The Effect of Rotary Mini-Brush During the Application of Two Self-Etch Adhesives on Shear Bond Strength

Introduction

Adhesion of resins to tooth structure has been a goal for dental researchers for many years. The interest of adhesion focused on the factors and techniques for enhancement of monomer penetration. The adhesion of dental resin composite to dentin has been improved by the introduction of smear layer removal reagents, dentin primers and dentin bonding agents.

The application of dentin primers to demineralized dentin enhances the monomer diffusion and facilitates the formation of a hybrid layer (Sugizaki, 1991). The present concept of dentin adhesion depends on “hybrid layer” formation. This concept is based on the removal of the smear layer and the mineral phase from the superficial dentin to open the dentinal tubules and create enough intertubular microporosity to allow monomer infiltration into the exposed collagen network, thus providing micro-mechanical retention.

Acid etching increases the surface tension, wettability and the degree of monomer penetration. A freshly acid etched enamel surface has a surface energy more than twice that of an unetched enamel surface (Jendresen MD and Glant, 1981). It has been suggested that the acidic treatment partially demineralizes a zone of dentin near the surface, facilitating the infiltration process of composite monomer (Nakabayshi, 1985).

The durability of resin-dentin bonding depends on how well the resin infiltrates these spaces and how well the resin is polymerized. Wettability is the first condition for the successful bonding of an adhesive on a surface. Good bonding always requires intimate contact between the adhesive and the dentinal substrate.

Coupling agents utilize the concept of hydrophobic and hydrophilic monomers, in which the hydrophilic monomer HEMA coats and infiltrates the demineralized surface dentin. Since liquid primers contain accessible hydrophilic groups that tend to spread more readily upon moist surfaces, the dentin surface should be kept moist after conditioning allowing for moist bonding. Water can retain the collagen framework and intertubular porosities patent in the subsequent infiltration of the monomers. In the case of dentin over-wetting, the collagen fibrils might swell slightly which reduces the width of the perifibrillar spaces making it difficult for the primer monomer to infiltrate the collagen fibril network. In the case of dentin over-drying, the collagen fibrils might shrink, water filling the interfibrillar spaces evaporates, the spaces between the collagen fibrils disappear and the collagen fibrils come into intimate contact. This all results in shrinkage of the height of the demineralized dentin matrix which will lead to lowered bond strengths.

Thus any attempts to produce an increased rate of water and solvent evaporation, such as increased application times of the primer and the bonding agent, delayed polymerization and adhesives’ rubbing can improve the strength of the polymer formed within the collagen fibrils and allow high bond strength values. On wet dentin, slight agitation seems to be enough to provide high bond strength to dentin. In the self-etching systems, the rinsing step is eliminated thus; the effect of extrinsic wetness is neglected. Besides, the self-etching adhesives act on the dentin surface by modifying the smear layer. In this way, the dentin permeability is lowered and the sensitivity of the dentin to water of the pulpal fluid from the pulp chamber is diminished (Pereira et al., 1999). Self-etching one-step adhesives exhibited the lowest bond strengths and the lowest predictable clinical performances over time when compared with multi-step-etch and rinse (Owens et al., 2006). However, one of the major disadvantages of the etch and rinse systems is incomplete adhesive infiltration into the exposed dentin matrix due to the collapse of the
collagen fibrils after removal of the mineral phase. A layer of disrupted collagen fibrils may interfere with adhesive penetration and the formation of the hybrid layer. The existence of incompletely infiltrated collagen fibrils within the hybrid layers and additional entrapped water within the polymerized adhesives may expedite the degradation of resin-dentin bonds, resulting in clinical and visibly detectable microleakage.

The greatest advantage of the self-etching system is that the degree of dentin demineralization is directly related to the depth of monomer infiltration (Bouillaguet et al., 2001). However, Courson et al., 2005 concluded that reducing the number of steps doesn't necessarily improve the shear bond strength of the bonding systems. Previous studies (Frankenberger et al., 2001) found that the application of multiple coats of self-etch adhesives significantly increases their bond strength to dentin due to elimination of the dry spots which appears on evaporation of water used as a solvent. Pashley et al., 2002 were able to improve the quality and strength of dentin bonding by applying multiple coats of Adper™ Prompt™ L-Pop™ (3M ESPE) to the surface of dentin and agitating it for 15 seconds then curing it for 10 seconds. Ito et al., 2005 have also concluded that the quality and strength of dentin bonding is improved significantly through the application of multiple coats of an adhesive.

Recently, a technique has been introduced that utilizes an electric field to enhance resin infiltration into the demineralized collagen matrices of acid-etched dentin (Pasquantonio et al., 2007). This electrical device is incorporated in a hand piece to which a small application sponge is attached. It creates an electric potential difference between the etched tooth substrate and the adhesive filled sponge that produces a constant electric flow during adhesives application. The use of electricity, increased adhesive adaptation to dentin substrate, revealed higher bond strength and improved dentin hybridization. This is due to the substrate modifications induced by an electric field on the demineralized dentin organic matrix.

The aim of this study was to evaluate the effect of a new technique for the enhancement of monomer penetration, water and solvent evaporation. In this technique, rotary mini-brushes that were specially designed, rotated at a speed of 800 rpm were used for this study with two-self etching adhesive systems and the shear bond strengths were evaluated and compared.

**Materials and Methods**

**The Following Materials Were Used in this Study:**

1. AdheSE® (Ivoclar Vivadent) is a self-etching adhesive (Figure 1). It is composed of a primer and a bonding component which are successively applied. Subsequently, the adhesive is light cured. The primer contains phosphoric acid acrylate, Bis-acrylamide, Water, initiators and stabilizers. The bond contains Dimethacrylate, Hydroxyethyl methacrylate, Silicon dioxide, Initiators and stabilizers.

2. Adper™ Prompt™ L-Pop™ (3M ESPE) is a light cured all in one bonding system (Figure 2). It is composed of two compartments. The first one contains methacrylated phosphoric acid esters, photo-initiators and stabilizers, while the second one contains zinc-fluoride complex, water and stabilizers.

3. Artemis composite resin (Ivoclar Vivadent).

4. Rotary mini-brushes:
   - Specially designed brushes were made with plastic rods that were 4mm in diameter and 5mm in length. A specially designed low speed contra-angle mandrill was fabricated for the attachment of the brush. The mandrill consisted of a shank for low speed contra-angle attachment and a hole on its top to accommodate the 4mm diameter brush hole (Figure 3).
   - The brush was introduced into the hole and it was made sure that it is tightly fit before use.

5. Micro-motor device (X-smart rotary device by Dentsply) (Figure 4), was used to standardize the speed by which the mini brushes were rotated. The speed was adjusted at 800 rpm and the torque at two Newtons.

**Selection of Teeth:**

A total of forty freshly extracted, caries free human permanent molars were selected for this study. The patients were diabetic and between 30-40 years of age. The collected teeth were immediately after extraction thoroughly washed by fluoride free tooth paste using a toothbrush. They were scrubbed and scaled to remove the remnants of blood, periodontal ligament, plaque and calculus. Teeth were stored in saline until further use.

**Specimen Preparation:**

The coronal enamel was removed using a low speed
diamond, sawed under water coolant to form a flat surface exposing the mid coronal dentin. The flat dentin surface was polished under coolant using 600-grit silicon carbide paper to produce a slandered smear layer. The teeth were randomly allocated into two groups with 20 specimens for each according to the type of adhesive system used. Each group was further subdivided into two subgroups according to whether the rotary mini brush was used or not.

**Subgroup I (a):** AdheSE was applied without rotary mini brush.
**Subgroup I (b):** AdheSE was applied with rotary mini brush.
**Subgroup II (a):** Adper™ Prompt™ L-Pop™ was applied without rotary mini brush.
**Subgroup II (b):** Adper™ Prompt™ L-Pop™ was applied with rotary mini brush.

**Split Copper Mold:**
A specially designed copper mold was fabricated for this study (Figure 5). It consisted of an external copper cylindrical ring that was 20mm in diameter and 20mm in height. Inside the ring there was a split copper cylinder with an external diameter of 20mm and an internal diameter of 14mm and having the same height of the external copper cylindrical ring. The specimens were embedded in an acrylic resin inside this specially fabricated copper mold to expose the flat dentin surface for the application of the bonding agent.

**Adhesive Application:**
**Group I (a) AdheSE Manual Application:** Two equal chaps of primer and bonding agent were dispensed in a special color coded plastic well. The primer was applied on dentin surface for 30 seconds; air dried for 5 seconds and then the bonding agent was applied, lightly distributed and light cured for 10 seconds.
**Group I (b) AdheSE Application With Rotary Mini Brush:** The primer was applied on dentin surface using the rotary mini brush at a speed of 800 rpm for 15 seconds (Figure 6). The bonding agent was after then applied, lightly distributed and light cured for 10 seconds.
**Group II (a) Adper™ Prompt™ L-Pop™ Manual Application:** Adper™ Prompt™ L-Pop™ was applied as described by the manufacturer. The blister foil was squeezed to mix the contents of the two compartments and then the mini sponge was rubbed onto the dentin surface for 15 seconds, gently air streamed by the triple syringe and then light cured for 20 seconds.
**Group II (b) Adper™ Prompt™ L-Pop™ Application With Rotary Mini Brush:** The blister foil was squeezed to mix the contents of the two compartments. A small cut by the scissor was made in the blister foil and the mix was dispensed in a plastic well. The dentin bonding agent was applied onto the dentin surface by using a rotary mini brush rotated at 800 rpm for 15 seconds and then light cured for 20 seconds.
Composite Build-Up:
For each specimen, a circular Teflon ring (with 5 mm internal diameter and 2 mm length) was secured to the flat dentin surface by using double face adhesive with a hole diameter of 5mm. The ring was filled with Artemis composite and light cured for 40 seconds (Figure 7).

Specimen Storage:
All specimens were stored in water at 37°C for 7 days.

Shear Bond Strength:
Each specimen was subjected to shear force using a universal testing machine (Figure 8) with cross head speed of 0.5 mm/min until failure point. Shear bond strength (kg/cm²) = load (kg) / surface area Ao cm²
Surface area Ao cm² = \[
\pi D^2/4 \quad (\pi \text{ is constant value equal to } 3.14)
\]
The shear bond strength values in kg/cm² were converted to Mpa using the following equation;
Mpa = kg/cm² x 0.09807
The results were calculated and statistically analyzed.

Results:
The mean shear bond strength of AdheSE with normal application was 18.15±1.06 Mpa, while with rotary application was 21.97 ±0.97 Mpa (Table 1).
The mean shear bond strength of Adper™ Prompt™ L-Pop™ with normal application was 12.45±0.86 Mpa, while using the rotary brush application the mean was 15.85±1.48 Mpa (Table 1).
Statistical analysis was performed using F ANOVA test showing that there was a significant difference between different groups. F test was 127.97 and P value < 0.0001 (Table 1).

Tukey test for post hoc comparison demonstrated a significant difference among all subgroups (Table 2).

In comparing the means and SD of shear bond strengths in Mpa between AdheSE and Adper™ Prompt™ L-Pop™ (P-LP) there was a significant difference in which the T test was 8.69 and P value 0.001 (Table 3).

In comparing the means and SD of shear bond strengths in Mpa between manual and rotary application of both bonding agents, there was a significant difference in which the T test was 3.54 and P value 0.001 (Table 4).

Discussion
The revolution of esthetic dentistry took place rapidly, increasing the interest from one day to another. The most commonly used esthetic materials are the resin composites that are bonded to the tooth structure via an adhesive material. Bond strength is the force per unit area that is required to break a bonded assembly with failure occurring in or near the adhesive/adherent interface. In a shear bond test, the bond is broken by a force working parallel to a tooth surface. Establishing adequate bond strength is considered the main goal for any bonding systems. The dentin bonding agents may act by way of chemical reaction or by their ability to penetrate not only the dentinal tubules but also the intertubular substance of the surface layer of dentin.

For a reliable bond between a restorative resin and dentin, different techniques have been used to enhance the infiltration of the adhesive. This is done by either modification or removal of the smear layer by different acidic conditioners. Also adhesive infiltration is increased by pre-application of the primers (HEMA in water), multiple coats and agitated action of the adhesive. Recently electro-bond has been invented to provide high bond strength.

In this study a new technique was used to enhance monomer infiltration and increase the rate of water and solvent evaporation. This new technique depends on using a rotary mini-brush for the application of an adhesive agent at 800 rpm for 15 seconds. Two types of self-etch adhesive systems were used in this trial. The AdheSE (Ivoclar Vivadent) which is a two step application system and the Adper Adper™ Prompt™ L-Pop™ (3M ESPE) which is a one step application system.
Shear bond strengths of the two adhesives with and without rotary mini-brush application were calculated. Bond strength results of AdheSE (two step adhesive) with a mean of (20.06) Mpa were significantly higher than those achieved by the Adper Adper™ Prompt™ L-Pop™ adhesive (one step application) with a mean of (14.15) Mpa. The explanation of these results is that, most monomers are unstable, phosphoric acid ester and methacryl acid ester compound in particular can be hydrolyzed byaqueous solutions and with acidic pH value. This is in agreement with Moszner et al., 2001. AdheSE has been developed with stable monomers such as phosphonic acid compound which is more stable as the phosphorous atom directly bonds with a carbon atom. These results were also in agreement with Thonemann et al., 1999 and Fogel et al., 1988. They reported that the application of the adhesive as a separate step may provide sufficient time for proper water/solvent evaporation and proper resin penetration. Also, this separate layer may provide additional free radicals to enhance the rate and extent of polymerization. In agreement, Cadenaro et al., 2005 and Breschi et al. 2007, concluded that the two step self-etch adhesive exhibited higher extent of polymerization and subsequently high bond strength. They stated that the increase in hydrophilic monomers and water in all-in-one self-etch adhesives leads to suboptimal curing of resin that may expedite water sorption and compromise the integrity of the hybrid and adhesive layer. Kinney and Oskoe, 2006, stated that pH of self etching adhesives may persist after polymerization. This may neutralize tertiary amine initiators of the overlying resin composite and thus inhibit its polymerization. Therefore, the use of a separate layer of adhesive would prevent such adverse interaction improving the bonding mechanism. Furthermore, De Munck et al., 2007 reported that this separate resin layer provided a relatively thick, rather than elastic and strong adhesive layer which may act as a shock absorbent reducing polymerization stresses according to the “Elastic bonding concept”. The results of using the new technique (i.e. rotary mini brush) showed significant increase of shear bond strength for both adhesive systems. This is in agreement with Pashley et al., 2002 findings where they applied Adper™ Prompt™ L-Pop™ to the surface of dentin and agitated it for 15 seconds then cured it for 10 seconds.

The significant increase in shear bond strength for both adhesive systems using the rotary brush application technique may be due to the mechanical force action of the rotary mini brush which enhances the infiltration of the monomer and helps in the removal of the smear layer and increase rate of both water and solvent evaporation.

References:


<table>
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<th>GROUP</th>
<th>AdheSE Normal application</th>
<th>AdheSE Rotary application</th>
<th>P-LP Normal application</th>
<th>P-LP Rotary application</th>
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<tr>
<td>Mean ± SD</td>
<td>19.15 ± 1.06</td>
<td>18.91 ± 3.37</td>
<td>15.30 ± 3.07</td>
<td>12.45 ± 0.86</td>
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<td>T test</td>
<td>127.97</td>
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<td>P value</td>
<td>&lt;0.0001 (statistically significant)</td>
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*Statistically significant

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<td>AdheSE rotary</td>
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<tr>
<td>AdheSE rotary</td>
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(Table 1) The mean and SD of shear bond strength in Mpa with normal and rotary brush applications of the two used adhesives.

<table>
<thead>
<tr>
<th>GROUP</th>
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<tr>
<td>Mean ± SD</td>
<td>20.06 ± 2.19</td>
<td>14.15 ± 2.21</td>
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<tr>
<td>T test</td>
<td>13.62</td>
<td>9.54</td>
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<td>P value</td>
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(Table 2) Tukey test for post hoc comparison.

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(Table 3) The mean and SD of shear bond strength in Mpa between AdheSE and Adper™ Prompt™ L-Pop™ adhesives.

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<thead>
<tr>
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<th>AdheSE</th>
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(Table 4) The mean and SD of shear bond strength in Mpa between normal and rotary brush applications.


