In Vitro Longevity of Bonding Properties of Universal Adhesives to Dentin

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Clinical Relevance
Clinicians should opt to use methacryloyloxydecyl dihydrogen phosphate–containing universal adhesives to improve the bonding longevity of dentin interfaces.

SUMMARY
Purpose: To evaluate the immediate and 6-month resin-dentin bond strength (μTBS) and nanoleakage (NL) of universal adhesives that contain or do not contain methacryloyloxydecyl dihydrogen phosphate (MDP) and are used in the etch-and-rinse and self-etch strategies.

Methods and Materials: Forty caries-free extracted third molars were divided into eight groups for μTBS (n=5). The groups were bonded with the Clearfil SE Bond (CSE) and Adper Single Bond 2 (SB) as controls; Peak Universal, self-etch (PkSe) and etch-and-rinse (PkEr); Scotchbond Universal Adhesive, self-etch (ScSe) and etch-and-rinse (ScEr); and All Bond Universal, self-etch (AlSe) and etch-and-rinse (AlEr). After composite restorations, specimens were longitudinally sectioned to obtain resin-dentin bonded sticks (0.8 mm²). The μTBS of the specimens was tested immediately (IM) or after 6 months of water storage (6M) at 0.5 mm/min. Some sticks at each storage period were immersed in silver nitrate and photo developed, and the NL was evaluated with scanning electron microscopy. Data were analyzed with two-way repeated-

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measures analysis of variance and Tukey test ($\alpha=0.05$).

Results: At the IM period, PkSe and PkEr showed $\mu$TBS similar to the control adhesives ($p>0.05$) but increased NL pattern and lower $\mu$TBS after 6M ($p<0.05$). ScSe and ScEr showed intermediary $\mu$TBS values at the IM period but remained stable after 6M ($p>0.05$). AISe showed the lowest $\mu$TBS ($p<0.05$), but $\mu$TBS and NL remained stable after 6M ($p>0.05$). AlEr showed higher IM $\mu$TBS but showed higher degradation after 6M ($p<0.05$).

Conclusions: Universal adhesives that contain MDP showed higher and more stable $\mu$TBS with reduced NL at the interfaces after 6 months of water storage.

INTRODUCTION

Current adhesive materials simplify bonding procedures by reducing the number of application steps and time required for application. This simpler protocol makes them less technique sensitive and allows for better application standardization. All of these factors are responsible for the large increase in the use of self-etch adhesives among clinicians.

Self-etch materials (Se; also known as nonrinsing adhesives or etch-and-dry adhesives) do not require a separate acid step, as demineralization and priming occur simultaneously. The preliminary use of phosphoric acid increases the probability of clinical errors due to the need of rinsing and adequate management of dentin moisture. Contrary to the etch-and-rinse approach (Er), Se adhesives do not remove but incorporate the smear layer in the hybridized complex. Although a complete and thorough resin infiltration is not observed for some acidic Se systems, some studies report a lower incidence of postoperative sensitivity after placement of direct composite posterior restorations.

On the other hand, some drawbacks may be listed for these Se materials. They do not produce an enamel conditioning pattern that is as retentive as that produced by phosphoric acid, which is likely responsible for the higher rates of marginal discoloration in the enamel margins of cervical restorations. Selective enamel etching on the enamel margins with phosphoric acid is the most recently accepted technique to solve this problem, showing good results in both in vitro and in vivo studies.

Keeping this concept in mind, a novel family of bonding systems, known as “universal” or “multi-mode” adhesives, was recently launched in the market. They are one-step Se adhesives that can be associated with phosphoric acid etching, mainly for enamel etching, which gives the dentist a more versatile adhesive system.

Universal adhesive differs from the current Se systems by the incorporation of monomers that are capable of producing chemical adhesion to the dental substrates. It is believed that this incorporation may increase the durability of the bonds produced with simplified Se adhesives, which was shown to be limited for the current Se under in vitro and in vivo studies. To the extent of our knowledge, the literature is still scarce with regard to the longevity of bonds produced by universal adhesives.

Thus, the aim of this study was to evaluate the immediate and six-month resin-dentin bond strength ($\mu$TBS) and nanoleakage (NL) of universal adhesive systems used in the Er and Se approaches. The following null hypotheses were tested: 1) the immediate and six-month resin-dentin $\mu$TBS of universal adhesives is not influenced by the adhesive strategy selected (Er or Se) and 2) the immediate and six-month NL of universal adhesives is not influenced by the adhesive strategy selected.

METHODS AND MATERIALS

Tooth Selection and Preparation

Forty extracted caries-free human third molars were used. The teeth were collected after obtaining the respective patients’ informed consent under a protocol approved by the local Ethics Committee Review Board. The teeth were disinfected in 0.5% sodium hypochlorite, stored in distilled water, and used within six months of extraction. A flat dentin surface was exposed after wet grinding the occlusal enamel on a No. 180-grit SiC paper. The exposed dentin surfaces were further polished on wet No. 600-grit silicon carbide paper for 60 seconds to standardize the smear layer.

Experimental Design

A total of five adhesive systems were evaluated. As control materials, the two-step Er, Adper Single Bond 2 (SB; 3M ESPE, St Paul, MN, USA), and the two-step Se, Clearfil SE Bond (CSE; Kuraray, Okayama, Japan), were used. The following three universal adhesive systems were tested in both the Er and Se strategies: Peak Universal Adhesive System (Peak LC Bond and Peak SE Primer Ultra; System) and two-step Er (PkEr) and two-step Se (PkSe);
Scotchbond Universal Adhesive (3M ESPE), applied as a two-step Er (ScEr) and one-step Se (ScSe); and All Bond Universal (Bisco Inc, Schaumburg, IL, USA), applied as a two-step Er (AlEr) and one-step Se (AlSe). A total of eight experimental conditions were tested in this study, and five teeth were randomly assigned for each group.

Restorative Procedure and Specimen Preparation

The adhesive systems were applied as per the manufacturer’s instructions (Table 1). After the bonding procedures, all teeth received a microhybrid composite restoration (Opallis, FGM Produtos Odontológicos, Joinville, SC, Brazil) in two increments of 2 mm. Each increment was light polymerized for 40 seconds using an LED light-curing unit set at 1200 mW/cm² (Radi-cal, SDI Limited, Bayswater, Victoria, Australia).

After the restored teeth had been stored in distilled water at 37°C for 24 hours, the specimens were sectioned longitudinally in the mesiodistal and buccal-lingual directions across the bonded interface using a slow-speed diamond saw (Isomet, Buehler Ltd, Lake Bluff, IL, USA) to obtain 25-30 resin-dentin sticks with a cross-sectional area of approximately 0.8 mm² as measured with a digital caliper (Digimatic Caliper, Mitutoyo, Tokyo, Japan). All sticks from each tooth were divided for μTBS and NL evaluation. Usually, six sticks per tooth were used for NL, three in each storage time; the remaining sticks were used for μTBS, half in the immediate time and half after six months of water storage time (37°C).

Microtensile Bond Strength

Resin-dentin bonded sticks were attached to a Geraldeli jig with cyanoacrylate adhesive and tested under tension (Kratos Dinamometros, Cotia, SP, Brazil) at 0.5 mm/min until failure. The μTBS values were calculated by dividing the load at failure by the cross-sectional bonding area.

The failure mode of the specimens was classified as cohesive (C; failure exclusive within dentin or resin composite), adhesive (A; failure at the resin-dentin interface), or mixed (M; failure at the resin-dentin interface, which included cohesive failure of the neighboring substrates). The classification was performed under a stereomicroscope at 100× magnification (Olympus SZ40, Tokyo, Japan). Specimens with premature failures were included in the tooth mean.

Nanolakage

Three resin-bonded sticks from each tooth at each period were not tested in tension and were prepared for NL evaluation. The sticks were placed in an ammoniacal silver nitrate solution in darkness for 24 hours, rinsed thoroughly in distilled water, and immersed in photo-developing solution for eight hours under a fluorescent light to reduce silver ions into metallic silver grains within voids along the bonded interface. Specimens were polished down to 2500-grit SiC paper and 1 and 0.25 μm diamond paste (Buehler Ltd) using a polishing cloth. They were ultrasonically cleaned, air dried, mounted on stubs, and coated with carbon-gold (Shimadzu IC 50, Toquio, Japão). Resin-dentin interfaces were analyzed in a field-emission scanning electron microscope (SEM) operated in the backscattered mode (SSX-550, Shimadzu).

Three images were captured of each resin-dentin stick. The relative percentage of NL in the adhesive and hybrid layers was measured by a blinded operator (UTHSCSA ImageTool 3.0 software, Department of Dental Diagnostic Science at The University of Texas Health Science Center, San Antonio, TX, USA). Values originating from the same specimen were averaged for statistical purposes. The mean NL of all sticks from the same tooth was taken for statistical purposes.

Statistical Analysis

The experimental unit in the current study was the hemi-tooth. The μTBS and NL of all sticks from the same hemi-tooth were averaged for statistical purposes. The μTBS (MPa) and NL (%) means for every testing group were expressed as the average of five hemi-teeth used per group. The premature failures during specimen preparation were not included in the tooth mean. The μTBS (MPa) and NL (%) data were subjected to a two-way repeated-measure analysis of variance (adhesive vs storage time) and a post hoc test (Tukey post hoc test at α=0.05) for pairwise comparisons.

RESULTS

The percentage of specimens with premature failure and the frequency of each fracture pattern mode are shown in Table 2. Few premature (5.7% on average) and cohesive failures (4.6% on average) were observed. Most of the specimens showed adhesive or adhesive/mixed failures.

Regarding μTBS, the cross-product interaction adhesive vs storage time was statistically significant.
The classic images of water trees \(^{21,22}\) (Figure 1). A deposition at the immediate period. This deposition resembles deposition throughout the hybrid and adhesive layer (Figure 1B,J) showed a thicker area of silver nitrate. Universal Adhesive System applied as Er and Se adhesives (CSE and SB; \(p<0.05\); Table 3). In the Se mode, only ScSe and AlSe showed no significant decrease of the \(\mu\)TBS after six months \((p>0.05)\). In the Er mode, only Al showed significantly lower \(\mu\)TBS after six months \((p<0.05)\).

The cross-product interaction adhesive vs storage time was statistically significant \((p=0.001; Table 4)\). PkSe and PkEr in both bonding strategies showed the highest NL at the immediate time \((p<0.05; Table 4)\), which significantly increased after six months \((p<0.05; Table 4)\). Sb and Al, when applied in Se and Er mode, showed lower NL at both storage periods, which was statistically similar to the control adhesives (CSE and SB; \(p>0.05\); Table 4).

Representative backscattered SEM images of the resin-dentin interfaces for all experimental conditions are depicted in Figure 1. Specimens of the Peak Universal Adhesive System applied as Er and Se (Figure 1B,J) showed a thicker area of silver nitrate deposition throughout the hybrid and adhesive layer at the immediate period. This deposition resembles the classic images of water trees \(^{21,22}\) (Figure 1). A higher amount of NL was detected for this adhesive after six months (Fig. 1F,N).

For both control adhesives, as well as the universal adhesives Scotchbond Universal Adhesive tested in Er and Se strategies, a thinner deposition of silver nitrate was observed, mainly restricted to the base of the hybrid layer at the immediate time (Figure 1). This NL remained stable after six months of water storage (Figure 1).

**DISCUSSION**

The results of the present study demonstrated that the universal adhesive tested had a heterogeneous behavior, since some adhesives diminished the bonding performance over the course of time and some did not.

Although the adhesive Peak showed high immediate \(\mu\)TBS values, this material produced an adhesive interface with high deposition of NL at the immediate time. NL represents the location of defects at the resin-dentin interface that may serve as pathways for degradation of the resin-dentin bond over time. \(^{22}\) Silver nitrate is capable of occupying nanometric-sized spaces present around the exposed collagen fibrils where the monomers were unable to infiltrate or where residual water was not displaced by the adhesive or even in areas with incomplete monomer conversion, \(^{22}\) factors preponderant for the degradation of the bond interface.

PkSe can be categorized as an aggressive Se, \(^{23,24}\) as this material has a very low pH (Peak SE Primer, pH=1.2) when compared with the other adhesives (Sb, pH=3.0; Al, pH=2.4). \(^{25}\) This might be why this material showed the highest NL at the immediate period. It was already reported that acid and unpolymerized monomers are more present in acidic adhesive infiltrate than are polymerizable monomers. \(^{5,6}\) Also, the hydrolysis of the ester bond of acidic monomer results in a strong phosphoric acid \(^{5}\) that continues to demineralize the surrounding dentin.

Only the Peak material recommends the application of an extra layer of Peak LC Bond. Various in vitro \(^{12,26,27,28}\) and in vivo studies \(^{29,30}\) have shown that the application of an additional layer increases the performance of one-step Se adhesives, provided that this is a layer with a hydrophobic nature. This additional layer incorporates nonsolvated hydrophobic monomers at the bonding interface, which diminishes the relative concentration of solvents retained and nonreacted monomers in the adhesive layer, \(^{31}\) making it less permeable \(^{32,33}\) and less prone to the effects of degradation over the course of time. \(^{34,35}\)

However, Peak LC Bond appears to be as hydrophilic as Peak SE Primer, since there are no hydrophobic monomers listed in the composition of Peak LC Bond (Table 1). In this way, the material does not take advantage of having a second adhesive layer; the high level of hydrophilicity must be responsible for the degradation of the adhesive interface.

Peak LC Bond is hydrophilic and is the recommended material to be used in the Er strategy. In the Er approach, the primer was not applied; the low pH of the Peak LC Bond (pH=2.0) might have caused an additional etching of the dentinal substrate. This probably resulted in an increase in the demineralization and collagen exposure, \(^{24,36}\) thereby increasing the NL \(^{37}\) even when used in the Er strategy, as can be seen in Figure 1.

Sc and Al are one-step Se adhesives and are therefore highly hydrophilic. In three of the four groups tested with these two adhesives, no degrada-
Table 1: Adhesive System (Batch Number), Composition, and Application Mode of the Adhesive Systems Used According to the Manufacturer’s Instructions

<table>
<thead>
<tr>
<th>Adhesive (Batch Number)</th>
<th>Composition</th>
<th>Self-Etch Strategy (Se)</th>
<th>Etch-and-Rinse Strategy (Er)</th>
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</thead>
<tbody>
<tr>
<td>Adper Single Bond 2 (BPBR)</td>
<td>1. Etchant: 35% phosphoric acid (Scotchbond Etchant) 2. Adhesive: Bis-GMA, HEMA, dimethacrylates, ethanol, water, photoinitiator, methacrylate functional copolymer of polyacrylic and polyitaconic acids, 10% by weight of 5-nm-diameter spherical silica particles</td>
<td>NA</td>
<td>1. Apply etchant for 15 s 2. Rinse for 10 s 3. Blot excess water 4. Apply 2-3 consecutive coats of adhesive for 15 s with gentle agitation 5. Gently air thin for 5 s 6. Light-cure for 10 s at 1200 mW/cm²</td>
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<tr>
<td>Clearfil SE Bond (Primer: 00954A - Bond: 01416*)</td>
<td>1. Primer: water, MDP, HEMA, camphorquinone, hydrophilic dimethacrylate 2. Bonding: MDP, Bis-GMA, HEMA, camphorquinone, hydrophobic dimethacrylate, N,N-diethanol p-toluidine bond, colloidal silica</td>
<td>1. Apply primer to tooth surface and leave in place for 20 s 2. Dry with air stream to evaporate the volatile ingredients 3. Apply bond to the tooth surface and then create a uniform film using a gentle air stream 4. Light-cure for 10 s at 1200 mW/cm²</td>
<td>NA</td>
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<tr>
<td>Peak Universal Adhesive System (Peak SE Primer: 0N062–Peak LC Bond: Y062)</td>
<td>1. Etchant: 35% phosphoric acid (Ultraetch) 2. Primer: ethyl alcohol, methacrylic acid, 2-hydroxyethyl methacrylate (Peak SE Primer) 3. Adhesive: Ethyl alcohol, 2-hydroxyethyl methacrylate (Peak LC Bond)</td>
<td>1. Initial use of Peak SE requires activation of the two components separated in the syringe 2. Application of the Peak SE with microbrush for 20 s using continuous scrubbing on dentin; do not scrub enamel 3. Thin/dry for 3 s using air/water syringe or high-volume suction directly over preparation 4. Apply a puddle coat of Peak LC Bond with gently agitate for 10 s 5. Thin/dry 10 s using to air pressure 6. Light polymerize for 10 s at 1200 mW/cm²</td>
<td>1. Apply etchant for 20 s 2. Rinse for 5 s 3. Air dry 2 s 4. Apply a puddle coat of Peak LC Bond with gently agitate for 10 s 5. Thin/dry 10 s using to air pressure 6. Light-cure for 10 s at 1200 mW/cm²</td>
</tr>
<tr>
<td>Scotchbond Universal Adhesive (D-82229)</td>
<td>1. Etchant: 34% phosphoric acid, water, synthetic amorphous silica, polyethylene glycol, aluminum oxide. (Scotchbond Universal Etchant) 2. Adhesive: MDP phosphate monomer, dimethacrylate resins, HEMA, methacrylate-modified polyalkenoic acid copolymer, filler, ethanol, water, initiators, silane</td>
<td>1. Apply the adhesive to the entire preparation with a microbrush and rub it in for 20 s; if necessary, rewet the disposable applicator during treatment 2. Direct a gentle stream of air over the liquid for about 5 s until it no longer moves and the solvent is evaporated completely 3. Light-cure for 10 s at 1200 mW/cm²</td>
<td>1. Apply etchant for 15 s 2. Rinse for 10 s 3. Air dry 2 s 4. Apply adhesive as for the self-etch mode</td>
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</table>
tion of the resin-dentin bonds was observed. This must be attributed to the presence of monomers capable of producing a chemical bond to the hard structures of teeth,\textsuperscript{14,15} as opposed to the lack of this compound in Pk.

Sc and Al contain methacryloyloxydecyl dihydrogen phosphate (MDP) in their composition, as does CSE, which was the first Se adhesive to incorporate this component. Studies with CSE have demonstrated that MDP allows for a stable chemical bond to dentin over the course of time, both in vitro\textsuperscript{30,38-40} and in vivo\textsuperscript{13,41,42} This monomer forms a stable nanolayer together with a deposition of stable MDP-Ca salts at the adhesive interface,\textsuperscript{43} which increases its mechanical strength.\textsuperscript{43,44} However, regardless of the MDP, the adhesives showed different behaviors.

The μTBS values of ScSe and AlSe at the immediate time were not equivalent to those of the control CSE. ScSe and AlSe are one-step adhesives, and this probably leads to the concentration of MDP being lower than it is in CSE, which has MDP incorporated into both the primer and the

<table>
<thead>
<tr>
<th>Table 1: Adhesive System (Batch Number), Composition,\textsuperscript{a} and Application Mode of the Adhesive Systems Used According to the Manufacturer’s Instructions (cont.)</th>
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</thead>
<tbody>
<tr>
<td>Adhesive (Batch Number)</td>
</tr>
<tr>
<td>All-Bond Universal (1200006111)</td>
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</tbody>
</table>

\textsuperscript{a} Bis-GMA, bisphenol glycidyl methacrylate; HEMA, 2-hydroxyethyl methacrylate; MDP, methacryloyloxydecyl dihydrogen phosphate.

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<tr>
<th>Table 2: Number of Specimens (%) According to Fracture Mode and the Premature Failure of All Experimental Groups</th>
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<tbody>
<tr>
<td>Adhesive System</td>
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<tr>
<td>Adper Single Bond 2</td>
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<td></td>
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<td>Clearfil SE Bond</td>
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<td></td>
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<tr>
<td>Peak Universal</td>
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<td>Scotchbond Universal</td>
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<tr>
<td>Allbond Universal</td>
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</tbody>
</table>

Abbreviations: A, adhesive fracture mode; C, cohesive fracture mode; A/M, adhesive/mixed fracture mode; PF, premature failure.
bond. Moreover, it has been demonstrated that the presence of 2-hydroxyethyl methacrylate, a component of Sc and Al, may compete with MDP by bonding to the calcium of hydroxyapatite, thereby harming the chemical bond of MDP to dentin.43

Many other variables in the composition of the ScSe and AlSe may account for the differences observed between these materials as, for instance, in the presence of the polyalkenoic acid copolymer (PAC) in Sc and the high concentration of solvent of Al. Sc contains specific PACs used in resin-modified glass ionomer Vitrebond (3M ESPE). PAC bonds chemically and spontaneously to hydroxyapatite in glass ionomer materials,45 and a recent study demonstrated that the presence of PAC showed more bond strength than a PAC-free adhesive with the same composition.41,45 Yoshida and others43 hypothesized that PAC may compete with the MDP present in Sc. However, if we compare the longevity results of Sc (MDP + PAC) with SB (PAC), two materials with similar compositions, the only difference being the presence of MDP in the former, it seems that the association MDP-PAC enhanced the bonding ability, since ScSe and ScEr showed stable bonds even after six months of water storage.

Al contains more solvent than Sc (30-60 wt% and 10-15 wt%, respectively).46,47 This leads to more residual solvent retained in the hybrid layer and adhesive layer,48 preventing the formation of a polymer with high reticulation.49-51 As a consequence, a reduced degree of conversion32 and μTBS values52-55 is produced, making the adhesive inter-

face more permeable after polymerization56,57 and more prone to degradation over time.3,58

This may explain the lower results of AlSe in the immediate time interval in comparison with the other adhesives. This is in agreement with a recent study published by Munoz and others,16 even when applied actively; whereas in the mentioned study, Al was applied passively.16 Active/vigorous application improves the immediate and long-term results of the bond to dentin of the one-step SE adhesive systems,59-62 because it increases the penetration of monomers into dentin and solvent evaporation. Agitation will also improve the efficacy of polymerization by improving the chemical interaction of the adhesive with the dental substrate, particularly for the acid Se adhesives.37,63 In addition, unreacted acid monomers present in the superficial layer of the adhesive may be taken to a basal area of dentin, increasing demineralization of the substrate and diffusion of monomers and improving the interaction with the smear layer and subjacent dentin.60-62

As only AlEr demonstrated degradation of the μTBS values over the course of time after six months of evaluation, we could hypothesize that the presence of PAC is more important for Er adhesives than for Se. Some authors have indicated that the function of PAC is to improve the stability to humidity,64,65 a crucial factor for Er adhesives, which, due to dentin demineralization, has a more sensitive technique when compared with that of the Se adhesives.2

We reject the first and second null hypotheses, given that the μTBS and NL values of universal

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### Table 3: Microtensile Bond Strength (μTBS) Values (Means ± Standard Deviations) of the Different Experimental Groups (*)

<table>
<thead>
<tr>
<th>Time</th>
<th>Adhesive System</th>
<th>Peak Universal Se Bond</th>
<th>Peak Universal Er Bond</th>
<th>Scotchbond Universal Se Bond</th>
<th>Scotchbond Universal Er Bond</th>
<th>Allbond Universal Se Bond</th>
<th>Allbond Universal Er Bond</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Immediate</td>
<td>47.6 ± 5.5 a</td>
<td>42.9 ± 4.4 a, b</td>
<td>39.5 ± 5.1 b</td>
<td>44.3 ± 1.6 a, b</td>
<td>33.3 ± 3.2 c</td>
<td>34.7 ± 4.6 b, c</td>
</tr>
<tr>
<td></td>
<td>6 mo</td>
<td>38.8 ± 5.7 b</td>
<td>36.2 ± 2.7 b, c</td>
<td>27.9 ± 4.9 d</td>
<td>34.2 ± 4.2 c</td>
<td>33.6 ± 5.8 c</td>
<td>34.6 ± 6.2 c</td>
</tr>
</tbody>
</table>

(*) Means identified with identical lower case letters are statistically similar (p > 0.05)

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### Table 4: Nanoleakage (NL) Values (Means ± Standard Deviations) of the Different Experimental Groups (*)

<table>
<thead>
<tr>
<th>Time</th>
<th>Adhesive System</th>
<th>Peak Universal Bond</th>
<th>Peak Universal Er Bond</th>
<th>Scotchbond Universal Bond</th>
<th>Scotchbond Universal Er Bond</th>
<th>Allbond Universal Bond</th>
<th>Allbond Universal Er Bond</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Immediate</td>
<td>47.6 ± 5.5 a</td>
<td>42.9 ± 4.4 a, b</td>
<td>39.5 ± 5.1 b</td>
<td>44.3 ± 1.6 a, b</td>
<td>33.3 ± 3.2 c</td>
<td>34.7 ± 4.6 b, c</td>
</tr>
<tr>
<td></td>
<td>6 mo</td>
<td>38.8 ± 5.7 b</td>
<td>36.2 ± 2.7 b, c</td>
<td>27.9 ± 4.9 d</td>
<td>34.2 ± 4.2 c</td>
<td>33.6 ± 5.8 c</td>
<td>34.6 ± 6.2 c</td>
</tr>
</tbody>
</table>

(*) Means identified with identical lower case letters are statistically similar (p > 0.05)
adhesives showed different results according to the Er or Se strategies employed.

CONCLUSIONS

Universal adhesives that contain MDP (Scochbond Universal Adhesive Er and Se and All Bond Universal Se) showed stable bond strengths and reduced NL, similar to the two-step SE adhesive tested (Clearfil SE Bond) after six months of water storage.

Acknowledgement

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Human Subjects Approval

This study was conducted in accordance with all the provisions of the local human subjects oversight committee guidelines and policies. The approval code for this study is 17878/13. This study was conducted at State University of Ponta Grossa, Paraná, Brazil.

Conflict of Interest

The authors have no proprietary, financial, or other personal interests of any nature or kind in any product, service, and/or company that is presented in this article.

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Figure 1. Representative backscatter SEM images of the resin-dentin adhesive interfaces of each experimental group for immediate and six-month periods. Control etch-and-rinse group = Adper Single Bond 2 and control self-etch group = Clearfil SE Bond. For the Peak Universal Adhesive System, the amount of nanoleakage was higher (red and white arrows) than for the other materials and increased after six months for strategies Er (B, F) and Se (J, N). The amount of nanoleakage was lower and stable after six months within the hybrid layer for Scotchbond Universal (C, G, K, O), AllBond Universal (D, H, L, P), and controls (white arrows) (A, E, I, M). Co indicates composite; De, dentin; HL, hybrid layer; AL, adhesive layer; Se, self-etch; Er, etch-and-rinse.
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Water sorption/solubility of dental adhesive resins Dental Materials 22(10) 973-980.


