Effect of temporary cements on the bond strength of ceramic luted to dentin


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KEYWORDS
Eugenol; Temporary cement; Sandblasting; Shear bond strength; Ceramic; Dentin; Excavator; Resin-based luting cement

Summary
Objectives. The purpose of this study was to evaluate the effect of either eugenol-containing or eugenol-free temporary cement removal by excavator or sandblasting on the shear bond strength of ceramic luted to dentin.

Methods. A self-etching primer system, Panavia F 2.0, Kuraray Medical (PF2), and a total-etch bonding system, Excite/Variolink II, Vivadent (EXV), were used. One hundred and forty human molars, ground to expose dentin surfaces, were divided into 14 groups (seven groups for each adhesive system). For each adhesive system, either a eugenol-containing (Temp bond) or a eugenol-free (Temp bond NE) temporary cement was applied to the dentin surface for 7 days, then removed by an excavator or sandblasting (four groups). Three control groups were studied where fresh dentin was either scratched by excavator or sandblasted, or underwent no surface treatment. After application of the adhesives, ceramic cones (Cerafil inserts) were adhesively luted to standardized dentin areas. After 24 h storage in distilled water, the shear bond strengths were determined at a cross-head speed of 0.75 mm/min.

Results. For each adhesive system, neither the method of temporary cement removal nor the type of temporary cement affected the bond strength significantly ($P \leq 0.05$). EXV showed statistically higher bond strengths (26.6–31.6 MPa) than PF2 (8.6–12.9 MPa) within all groups.

Significance. The use of temporary cements, either containing eugenol or not, does not alter the retentive strength of ceramic restorations luted to dentin using the tested adhesive systems, whether the temporary cements are removed by excavator or sandblasting.

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Introduction

The use of all-ceramic restorations has increased in recent years, mainly due to improved adhesion...
technology and new ceramic materials. Clinical data show that all-ceramic restorations can be regarded as clinically acceptable [1]. However, bonding technology is generally complicated, and especially when ceramic restorations have to be inserted in the posterior region. Furthermore, most all-ceramic techniques require dental laboratory work. This means that a temporary restoration is necessary in order to avoid sensitivity, infection and tooth movement.

Zinc oxide-eugenol (ZOE) temporary luting cements are commonly used because of their sedative effect on sensitive teeth. Like other phenolic compounds, eugenol is a radical scavenger, which inhibits the polymerization of resin materials [2, 3]. The set mass of the cement consists of unreacted zinc oxide particles in a matrix of zinc eugenolate. It is well-documented that eugenol is able to penetrate dentin. In the literature, the diffusion rate of eugenol released from zinc oxide-eugenol (ZOE) increased to a peak after 1 day (about 0.3 nmol/min) and then decreased slowly to 0.08 nmol/min after 14 days [4]. Therefore, for the present investigation, a period of 7 days was considered appropriate to allow eugenol to diffuse into dentin and eventually affect the bond strength. Furthermore, 7 days is also the approximate period of time a temporary restoration would be used under clinical conditions.

Contradictory findings have been published with regard to bond strength to dentin after ZOE placement. Recent studies found that eugenol-containing cements did not reduce bond strength to dentin [5–8]. However, other studies reported contradictory results [9,10]. It is noteworthy that the use of eugenol-free cement was also found to reduce the bond strength to dentin, when compared to fresh dentin [5,11] or to surface-treated fresh dentin [12]. As suggested by Woody and Davis [13], the negative effect may not be caused by eugenol but by the presence of residual cement. It was found that mechanical removal of temporary cements was not fully effective; remnants of the cements were observed microscopically on the surfaces, which appeared macroscopically clean [11,12,14]. Therefore, different attempts have been made to eliminate the remaining provisional cement [10,12,15].

'Sandblasting' or 'air abrasion', a system which propels a fine aluminum oxide powder in a high-velocity stream of air against the tooth structure [16], may be capable of removing the provisional cement remnants, which may be difficult to be completely removed under clinical conditions. In addition, sandblasting can remove the superficial thin layer of dentin which contains the highest eugenol concentration [4]. No data are available in the literature about sandblasting as a method of cleansing. It was found that the aluminum oxide particles used in the procedure produce roughness on both enamel and dentin surfaces [17]. It was suggested in the literature that sandblasting could replace acid etching in preparation of the surface [18]. However, it has been frequently shown that the use of air abrasion cannot replace acid etching [19]. Sandblasting plus conditioning of the dentin surface resulted in bond strengths of the dentin bonding agents either similar to [20–22] or higher than [23] the conditioned only controls.

The objective of this study was to test the following hypotheses. (1) Removal of temporary cements by sandblasting will influence the shear bond strength of ceramic luted to dentin—using two different resin-based luting cements—when compared to an established procedure for temporary cement removal using an excavator. (2) The bond strength of ceramic luted to dentin will be affected when eugenol-containing and eugenol-free temporary cements are compared to one another.

### Materials and methods

#### Specimens preparation

One hundred and forty non-caries human third molars were collected, stored in 0.5% Chloramine solution, then cleaned and stored in distilled water (4 °C) for a maximum of 6 months. The teeth were embedded in chemically cured acrylic resin (Saml Kwick, Buehler, Lake Bluff, IL, USA). They were ground flat with a series of SiC-papers ending with 600 grit used on a polisher (Polimet, Buehler) to obtain a tangential buccal dentin surface of about 4 mm diameter (about 1.5–2.0 mm distance from the pulp).

The teeth specimens were randomly and equally divided into two main groups for two adhesive systems/corresponding luting materials: a self-etching primer system (ED-primer II/Panavia F 2.0, Kuraray Medical, Okayama, Japan) (PF2) and a total-etch bonding system (Excite/Variolink II, Vivadent, Schaan, Liechtenstein) (EXV) (Table 1). Each group was further subdivided into seven groups of 10 specimens each (Fig. 1). Simulating the temporary restorations, discs of a temporary composite resin (Luxa temp, DMG, Hamburg, Germany) were cemented to the dentin surface with the tested temporary cements (Temp-bond and Temp-bond NE, Kerr Italia S.P.A., Scafati, Salerno, Italy). After 7 days, the provisionally cemented discs were
removed from the dentin surface and any remaining cement was removed using either sandblasting or an excavator. Sandblasting was performed with 30 μm alumina particles (Korox™, Bego, Germany), at 4 bar pressure, at 3 mm distance from the dentin surface using DENTO-PREP® Microblaster (RONVIG Dental Mfg, Daugaard, Denmark). The excavator was used with very close (mostly overlapping) parallel strokes under moderate pressure and the procedure was repeated in an overlapping direction if any remnants were detected macroscopically. All the operations were performed by one researcher.

### Luting procedure

Prefabricated IPS-Empress ceramic inserts (Cerafil, Komet, Gebr. Brasseler, Lemgo, Germany) of 3 mm diameter at their bases were used. A layer of about 100 μm was removed from the base of the ceramic cone using Soflex discs (3M ESPE, St Paul, MN, USA) to remove any surface treatment provided by the manufacturer. Then, the surface (base) was roughened with 240 grit SiC-paper (about 58 μm grain size, according to the manufacturer) to obtain a flat bonding surface in a circular form of 2.9-3.0 mm in diameter.

For each tooth specimen, a standardized circular surface of dentin of 3 mm in diameter was prepared for bonding using a Teflon ring (two halves) with a hole of 3 mm diameter. Using a special device designed for specimen preparation (Fig. 2), the ring was fixed securely and with maximally possible vertical pressure over the dentin to create a cavity with a dentin surface as a base. First, the ceramic surface was conditioned according to the manufacturers’ instructions, and then the dentin surface was treated with one of the adhesive systems (Table 1). Within the working time of the luting resin, the ceramic cone was cemented to the treated dentin surface (Table 2) and a load of 400 g (0.58 MPa) was applied over it (Fig. 2). While the ceramic cone was fixed in place by the load, the Teflon ring was removed carefully and the excess luting cement was removed with small cotton pellets. Then, visible light (Spectrum™ curing light, Dentsply/Detrey, Konstanz, Germany) of 500 mW/cm² intensity, as determined with a radiometer (Caulk Dentsply, Milford, DE, USA), was directed at the intersection of ceramic bonding sites to dentin. Four polymerization sequences of 20 s, divided equally around the circumference of the ceramic cone, were completed. Then, the load was removed and

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**Table 1** Composition of the luting cements and their adhesive systems.

<table>
<thead>
<tr>
<th>Adhesive system (component)</th>
<th>PFZ (Kuraray Medical, Okayama, Japan)</th>
<th>EXV (Vivadent, Schaan, Liechtenstein)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Etchant</td>
<td>ED II Primer:</td>
<td>Total Etch™ (E44932): 37% phosphoric acid</td>
</tr>
<tr>
<td>Primer</td>
<td>Primer A (00161A): HEMA, MDP, 5-NMSA, water, accelerator</td>
<td>Primer-adhesive (E15084): HEMA, DMA, phosphoric acid acrylate, silica (0.5 wt%), ethanol, initiators</td>
</tr>
<tr>
<td>Luting resin</td>
<td>Panavia F2 (filler content 78 wt%): base paste (0001A): hydrophobic aromatic (and aliphatic) dimethacrylate, hydrophilic dimethacrylate, sodium aromatic sulfinate (TPBSS), N,N-diethanol-p-toluidine, functionalized sodium fluoride, silanized barium glass</td>
<td>Variolink II low viscosity (filler content 72.3 wt%): base paste (E43489): Bis-GMA, UDMA, TGDMA, fillers (73.4 wt%), pigments and stabilizers</td>
</tr>
<tr>
<td>Materials used for ceramic surface treatment</td>
<td>Catalyst paste (00001A): MDP, hydrophobic aromatic (and aliphatic) dimethacrylate, hydrophilic dimethacrylate, silanized silica, photoinitiator, dibenzoyl peroxide</td>
<td>Catalyst paste/low viscosity (E45892): Bis-GMA, UDMA, TGDMA, fillers (71.2 wt%), pigments, stabilizers and catalysts</td>
</tr>
<tr>
<td></td>
<td>K-etchant gel (0298A): 40% phosphoric acid, colloidal silica</td>
<td>IPS Ceramic etching gel (E57837): 5% hydrofluoric acid (HF)</td>
</tr>
<tr>
<td></td>
<td>Clearfil Porcelain Bond Activator (00134B): Silane coupling agent</td>
<td>Monobond-S (E34242): 3-methacryloxypropyl-trimethoxysilane (1 wt %), water/ethanol solution containing acetic acid set to pH 4 (99 wt%)</td>
</tr>
</tbody>
</table>
the light beam was directed to the top surface of the ceramic cone for 2 × 40 s. The specimens were stored in distilled water at 37 °C for 24 h.

**Shear bond strength test**

After storage, shear bond strength was determined using a Universal Testing Machine (Zwick 010, Ulm, Germany) at a cross-head speed of 0.75 mm/min. Bond strength was recorded in Newtons (N) and calculated in megaPascals (MPa). Bond failure sites were inspected visually under a stereomicroscope (Wild M420, Leica, Heerbrugg, Switzerland) at 50 × magnification to determine fracture modes. The fracture mode of each specimen was observed and classified into one of four categories: either complete or partial adhesive fracture at the resin-dentin interface, where remnants of the dentin bonding agent remained adherent to the dentin surface (Adh/Padh), or mixed fracture modes (Padh/CohR: partial adhesive fracture at the resin-dentin interface mixed with cohesive fracture in the luting resin; Padh/CohR/AdhC: partial adhesive fracture at the resin-dentin interface, cohesive fracture in the luting resin and adhesive fracture at the resin-ceramic interface; Padh/CohR/CohC: partial adhesive fracture at the...
resin–dentin interface and cohesive fracture in the luting resin and in the ceramic). For each experimental group, cohesive fracture within dentin (CohD) was inspected. The ratio of the number of specimens, where cohesive fracture in dentin was observed, to the total number of the specimens in each group ($n = 10$) was calculated and represented as a percentage.

Measurement of the luting resin thickness

Ten specimens were prepared (five specimens for each adhesive system) to measure the luting resin thickness. The specimens were embedded in chemically cured acrylic resin. Using the polisher (Polimet), each embedded specimen was consecutively ground flat in 500 $\mu$m intervals to expose five longitudinal sections. After each 500 $\mu$m removal by the polisher, digital images were taken. On the images, resin cement thickness was measured (Optimas 6.2, Media Cybernetics, MD, USA) at three measurement points as demonstrated in Fig. 3, obtaining 15 measurements per specimen. The median luting resin thickness, using PF2 was 31.5 $\mu$m (25/75% quartiles: 27.1/43.4 $\mu$m), whereas that of EXV, was 56.6 $\mu$m (49.7/71.2 $\mu$m).

Statistical analysis

Medians and 25–75% quartiles were determined from 10 replications of each experimental group, and pairwise comparisons between groups were performed using the Mann-Whitney-Wilcoxon rank sum test (PC+, version 5.01, SPSS, Chicago, IL, USA) at the 0.05 level of significance ($\alpha$). In order to assess the influence of the cleansing method, the temporary material and the adhesive system in general and irrespective of all other parameters, the levels of significance were adjusted to $\alpha^* = 1 - (1 - \alpha)^{1/k}$ ($k =$ number of performed pairwise tests) using the error rates method [24].

Results

The median shear bond strengths of freshly prepared dentin and dentin previously exposed to temporary cements with different surface treatments as well as the corresponding 25-75% quartiles are shown in Figs. 4 and 5. Results of pairwise comparisons between groups within each adhesive system are shown in Figs. 4 and 5. Results of pairwise comparisons for adhesive systems vs. each other are shown in Table 3.

Regarding the influence of the method of temporary cement removal (Figs. 4 and 5), only the removal of Temp bond NE by excavator produced significantly higher bond strength than its removal by sandblasting (12.9 and 8.6 MPa, respectively) when PF2 was used. On the other hand, using EXV, the method of temporary cement removal did not affect the bond strength significantly. Regarding the effect of the surface treatments (sandblasting or excavator) on the fresh dentin, both surface treatments did not affect the bond strength significantly within each adhesive system.

For each adhesive system, the type of temporary cement did not affect the bond strength significantly. In general, the error rates method indicates that neither the method of temporary cement removal nor the type of the temporary cement used affected the bond strength significantly, irrespective of the type of adhesive system.
As shown in Figs. 4 and 5, the median of the bond strength values for the ED-primer II/Panavia F 2.0 system (PF2) ranged from 8.7 to 12.9 MPa. For the Excite/Variolink II system (EXV), they ranged from 26.6 to 31.6 MPa. The PF2 system showed statistically lower bond strength values than the EXV system within all groups (Table 3).

The recorded fracture modes are listed in Table 4. Padh/CohR/AdhC (partial adhesive fracture at the resin-dentin interface, cohesive fracture in the luting resin and adhesive fracture at the resin-ceramic interface) was recorded for most of the PF2 groups, whereas it was absent in EXV groups. On the other hand in the case of EXV, Padh/CohR/CohC (partial adhesive fracture at the resin-dentin interface and cohesive fracture in the luting resin and in the ceramic) was recorded in all groups, whereas it was absent in PF2. Regarding the percentage of the presence of cohesive dentin fracture (CohD), it ranged from 10 to 50% in some groups of EXV, whereas no dentin cohesive fracture was observed in all PF2 groups.

**Table 2** Cementation procedure of the ceramic to dentin.

<table>
<thead>
<tr>
<th>Adhesive system (component)</th>
<th>PF2 (Kuraray Medical, Okayana, Japan)</th>
<th>EXV (Vivadent, Schaan, Liechtenstein)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dentin surface treatment</strong></td>
<td>ED-primer II: dispense one drop each of liquid A and B, mix and apply (30 s), completely dry with gentle air flow</td>
<td>Total Etch™: Etch (15 s), rinse (30 s), dry with lint-free absorbent tissue Primer-adhesive: agitate gently (30 s), gently air-dry (3 s) at 5 mm from the dentin surface, light cure (20 s)</td>
</tr>
<tr>
<td><strong>Ceramic surface treatment</strong></td>
<td>K-etchant gel: etch ceramic surface (5 s), rinse (30 s), air-dry</td>
<td>IPS ceramic etching gel: etch ceramic surface (2 min), rinse (30 s), air-dry</td>
</tr>
<tr>
<td><strong>Dispense one drop each of Clearfil Porcelain Bond Activator and Clearfil SE Bond Primer, mix, apply over the ceramic surface, leave in place for (5 s), air-dry and protect from light</strong></td>
<td>Monobond-S: apply on the etched ceramic surface (60 s), air-dry, protect from dust</td>
<td></td>
</tr>
<tr>
<td><strong>Luting of the ceramic to dentin</strong></td>
<td>Panavia F2: mix in a 1:1 ratio (20 s), apply to the ceramic surface, insert the ceramic cone, apply the load, remove the excess, polymerize at the intersection of ceramic bonding sites to dentin at four aspects, remove the load, polymerize at the top of the ceramic resin</td>
<td>Variolink II low viscosity: mix in a 1:1 ratio (20 s), apply to dentin, insert the ceramic, apply the load, remove the excess, polymerize (as in PF2 system)</td>
</tr>
</tbody>
</table>

As shown in Figs. 4 and 5, the median of the bond strength values for the ED-primer II/Panavia F 2.0 system (PF2) ranged from 8.7 to 12.9 MPa. For the Excite/Variolink II system (EXV), they ranged from 26.6 to 31.6 MPa. The PF2 system showed statistically lower bond strength values than the EXV system within all groups (Table 3).

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**Discussion**

In the present study, in a preliminary experiment, the abrasion depth of dentin using 30 μm particles for 1 s was less than 30 μm (Perthometer 56P, Corp. Feinprüf Perthen GmbH, Göttingen, Germany). Three seconds of sandblasting using 30 μm particles
was chosen to be used for the dentin surface of about 4 mm in diameter to assure removal of the dentin in direct contact with the temporary cement and not to hinder the fit of the restorations [25]. In the literature, the abrasion depth of dentin increased as the particle size and air pressure increased [26].

In the present study, a load (pressure of 0.58 MPa) was applied over the ceramic, while the excess cement was removed. This pressure is in the range of that applied in ISO 4049:2000 [27] for determination of the film thickness of the resin luting cements (0.75 MPa).

Non-carious human third molars with roots completed were used for shear bond strength testing to standardize the dentin substrate as far as possible (ISO TR 11405 [28]). Bond strengths may be lower when previously carious or sclerotic dentin—as in the clinical situation—is used as a substrate [29].

Figure 4  Results of the shear bond strength tests using PF2 system (medians with 25-75% percentiles). *Lines indicate significant differences between groups at \( P \leq 0.5 \).

Figure 5  Results of the shear bond strength tests using EXV system (medians with 25-75% percentiles).
The results of the present study showed that the PF2 system exhibited a lower median shear bond strength (12.9 MPa) than the EXV system (29.5 MPa). There are three possible explanations for the bond strength of PF2 being lower than EXV.

The first reason may be that whereas the PF2 system employs a self-etching, water-based, one-step primer system applied without light-curing prior to the application of the luting resin, the EXV system includes a total etch, two-step, ethanol-based filled primer-adhesive, which is light-cured prior to the application of the luting resin. Although the PF2 self-etching primer provides good penetration into the dentin, it creates only a thin adhesive- and hybrid-layer. The EXV primer-adhesive also readily penetrates the moist, conditioned dentin, but due to its filler content and additional light-curing step prior to application of the luting resin, it forms a continuous adhesive layer of considerable thickness. This layer may act as an intermediate elastic layer and relieve stresses of polymerization shrinkage of the luting resin [30]. It has been reported in the literature that pre-curing of the dentin bonding agents increased the dentin bond strength of both direct and indirect restorations [31,32].

The second reason may be that with PF2, ED-primer II for the conditioning of the dentin as well as the Clearfil SE Bond Primer (Kuraray Medical) used for the conditioning of the ceramic, contain an acidic monomer. After application and air-thinning of the primer, the remaining acids of ED-primer II and Clearfil SE Bond Primer could inhibit the chemical curing of the luting resin in the central area away from light due to an interaction with the initiators in the PF2 luting resin mixture [33]. Although PF2 contains ternary redox initiators, like sodium benzene sulfinate, to ensure optimal polymerization of the resin cements when they are used in dual-cured mode, it was found that the addition of sodium benzene sulfinate to acid-contaminated chemically cured resin could not fully revive the rate and extent of polymerization [34]. This can explain why the fracture occurred not only at the interface between resin and dentin, but also between ceramics and resin. On the other hand, with EXV, the primer-adhesive was light-cured prior to the application of the luting resin and became chemically much more stable than the self-etching primer of PF2.

A third explanation for the lower bond strength exhibited by the PF2 system may be related to an increase in adhesive permeability of hydrophilic one-step self-etching adhesives which has been reported in the literature [35]. A slowed rate of polymerization in the dual-cured mode eventually predominant in the central area of the samples away from light may allow water to diffuse from dentin across the adhesive layer, which acts as a semi-permeable membrane, and thus compromise the

### Table 3  Adhesive systems vs. each other.

<table>
<thead>
<tr>
<th>Temporary material</th>
<th>Cleansing method</th>
<th>P-value EXV vs. PF2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fresh dentin</td>
<td>NT</td>
<td>0.0002</td>
</tr>
<tr>
<td>Fresh dentin</td>
<td>ex</td>
<td>0.0002</td>
</tr>
<tr>
<td>Fresh dentin</td>
<td>sb</td>
<td>0.0002</td>
</tr>
<tr>
<td>Temp bond NE</td>
<td>ex</td>
<td>0.0002</td>
</tr>
<tr>
<td>Temp bond NE</td>
<td>sb</td>
<td>0.0002</td>
</tr>
<tr>
<td>Temp bond</td>
<td>ex</td>
<td>0.0002</td>
</tr>
<tr>
<td>Temp bond</td>
<td>sb</td>
<td>0.0003</td>
</tr>
</tbody>
</table>

### Table 4  The mode of fracture.

<table>
<thead>
<tr>
<th>Fracture mode</th>
<th>Fresh dentin (NT)</th>
<th>Fresh dentin (ex)</th>
<th>Fresh dentin (sb)</th>
<th>Temp bond NE (ex)</th>
<th>Temp bond NE (sb)</th>
<th>Temp bond (ex)</th>
<th>Temp bond (sb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PF2 Adh/Padh</td>
<td>6</td>
<td>5</td>
<td>5</td>
<td>4</td>
<td>9</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>PAdh/CohR</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>PAdh/CohR/AdC</td>
<td>4</td>
<td>5</td>
<td>5</td>
<td>4</td>
<td>0</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>PAdh/CohR/CohC CohD (%)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>EXV Adh/Padh</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>PAdh/CohR</td>
<td>3</td>
<td>2</td>
<td>5</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>PAdh/CohR/AdC</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<tr>
<td>PAdh/CohR/CohC CohC</td>
<td>5</td>
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<td>1</td>
<td>4</td>
<td>4</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>CohD (%)</td>
<td>30</td>
<td>0</td>
<td>0</td>
<td>50</td>
<td>20</td>
<td>10</td>
<td>0</td>
</tr>
</tbody>
</table>
bond. On the other hand, with the EXV system, the filled, ethanol based primer-adhesive is light-cured and does not act as a semipermeable membrane.

The significant difference between the bond strength values using the two adhesive systems was associated with a considerable difference in the mode of fracture. Using EXV, cohesive fractures within dentin and within ceramic were observed, whereas they were absent using the PF2 system. Only adhesive fractures between the resin and the dentin, cohesive fracture within the resin in addition to partial adhesive fracture at the ceramic surface were observed using the PF2 system.

In the present study, the median luting resin thickness, using the EXV system (56.6 μm) was higher than that of the PF2 system (31.5 μm). Precuring of the dentin bonding agent (EXV system) resulted in a polymerized layer with elevated boundaries due to the surface tension of the dentin bonding agent when applied in a cavity form (Fig. 3). This polymerized layer contributed to the luting resin thickness of the EXV system, and resulted in higher resin cement thickness than the PF2 system. This is in agreement with the literature, where it was found that pre-curing of the dentin bonding agent improved the marginal seal and increased the bond strength. However, this was associated with an increase in the luting space [32,36].

In the present study, eugenol-containing and eugenol-free temporary cements, removed either by sandblasting or by excavator did not affect the bond strength significantly within each adhesive system. It is clear that the additional removal of the dentin in direct contact with the temporary cement by sandblasting makes this procedure a reliable method for the removal of temporary cement, especially in inaccessible areas. On the other hand, careful removal of the temporary cements by excavator also appears to be a good procedure [no remnants were observed on single specimens by the scanning electron microscope (SEM)]. Careful removal of the temporary cements (parallel and very close, mostly overlapping strokes), the brittleness of the temporary cements and their lack of adhesion to dentin allowed the cement remnants to be easily fractured and removed by the strokes of the excavator. In the literature, SEM and X-ray micro-analysis techniques have demonstrated that mechanical removal with a dental probe does not remove all of the temporary cement from both enamel and dentin surfaces [14]. The use of pumice for temporary cement removal resulted in contradictory results [9,15]; in addition, cleansing with soap and pumice resulted in very low shear bond strength values [10]. In the literature, the decreased bond strength caused by the use of provisional cement was completely restored by phosphoric acid etching and subsequent sodium hypochlorite gel application. This procedure completely eliminated residual cement remnants as evidenced by energy dispersive X-ray spectroscopy and SEM [12].

The results of this study showed that, as with eugenol-free cement, eugenol-containing cement did not influence the bond strength of ceramic luted to dentin using either a total-etch adhesive system or a self-etching adhesive system. This is in agreement with several studies performed with other adhesive systems such as Syntac (Vivadent) [6], Gluma CPS (Heraeus Kulzer) Scotchbond Multipurpose Plus (3M ESPE) [7] Ecusit (DMG), Optibond (Kerr) [8] and Prisma Universal Bond 3 (Dentsply) [15]. In the literature, the bond strength was only found to be reduced after the application of pure eugenol, however, histomorphological changes at the resin-dentin interdiffusion zone were observed after application of both pure eugenol and eugenol-containing temporary cements [8].

Regarding the influence of the methods of temporary cement removal, surface treatment of the fresh dentin either by excavator or sandblasting did not affect the bond strength significantly within each adhesive system and within each temporary cement. Although sandblasting plus conditioning of the dentin surface produced a rougher surface than the conditioned only polished dentin, as measured by Perthometer in a preliminary experiment, no significant difference was found; this is in agreement with other studies [20-22]. Increased roughness cannot be the only factor that improves the bond strength. Other factors may have a stronger influence on the adhesion. One of these factors may be the chemical composition of the dentin surface, which together with the surface roughness and physical parameters (e.g. capillary action) will be decisive for the dentin surface free energy [37] and consequently the diffusion of the adhesive into the demineralized dentin surface [19].

Conclusions

Within the limitations of this study, it is concluded that removal of temporary cements by sandblasting does not affect the bond strength of ceramic luted to dentin compared to an established removal procedure. Bond strength is not influenced by either eugenol-containing or eugenol-free temporary cements on condition that the remaining temporary cement is carefully removed either by excavator or sandblasting. However, the bond
strength of ceramic luted to dentin is dependent upon the luting system used.

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References


