Original Article

A Comparison of Liners and Adhesive Systems in Preventing Coronal Dye Penetration in Root-filled Teeth Subjected to Functional Forces

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Abstract

Root-filled teeth must be restored with materials that prevent penetration of bacteria and fluids containing nutrients. Different liners materials and etching techniques are available for use with composite resins. The aim of this study was to compare dye penetration with two liners and two adhesive systems in access cavities of root-filled premolars whilst simultaneously subjected to functional loading. Extracted human premolars were accessed and root-filled. Teeth in groups I and II were lined Vitrebond while groups III and IV were lined with Ionosit. Groups I and III were etched and primed with Optibond FL primer. Optibond FL adhesive was placed and filled with Premise composite resin. Groups II and IV had Optibond XLR primer, Optibond FL adhesive and the same composite. Specimens were then mounted and subjected to the equivalent of three months mastication whilst simultaneously immersed in India ink. Specimens were retrieved and sectioned. Dye penetration was measured and expressed as a ratio of the tooth length. Data were analysed by one-way ANOVA, followed by the Bonferroni test. The results showed that controls performed as designed. There was no statistically significant difference between the four experimental groups ($p = 0.051$). Neither Vitrebond nor Ionosit showed significant differences in preventing dye penetration (t-test, $p = 0.663$) but the total-etch system had significantly less dye penetration than the self-etch system (t-test, $p = 0.007$). In conclusions, there was no difference between the two liners in preventing dye penetration. The total-etch system was significantly better at preventing dye penetration than the self-etch system in ideal endodontic access cavities in root-filled premolar teeth.

Keywords: liners, adhesive system, dye penetration, functional forces

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Introduction

Root canal therapy should not be considered complete until a definitive coronal restoration has been placed. The ideal restoration for endodontically-treated teeth should restore function and esthetics, protect the remaining tooth structure and resist bacterial penetration. At present, improved restorative adhesive bonding techniques and materials have led researchers to advocate the use of adhesive restorative systems to restore the ideal standard access cavities.[1-3] They could improve the tooth's fracture resistance and longevity, moreover, they may provide potential periodontal and economic benefits to patients. Nevertheless, endodontically-treated teeth may offer different conditions for bonding and restoration - for instance, exposure of root-treated dentin to various irrigation solutions such as sodium hypochlorite may influence the hybridization quality of intra-radicular dentin.[4,5] Moreover, bonding to the pulp chamber may be different from bonding to coronal dentin because the volume of the restoration is larger in endodontically-treated teeth, and more resin increments are necessary to fill the access cavity. Cusps lose their support from the roof of the pulp chamber and may flex owing to shrinkage stresses. All these factors may affect the marginal quality of bonded restorations in endodontically-treated teeth.

Numerous commercial bonding systems are available using two concepts: "total-etch" and "self-etch" adhesive systems. One-step self-etch or seventh generation adhesives have the combination of etchant and primer in the one system. The manufacturers claim that its advantage is to reduce the application time and technique-related sensitivity. On the other hand, there is an ongoing debate regarding the efficacy of bonding to enamel with self-etch adhesive systems.

There are many factors that can affect the marginal integrity of coronal restorations such as the types and techniques of material used, the thickness, the mastication forces, etc. The use of glass ionomer cements, resin modified glass ionomers and flowable composites have been advocated to prevent the entrance of oral fluids and micro-organisms into the root canal system. However, they have shown contradictory results.[6,7] Functional forces have been shown to contribute to the degradation of the resin bond in restorative applications.[8] Repeated stress causes micro-fractures and cracks within the resin.[8]

The purpose of this *in vitro* study was to compare coronal dye penetration of two liners and two adhesive systems in access cavities of root-filled teeth whilst simultaneously subjected to functional loading.

Materials and Methods

Seventy-six extracted, human, caries-free maxillary first premolars with two distinct root canals were used. Two teeth were used as negative controls without access cavities. The other 74 teeth had standard access cavities prepared and the root canals were negotiated. Patency of the apical foramen was determined using a #15 K-flex file (Kerr, MI, USA). The working length was established 1-mm short of the length at which the file exited the apical foramen. The canals were chemo-mechanically prepared using the step back technique to a #35 master apical file. Copious irrigation with 2.5 % sodium hypochlorite (Kao Industrial (Thailand) Co., Ltd., Bangkok, Thailand) was used throughout the canal preparation. The canals were dried with paper points followed by apical clearing. Root canal fillings were placed by using cold lateral compaction, freshly mixed Grossman type cement (CU sealer, Chulalongkorn University, Bangkok, Thailand) and gutta percha (Dentsply (Thailand) Ltd., Bangkok, Thailand). Excess gutta-percha was removed with a heated instrument at the level of cemento-enamel junction. The teeth were kept at room temperature for at least three months until needed for the remainder of the experiment.

The 74 teeth were randomly divided into four experimental groups (N = 18) and a positive control group (N = 2). The experimental design is summarized in Fig. 1. Groups I and II teeth were lined with freshly mixed Vitrebond (3M ESPE, St. Paul, USA) to a thickness of 2 mm and light cured for 40 seconds. Groups III and IV teeth were lined with Ionosit (DMG, Hamburg, Germany) to a thickness of 2 mm and light cured for 40 seconds.

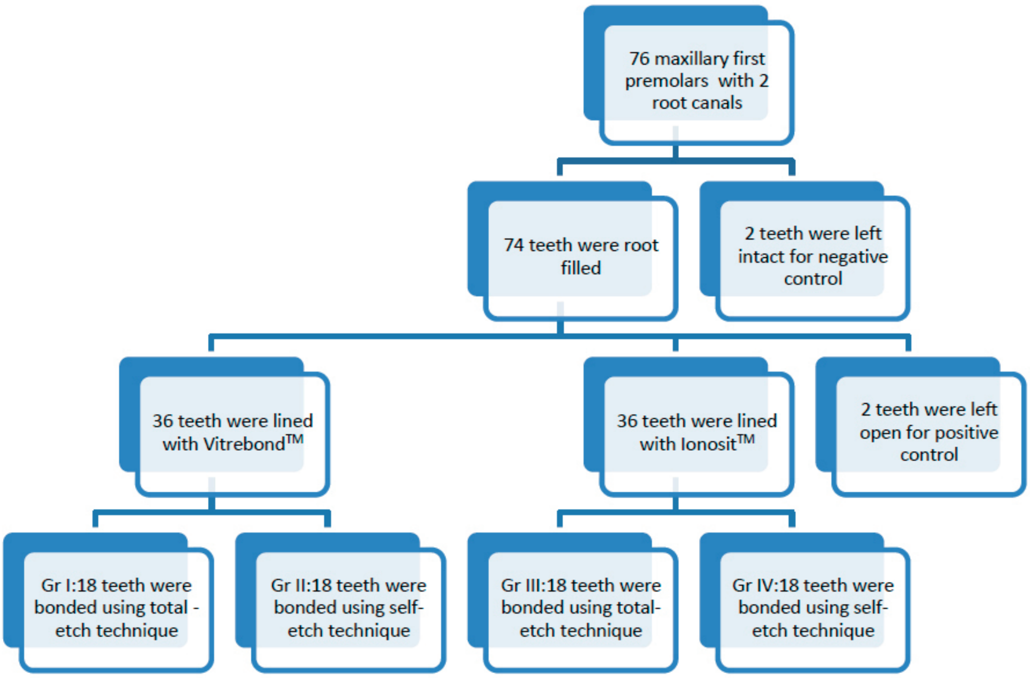

Figure 1 *Flow chart of the experimental design*

After the liners had been placed, teeth in groups I and III were etched with 37.5 % phosphoric acid for 15 seconds. They were rinsed with water until the etchant was completely removed and gently air dried. Optibond FL primer (Kerr, MI, USA) was then applied to the prepared surfaces with a light scrubbing motion. The teeth were gently air dried and Optibond FL adhesive (Kerr, MI, USA) was applied to the cavity. A triplex syringe was used to blow a gentle stream of air over the material for 3 seconds in order to thin it out as per the manufacturer's instructions before being light cured for 20 seconds. The access cavities were filled with a nano-filled resin composite resin material, Premise (Kerr, MI, USA) shade A3, using the incremental layering technique and light curing each layer for 40 seconds.

The access cavities in groups II and IV teeth were brushed with Optibond XLR primer (Kerr, MI, USA) for 20 seconds. They were air thinned with a triplex syringe for 5 seconds and Optibond FL adhesive (Kerr, MI, USA) was applied to the cavity surface with a light brushing motion for 15 seconds. This was air thinned for 10 seconds and light cured for 20 seconds. The cavities were then filled with the same material and technique described above for groups I and III. All restorations were finally polished using a fine grit diamond bur (Composhape) and aluminium oxide mixed with diamond dust bur (Kerr Hawe Hiluster polishing system: Kerr, MI, USA).

Two root-filled teeth were left open to serve as the positive control group and the two intact teeth served as the negative control group. The root surfaces of all teeth were dried with oil-free compressed air prior to painting them with polyvinyl siloxane tray adhesive (PVS Tray Adhesive; 3M ESPE, Germany) which was allowed to dry on the bench for at least 30 minutes. This layer of adhesive was used to simulate the periodontal ligament due to the resilience of the material. It also acted as another barrier against potential dye penetration into the root canal system through the root surfaces and lateral canals.

Each tooth was individually mounted in a lower sample holder for the Willytec dual-axis Chewing Simulator (Munich, Germany) (Fig. 2) using polymethylmethacrylate (PMMA) resin (Orthoplast Light Pink; Vertex-Dental, Netherlands) to the level of the cemento-enamel junction. They were then cured in a pressure pot (Palamat Pratic ELT; Heraeus Kulzer, Germany), as per the manufacturer's instructions. In order to compensate for the polymerisation shrinkage of the PMMA resin, the gaps between the resin block and the inner surface of the sample holders were filled with polyvinyl siloxane (PVS) impression material (Imprint II Garant, Regular Body; Kerr, USA) which further acted to simulate the periodontal ligament during masticatory loading of the samples.

Figure 2 *The Willytec dual-axis Chewing Simulator*

Aliquots of 10 mL of 1 % India ink and 90 mL of physiologic saline were introduced to submerse the entire coronal segment of the teeth in each sample holder (Fig. 3). A precision grade 6.35 mm ceramic ball bearing was fixed to the upper sample holders of the Willytec Chewing Simulator to simulate an opposing cusp. The antagonist ball was centered on the occlusal surface of the specimens. The cyclic loading parameters were set according to the parameters outlined by Kern et al.[9] in 1999 to replicate three months of clinical mastication (Table 1). The experiment was conducted at room temperature and the overall time period of loading was approximately 14 hours.

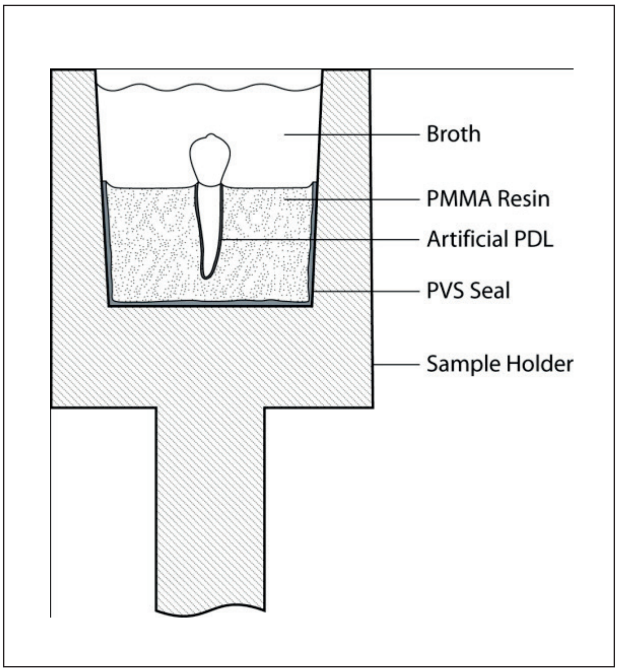

Figure 3 *Cross-section diagram of a mounted tooth in a sample holder*

Table 1 Chewing simulation parameters used for the Willytec dual-axis Chewing Simulator

Parameter	Value
Vertical Movement	6 mm
Rising Velocity	55 mm/s
Descending Velocity	30 mm/s
Mass Per Sample	5 kg
Kinetic Energy	2250×10^{-6} J
Dwell Time	60 s
Horizontal Movement	0.3 mm
Forward Velocity	30 mm/s
Backward Velocity	55 mm/s
Cycle Velocity	1.2 Hz

Immediately after the completion of each chewing sequence, the tooth-PMMA units were retrieved from the sample holders. The tooth was rinsed with tap water to remove excess India ink. They were then sectioned longitudinally in the bucco-lingual plane to provide two halves using a disc (Isomet, Buchler, Illinois, USA) with water coolant. The internal surfaces of each half were measured for the maximum dye penetration (millimeter) under a microscope (Nikon, Japan) at 10x magnification. Each half was assessed by two independent observers who had not performed the earlier phases of the experiment. Inter-examiner and intra-examiner agreement exceeded 90 % at a regular calibration exercise. The maximum dye penetration was measured from the cavosurface margin of the cavity along the tooth/material interface (Fig. 4). The mean of maximum dye penetration, the mean of tooth length and the ratio between the maximum dye penetration and the tooth length in each experimental group were calculated. The ratio between the maximum dye penetration and the tooth length of the four groups were tested using one-way analysis of variance (ANOVA), followed by the Bonferroni test. The comparison between 2 types of liners or 2 types of adhesive systems were tested by the Independent sample t-test. P-values less than 0.05 were considered statistically significant.

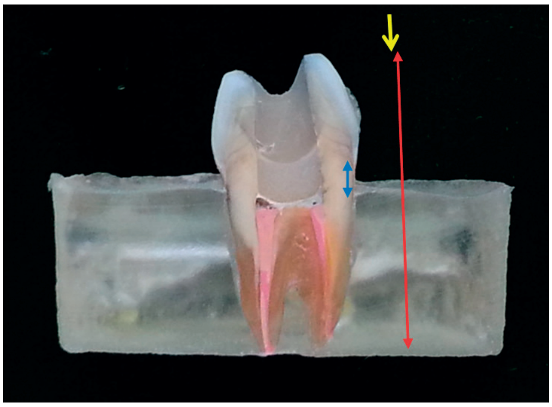

Figure 4 *Tooth half in the resin block showed gutta-percha root filling at the level of cement-enamel junction, liner 2 mm thick (blue arrow), the cavosurface margin (yellow arrow) and tooth length (red arrow)*

Results

There was no dye penetration in teeth in the negative control group whilst teeth in the positive control group showed dye penetration throughout their full length. Hence, the experimental model was valid. The mean of maximum dye penetration, the mean of tooth length and the ratio between the maximum dye penetration and the tooth length in each experimental group are shown in Table 2. Vertical root fractures were noted in eight teeth (four from group III and four from group IV) after the completion of the simulated chewing and hence these teeth were eliminated from the study.

Table 2 *The maximum dye penetration, the tooth length and the ratio between maximum dye penetration and tooth length in each experimental group*

Experimental groups (teeth)	Maximum dye penetration		Tooth length		Ratio between maximum dye penetration and tooth length	
	Mean (mm)	Std deviation	Mean (mm)	Std deviation	Mean (mm)	Std deviation
I. Total-etch and Vitrebond (18)	4.41	3.75	18.69	1.35	0.2388	0.19921
II. Self-etch and Vitrebond (18)	7.84	3.61	19.87	1.50	0.3902	0.16739
III. Total-etch and Ionosit (14)	5.58	3.62	19.47	2.23	0.2880	0.18699
IV. Self-etch and Ionosit (14)	7.68	3.59	19.94	1.56	0.3835	0.17958

One way ANOVA showed no statistically significant difference between the four experimental groups (p = 0.051). When comparison between liners or adhesive systems, neither Vitrebond nor Ionosit showed significant differences in preventing dye penetration (t-test, p = 0.663) but the total-etch system had significantly less dye penetration than the self-etch system (t-test, p = 0.007) in endodontic access cavities.

Discussion

Ideally, endodontic access cavities should be restored with a restorative material that provides a permanent barrier against the penetration of potential irritants such as bacteria and nutrients that may support bacterial growth. Not all endodontically treated teeth require complete rebuilding, i.e., post and core, followed by crown placement. At present, improved restorative adhesive bonding techniques and materials have led researchers to advocate the use of adhesive restorative systems to restore the ideal standard access cavities.[1-3] Unfortunately, no such material is available, and all materials that are currently available allow penetration to some extent. This includes materials used for intra-coronal restorations such as bonded resin and glass ionomer materials.[10]

In this study, we compared the dye penetration of liners and adhesive systems by mimicking the clinical parameters such as the gutta-percha root filing was removed at the cemento-enamel junction, the liner was 2 mm thick and the depth of the composite resin in the access cavity varied. Since each tooth varies in the tooth length, therefore the ratio between the maximum dye penetration and the tooth length in each tooth was calculated. No difference was found between Vitrebond nor Ionosit in preventing dye penetration but the total-etch system had less dye penetration than the self-etch system. This is in agreement with several studies[8,11,12] which have shown that functional forces play an important role in the degradation of the adhesive system. Repeated stress causes micro-fractures and cracks within the resin composite.[8] The three step adhesive systems perform better in *in vitro* tests than the adhesive systems that combine steps,[12-14] although the differences lessen with time as the bonds degrade.[13,14]

In this study, enamel was present and intact along the margins of the access cavity without any beveling. Etching the enamel with 30 to 40 % phosphoric acid in total-etch adhesive systems results in selective dissolution of the enamel prisms and creates a surface with high surface energy that allows effective wetting by low viscosity resin.[15] Microporosities are created within and around the enamel prisms that can be infiltrated with resin and polymerized *in situ.*[15] These "resin tags" provide good micro-mechanical retention for the restoration. Self-etching adhesive systems etch ground enamel fairly well, but do not effectively etch unground enamel.[16-18] A good enamel bond protects the underlying dentin bond which is less durable.[13]

The major advantage of the dual-axis chewing simulator used in this study is that it allows both vertical and horizontal movements of the antagonist "occluding" against the samples in a state of static point of contact. These two movements mimic the anatomical chewing cycle. The model also included a simulated periodontal ligament by coating polyvinyl siloxane tray adhesive to the root surfaces prior to mounting the samples, plus by using the polyvinyl siloxane impression material to fill the gaps between the resin block and the inner surface of the sample holders. In addition, the cyclic loading parameters were set to replicate three months of clinical mastication because to be clinically relevant, published bonding studies should report results with no less than three months of aging.[19] Finally, this model also allowed the simultaneous testing of dye penetration during the chewing simulation rather than applying the dye after simulation. This is a more realistic test since the dye is continuously in contact with the specimen during function rather than just for a brief time after function.

It is interesting that vertical root fractures were noted in eight teeth from Ionosit liners (four from group III and four from group IV) after the completion of the simulated chewing. These may be due to the composition of Ionosit is different from Vitrebond. Ionosit is a light-cure compomer liner composed of glass ionomer in a matrix of polymerizable oligo- and polycarbonic acids and other light-cure dental resins[20] whilst the liquid component of vitrebond is a modified polyacrylic acid with pendant methacrylate groups, HEMA (2-hydroxyethylmethacrylate), water and photoinitiator.[21]

Conclusion

There was no significant difference between Vitrebond and Ionosit liners in preventing dye penetration, but the total-etch system (Optibond FL) was significantly better at preventing dye penetration than the self-etch system (Optibond XLR) in ideal endodontic access cavities in root-filled premolars whilst simultaneously subjected to functional loading.

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