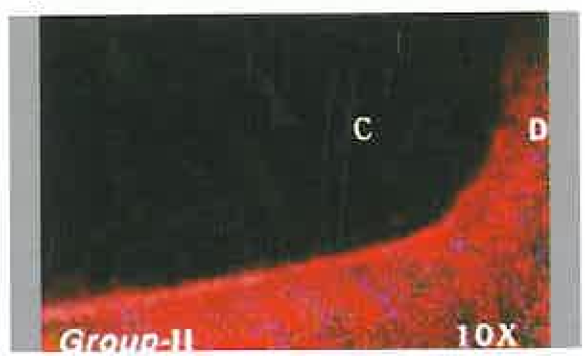


Fig 2:

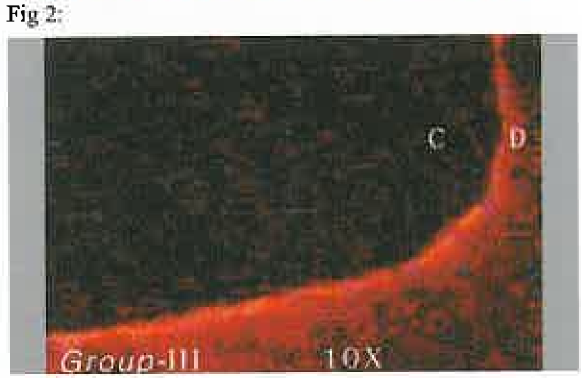


Fig 3:

light microscope was used to evaluate the depth of dye penetration in this study. The advantages of this technique over the other conventional methods are more accurate evaluation of the microleakage, high-resolution imaging and direct viewing. Also specimen dessication can be avoided[17,18]. Hence, this in-vitro study was done by using fluorescent dye microscope to evaluate the marginal sealing ability of three different bonding agents namely, Single bond, Prompt L-Pop and Fuji bond LC.

The composite resin restoration has some effect on leakage, as a more highly filled composite shrinks less and therefore should have smaller marginal gaps. On the other hand, a viscous, highly filled resin may not adapt to margins as well as a relatively fluid Micro fill[19]. Hence Charisma (Microfill) was employed for all the specimens in this study.

Dentin bonding agents should exhibit higher bond strengths to both enamel and dentin in order to withstand the contraction stresses during polymerization of composite. The stresses generated by contraction of resin composite have been reported to be about 13-17Mpa, and a shear bond strength of approximately 21Mpa is believed to be necessary to prevent marginal contraction gaps[20,21].

None of the dentin bonding systems evaluated in this study completely inhibited microleakage at margins in dentin (or) cementum.

- Among all the bonding agents Prompt L-Pop showed the maximum microleakage at composite dentin interface, followed by single bond and Fuji bondLC.
- Fuji bond LC exhibited less microleakage than Prompt L-Pop and single bond, but statistically there is no difference between Fuji bond LC and Single bond.

In spite of manufacturer's claims Prompt L-Pop showed poor bond strength in our study. This was proved by high microleakage at composite dentin interface. The probable reason for the failure of Prompt L-Pop is it's low pH (0.4-0.8). According to Van Meerbeek, acids that are too 'strong' may give rise to certain clinical problems. First of all these 'strong' self etching adhesives exhibit high acidity levels which may result in deep demineralization defects thereby exposing the collagen so deeply that resin may not penetrate completely. This may leave behind an uninfiltrated weak collagenous layer of dentin that is susceptible to long term degradation[22]. Secondly, the too 'strong' acid treatment may alter or denature the collagen, hence affecting the bonding. This is in accordance with Inoue et al 2001, Frankenberger et al 2001, De Munck et al 2003 and, whose studies demonstrated rather low bond strength values with the 'strong' self-etch adhesive Prompt L-Pop. Finally according to Van Meerbeek, the effect of residual solvent (water) that remains within the adhesive interface, can not be completely removed[14].

Single bond was less effective than Fuji bond LC but more effective than Prompt L-Pop in reducing microleakage. This could be attributed to the fact that ethanol based adhesive Single bond, exhibits superior bond strength when compared to the water based adhesives, namely Prompt L-Pop & Fuji bond LC. This is in accordance with an earlier study done by Satoshi Inoue[23], Marcos & Van Meerbeek (2001), who demonstrated that ethanol based adhesives showed better bond strength than the water based adhesives.

Fuji bond LC was most effective in reducing microleakage in this in vitro study. Based on the elastic bonding concept a thick adhesive layer acts as a stress-relaxation buffer due to its relatively high elasticity[24] This will absorb the tensile stresses imposed by polymerization contraction of the resin composite subsequently placed over the adhesive resin by elastic elongation[4].

In support of this elastic bonding concept dentin adhesive systems that provide a low viscosity resin have been reported to produce higher bond strength and less microleakage (W. Inoue-2000)[25]. Moreover this elastic bonding concept can be regarded as an efficient means to counteract the polymerization contraction stress of resin composite. This also aids in absorbing masticatory forces, tooth flexure effects and thermal cycling shock, which during clinical function may jeopardize the integrity of the resin tooth bond. These findings encourage, the use of glass ionomer based adhesive (Fuji bond LC) as a bonding agent for better marginal seal between composite and dentin

CONCLUSION

The following conclusions were arrived at:

- None of the bonding agents used in the study could completely prevent the microleakage.
- Among all the bonding agents tested, Prompt L-Pop exhibited the maximum microleakage at the composite dentin interface, followed by Single bond and Fuji bond LC.
- Fuji bond LC exhibited the least microleakage compared to both Prompt L-Pop and Single bond, although there was no statistical difference with Single bond. Among all the groups tested Fuji bond LC performed better.

ACKNOWLEDGEMENT

Dr. Sivapathasundharam, Professor and Head, Dept. of Oral and Maxillo Facial Pathology, Meenakshi Ammal Dental College, Chennai for his collabrative support.

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