Interfacial microscopic examination and chemical analysis of resin-dentin interface of self-adhering flowable resin composite
[version 1; referees: awaiting peer review]

Tamer M. Hamdy

1Dr. Tamer Hamdy Dental Clinic, Giza, Embaba, Egypt
2Endodontics, Restorative & Dental Materials Research Department, National Research Centre (NRC), Giza, Dokki, 12622, Egypt

Abstract

Background: The newly introduced self-adhering flowable resin-composites decrease the required time for application by incorporation of an acidic adhesive monomer, thus reducing the number of the steps, but its bonding is still uncertain. The aim of this study was to evaluate the interfacial microscopic examination and chemical analysis at the resin-dentin interface of a self-adhering flowable resin composite (Vertise-Flow) versus a total-etch (Te-Econom Plus) resin composite, using an etching agent (Eco-Etch gel) and bonding agent (Single Bond Universal).

Methods: Sixteen freshly extracted sound human posterior teeth were used. The teeth were randomly divided into two groups: 8 specimens per type of composite. Standard-shaped class V cavities were prepared on the buccal surface. One group was restored by Te-Econom Plus resin composite by total-etch technique using Eco-Etch gel, which was applied to dentine for 15 seconds, followed by rinsing, drying and bonding agent application (Single Bond Universal). The other group restored directly with self-adhering resin composite (Vertise-Flow) without application of etch or bond. Curing was done for 20 seconds using a light emitting diode light curing unit. Evaluation of the resin-dentin interface was done microscopically by examination of marginal gap distance in μm using scanning electron microscope (SEM), and chemical analysis of silver particles was observed using SEM with energy-dispersive X-ray spectrometry after 24 hours of specimen storage in ammoniacal silver nitrate.

Results: Regarding marginal gap distance (μm) and silver atomic % mean values, teeth restored with self-adhering resin composite (Vertise-Flow) showed significantly higher mean values than the multi-step etch and rinse resin composite group (5.2 vs 0; 12.2 vs 8.2, respectively).

Conclusions: Resin-dentin bonding using total-etch resin composite technique was more effective than self-adhering flowable resin composite (Vertise-Flow) regarding marginal gap formation and penetration of silver particles. Further studies for bond strength could be performed.
Corresponding author: Tamer M. Hamdy (dr_tamer_hamdy@yahoo.com)

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Introduction
Adhesive dentistry has seen a paradigm shift from the invasive to be minimally invasive, due to a revolution in bonding systems. There are great demands for simplified restorative materials. A new self-adhering flowable resin composite (Vertise™ Flow Self-Adhering Flowable Composite, Kerr Dental, USA), was recently introduced onto the market. Bonding is achieved by incorporation of an acidic adhesive monomer into the flowable composites. It is still a big challenge to seal the resin-dentin interface, due to the heterogeneous nature of dentin, the wet tubular structure, composition and surface morphology and or improperly designed adhesives.

The total-etch (etch and rinse) technique is a widely accepted technique to improve bonding of dental resins. The dentin bonding mechanism is based on the micro-mechanical interlocking of the infiltrated resin monomers into porosities created by demineralized inorganic part of dentin. Restoration debonding may arise from gap formation at the resin-dentin interface and hence recurrent caries, discoloration and tooth pain. Thus sufficient marginal seal should be obtained. Recently, an innovative self-adhesive and flowable resin composite was developed. These materials are claimed to eliminate the need for a separate bonding application step, thus simplifying the restorative procedure. Thus, the aim of this study was to evaluate the sealing performance of this new material.

Methods
Preparation of specimens
After attaining written informed consent from each patient to use their extracted teeth in research, sixteen sound human posterior molar teeth were extracted in a private dental clinic (Dr. Tamer Hamdy Dental Clinic), which were randomly divided into two groups (eight specimens per group). Standard-shaped class V cavities (3x3 mm, 2 mm of depth) were prepared in the teeth using a #169L carbide bur (KG Sorensen, Brazil) on the buccal surface. One group’s (Group A) cavities were filled with Te-Econom Plus® (Ivoclar Vivadent, Africa) resin composite after etching and bonding application. The etching agent, Eco-Etch gel (Ivoclar Vivadent), was applied to dentine for 15 seconds, followed by rinsing and drying. A bonding agent (Single Bond Universal, 3M ESPE, USA) was applied to the teeth for 20 seconds, then air-dried for 5 seconds, then light-cured for 10 seconds. Finally, the Te-Econom Plus resin composite was applied. The other group’s (Group B) cavities were filled with self-adhering resin composite (Vertise-Flow), which was applied without etch or bond. Curing was done for 20 seconds using a light emitting diode (LED) light curing unit (Satelec, Acteon, France).

Interfacial microscopic examination
All teeth were stored in distilled water for 24 hours at 37°C. Subsequently, the specimens were vertically sectioned with a diamond saw (Isomet, Buehler Ltd., USA) under water lubrication into approximately 1mm thick slabs. These were examined for marginal gap distance in μm using scanning electron microscope (SEM; Model Quanta 250 FEG; FEI, Thermo Fisher Scientific, USA): accelerating voltage 30 K.V., magnification 14x up to 1000000 and resolution for Gun.In, to ensure high brightness and resolution at low accelerating voltage.

Chemical analysis of the interface
Specimens slab were then placed in freshly prepared 50 weight/volume % ammoniacal silver nitrate solution for an additional 24 hours at 37°C in the dark. Ammoniacal silver nitrate solution (pH=9.5) was prepared according to the protocol of Tay et al. (2002). After 24 hours of storage in ammoniacal silver nitrate, the silver impregnated specimens were then rinsed thoroughly in distilled water and placed in photo-developing solution for 8 hours under a fluorescent light (200 Watt).

The specimens were then observed under environmental SEM Model Quanta 250 FEG attached with energy-dispersive X-ray (EDX; Inspect S 50, FEI, Netherlands): accelerating voltage 30 K.V., magnification 4000x and resolution for Gun.In. Backscattered electron mode was used for elemental analysis of the atomic silver %.

Statistical analysis
Numerical data were explored for normality using Kolmogorov-Smirnov and Shapiro-Wilk tests, followed by Student’s t-test to compare between the two groups. The significance level was set at P ≤ 0.05. Statistical analysis was performed with IBM®SPSS® Version 20 for Windows (SPSS Inc., IBM Corporation, USA).

Results
Regarding marginal gap formation, Group A showed a significantly lower mean gap distance values than Group B (p<0.001), as shown in Table 1 and Figure 1 and Figure 2.

The SEM with EDX analysis results revealed that Group A showed significantly lower mean silver atomic % values than Group B (p<0.001), as shown in Table 2 A. Selected SEM/EDX analysis is shown in Figure 3 and Figure 4.

Table 1. Marginal gap formation (µm) between groups of teeth treated with different composites. Group A, treated with total-etch technique; Group B, treated with self-adhering resin composite. Mean and standard deviation (SD) values and results of Student’s t-test for the comparison between gap distances are shown (n=8/group).

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean</th>
<th>SD</th>
<th>Mean</th>
<th>SD</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0.0</td>
<td>0.0</td>
<td>5.2</td>
<td>0.3</td>
<td>&lt;0.001*</td>
</tr>
</tbody>
</table>

*: Significant at P ≤ 0.05
Figure 1. Selected scanning electron microscopy shows absence of gap formation in dentin in teeth treated with total-etch technique. Image representative of 8 teeth.

Figure 2. Selected scanning electron microscopy shows presence of gap formation in dentin in teeth treated with self-adhering resin composite. Image representative of 8 teeth.

Table 2. Chemical analysis of the interface between groups of teeth treated with different composites. Group A, treated with total-etch technique; Group B, treated with self-adhering resin composite. Mean and standard deviation (SD) values and results of Student’s t-test for the comparison between silver atomic % values are shown (n=8/group).

<table>
<thead>
<tr>
<th></th>
<th>Group A</th>
<th></th>
<th>Group B</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>8.2</td>
<td>Mean</td>
<td>12.2</td>
<td></td>
</tr>
<tr>
<td>SD</td>
<td>0.4</td>
<td>SD</td>
<td>0.7</td>
<td></td>
</tr>
<tr>
<td>P-value</td>
<td>&lt;0.001*</td>
<td></td>
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<td></td>
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</tbody>
</table>

*: Significant at P ≤ 0.05

Figure 3. Selected scanning electron microscopy/energy-dispersive X-ray analysis at the resin-superficial dentin interfaces in teeth treated with total-etch technique. Image representative of 8 teeth.

Figure 4. Selected scanning electron microscopy/energy-dispersive X-ray analysis at the resin-superficial dentin interface in teeth treated with self-adhering resin composite. Image representative of 8 teeth.

Dataset 1. Raw values for silver atomic % in teeth treated with total-etch technique (Group A) and self-adhering resin composite (Group B) (n=8/group/method)

http://dx.doi.org/10.5256/f1000research.12306.d17706

Dataset 2. Scanning electron microscopy (SEM) showing gap formation (raw values included on the images) and SEM/energy-dispersive X-ray analysis (EDX) at the resin-superficial dentin interface in teeth treated with total-etch technique (Group A) and self-adhering resin composite (Group B) (n=8/group/method)

http://dx.doi.org/10.5256/f1000research.12306.d177062
Discussion
A proper marginal sealing is essential to improve the durability of resin composite/bonding systems. Most of the clinical studies assessing the performance of an adhesive system use class V cavities. EDX analysis permits identification of silver particles, thus giving an indication about the chemical analysis of the interface.

From the present results, it was obvious that the multi-step etch and rinse technique provides better sealing regarding marginal gap formation and penetration of silver particles than that of self-etch “Vertise-Flow”. This may be attributed to the fact that phosphoric acid included in acid-etch step demineralized the smear layer, exposing the collagen fibers of superficially demineralized dentin. These could increase micromechanical interlocking of the bonding agent within the dentin surface. The poorer sealing of Vertise-Flow may be due to the included adhesive monomer, which is called glycerol phosphate dimethacrylate “GPDM”, that etches instead of bonds to hydroxyapatite.

Conclusions
Total-etch resin composite technique was more effective regarding marginal gap formation and penetration of silver particles as compared to a flowable resin composite (Vertise-Flow). Further studies for bond strength could be performed. It is important to emphasize that this study ignored the effect of oral condition, thus further clinical studies are suggested.

Data availability
Dataset 1: Raw values for silver atomic % in teeth treated with total-etch technique (Group A) and self-adhering resin composite (Group B) (n=8/group/method). doi, 10.5256/f1000research.12306.d177061

Dataset 2: Scanning electron microscopy (SEM) showing gap formation (raw values included on the images) and SEM/energy-dispersive X-ray analysis (EDX) at the resin-superficial dentin interface in teeth treated with total-etch technique (Group A) and self-adhering resin composite (Group B) (n=8/group/method). doi, 10.5256/f1000research.12306.d177062

Competing interests
No competing interests were disclosed.

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References