Effect of air abrasion and thermocycling on resin adaptation and shear bond strength to dentin for an etch-and-rinse and self-etch resin adhesive

Rebecca FREEMAN, Srinivas VARANASI, Ian A. MEYERS and Anne L. SYMONS

The University of Queensland, School of Dentistry, 200 Turbot Street, Brisbane, Queensland 4000, Australia
Corresponding author, Anne L. SYMONS; E-mail: a.symons@uq.edu.au

This study examined the effect of air abrasion and thermocycling on the adaptation and shear bond strength of composite resin bonded to dentin using etch-and-rinse and self-etch resin adhesives. Confocal microscopy showed both adhesives closely adapted to dentin and a significantly (p<0.001) greater number of resin tags were observed for the etch-and-rinse adhesive. Air abrasion significantly increased resin tag length (p<0.05) for the etch-and-rinse adhesive and significantly increased the number (p<0.001), length (p<0.001) and thickness (p<0.01) of tags for the self-etch adhesive. However, air abrasion resulted in defect formation within the hybrid layer and thermocycling caused separation of the hybrid layer from adjacent dentin containing resin tags. A significant (p<0.05) reduction in shear bond strength was observed for the etch-and-rinse adhesive following thermocycling. Both adhesive systems adapted well to dentin in vitro and shear bond strengths were similar. The area of tag penetration into dentin was significantly (p<0.001) enhanced following air abrasion.

Keywords: Air abrasion, Confocal microscopy, Resin adhesive

INTRODUCTION

The long term success of modern dental adhesive restoratives is limited by the durability of these materials in the oral environment1). Historically, the most cited reasons for the failure of adhesive restorations are loss of retention and poor marginal adaptation2). While it is not uncommon to restore posterior teeth with direct composite resin, these restorations in posterior teeth have a relatively high failure rate3).

The etch-and-rinse technique is susceptible to operator error, is technique sensitive and may be compromised by the local environment. Self-etch adhesive systems, which use non-rinse acidic monomers to condition and prime dentin, were developed to reduce clinical application time and minimize technique sensitivity4). However, a systematic analysis of the clinical effectiveness of contemporary adhesives reports restorations placed using a self-etch adhesive have a higher annual failure than those using an etch-and-rinse adhesive5). While further development of resin adhesive systems is required, manipulation of the dentin surface to enhance resin bonding may improve long term clinical success.

Current dental adhesive strategies depend on how dental adhesives interact with the smear layer and obtain an intimate adaptation to tooth structure6). However, dentin bonding is compromised by the relatively high water and organic content of dentin7). In addition, the formation of a ‘smear layer’ on the cut tooth surface following cavity preparation creates a physical barrier which must be dissolved or made permeable so adhesive monomers can directly contact dentin. Successful bonding of dental adhesives to dentin is recognized by the formation of a hybrid layer8) and the penetration of the adhesive resin into the dentin tubules to form ‘resin tags’9,10). The contribution of resin tag formation to the quality of the bond remains to be determined. Greater bond strengths have been reported to occur in areas where dentin tubule density is high and long resin tag formation observed11-13). However, others report no correlation between bond strength and resin penetration into dentin tubules14,15).

Air abrasion is reported to increase the surface area available for adhesion, enhance resin tag formation16) and improve bond strength to dentin17-18). A thinner smear layer remains following air abrasion19) and while air abrasion does not eliminate the need for etching, the resulting thinner smear layer may be easily penetrated by acid20-23). Reducing the thickness of the smear layer may encourage hybrid layer and resin tag formation for self-etch adhesives24) which are reported to show a thinner hybrid layer structure25). In addition, the clinical performance of the self-etch adhesive systems may be improved following air abrasion by superior micromechanical intermeshing of resin monomers with etched dentin and enhanced resin tag formation, both of which contribute to sealing the pulp, reducing microleakage and minimizing the effects of polymerization shrinkage26).

Therefore, the aim of this in vitro study was to determine the effect of air abrasion on the adaptation of resin adhesives and shear bond strength of composite resin bonded to dentin using etch-and-rinse (Adper Single Bond Adhesive, 3M ESPE, St. Paul, MN, USA) and self-etch (Adper Prompt-L-Pop Self-Etch Adhesive, 3M ESPE) resin adhesives.
MATERIALS AND METHODS

Restorative procedures
Forty-eight freshly extracted third molars, stored in phosphate-buffered saline (PBS, pH 7.2–7.4), were used. Teeth were free of caries and restorations. Sixteen teeth were used for the adhesive resin analysis and 32 for testing shear bond strength.

Prior to cavity preparation, an orientation groove, confined to enamel, was placed on the proximal surface, as a point of reference to identify each restorative procedure. Anticlockwise from this groove, restorations in groups A, B, C and D were identified (Fig. 1). Restorative materials and composition are listed in Table 1, procedures described in Table 2 and techniques described in Table 3.

The enamel surface was cleaned with pumice and water. Standardized buccal and lingual preparations (2 mm diameter, 2 mm depth) were placed in the middle third of the crown. Preparations were cut using a cylindrical diamond bur in a high-speed hand piece with water coolant. A prefabricated jig was placed against the tooth surface to standardize the diameter and depth of the cavity preparation. For each tooth, cavity preparation A was completed and restored followed by cavity preparations and restorations B, C and D.

A fluorescent dye, Rhodamine B (Sigma-Aldrich Pty. Ltd, Sydney, NSW, Australia), was dissolved in PBS (1.0 mg Rhodamine B in 10 mL PBS) and 1.5 µL of this dye-containing solution was added to 15 µL of the bonding agent, immediately before the adhesive was applied to the cavity preparation. The dye was used to label the hybrid layer and tags for examination using confocal laser scanning microscopy (CLSM). Preparations were then restored with a 2 mm increment of micro-hybrid

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Table 1  Adhesive materials and composition

<table>
<thead>
<tr>
<th>Material</th>
<th>Composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adper Single Bond Adhesive*</td>
<td>Ethyl alcohol, silane-treated silica, bisphenol A-diglycidyl ether dimethacrylate (Bis-GMA), 2-hydroxyethyl methacrylate, glycerol, 1,3-dimethacrylate copolymer of acrylic and itaconic acids, water, diurethane dimethacrylate</td>
</tr>
<tr>
<td>Adper Prompt L Pop Self-Etch Adhesive*</td>
<td>2-propenoic acid, 2-methyl-phosphinicobis (oxy-2,1-ethandiyl) ester, mono HEMA phosphate, methacrylated pyrophosphates, Tris[2-(methacryloyloxy) ethyl] phosphate ethylene dimethacrylate, phosphoric acid, Bis (2,6-dichlorobenzoyl) butylphenyl phosphine oxide, 2-hydroxyethyl methacrylate, 4-methoxyphenol, hydroquinone, Bis-GMA, DL-camphorquinone, ethyl 4-dimethyl aminobenzoate</td>
</tr>
<tr>
<td>Z100 Restorative Composite*</td>
<td>Silanetreated ceramic, Bis-GMA, triethylene glycol dimethacrylate (TEGDMA),2-benzotriazolyl-4-methylphenol</td>
</tr>
</tbody>
</table>

*3M ESPE, St. Paul, MN, USA.

Table 2  Restorative procedures for each restorative group A–D (n=16)

<table>
<thead>
<tr>
<th>Group</th>
<th>C/T</th>
<th>Air abrasion</th>
<th>Restorative Procedure</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>C</td>
<td>No</td>
<td>3M Z100 Restorative Dental Composite* plus Adper Single Bond Adhesive*</td>
</tr>
<tr>
<td></td>
<td>T</td>
<td>Yes</td>
<td>3M Z100 Restorative Dental Composite* plus Adper Single Bond Adhesive*</td>
</tr>
<tr>
<td>B</td>
<td>C</td>
<td>Yes</td>
<td>3M Z100 Restorative Dental Composite* plus Adper Single Bond Adhesive*</td>
</tr>
<tr>
<td></td>
<td>T</td>
<td>No</td>
<td>3M Z100 Restorative Dental Composite* plus Adper Prompt-L-Pop Self-Etch Adhesive*</td>
</tr>
<tr>
<td>C</td>
<td>C</td>
<td>No</td>
<td>3M Z100 Restorative Dental Composite* plus Adper Prompt-L-Pop Self-Etch Adhesive*</td>
</tr>
<tr>
<td></td>
<td>T</td>
<td>Yes</td>
<td>3M Z100 Restorative Dental Composite* plus Adper Prompt-L-Pop Self-Etch Adhesive*</td>
</tr>
</tbody>
</table>

Half of the specimens served as controls (C, n=8) and the remainder thermocycled (T, n=8). *3M ESPE, St. Paul, MN, USA.
composite resin 3M Z100 Restorative Dental Composite (3M ESPE). Following restoration, teeth were separated into two groups, control (C, stored in PBS until sectioned) or thermocycled (T), \((N=8)\). Thermocycled teeth were stored in PBS for 20 h prior to thermocycling for 1,000 cycles between water baths at 5°C and 55°C, with a dwell time of 30 s per bath, prior to sectioning.

Control and thermocycled teeth were sectioned mesio-distally along the central occlusal fissure using a slow speed rotating diamond blade. Each restoration was sectioned bucco-lingually, perpendicular to the outer surface of the restoration (Fig. 1, cuts 2–7). Sections were viewed using a dissecting microscope at a magnification of X64 and stored in PBS prior to CLSM examination.

### Confocal microscopy

Tooth-restoration sections of control and thermocycled teeth were examined using CLSM (LSM510, Carl Zeiss, Tessovar, West Germany) with a 10× objective and oil immersion 40× and 60× objectives. The fluorescence emission of the resin layer along the axial wall of the cavity preparation and within the dentin tubules was detected using a 488 nm excitation line. Sections were immersed in water and covered with a transparent cover slip. A length of 100 µm in the central region of the axial wall was examined for the presence of defects, adhesive resin adaptation and penetration into dentinal tubules.

Using CLSM, the number, length, thickness and area of the adhesive resin tags within the dentin tubules were determined using interpolated image stacks (400× magnification) of tooth sections containing the fluorescent adhesive resin. These images were reconstructed into a 2-D data set, using surface rendering techniques. Following surface rendering, the 2-D images were intensity thresholded, for isosurfacing and isocountering, using the Axiovision Automeasure 4.3 Image Analysis Software (Carl Zeiss).

The number of adhesive resin tags penetrating dentin tubules were counted along a 100 µm length of the axial wall (Fig. 2). The length of the resin tags was measured from the axial wall of the tooth (below the hybrid layer) to the end of the tag penetrating the tubule. For each specimen the mean adhesive tag length was determined. The thickness of the tag was measured approximately 5 µm beneath the hybrid layer, within the dentin tubule. The area occupied by adhesive resin tag penetration into dentin was measured using densitometry (Fig. 2). Data obtained for each group was compared using the Axiovision Automeasure 4.3 Image Analysis Software Program (Carl Zeiss).
Shear bond strength
A 1.00 mm thick sagittal slice of coronal dentin, from a region 0.5–1.5 mm below the dento-enamel junction on the buccal or lingual aspect of the crown, was cut using a slowly rotating diamond blade. Dentin tubules in the center of the slice were estimated to be perpendicular to the cut surface. The dentin slice was covered with a waterproof, 1 mm thick, double-sided, adhesive polyvinylchloride tape, pre-punched to expose a circular area of dentin, 2.00 mm in diameter in the center of the tooth section. The exposed dentin was treated as described for A, B, C or D above and a 1.5 mm high disk of composite with a diameter of 2.00 mm bonded to the dentin surface. Sections were stored in PBS at 25°C for 2 weeks prior to testing. Sections were divided into control or thermocycled (N=8). Shear bond strength was measured at 25°C using a custom-made, single-plane jig attached to a tensometer (Monsanto Houndsfield Tensometer, Test Equipment, Croydon, England) fitted with an electric load cell. The force was registered using a strain gauge (400×, 0.02 N). Specimens were tested to failure using a cross-head speed of 5.00 mm/min. Testing was performed without knowledge of the treatment procedures undertaken. The force at failure was used to calculate shear bond strength. Data was analysed using Graph Pad Instat 3 (San Diego, California, USA). For resin tag measurements, data was tested for normality using the Kolmogorov-Smirnov test and analysed using t-tests. Statistical differences in resin tag number, length, thickness and area were determined between the two adhesive systems (Groups A and C) and within each adhesive system following air abrasion (Groups A and B; Groups C and D). Differences were considered significant with p<0.05. Normality and equality of variances were confirmed for shear bond strength data which was analysed using t-tests comparing adhesive systems (Groups A and C) and the effect of air abrasion (Groups A and B; Groups C and D). In addition, the effect of thermocycling on shear bond strength, in each restorative group, was analysed using t-tests and significance determined where p<0.05.

RESULTS
Macroscopic examination of the axial wall using a dissecting microscope revealed Rhodamine B colouration along the interface between the restoration and dentin.

Fig. 3 Confocal micrographs showing resin tag formation and adaptation to dentin for control specimens from each restorative group: (a) Group A, (b) Group B, (c) Group C and (d) Group D. Bar represents 10 µm.
For all groups, the dye penetrated the dentin and the restorative material appeared well adapted.

CLSM examination showed that for groups A and C, the adhesive resin was well adapted to dentin in the mid portion of the axial wall and penetrated the dentin tubules (Fig. 3). Following air abrasion and thermocycling, specimens exhibited adhesive defects along the axial dentin (Fig. 4). Defects were located at the adhesive

Fig. 4 Confocal micrographs showing separation of the hybrid layer from dentin containing resin tags following thermocycling for each restorative group (a) Group A, (b) Group B, (c) Group C, (d) Group D. In addition to separation, disturbances in the hybrid layer were also observed in some thermocycled specimens as shown in (e) section from a Group B specimen. Bar represents 10 µm.
resin-dentin interface and included separation of the hybrid layer from resin penetrating tubules, presence of clefts and/or voids within the hybrid layer (Fig. 4) or a combination of both (Fig. 4e). Clefts or voids in the hybrid layer were observed in air abraded specimens and separation of the hybrid layer from the dentin surface containing resin tags was characteristic of thermocycling. Thermocycling did not appear to disrupt penetration of resin into the tubules. Air abraded, thermocycled specimens contained the greatest distribution of adhesive defects with a combination of clefts or voids in the hybrid layer and separation from the dentin (Table 4). The distribution of defects was similar for both adhesive systems (Table 4).

There was no significant difference in shear bond strength (Table 6) between the two adhesives tested (Group A and C) and air abrasion did not significantly increase shear bond strength (Group A and B; C and D). Thermocycling significantly (p<0.05) reduced the shear bond strength of the Group A etch-and-rinse adhesive, but within other restorative groups, no reduction in shear bond strength was observed following thermocycling. In general, thermocycling tended to reduce and air abrasion tended to increase the mean shear bond strength to dentin (Table 6). The mode of bond failure was adhesive for each material tested. Dentin surfaces were smooth and clean indicating that fracture occurred at the interface between dentin and resin.

**DISCUSSION**

The current *in vitro* study observed close adaptation of adhesive resin to the dentin surface for the etch-and-rinse and self-etch systems. Adaptation to dentin was compromised by air abrasion and thermocycling, with specimens showing separation of the hybrid layer from the underlying dentin. Thermocycling significantly (p<0.05) reduced the shear bond strength for the etch-and-rinse adhesive to dentin. Pre-treatment with air abrasion

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**Table 4** Distribution of defects in the adhesive layer for control (C) and thermocycled (T) specimens in each restorative group (n=8)

<table>
<thead>
<tr>
<th>Restorative group</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>T</td>
<td>C</td>
<td>T</td>
<td>C</td>
</tr>
<tr>
<td>Adaptation defects present</td>
<td>0</td>
<td>7</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>Well adapted (no defects)</td>
<td>8</td>
<td>1</td>
<td>4</td>
<td>0</td>
</tr>
</tbody>
</table>

**Table 5** Resin tag measurements, mean (SD), comparing adhesives (A vs C) and the effect of air abrasion on tag number, length, thickness and area for each adhesive system (Groups A vs B, C vs D)

<table>
<thead>
<tr>
<th>Resin tag measurements</th>
<th>Group</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number/100 µm</td>
<td>17.5 (7.26)</td>
<td>20.47 (8.4)</td>
<td>5.06 (4.8)AC***</td>
<td>18.56 (8.15)CD****</td>
<td></td>
</tr>
<tr>
<td>Length (µm)</td>
<td>9.6 (9.0)</td>
<td>23.09 (13.7)AB*</td>
<td>3.63 (3.21)AC**</td>
<td>31.79 (16.84)CD***</td>
<td></td>
</tr>
<tr>
<td>Thickness (µm)</td>
<td>0.77 (0.58)</td>
<td>1.28 (0.26)</td>
<td>0.41 (0.42)</td>
<td>1.26 (0.21)CD**</td>
<td></td>
</tr>
<tr>
<td>Area (µm²)</td>
<td>104.7 (41.09)</td>
<td>405.76 (183.16)AB****</td>
<td>65.6 (32.58)AC**</td>
<td>412.24 (177.21)CD****</td>
<td></td>
</tr>
</tbody>
</table>

**Table 6** Mean (SD) shear bond strength (MPa) for each restorative procedure comparing resin adhesives (Group A vs Group C), effect of air abrasion (Groups A vs B, Group C vs D) and thermocycling (within the restorative group) on bond strength (n=8)

<table>
<thead>
<tr>
<th>Shear bond strength MPa Mean (SD)</th>
<th>Group</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>16.15 (4.64)</td>
<td>17.96 (5.99)</td>
<td>17.50 (5.36)</td>
<td>15.05 (3.93)</td>
<td></td>
</tr>
<tr>
<td>Thermocycled</td>
<td>9.57 (2.86)C-T*</td>
<td>14.96 (3.94)</td>
<td>11.52 (2.94)</td>
<td>14.59 (1.37)</td>
<td></td>
</tr>
</tbody>
</table>

C-T compares bond strength for Group A controls (C) with Group A thermocycled (T) specimens. *p<0.05.
abraded increased the number of resin tags penetrating the dentin tubules for both adhesives. Air abrasion had a more profound effect on resin tag formation for the self-etch adhesive where tag number (p<0.001) and thickness (p<0.01) were significantly increased. Both adhesive systems demonstrated similar shear bond strengths to dentin which was not significantly enhanced following air abrasion. However, shear bond strength values tended to remain higher, following thermocycling, for air abraded specimens.

While the aim of dental adhesion is to obtain intimate adaptation of the restorative material to tooth structure\(^6\), bonding is challenged by the high water and organic content of dentin\(^7\). The smear layer created during cavity preparation forms a physical barrier which must be dissolved or made permeable so adhesive monomers can contact the dentin surface\(^6\). The basic composition of the smear layer is hydroxyapatite and altered collagen\(^22\), and the morphology of the smear layer varies with the type of instrument that creates it and the site where it is formed\(^6,28,29\). Although the dentin surface prepared with airborne-particle abrasion is covered by a thin smear layer, use of an acidic conditioner following air abrasion is essential for clinical success of the restoration, prevention of postoperative sensitivity and to counteract forces resulting from the polymerization shrinkage of composite resins\(^6\). A thinner smear layer covering a macerated dentin surface may potentiate the activity of the conditioning agent and result in an over etching of the fragile dentin surface\(^25,33\).

Development of the self-etch adhesive systems aimed to simplify and improve the efficacy of resin adhesion to dentin\(^6\). However, resin restorations placed using self-etch adhesives are reported to demonstrate lower bonding effectiveness in vitro\(^34\) and clinical trials report a less favourable clinical effectiveness for composite restorations using this adhesive system\(^31\). In the current study, confocal microscopy showed that both adhesive systems demonstrated an ability to closely adapt to dentin, via the formation of a hybrid layer and resin tags. This intimate contact with dentin is considered essential for clinical success of the restoration, prevention of postoperative sensitivity and to counteract forces resulting from the polymerization shrinkage of composite resins\(^6\). However, the diminished ability of the self-etch adhesive to form resin tags may reduce their clinical effectiveness.

Hybrid layer and resin tag formation are dependent on the adhesive system used, dentin surface characteristics, tubule orientation, mineral content of intertubular dentin and the density, morphology and approximation of the dentin tubules to the pulp\(^35\). This study attempted to minimize these variations by selecting third molars extracted from young adults, confining the surface examined to the axial dentin wall and placing dimensionally similar restorations in the same tooth. Hybrid layer and resin tag formation were observed for all groups studied. Resin tag formation for the etch-and-rinse adhesive was longer and more numerous than that observed for the self-etch adhesive. Following air abrasion, resin tag length significantly increased for both adhesive systems and for the self-etch adhesive, tag number and thickness significantly increased. Reducing the thickness of the smear layer and altering the dentin surface structure following air abrasion may potentiate the penetration and efficacy of the etch component in an adhesive system. Thus, a thin smear layer occluding the dentin tubule may be easily removed when etched. This could enhance resin tag formation for all adhesive systems, having a greater impact for self-etch adhesives.

The self-etch adhesive system used in this study, Prompt-L-Pop, has an initial pH of approximately 0.9 compared with the standard 37% phosphoric acid gel which has a pH of approximately 0.6. The slightly lower pH of the phosphoric acid may be more effective in removing the smear layer and opening dentin tubules to allow resin penetration and tag formation. The process of washing off the acid and gently air drying is not reliable in producing the ideal surface moisture to enable resin interpenetration and tag formation. The Prompt-L-Pop system avoids this step, as it dissolves the smear layer and incorporates remnants of the smear layer within the hybrid layer and resin tags and which may in turn affect resin interpenetration and tag formation. Failure to remove the smear layer which forms a plug at the tubule opening may inhibit tag formation. It is clear from the air abraded specimens that the resin components in both adhesive systems have the potential to penetrate dentin tubules and form a hybrid layer.

A more intimate contact with dentin may improve the reliability of the dentin-adhesive interface and enhance clinical durability of the resin bond. The importance given to the infiltration and flow of the adhesive resin inside the acid-treated dentinal tubules remains to be determined. For optimal dentin bonding, the adhesive must penetrate the demineralised dentin tubule prior to polymerization\(^39\). Resin tags are believed to have the capacity to adhere to the tubular surface only where they infiltrate the interfibrillar spaces in the surrounding demineralised intertubular dentin\(^37\). However, polymerization shrinkage may cause separation of the adhesive from the tubule wall\(^39\). It has also been shown that the length of the resin tag may exceed the area where dentin has been demineralised\(^40\). The relative importance of resin tag formation with respect to sealing the pulp-dentin complex and bond strength may vary according to location. Resin tags approximating the hybrid layer may play a greater role with respect to bond strength and permeability of the pulp-dentin complex\(^36\). Deeper resin tags may occupy the tubule without adhering to the walls and where the bonding agent adheres to dentin, polymerization shrinkage may produce hollow resin tags\(^37\). In addition, polymerization shrinkage may result in tearing of the dentin surface damaged by air abrasion, compromising adhesion. However, resin tag formation may not contribute to shear bond strength where the hybrid layer becomes separated from the adjacent dentin following polymerisation shrinkage and aging of the restoration. Where separation occurs, resin tags penetrating the
dentin may only contribute to the protection of the pulp by sealing the tubules.

Confocal micrographs revealed defects in the adhesive layer of thermocycled and air-abraded specimens. These defects include separation of the hybrid layer from underlying dentin and disturbances within the hybrid layer and were observed for both adhesive systems. Thermocycled specimens tended to show separation of the hybrid layer from dentin in which resin tags were located. This separation may account for the reduction in shear bond strength observed for the etch-and-rinse adhesive. Air abrasion has been suggested to cause superficial maceration of the collagen fibers on the dentin surface\(^{39}\) and increase the incidence of adhesive fractures\(^{40}\). This effect may weaken the superficial structure of the dentin and affect the quality of the hybrid layer\(^{39}\) resulting in the formation of defects such as voids and clefts.

Thermocycling protocols to evaluate bond durability range from 100 cycles\(^{41}\) to more than 50,000 cycles\(^{42}\). The current study used 1,000 thermal cycles, which is more than the regimen proposed by the ISO standard\(^{43}\). A significant reduction in shear bond strength was observed for the etch-and-rinse adhesive controls following 1,000 cycles but not for the other restorative protocols. Similar bond strengths and the failure of 1,000 cycles to significantly reduce shear bond strength have been reported previously\(^{44,45}\) and may indicate bond failure had not occurred across the entire dentin surface. Increasing the number of cycles may result in a more significant reduction in shear bond strength. The addition of 10% Rhodamine B dye to the bonding system had the potential to disturb adhesion but CLSM images demonstrated good adaptation and shear bond strengths similar to that previously reported\(^{44,45}\). In the restorative groups examined, resin adhesion to dentin was reduced following air abrasion and thermocycling. Polymerisation shrinkage of the restorative composite within the cavity preparation may subject the adhesive layer to stresses not present in the shear bond strength specimens and could explain why bond strength results did not reflect the loss of adaptation observed with CLSM.

Controversy remains as to the effect of air abrasion on resin-dentin bond strength. Air abrasion has been suggested to decrease resin bond strength to etched surfaces due to the increased capability of acid to over demineralise the dentin surface, causing collagen collapse and the deposition of calcium phosphate, which disrupts penetration of the adhesive\(^{32,33}\). In primary teeth, air abrasion of dentin prior to etching has been recommended to improve adhesive bond strengths. Increased bond strengths have been suggested to arise from air abrasion creating a rough irregular surface, thereby increasing the surface area\(^{22,31,46-48}\) and enhancing hybrid layer and resin tag formation\(^{8}\). Similar to the findings of the current study, others report the use of airborne-particle abrasion did not improve the shear bond strength of composite to dentin\(^{19,22,49}\).

For both adhesive systems examined, an increase in the number of defects located at the dentin-adhesive surface was observed following thermocycling. Where air-abrasion has severely damaged the dentin surface, the permeation of biological fluids that cause hydration of the resin matrix and breakdown adhesion to the collagen fibers\(^{50}\) may be enhanced and result in reduce long term clinical durability.

**CONCLUSION**

Using conventional preparation techniques, good adaptation of both resin adhesives to dentin was observed but resin tag formation was markedly reduced for the self-etch adhesive. Resin adhesives initially showed close adaptation to dentin and this adaptation was compromised following thermocycling. Air abrasion significantly increased the area of resin tag formation into dentin. This effect was more apparent for the self-etch adhesive. Although air abrasion tended to increase the number, length and diameter of resin tags, it increased the number of defects observed in the hybrid layer on the dentin surface and minimally enhanced shear bond strength of resin to dentin. The clinical significance of enhanced resin tag formation in air abraded dentin for self-etch adhesive restorations remains to be determined.

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**REFERENCES**


