

A Collection of Scientific Facts



# Scotchbond™

## Universal Adhesive



**3M** ESPE

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Scotchbond™ Universal and Single Bond Universal are the same adhesive with different product names that are sold in different regions of the world.

Adper™ Easy Bond and Adper™ Easy One are the same adhesive with different product names that are sold in different regions of the world.

Adper™ Single Bond Plus, Adper™ Single Bond 2 and Scotchbond™ 1 XT are the same adhesive with different product names that are sold in different regions of the world.

# Scotchbond™

Universal Adhesive

## Letter from the Director...

Dear Dental Professional,

Adhesives comprise one of the broader 3M Company's most sophisticated technology platforms, and 3M ESPE has successfully leveraged this platform to respond to the unique needs of the dental industry. Our aim is to bring you products that make a real difference in your dental practice. Over 25 years of dental science has led to the development of Scotchbond™ Universal Adhesive. Scotchbond Universal Adhesive incorporates our core adhesive technology, filler technology, silane technology and Vitrebond™ Copolymer technology to bring you an adhesive that is reliable, simple and allows virtually no post-op sensitivity.

During the development of Scotchbond Universal Adhesive, extensive voice of customer research was conducted with global opinion leaders and researchers to define the desired features of the adhesive. The



Dr. Al Viehbeck

adhesive was then tested by researchers worldwide to evaluate its performance in numerous studies. These studies — involving clinical use, adhesion, bond stability, marginal integrity and technique variability — have been collected and summarized in this booklet. Additional in-vitro studies are ongoing and Clinical Studies continue to be carried out to investigate the long-term behavior and performance of Scotchbond Universal Adhesive.

Best Regards

**Dr. Al Viehbeck**

3M ESPE Global Technical Director

St. Paul, MN and Seefeld, Germany

June 2012

## Introduction

Scotchbond™ Universal Adhesive is a unique dental adhesive built on a trusted 3M ESPE bonding legacy. It is the single-bottle solution for both tooth and indirect restoration surfaces. It can be used reliably in total-etch or selective-enamel etch mode to dentin and enamel or the self-etch mode to dentin and cut enamel for both direct and indirect restorations. It provides the flexibility for the clinician to choose one adhesive to use independently of their preference of technique. It bonds methacrylate-based restoratives, cement and sealant materials to dentin, enamel, glass ionomer and various indirect restorative substrates (metal, glass ceramics, alumina and zirconia) without a separate primer. The primary use of the adhesive will be with light-cured materials, however, if self- or dual-cure composite or cement materials, which rely on the self-cure polymerization, are used, a separate activator solution, Scotchbond™ Universal DCA Dual Cure Activator is available as an accessory item.

Scotchbond Universal Adhesive has a very unique set of features that include:

- Combined Total-Etch, Selective-Enamel Etch and Self-Etch bonding capability
- Uncompromising and consistent bond strengths
- High moisture tolerance to allow consistent bonding to both moist- and dry-etched dentin
- Virtually no post-op sensitivity
- Combined primer/adhesive capability to provide high bond strengths to indirect surfaces (metals, zirconia, alumina and glass ceramics) without a separate primer
- Excellent marginal integrity
- Self-cure material compatibility with Scotchbond DCA Activator
- 2-year room temperature shelf life
- New “Flip-Top” cap design for the orange vial and unit dose delivery
- Improved, easy-to-place etchant with Scotchbond™ Universal Etchant

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### Chemistry

How is Scotchbond™ Universal Adhesive able to provide all of these unique features in one material? It starts with the chemistry.

Composition:

- MDP Phosphate Monomer
- Dimethacrylate resins
- Vitrebond™ Copolymer
- Filler
- Ethanol
- Water
- Initiators
- Silane

Building on 3M ESPE's adhesives and silane expertise and trusted bonding legacy, Scotchbond Universal Adhesive features a unique chemistry for true versatility in one bottle. The "VMS" technology within the adhesive allows for the distinct features and performance.

**Vitrebond Copolymer:** This unique to 3M ESPE component is a methacrylate-modified polyalkenoic acid copolymer developed to allow the invention of resin-modified glass ionomers. When incorporated into the adhesive, along with optimized ratios of HEMA and water, it provides for more consistent bond performance to dentin under moist and dry conditions.

**MDP Monomer:** Well known phosphate monomer that provides for self-etching performance (pH of adhesive is 2.7), provides chemical bonding to zirconia, alumina and metals without a separate primer and increases shelf life stability to allow a 2-year shelf life with no refrigeration.

**Silane:** The active and stable silane within the adhesive (based on patented 3M ESPE silane technology) allows for chemical bonding to glass ceramic surfaces without using a separate ceramic primer.

Based on this truly unique chemistry, Scotchbond Universal Adhesive is in a class by itself and is capable of providing high and consistent adhesion performance to a wide variety of dental surfaces. Due to the broad versatility of the Scotchbond Universal Adhesive, it can greatly simplify the clinician's needs for adhesives and primers in their office. The compilation of studies within this booklet will show evidence to support the performance.



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## Universal Adhesive

## Clinical Results

Clinical performance is the true test of a dental adhesive. In the laboratory setting, isolation is complete, visibility is perfect and the surface is flat. Contrast this with the clinical setting where isolation is variable, visibility is limited and the surface is three-dimensional.

After placement of a restoration, the clinical setting stresses the restoration via thermal loading, occlusal forces stress the fatigue resistance of the bond and various staining solutions from coffee to wine serve as continual indicators of the marginal integrity.

The ability for an adhesive to be easy to use, resistant to the variables that arise in the clinical situation and adequately seal the tooth, allow for a good patient experience from the perspective of post-operative sensitivity.

There are currently four formal clinical studies underway with Scotchbond™ Universal Adhesive. Initial reports from these studies will be available in late 2012.

## 1. Clinical Results

### Clinical Use of Scotchbond™ Universal Adhesive

**1** **Authors:** R. Guggenberger, B. Cerny, C. Thalacker, K. Wiggins and A.B. Soares, Dept. of Research and Development, 3M ESPE Dental Products, Seefeld, Germany, 3M ESPE Dental, St. Paul, MN, 3M ESPE Dental Products, Sao Paulo, Brazil

**Reference:** IADR 2012, Iguacu Falls, Brazil, Abstract #186

**Aim of the Study:** The new Scotchbond Universal Adhesive (SBU, 3M ESPE) can be applied either with or without a prior phosphoric acid etch, depending on the preference of the dentist. Aim of this work was to compare the occurrence of initial post-operative sensitivities (POS) for the different application modes total-etch (TE), self-etch (SE), selective enamel-etch (SEE) of SBU.

**Method:** SBU was evaluated by 120 dentists in a non-interventional study. The dentists were asked in which application modes they applied SBU, how many cases they performed and about the occurrence of POS.

**Results:** The table summarizes the pooled data (n = 120 dentists). Occurrence of POS was analyzed by pair-wise comparisons using Fisher’s Exact Test (p < 0.05). Values with the same letter are statistically the same.

| Application Mode | Number of Cases | Number of POS Cases | Percentage of POS Cases (%) |
|------------------|-----------------|---------------------|-----------------------------|
| TE               | 3467            | 14 <sup>A</sup>     | 0.4 <sup>A</sup>            |
| SE               | 3495            | 2 <sup>B</sup>      | 0.1 <sup>B</sup>            |
| SEE              | 1544            | 0 <sup>B</sup>      | 0.0 <sup>B</sup>            |

**Conclusions:** With respect to literature data on adhesive restorations, the number of POS cases with SBU was very low for all application modes. Occurrence of POS was found to be significantly lower for SE and SEE than for TE modes.



## Interfacial Analysis to Dentin and Enamel

Scanning electron microscopy (SEM), transmission electron microscopy (TEM) and confocal laser scanning imaging are powerful tools for characterizing how adhesives interact and bond to the enamel and dentin surfaces. These tools provide the researcher with highly magnified images to study the effect of adhesive systems on the organic and inorganic components of the tooth and provide insight into the bonding mechanism for the system.

In addition to evaluating the interface visually, research has been conducted to look at the potential capability of components in the adhesive to provide an additional chemical bond.

The following pages provide images of the bonding interface of Scotchbond™ Universal Adhesive to enamel and dentin in both the self-etch and total-etch modes of application.

## 2. Interfacial Analysis to Dentin and Enamel

### Interfacial Characterization of a New Universal Dentin Adhesive

2

**Authors:** A. Sezinando, CiiEM, Centro de Investigação Interdisciplinar Egas Moniz, Instituto Superior de Ciências da Saúde Egas Moniz, Monte da Caparica, Portugal and J. Perdigao, Department of Restorative Sciences, University of Minnesota, Minneapolis, MN

**Reference:** AADR 2012, Tampa, Florida, Abstract #469

**Aim of the Study:** To study the dentin-resin interface and nanoleakage of a novel universal adhesive.

**Method:** Dentin: 12 human molars (middle dentin) were assigned to six groups:

- Group 1:** CSE – Clearfil SE Bond (Kuraray), a 2-bottle self-etch adhesive (self-etch control);
- Group 2:** OSL – OptiBond SOLO Plus (OSL, Kerr), a 2-bottle etch and rinse adhesive applied on etched moist dentin (etch and rinse control);
- Group 3:** OSL-d – OSL applied on etched dried dentin;
- Group 4:** SBU-SE – Scotchbond™ Universal Adhesive (SBU, 3M ESPE), a 1-bottle universal adhesive, applied as a self-etch adhesive;
- Group 5:** SBU-ER – SBU applied as an etch and rinse adhesive on etched moist dentin;
- Group 6:** SBU-ERd – SBU applied as an etch and rinse adhesive on etched dried dentin.

Specimens were restored and processed for FESEM evaluation. For nanoleakage assessment, 42 sound molars were randomly assigned to the same experimental groups with an additional group 7 (selective enamel-etching, SBU-En). Buccal and lingual Class V preparations were restored with Filtek™ Z250 and processed with 50% ammoniacal silver nitrate. After sectioning, specimens were observed under a stereomicroscope to evaluate the depth of silver penetration (0–4). The scores were compared using Mann-Whitney test ( $p < 0.05$ ).

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Universal Adhesive

## 2. Interfacial Analysis to Dentin and Enamel

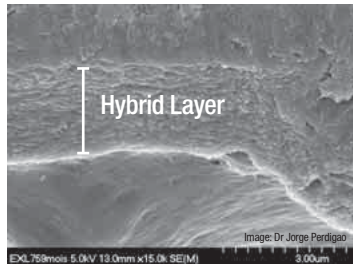
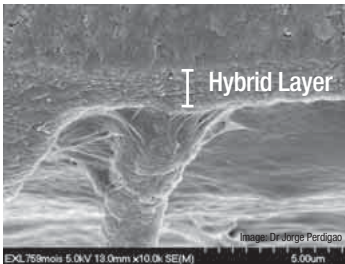
### Interfacial Characterization of a New Universal Dentin Adhesive (cont.)

2

**Method (cont.):** Selected specimens were processed for backscattered FESEM to evaluate the nanoleakage pattern into the resin-dentin interface.

**Results:** SBU-SE and CSE formed a continuous dentin-resin interface with a 0.2 $\mu$ m-0.3 $\mu$ m thick hybrid layer (HL). Air-drying did not affect the HL for SBU-ERd. OSL-d resulted in an inconsistent HL with areas of debonding. SBU-SE and SBU-En resulted in statistically lower silver infiltration than all other groups. These two adhesives virtually prevented nanoleakage in all specimens. CSE and OSL were ranked in the intermediate subset. OSL-d, SBU-ER and SBU-ERd resulted in significantly greater silver penetration than the remaining groups.

**Conclusions:** SBU-SE and CSE form a very similar resin-dentin interface/HL. SBU-SE and SBU-En (selective enamel-etching) seal dentin margins.

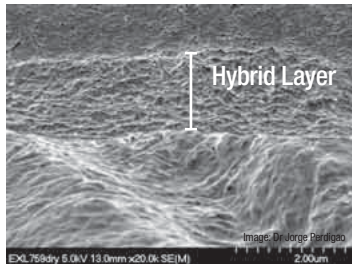
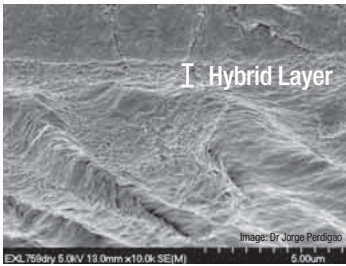


Scotchbond™ Universal Adhesive interface with dentin after phosphoric acid etching and maintaining a **MOIST** surface prior to adhesive application. There is a distinct hybrid layer and resin tags formed at the interface.

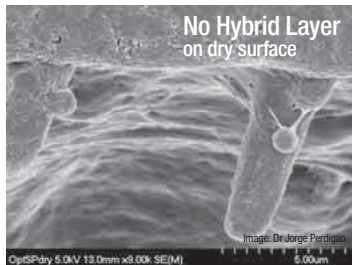
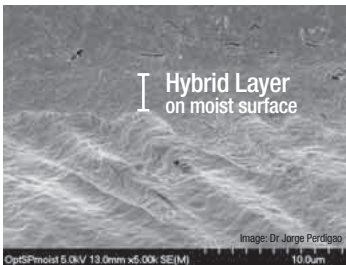
2. Interfacial Analysis to Dentin and Enamel

Interfacial Characterization of a New Universal Dentin Adhesive (cont.)

2



Scotchbond™ Universal Adhesive interface with dentin after phosphoric acid etching and **DRYING** the etched surface for 5–10 seconds prior to adhesive application. There is still a distinct hybrid layer and resin tags formed at the interface.



Optibond Solo Plus interface with dentin after phosphoric acid etching and maintaining a **MOIST** surface and after **DRYING** the etched surface for 5–10 seconds prior to adhesive application. There is a distinct hybrid layer formed on the moist surface but is not evident on the dried surface.

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Universal Adhesive

## 2. Interfacial Analysis to Dentin and Enamel

### TEM Evaluation of the Interface Between Scotchbond Universal Adhesive and Dentin when used in the Self-Etch and Total-Etch Mode

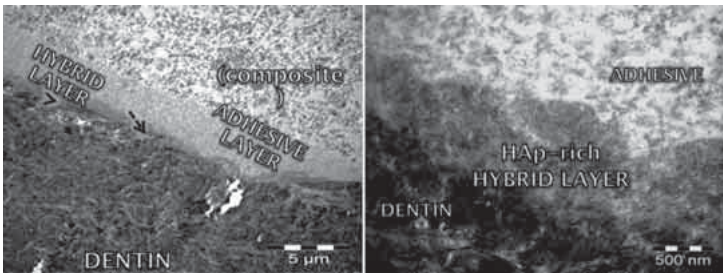
Author: Dr. Bart Van Meerbeek, Catholic University of Leuven, Belgium

Reference: Unpublished

2

#### Aim of the Study:

To use TEM to evaluate the bonding interface for Scotchbond™ Universal Adhesive in both the self-etch and total-etch mode to dentin.



Scotchbond Universal Adhesive interface with dentin in self-etch mode.



Scotchbond Universal Adhesive interface with dentin in total-etch mode. The adhesive film thickness is in the range of 5–10 microns with a well defined hybrid layer of approximately 5 microns.

## 2. Interfacial Analysis to Dentin and Enamel

### Pre-etching Dentin Effects on Morphology of Adhesives

**Authors:** M.S. Shinohara, Restorative Dentistry, Faculdade de Odontologia Araçatuba – Universidade Estadual Paulista Júlio de Mesquita Filho, Araçatuba, Brazil, C. Azevedo, Campinas State University, Piracicaba, Brazil and M. De Goes, Dept of Dental Materials, Campinas State University, Piracicaba SP, Brazil

**Reference:** IADR 2012, Iguazu Falls, Brazil, Abstract #1659

2

#### Aim of the Study:

A new versatile all-in-one self-etch adhesive system has been developed to combine total-etch and self-etch features. The objective was to evaluate the tensile bond strength ( $\mu$ TBS) and interface bond morphology of self-etching adhesives on phosphoric acid pre-etched dentin surface.

#### Method:

Ten extracted human molars were ground to obtain flat dentin surfaces and polished with 600-grit SiC paper. The specimens were randomly divided into five groups:

- Group 1:** Scotchbond™ Universal Adhesive – SU (3M ESPE);
- Group 2:** Pre-etched SU;
- Group 3:** Adper™ Easy Bond Self-Etch Adhesive – EB (3M ESPE);
- Group 4:** Pre-etched EB;
- Group 5:** Adper™ Single Bond Plus Adhesive – SB (3M ESPE).

Pre-etching specimens were conditioned with 35% phosphoric acid (PA) for 15 seconds. All adhesives were applied according to manufacturer's instructions and composite resin crowns were incrementally built up. After 24 hours, 0.8mm<sup>2</sup> beams were obtained and tested to  $\mu$ TBS. In order to observe dentin-adhesive interface, selected beams from each group were stained with 0.1% Rodhamine B for one hour and analyzed using Confocal Laser Scanning Microscopy (CLSM). Data were analyzed using ANOVA and Fisher's PLSD test ( $\alpha = 0.05$ ).

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Universal Adhesive

## 2. Interfacial Analysis to Dentin and Enamel

### Pre-etching Dentin Effects on Morphology of Adhesives (cont.)

2

**Results:** No statistical difference was observed among the groups ( $P > 0.05$ ):

**Group 1:** 46.96 (18.7) MPa;

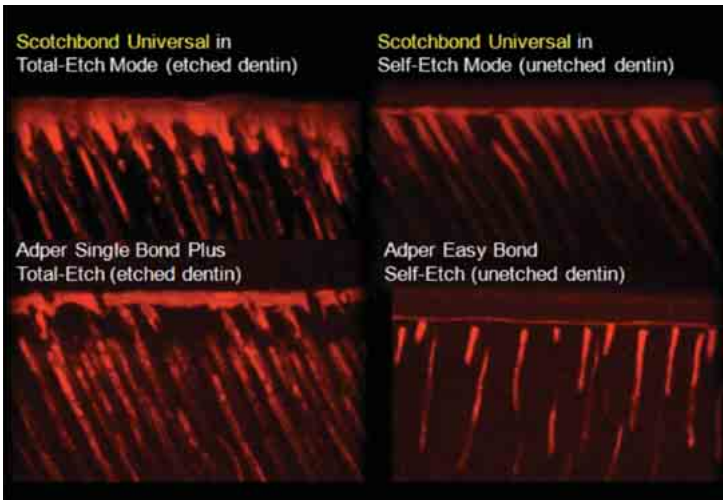
**Group 2:** 44.14 (13.7) MPa;

**Group 3:** 42.72 (13.8) MPa;

**Group 4:** 41.59 (13.6) MPa;

**Group 5:** 40.74 (12.0) MPa.

**Conclusions:** Pre-etching dentin using PA did not affect  $\mu$ TBS values of one-step self-etching adhesives. The resin-dentin bond interface thickness of self-etching adhesives increased on pre-etched dentin approach.



Scotchbond™ Universal Adhesive interface to dentin in total-etch mode and self-etch mode compared to a standard total-etch adhesive (Adper™ Single Bond Plus Adhesive) and a standard self-etch adhesive (Adper™ Easy Bond Self-Etch Adhesive). Distinct formation of hybrid layers and resin tags are seen for each mode.

## Adhesion to Dentin and Enamel

The section presents results into the bonding capabilities of Scotchbond™ Universal Adhesive. Testing the ability of an adhesive to bond to enamel and dentin is perhaps the most popular in-vitro test performed on a dental adhesive. Adhesion testing is used to design new adhesives, compare existing products, investigate variables such as the effects of moisture levels and saliva contamination and ultimately to try to predict clinical performance.

There are many different test procedures used to evaluate bond performance. They include varying types of shear and tensile methods. They can also vary in the type of surface treatment, sample preparation, storage time and conditions, thermal and mechanical stress and test geometry. Thus it is important to look at several results in order to draw conclusions pertaining to performance.

It is also important to look at different surfaces and surface treatments for the dentin and enamel. There are preferences for a clinician as to whether they like to treat the dentin in a self-etch or a total-etch mode. The decision to etch or not etch dentin can be based on personal preference or for specific clinical situations. Historically, a single adhesive system could not function under both conditions. For Scotchbond Universal Adhesive, it is important to see that it can perform at a high level for both modes of dentin surface treatment.

For enamel, we must consider the cut or prepared surface as well as the intact or uncut surface. This is especially important when assessing the self-etch materials that typically have a higher pH than the phosphoric acid from the total-etch systems, which can impact the clinical performance and bond to the more highly mineralized intact enamel. For this reason, the selective enamel etch technique has been recommended. It limits the application of the phosphoric acid to the enamel surface leaving the dentin surface intact allowing for higher bond performance to both the cut and the uncut enamel surface when using the adhesive in the self-etch mode to dentin.



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## Universal Adhesive

This section will highlight the broad versatility and consistency in performance for Scotchbond Universal Adhesive. The adhesion data in this section will cover a variety of techniques and variables/topics including:

- Bonding to self-etched dentin and enamel
- Bonding to etched dentin and enamel
- Bonding to cut and uncut enamel
- Bonding to cervical lesion dentin
- Aged bonding to etched and self-etched dentin and enamel
- Thermal and mechanical stressed adhesion
- Bonding to etched moist and dry dentin
- Impact of Vitrebond™ Copolymer on adhesion to etched and dried dentin
- Bonding to primary dentin and enamel

3

## 3. Adhesion to Dentin and Enamel

### Pre-etching Dentin Effects on Bond Strength of Adhesives

**Authors:** M.S. Shinohara, Restorative Dentistry, Faculdade de Odontologia Araçatuba – Universidade Estadual Paulista Júlio de Mesquita Filho, Araçatuba, Brazil, C. Azevedo, Campinas State University, Piracicaba, Brazil and M. De Goes, Dept of Dental Materials, Campinas State University, Piracicaba SP, Brazil

**Reference:** IADR 2012, Iguazu Falls, Brazil, Abstract #1659

#### Aim of the Study:

A new versatile all-in-one self-etch adhesive system has been developed to combine total-etch and self-etch features. The objective was to evaluate the tensile bond strength ( $\mu$ TBS) and interface bond morphology of self-etching adhesives on phosphoric acid pre-etched dentin surface.

#### Method:

Ten extracted human molars were ground to obtain flat dentin surfaces and polished with 600-grit SiC paper. The specimens were randomly divided into five groups:

- Group 1:** Scotchbond™ Universal Adhesive – SU (3M ESPE);
- Group 2:** Pre-etched SU;
- Group 3:** Adper™ Easy Bond Self-Etch Adhesive – EB (3M ESPE);
- Group 4:** Pre-etched EB;
- Group 5:** Adper™ Single Bond Plus Adhesive – SB (3M-ESPE).

Pre-etching specimens were conditioned with 35% phosphoric acid (PA) for 15 seconds. All adhesives were applied according to manufacturer's instructions and composite resin crowns were incrementally built up. After 24 hours, 0.8mm<sup>2</sup> beams were obtained and tested to  $\mu$ TBS. In order to observe dentin-adhesive interface, selected beams from each group were stained with 0.1% Rodhamine B for 1 hour and analyzed using Confocal Laser Scanning Microscopy (CLSM). Data were analyzed using ANOVA and Fisher's PLSD test ( $\alpha = 0.05$ ).

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## Universal Adhesive

### 3. Adhesion to Dentin and Enamel

#### Pre-etching Dentin Effects on Bond Strength of Adhesives (cont.)

3

#### Results:

No statistical difference was observed among the groups ( $P > 0.05$ ):

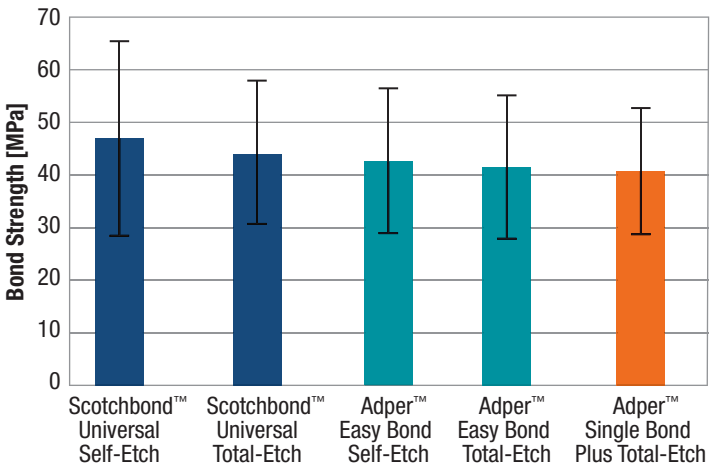
**Group 1:** 46.96 (18.7) MPa

**Group 2:** 44.14 (13.7) MPa

**Group 3:** 42.72 (13.8) MPa

**Group 4:** 41.59 (13.6) MPa

**Group 5:** 40.74 (12.0) MPa



#### Conclusions:

Pre-etching dentin using PA did not affect  $\mu$ TBS values of one-step self-etching adhesives. The resin-dentin bond interface thickness of self-etching adhesives increased on pre-etched dentin approach.

## 3. Adhesion to Dentin and Enamel

### Performance of an Experimental Total-Etch/Self-Etch Adhesive

Authors: C. Thalacker<sup>1</sup>, H. Loll<sup>1</sup>, D.D. Krueger<sup>2</sup>, R. Guggenberger<sup>1</sup> and E. Wanek<sup>1</sup>, <sup>1</sup>3M ESPE AG, Seefeld, Germany, <sup>2</sup>3M ESPE Dental, St. Paul, MN

**3** Reference: IADR 2011, San Diego, USA, Abstract #263

#### Aim of the Study:

Most dentists use several total-etch (TE) and self-etch (SE) adhesives for different indications. Aim of this study was to assess the shear bond strength (SBS) of an experimental adhesive (Scotchbond™ Universal Adhesive/EXL-759, 3M ESPE) used in TE and SE mode.

#### Method:

Bovine incisors were embedded in cold-cure acrylic resin. The labial surface of each tooth was ground to expose enamel or dentin. A cylindrical button of Filtek™ Supreme Ultra XTE Universal Restorative/A2E (3M ESPE, 2.36mm diameter, 2mm height) was cured on the tooth surfaces treated with Scotchbond Universal Adhesive/EXL-759, (3M ESPE), Optibond Solo Plus (OSP, Kerr), Prime&Bond NT (PBNT, Dentsply), Clearfil SE Bond (CSE, Kuraray), iBond SE (IBSE, Heraeus Kulzer), Xeno IV (XIV, Dentsply) according to the manufacturer's instructions (n = 10). A notched-edge shear method (Ultradent) was used to measure the SBS.

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## Universal Adhesive

### 3. Adhesion to Dentin and Enamel

#### Performance of an Experimental Total-Etch/Self-Etch Adhesive (cont.)

3

#### Results:

The table shows the SBS in MPa. The standard deviations (SD) are given in parentheses. All data per substrate were analyzed by ANOVA and multiple comparisons using Fisher's LSD procedure ( $p < 0.05$ ). Means with the same letters are statistically the same.

| Material    | Application Mode | Enamel SBS (MPa)          | Dentin SBS (MPa)          |
|-------------|------------------|---------------------------|---------------------------|
| SBU/EXL-759 | TE               | 27.5 (5.0) <sup>a</sup>   | 27.6 (5.2) <sup>A,B</sup> |
| OSP         | TE               | 19.1 (2.8) <sup>c</sup>   | 14.0 (2.8) <sup>D</sup>   |
| PBNT        | TE               | 25.5 (4.2) <sup>a,b</sup> | 21.2 (2.4) <sup>C</sup>   |
| SBU/EXL-759 | SE               | 24.1 (3.2) <sup>b</sup>   | 30.5 (5.4) <sup>A,B</sup> |
| CSE         | SE               | 27.2 (3.1) <sup>a,b</sup> | 29.0 (3.6) <sup>A,B</sup> |
| IBSE        | SE               | 23.7 (2.8) <sup>b</sup>   | 20.8 (3.5) <sup>C</sup>   |
| XIV         | SE               | 13.6 (4.1) <sup>d</sup>   | 24.0 (8.2) <sup>B,C</sup> |

#### Conclusions:

Multiple statistically significant differences were found for Scotchbond™ Universal Adhesive compared to other adhesives.

### 3. Adhesion to Dentin and Enamel

#### Bonding Performance of Recent All-in-one Adhesive Systems to Sound Cervical Dentin and Enamel and Abrasion-lesion Dentin

Authors: M. Maeno<sup>1</sup>, S. Akiyama<sup>1</sup>, S. Ogawa<sup>1</sup>, M. Hara<sup>1</sup>, T. Maseki<sup>1</sup>, Y. Nara<sup>1</sup> and I.L. Dogon<sup>2</sup>, <sup>1</sup>Dept. of Operative Dentistry, Nippon Dental University, Tokyo, Japan, <sup>2</sup>School of Dental Medicine, Harvard University, Boston, MA

Reference: AADR 2012, Tampa Bay, USA, Abstract #1307

**3****Aim of the Study:**

The purpose of this study was to examine the bonding performance of recent all-in-one adhesive systems to cervical abrasion lesion dentin in comparison with the surfaces of cervical sound enamel and dentin.

**Method:**

Four recent all-in-one adhesive systems, two latest experimental systems; Scotchbond™ Universal Adhesive/EXL759 (EXL, 3M ESPE) and MTB200 (MTB, Kuraray) and two systems on the market; Adper™ Easy Bond Self-Etch Adhesive (AEB, 3M ESPE) and Clearfil Tri-S Bond (CTS, Kuraray) and a popular self-etching primer system; Clearfil SE Bond (CSE, Kuraray, for control) were used. The exposed dentin surface of cervical abrasion lesion (AD) of 25 extracted human premolars were cleaned with a polishing brush and water. Standardized V-shaped cavity with a bevel at occlusal enamel was prepared in the buccocervical region of 25 extracted human premolars. The surface of AD and the surfaces of beveled sound enamel (SE) and gingival sound dentin wall (SD) of the standardized cavity were pretreated clinically with the five systems according to the manufacturer's instructions. The immediate tensile bond strength (ITBS) of each system to AD, SE and SD were measured (n = 5) with a custom-made portable adhesion tester (JDR 75, 1996). The data were statistically analyzed using ANOVA, Tukey's q-test and Student's t-test.

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### 3. Adhesion to Dentin and Enamel

#### Bonding Performance of Recent All-in-one Adhesive Systems to Sound Cervical Dentin and Enamel and Abrasion-lesion Dentin (cont.)

3

#### Results:

The mean ITBS (s.d.) in MPa to AD/SE/SD are shown in the graph. There were no differences in the ITBS among five systems, regardless of the difference in tooth surface. The ITBS of TSB to AD was significantly smaller than the value to SD at  $p < 0.05$ , no differences in the ITBS of other systems among three tooth surfaces were recognized.

|                     | Abrasion Lesion Dentin | Sound Dentin | Sound Enamel |
|---------------------|------------------------|--------------|--------------|
| SBU/EXL-759         | 23.7 (5.1)             | 24.3 (5.9)   | 24.0 (5.8)   |
| MTB200              | 24.4 (6.0)             | 24.6 (5.5)   | 22.9 (5.2)   |
| Adper Easy Bond     | 22.3 (6.3)             | 26.0 (6.1)   | 23.5 (5.3)   |
| Clearfil Tri-S Bond | 17.5 (3.8)             | 24.4 (4.4)   | 22.0 (6.5)   |
| Clearfil SE Bond    | 21.5 (4.4)             | 24.9 (5.3)   | 22.7 (3.2)   |

#### Conclusions:

The bonding performance of recent all-in-one adhesive systems to cervical abrasion lesion dentin was equivalent to that to the surfaces of sound enamel and dentin. In addition the systems could obtain clinically acceptable ITBS that was similar to SE Bond.

## 3. Adhesion to Dentin and Enamel

### Shear Bond Strengths to Restorative Materials and Tooth Structure

Authors: J. Burgess, S. Shah, D. Cakir, P. Bekc and L. Ramp, University of Alabama at Birmingham, Birmingham, AL

**3** Reference: AADR 2012, Tampa Bay, USA, Abstract #636

#### Aim of the Study:

1) Measure 24 hour and thermocycled shear bond strength/(SBS) of Scotchbond™ Universal Adhesive/3M ESPE to Paradigm™ C, Lava™ core, IPS e.max CAD, gold and base metal alloy. 2) Measure 24 hours and 10 months SBS of an experimental adhesive to unetched and etched ground human dentin and enamel.

#### Method:

Paradigm C, e.max CAD, Lava blocks and non-noble metal alloy were sectioned ( $t = 4\text{mm}$ ). Noble metal alloy was received in 2mm thick blocks. Specimens were polished (180-, 320-grit SiC-paper/4 minutes), finished ( $0.5\mu\text{Al}_2\text{O}_3$  slurry/2 minutes) and cleaned (ultrasonic/distilled water/15 seconds). Molars were wet-ground (320-grit) to obtain flat enamel and dentin. Following surface treatments (table) and bonding agent application, Z100™ Restorative/3M ESPE cylinders ( $d = 1.5\text{mm}$ ) were bonded and light-cured (Elipar™ S10 LED Curing Light/3M ESPE/1000mW/cm<sup>2</sup>). Half were debonded after 24 hours storage/37°C (Instron-1mm/minute). Remainder of ceramic and alloy specimens were debonded after thermocycling (10,000 cycles/6–60°C/15 seconds dwell time). Remaining enamel and dentin specimens were stored for 10 months after thermocycling then debonded. Data analyzed with ANOVA and Tukey/Kramer post-hoc tests ( $p = 0.05$ ).



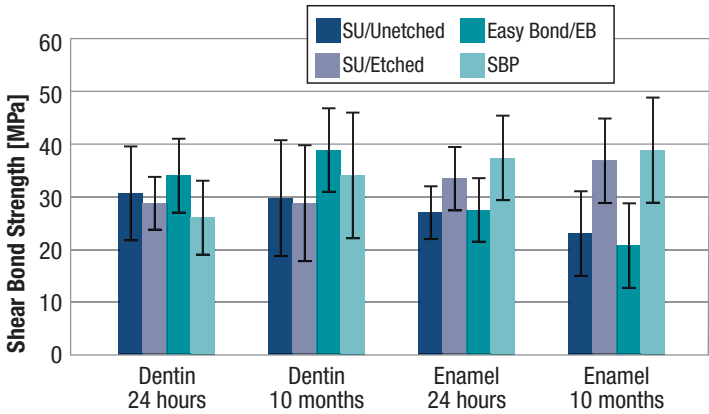
# Scotchbond™ Universal Adhesive

## 3. Adhesion to Dentin and Enamel

### Shear Bond Strengths to Restorative Materials and Tooth Structure (cont.)

3

**Results:** MPa/(Mean ± SD) Same letters in same row are not statistically different.



**Conclusions:** Scotchbond™ Universal Adhesive is a promising universal adhesive.

## 3. Adhesion to Dentin and Enamel

### Shear Bond Strength of Adhesives on Cut/Uncut Enamel

**Authors:** L. Fox, M. Harsono, R.D. Perry and G. Kugel, Tufts University, Boston, MA

**Reference:** AADR 2012, Tampa Bay, USA, Abstract #797

3

**Aim of the Study:**

To compare shear bond strength of adhesive systems on cut and uncut enamel prepared with self-etch or preferential etch technique.

**Method:**

One-hundred extracted caries-free human teeth were obtained for this study. Each tooth was embedded in acrylic resin. The samples were randomly divided into ten groups (n = 10, five groups cut [C], five uncut [U]). Cut enamel surfaces were prepared using SiC paper up to 600-grit (Ecomet3, Buehler). Uncut were embedded with their buccal surface exposed. Three adhesive systems were tested with variations in etching: Prime&Bond NT (PBNT, Dentsply), Adper™ Easy Bond Self-Etch Adhesive (AEB, 3M ESPE) and Scotchbond™ Universal Adhesive/EXL-759 (SBU/EXL, 3M ESPE). Adhesives were applied according to manufacturers' instructions with exceptions of using the self etch mode (SE) or pre-treating with etch (PE). Filtek™ Z250 Universal Restorative (3M ESPE) composite was filled into a bonding jig (Ultradent) and cured for 40 seconds with a halogen light (Elipar™ 2500 Curing Light). After storage in de-ionized water for 24 hours at 37°C, the shear bond strength was carried out using a universal testing machine (Instron 5566A, Norwood, MA) with a cross head speed at 1mm/minute. Statistical analysis was done by one-way ANOVA, with post-hoc analysis conducted via Fisher LSD. Significance was predetermine at  $p < 0.05$ .

# Scotchbond™

Universal Adhesive

## 3. Adhesion to Dentin and Enamel

### Shear Bond Strength of Adhesives on Cut/Uncut Enamel (cont.)

3

#### Results:

|              | SBU/EXL Etched  | SBU/EXL Self-Etched | PBNT Etched     | AEB Etched      | AEB Self-Etched |
|--------------|-----------------|---------------------|-----------------|-----------------|-----------------|
| Cut Enamel   | 34.11<br>(5.68) | 23.51<br>(6.47)     | 31.93<br>(4.99) | 35.18<br>(4.03) | 26.56<br>(5.83) |
| Uncut Enamel | 41.65<br>(7.11) | 36.86<br>(11.81)    | 32.03<br>(9.26) | 31.10<br>(7.61) | 26.06<br>(11.2) |

#### Conclusions:

In terms of mean values, SBU/EXP with etching has higher bond strength than AEB self-etch on both cut and uncut enamel. Uncut enamel yields significantly higher bond strength compared with the cut enamel on SBU/EXL self-etch.

### 3. Adhesion to Dentin and Enamel

#### Bonding Durability of Recent All-in-one Adhesive Systems under Thermocycled Repeated Load

Authors: Y. Nara<sup>1</sup>, S. Akiyama<sup>1</sup>, M. Maeno<sup>1</sup>, M. Hara<sup>1</sup>, T. Yamada<sup>1</sup>, T. Maseki<sup>1</sup> and I.L. Dogon<sup>2</sup>, <sup>1</sup>Dept. of Operative Dentistry, Nippon Dental University, Tokyo, Japan, <sup>2</sup>School of Dental Medicine, Harvard University, Boston, MA  
Reference: AADR 2012, Tampa Bay, USA, Abstract #1306

**3**

#### Aim of the Study:

The purpose of this study was to examine the bonding durability of three recent all-in-one adhesive systems, two latest one-bottle one-step systems; Scotchbond™ Universal Adhesive/EXL759 (SBU/EXL, 3M ESPE) and MTB200 (MTB, KURARAY) and a popular system on the market; Adper™ Easy Bond Self-Etch Adhesive (EB, 3M ESPE), as compared with that of a two-bottle two-step self-etching primer system; Clearfil SE Bond (SE, control, KURARAY).

#### Method:

Standardized V-shaped cavity was prepared in the cervical region of 80 extracted human premolars. The cavities were pretreated with the four systems (20 each) and then restored clinically according to the manufacturer's instructions. Half of the restored specimens (10 each system) were subjected to thermo-mechanical repeated stress condition simulating intra-oral environment; thermocycling (5°C/55°C x 2,000 sets) and simultaneous repeated-load (12kgf x 10<sup>5</sup> times). Another half of specimens were supplied as non-stress control group. Micro-tensile bond strengths (μTBS) to the gingival dentin wall of the specimens with and without the stress load were measured. The data of μTBS were examined using ANOVA, Tukey's q-test and Student's t-test.

# Scotchbond™

## Universal Adhesive

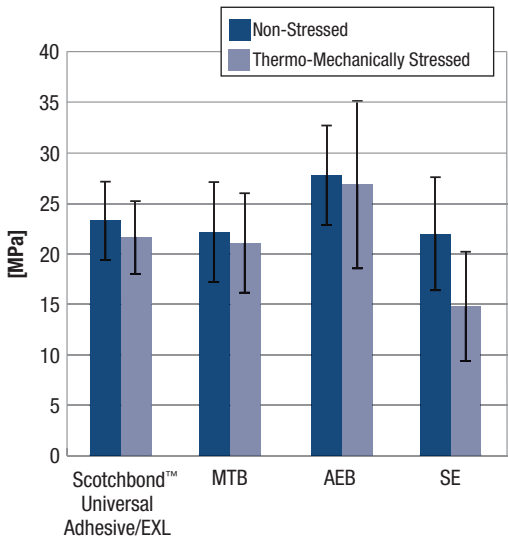
### 3. Adhesion to Dentin and Enamel

#### Bonding Durability of Recent All-in-one Adhesive Systems under Thermocycled Repeated Load (cont.)

3

#### Results:

The mean  $\mu$ TBS (s.d.) in MPa of the specimens with/without the stress load are shown in the table. The  $\mu$ TBS of three recent all-in-one adhesive systems with the stress were significantly greater than that of SE at  $p < 0.01$ , the values without stress were similar to or greater than the value of SE. The mode of the stress did not influence the  $\mu$ TBS of recent all-in-one systems, but had effect upon the  $\mu$ TBS of SE.



#### Conclusions:

The bonding durability, based on the  $\mu$ TBS with and without a stress simulating intra-oral environment, of the three recent all-in-one adhesive systems was superior to that of SE. Two latest all-in-one systems; Scotchbond™ Universal Adhesive/EXL and MTB, demonstrated excellent bonding durability that could maintain the  $\mu$ TBS even under the stress condition.

## 3. Adhesion to Dentin and Enamel

### Total-Etch Performance of One Bottle Self-Etch Adhesives

**Authors:** C. Thalacker, H. Loll, C.A. Wiedig and D.D. Krueger, 3M ESPE AG, Seefeld, Germany

**Reference:** AADR 2012, Tampa Bay, USA, Abstract #790

**3**

#### **Aim of the Study:**

Recently a combined total-etch (TE) and self-etch (SE) one bottle adhesive was introduced (Scotchbond™ Universal Adhesive, SBU, 3M ESPE). The objective of this study was to assess the shear bond strength (SBS) of current one bottle SE adhesives and SBU in SE and TE modes. Moisture tolerance in TE was assessed by measuring SBS to moist and air dried etched dentin.

#### **Method:**

Bovine incisors were embedded in cold-cure acrylic resin. The labial surface of each tooth was ground to expose enamel (E) or dentin (D). A cylindrical button of Filtek™ Z250 Universal Adhesive A3 (3M ESPE, 2.36mm diameter, 2mm height) was cured on the tooth surfaces treated with Scotchbond Universal Adhesive (SBU, 3M ESPE), Xeno IV (XE4, Dentsply), Xeno V+ (XE5, Dentsply), Clearfil SE Bond, (CSE, Kuraray), G-aenial Bond (GAE, GC), iBond SE (IBS, Heraeus Kulzer), Optibond All-in-one (OAI, Kerr), AdheSE One F (AOF, Ivoclar-Vivadent) in SE mode according to the manufacturer's instructions and in TE mode after a 15 second phosphoric acid etch (n = 6). A notched-edge shear method (Ultradent) was used to measure the SBS.

# Scotchbond™

## Universal Adhesive

### 3. Adhesion to Dentin and Enamel

#### Total-Etch Performance of One Bottle Self-Etch Adhesives (cont.)

3

#### Results:

The table shows the SBS in MPa. The standard deviations (SD) are given in parentheses. All data per substrate were analyzed by ANOVA and multiple comparisons using Fisher's LSD procedure ( $p < 0.05$ ). Means with the same letters are statistically the same.

| Material | Enamel SE                 | Dentin SE                 | Enamel TE                 | Den TE Moist              | Den SE Dry                |
|----------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|
| SBU      | 27.7 (5.5) <sup>a</sup>   | 28.7 (5.3) <sup>a</sup>   | 32.8 (4.8) <sup>a,b</sup> | 29.3 (4.7) <sup>a</sup>   | 21.8 (3.3) <sup>a</sup>   |
| XE4      | 18.1 (2.5) <sup>b</sup>   | 28.4 (5.8) <sup>a</sup>   | 29.3 (6.0) <sup>b</sup>   | 28.8 (7.7) <sup>a</sup>   | 15.0 (2.1) <sup>b,c</sup> |
| XE5      | 13.1 (7.1) <sup>b,c</sup> | 13.9 (4.0) <sup>b,c</sup> | 19.5 (4.9) <sup>c,d</sup> | 15.4 (2.8) <sup>b,c</sup> | 17.4 (5.2) <sup>b</sup>   |
| GAE      | 22.2 (2.9) <sup>b</sup>   | 13.1 (3.5) <sup>b,c</sup> | 21.8 (2.9) <sup>c,d</sup> | 12.4 (1.8) <sup>c</sup>   | 9.5 (3.3) <sup>d</sup>    |
| IBS      | 19.8 (3.0) <sup>b</sup>   | 12.5 (1.4) <sup>c</sup>   | 23.4 (5.1) <sup>c</sup>   | 13.1 (1.9) <sup>c</sup>   | 7.4 (0.9) <sup>d</sup>    |
| OAI      | 22.7 (5.2) <sup>a,b</sup> | 31.0 (3.0) <sup>a</sup>   | 35.4 (1.3) <sup>a</sup>   | 19.1 (2.2) <sup>b</sup>   | 11.0 (5.2) <sup>c,d</sup> |
| AOF      | 13.1 (1.4) <sup>b,c</sup> | 15.3 (0.7) <sup>b</sup>   | 17.3 (1.7) <sup>d</sup>   | 16.6 (0.2) <sup>b,c</sup> | 14.1 (3.9) <sup>b,c</sup> |

#### Conclusions:

Multiple statistically significant differences were found. Scotchbond™ Universal Adhesive yielded equivalent or higher SBS in SE and TE modes than the one bottle SE adhesives.

## 3. Adhesion to Dentin and Enamel

### Shear Bond Strength of Different Products on Etched Dentin

Authors: L. Fox, M. Harsono, J. Towers, R.D. Perry and G. Kugel, Tufts University, Boston, MA

**3** Reference: IADR 2011, San Diego, USA, Abstract #3183

**Aim of the Study:**

To compare shear bond strength of adhesive systems on dentin prepared with etch in moist and dry conditions.

**Method:**

Eighty extracted caries-free human teeth were obtained for this study. Each tooth was embedded in acrylic resin. Flat dentin surfaces were prepared using SiC paper to 600-grit (Ecomet3, Buehler). The samples were randomly divided into eight groups (n = 10). Three adhesive systems were tested with variations in etching and dryness. Adhesives: Prime&Bond NT (PBNT, Dentsply), Adper™ Easy Bond Self-Etch Adhesive (AEB, 3M ESPE) and new adhesive Scotchbond™ Universal Adhesive/EXL-759 (EXL, 3M ESPE). Adhesives were applied according to manufacturers' instructions with exceptions of using the self-etch mode (SE) or pre-treating with total-etch (PE) and applying to moist (M) or dry (D) dentin. Filtek™ Z250 Universal Restorative (3M ESPE) composite was filled into a bonding jig (Ultradent) and cured for 40 seconds with a halogen light (Elipar™ 2500 Curing Light). After storage in de-ionized water for 24 hours at 37°C, the shear bond strength was carried out using a universal testing machine (Instron 5566A, Norwood, MA) with a cross head speed at 1mm/minute. Statistical analysis was done by one-way ANOVA, with post-hoc analysis conducted via Turkey's HSD.



# Scotchbond™

## Universal Adhesive

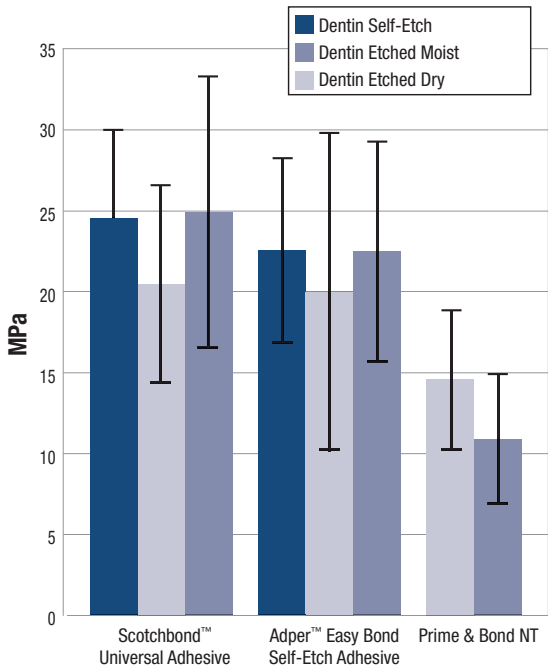
### 3. Adhesion to Dentin and Enamel

#### Shear Bond Strength of Different Products on Etched Dentin (cont.)

3

#### Results:

Mean shear adhesion results in MPa.



#### Conclusions:

In terms of mean values, Scotchbond™ Universal Adhesive and Adper™ Easy Bond Self-Etch Adhesive yield higher bond strength in dry etched and moist etched conditions compared with the PBNT adhesive under the same conditions. There is no significant difference ( $p \geq 0.05$ ) in the change of shear bond strength values when adhesives are used in different conditions of dryness or pretreated with total etch.

### 3. Adhesion to Dentin and Enamel

#### Evaluation of a New Universal Adhesive Using Different Bonding Strategies

**Authors:** J. Perdigao, Dept. of Restorative Sciences, University of Minnesota, Minneapolis, MN, A. Sezinando, CiiEM, Centro de Investigação Interdisciplinar Egas Moniz, Instituto Superior de Ciências da Saúde Egas Moniz, Monte da Caparica, Portugal and P. Monteiro, CiiEM, Centro de Investigação Interdisciplinar Egas Moniz, Instituto Superior de Ciências da Saúde Egas Moniz, Monte de Caparica, Portugal

**Reference:** AADR 2012, Tampa Bay, USA, Abstract #18

**Aim of the Study:** To measure the dentin/enamel microtensile bond strengths ( $\mu$ TBS) of a novel universal adhesive.

**Method:** Eighty extracted caries-free human teeth were obtained for this study. Each tooth was embedded in acrylic resin. Flat dentin surfaces were prepared using SiC paper to 600-grit (Ecomet3, Buehler). The samples were randomly divided into eight groups ( $n = 10$ ). Three adhesive systems were tested with variations in etching and dryness. Adhesives: Prime&Bond NT (PBNT, Dentsply), Adper™ Easy Bond Self-Etch Adhesive (AEB, 3M ESPE) and new adhesive Scotchbond™ Universal Adhesive/EXL-759 (EXL, 3M ESPE). Adhesives were applied according to manufacturers' instructions with exceptions of using the self-etch mode (SE) or pre-treating with total-etch (PE) and applying to moist (M) or dry (D) dentin. Filtek™ Z250 Universal Restorative (3M ESPE) composite was filled into a bonding jig (Ultradent) and cured for 40 seconds with a halogen light (Elipar™ 2500 Curing Light). After storage in de-ionized water for 24 hours at 37°C, the shear bond strength was carried out using a universal testing machine (Instron 5566A, Norwood, MA) with a cross head speed at 1mm/minute. Statistical analysis was done by one-way ANOVA, with post-hoc analysis conducted via Turkey's HSD.

# Scotchbond™

## Universal Adhesive

### 3. Adhesion to Dentin and Enamel

#### Evaluation of a New Universal Adhesive Using Different Bonding Strategies (cont.)

3

**Results:** (MPa ± SD, different superscript letters indicate statistical difference):

|        | SBU-SE                      | SBU-ERm                     | SBU-ERd                     | OSL ERm                     | OSL-ERd                       | CSE -SE                     |
|--------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-------------------------------|-----------------------------|
| Dentin | 54.4<br>(18.5) <sup>b</sup> | 54.0<br>(18.8) <sup>b</sup> | 53.9<br>(18.4) <sup>b</sup> | 63.0<br>(25.0) <sup>a</sup> | 50.2<br>(20.6) <sup>b,c</sup> | 47.2<br>(22.9) <sup>c</sup> |
| Enamel | 28.7<br>(10.5) <sup>b</sup> | 40.1<br>(17.9) <sup>a</sup> | —                           | 41.1<br>(17.6) <sup>a</sup> | —                             | —                           |

OSL resulted in significantly higher mean  $\mu$ TBS than those of the other five groups. All SBU groups ranked in the same statistical subset regardless of the dentin treatment. The lowest mean  $\mu$ TBS was obtained with CSE, but was not statistically different from that of OSLd. Enamel – OSL and SBU-ERm resulted in statistically similar mean  $\mu$ TBS, which were statistically higher than those of SBU-SE.

**Conclusions:** On dentin, Scotchbond™ Universal Adhesive was not affected by the adhesion strategy or by dentin moisture. On enamel, phosphoric acid etching is still recommended.

### 3. Adhesion to Dentin and Enamel

#### Influence of Vitrebond™ Copolymer on Bonding to Dry Etched Dentin

Authors: C. Thalacker, R. Guggenberger, A. Syrek, H. Loll and D. Krueger, 3M ESPE AG, Seefeld, Germany

**3** Reference: IADR 2010, Barcelona, Spain, Abstract #2937

#### Aim of the Study:

Aim of this study was to investigate the effect of Vitrebond™ Copolymer (VBCP), a methacrylate functionalized polyalkenoic acid, on the bond strength of Scotchbond™ Universal Adhesive to dry etched dentin.

#### Method:

Bovine incisors were embedded in cold-cure acrylic resin. The labial surface of each tooth was ground to expose dentin. The dentin surface was etched with 35% phosphoric acid for 15 seconds, rinsed with water and aggressively dried with pressurized air for 15 seconds. Scotchbond Universal Adhesive formulations containing varying amounts of VBCP were applied to the dentin for 20 seconds, air thinned for 5 seconds and light cured for 10 seconds (Elipar™ Freelight 2 LED Curing Light, 3M ESPE). Then a cylindrical button of Filtek™ Z250 Universal Restorative (4.67mm diameter, 2mm height, 3M ESPE) was cured on the adhesive surface (n = 5). After storage in water at 37°C for 24 hours, the specimens were tested in shear mode using a Zwick Z010 universal testing machine (crosshead speed 2mm/minute).

# Scotchbond™

## Universal Adhesive

### 3. Adhesion to Dentin and Enamel

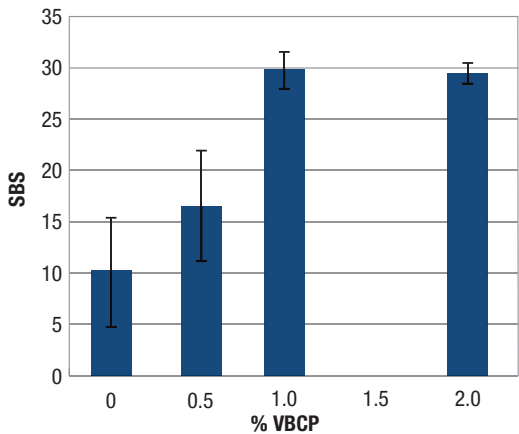
#### Influence of Vitrebond™ Copolymer on Bonding to Dry Etched (cont.)

3

##### Results:

The table shows the shear bond strength in MPa. The standard deviations (SD) are given in parentheses. All data were analyzed by ANOVA and multiple comparisons using Fisher's LSD procedure ( $p < 0.05$ ). Means with the same letters are statistically the same.

| % VBCP | 0%                      | 0.5%                    | 1.0%                    | 2.0%                    |
|--------|-------------------------|-------------------------|-------------------------|-------------------------|
| SBS    | 10.1 (5.9) <sup>a</sup> | 17.6 (5.1) <sup>b</sup> | 29.6 (3.1) <sup>c</sup> | 28.9 (2.4) <sup>c</sup> |



##### Conclusions:

The addition of Vitrebond™ Copolymer significantly increased shear bond strength of Scotchbond™ Universal Adhesive to dry etched dentin. The commercially sold adhesive formulation contains approximately 2% of the VBCP. This could potentially enhance tolerance toward variation in the application procedure and lower the risk of post-operative sensitivity.

### 3. Adhesion to Dentin and Enamel

#### Shear Bond Strength of Self Etch Adhesives to Primary Teeth

Authors: C. Thalacker, H. Loll, R. Zerquine and F. Van Vliet, 3M ESPE Dental Products, 3M Deutschland GmbH, Seefeld, Germany

**3** Reference: PER/IADR, Helsinki, Finland, Abstract #108

**Aim of the Study:**

Due to their ease of use and reportedly lower incidence of post-operative sensitivities, self etch (SE) adhesives are especially popular for pediatric dentistry. Aim of this study was to assess the shear bond strength (SBS) of a new universal adhesive in SE mode (Scotchbond™ Universal, SBU, 3M ESPE) and current SE adhesives to primary teeth.

**Method:**

Extracted human primary molars were embedded in cold-cure acrylic resin. The labial surface of each tooth was ground to expose enamel or dentin. A cylindrical button of Filtek™ Supreme XTE/Ultra A2 (3M ESPE, 2.36mm diameter, 2mm height) was cured on the tooth surfaces treated with SBU, Adper Prompt L-Pop (APLP, 3M ESPE), Xeno IV (XE4, Dentsply Caulk), Xeno V+ (XE5+, Dentsply DeTrey), AdheSE One F (AOF, Ivoclar-Vivadent), iBond SE (IBSE, Heraeus Kulzer) according to the manufacturer's instructions (n = 5). A notched-edge shear method (Ultradent) was used to measure the SBS.

# Scotchbond™

## Universal Adhesive

### 3. Adhesion to Dentin and Enamel

#### Shear Bond Strength of Self Etch Adhesives to Primary Teeth (cont.)

3

#### Results:

The table shows the SBS in MPa. The standard deviations (SD) are given in parentheses. All data per substrate were analyzed by ANOVA and multiple comparisons using Fisher's LSD procedure ( $p < 0.05$ ). Means with the same letters are statistically the same.

| Material | Primary Enamel (MPa)      | Primary Dentin (MPa)    |
|----------|---------------------------|-------------------------|
| SBU      | 24.3 (2.3) <sup>a</sup>   | 26.9 (2.4) <sup>A</sup> |
| APLP     | 16.2 (2.0) <sup>b,c</sup> | 20.5 (4.0) <sup>B</sup> |
| XE4      | 14.0 (1.1) <sup>c,d</sup> | 27.6 (2.3) <sup>A</sup> |
| XE5+     | 19.1 (3.6) <sup>b</sup>   | 18.4 (3.8) <sup>B</sup> |
| AOF      | 9.9 (4.2) <sup>d</sup>    | 16.9 (2.0) <sup>B</sup> |
| IBSE     | 18.1 (6.6) <sup>b,c</sup> | 17.1 (4.3) <sup>B</sup> |

#### Conclusions:

Multiple statistically significant differences were found. SBU yielded higher SBS to primary enamel and equivalent or higher SBS to primary dentin than the other SE adhesives.

## Bond Durability

The true test in the performance of an adhesive is, obviously, actual clinical performance. As mentioned earlier, multiple clinical studies are underway to evaluate the long term clinical performance of the adhesive. However, there are many in-vitro tests that can be conducted to evaluate the durability of the bond which can hopefully predict the longer term clinical performance.

Several tests have been conducted for Scotchbond™ Universal Adhesive to evaluate the bond integrity and measure its potential to resist degradation.

In the previous Adhesion Section, data was presented from Dr. Burgess's group showing adhesion to both dentin and enamel after extensive thermocycling and aging for 10 months. Scotchbond Universal adhesive showed good stability for each condition tested.

Also in the Adhesion Section, data was presented from Dr. Nara's group showing adhesion to Class V preparations that were subjected to both thermal and mechanical stress. Scotchbond Universal adhesive withstood the stress and maintained bond strength.

In addition to bond strength testing, studies were conducted to look at the interface. Many of these were highlighted in Section 2 showing the uniform formation of hybrid layers and resin tags.

The integrity of the resin interface can also be evaluated by looking at the Degree of Conversion of the adhesive monomers in the cured adhesive within the hybrid layer. A high degree of conversion can provide additional strength and resistance to permeability, water uptake and degradation. A study showing the degree of conversion will be presented in this section.

Much research has been conducted over the last few years studying the impact that MMP (matrimetalloproteases) enzymes have on the degradation of collagen when adhesives are bonded to etched dentin. The enzymes can break down collagen fibers that have not been properly infiltrated with adhesive and can result in a loss of bond strength over time. Certain adhesives and acidic agents can stimulate the activity more than others. A study showing the MMP activation with Scotchbond Universal Adhesive will be presented in this section.



# Scotchbond™

## Universal Adhesive

The mechanism for bonding adhesives to tooth structure is primarily micromechanical through demineralization of the dentin and enamel and flowing the adhesives into the demineralized areas and allowing them to polymerize. Studies have been conducted on specific components within the adhesive to determine if they can also contribute a chemical bond to the hydroxyapatite (HAP). Published research has shown that the 10-MDP and the Vitrebond™ Copolymer have the ability to chemically bond to the Calcium in the hydroxyapatite to form hydrolytically stable salts. This chemical bond to the HAP could increase the overall bond strength but, more importantly, could contribute to the longevity of the bond strength over time. Studies showing the bonding potential of the MDP and the Vitrebond Copolymer will also be presented in this section.

## 4. Bond Durability

### Micro-Raman Analysis of the Hybrid Layer Created by Three Adhesives

**Authors:** C.O. Navarra<sup>1</sup>, M. Cadenaro<sup>1</sup>, G. Marchesi<sup>2</sup>, G. Turco<sup>1</sup>, A. Mazzoni<sup>3</sup>, R. DI Lenarda<sup>4</sup> and L. Breschi<sup>2</sup>, University of Trieste, Trieste, Italy, <sup>2</sup>Department of Biomedicine, University of Trieste, Trieste, Italy, <sup>3</sup>Department of Anatomical Sciences, University of Bologna, Bologna, Italy, <sup>4</sup>Special Surgical Sciences, University of Trieste, Trieste, Italy

**Reference:** IADR 2011, San Diego, USA, Abstract #1961

#### Aim of the Study:

This study examined quality and morphology of the hybrid layer (HL) created by one-step self-etch adhesives used on smear-layer covered or on etched dentin by means of a micro-Raman analysis. The tested hypothesis was that preliminary etching does not affect degree of conversion.

#### Method:

Adper™ Easy Bond Self-Etch Adhesive (AEB, 3M ESPE, 1-step self-etch) and an experimental adhesive formulation (Scotchbond™ Universal Adhesive, 3M ESPE, 1-step self-and total-etch) were applied on etched dentin (etch-and-rinse mode) or on smear-layer covered dentin (self-etch mode, following manufacturer's instructions) with simulated pulpal pressure. Prime&Bond NT (PB, Dentsply, 2-step etch-and-rinse) was used as control (on etched dentin). Specimens were transversally cut to expose the bonded interfaces to the micro-Raman beam (Renishaw InVia; laser wl 785nm). Peaks associated with mineral dentin components (PO functional group at 960cm<sup>-1</sup>) and adhesive (phenyl C = C group at 1610cm<sup>-1</sup>) within the bonded interface were used to detect the hybrid layer (HL) depth and the ratio between a reaction peak (C = C at 1640cm<sup>-1</sup>) and a reference peak (phenyl C = C 1610cm<sup>-1</sup>) was used to calculate the degree of conversion (DC) of the adhesives into the HL. Statistical analysis was performed with one-way ANOVA (p < 0.05).

# Scotchbond™

## Universal Adhesive

### 4. Bond Durability

#### Micro-Raman Analysis of the Hybrid Layer Created by Three Adhesives (cont.)

##### Results:

The result are shown in the table below. Different superscript letters indicate statistical differences ( $p < 0.05$ ).

4

| Adhesive             | Substrate      | HL Thickness | Degree of Conversion (%) |
|----------------------|----------------|--------------|--------------------------|
| Scotchbond Universal | SE Smear-layer | 2–4 $\mu$ m  | 85 <sup>b</sup> + 5      |
| Scotchbond Universal | Etched-dentin  | 2–4 $\mu$ m  | 83 <sup>b</sup> + 4      |
| Adper Easy Bond      | SE Smear-layer | 1–4 $\mu$ m  | 92 <sup>b</sup> + 10     |
| Adper Easy Bond      | Etched-dentin  | 1–4 $\mu$ m  | 89 <sup>b</sup> + 8      |
| Prime & Bond NT      | Etched-dentin  | 2–9 $\mu$ m  | 66 <sup>a</sup> + 4      |

##### Conclusions:

One-step self-etch and total-etch adhesives showed a higher DC than control (2-step etch-and-rinse). The tested hypothesis was accepted since DC of tested one-step adhesives was irrespective from the substrate (i.e. smear-layer covered vs etched dentin).

**4. Bond Durability****Expression of MMP-2 and MMP-9 by Zymographic Analysis for Two Adhesive Systems**

**Authors:** Breschi<sup>1</sup>, A. Mazzone<sup>2</sup> and R. Di Lenarda<sup>4</sup>, <sup>2</sup>Department of Biomedicine, <sup>1</sup>University of Trieste, Trieste, Italy, <sup>2</sup>Department of Anatomical Sciences, University of Bologna, Bologna, Italy

**Reference:** Unpublished

**4****Aim of the Study:**

To determine the MMP activating ability of two bonding systems, Scotchbond™ Universal Adhesive (SBU, 3M ESPE), Prime & Bond NT (PBNT) Caulk Dentsply).

**Method:**

Dentin powder obtained by recently extracted human sound teeth was prepared and mixed with the adhesive systems to simulate the biochemical behavior of the hybrid layer. Mineralized dentin powder was mixed with SBU to simulate self-etch interaction. Acid-etched dentin was mixed with SBU and PBNT to simulate application to etched dentin. A standard acid-etched dentin with no adhesive was also evaluated as a control. The effect of MMP-2 and MMP-9 collagenolytic/gelatinolytic activity was assayed on zymographic gels to correlate potential activating ability of the bonding systems in accordance with Breschi, et al, 2010.

# Scotchbond™

Universal Adhesive

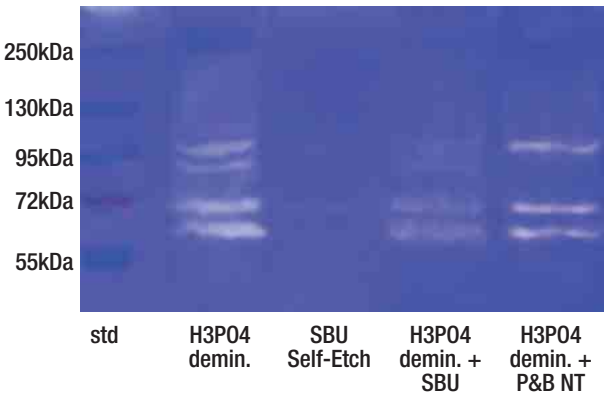
## 4. Bond Durability

### Expression of MMP-2 and MMP-9 by Zymographic Analysis for Two Adhesive Systems (cont.)

4

#### Results:

The zymograms for phosphoric acid showed multiple forms of gelatinolytic enzymes, with the 66kDa as MMP-2 active-form and a fainter band of 86kDa corresponding to the active form of MMP-9. The mineralized/SBU band shows no band, thus no activity was found for use in the self-etch mode. The demin/SBU band shows faint gelatinolytic activity for both MMP-2 and -9 for the etched mode. The demin/PBNT band shows an intense band for the MMP-2 active-form, a 72kDa band corresponding to the pro-form of MMP-2 and a fainter band at 86kDa corresponding to the MMP-9 active form.



#### Conclusions:

The analysis showed that if Scotchbond™ Universal Adhesive was applied in the self-etch mode, MMP activity was almost absent, while its application in the etch-and-rinse mode showed minor activation of MMPs. Prime & Bond NT resulted in massive activation of MMP-2.

## 4. Bond Durability

### Sealing Abilities of Latest All-in-one Adhesives Under Thermo-mechanical Cyclic Stress

Authors: S. Akiyama<sup>1</sup>, M. Maeno<sup>1</sup>, M. Hara<sup>1</sup>, T. Yamada<sup>1</sup>, Y. Nara<sup>1</sup> and I.L. Dogon<sup>2</sup>, <sup>1</sup>Dept. of Operative Dentistry, Nippon Dental University, Tokyo, Japan, <sup>2</sup>School of Dental Medicine, Harvard University, Boston, MA

Reference: AADR 2012, Tampa Bay, USA, Abstract #464

4

#### Aim of the Study:

The purpose of this study was to examine the sealing ability of a latest all-in-one adhesive; Scotchbond™ Universal Adhesive/EXL759 (SBU/EXL, 3M ESPE), as compared with an all-in-one system; Adper™ Easy Bond Self-Etch Adhesive (EB, 3M ESPE) and a popular self-etch system; Clearfil SE Bond (SE, Kuraray), under thermo-mechanical cyclic stress simulating intra-oral environment.

#### Method:

Sixty standardized wedge-shaped cavities with occlusal margin on enamel and gingival margin on dentin were prepared in the buccocervical region of extracted human lower premolars. Three systems were applied to the cavities according to manufacturers' instruction and resin composites; Filtek™ Supreme Ultra Universal Restorative (3M ESPE) for SBU/ EXL and EB specimens and Clearfil AP-X (Kuraray) for SE specimens, were placed and light-cured. All specimens were stored in a moisture box at 37°C for 24 hours, then polished and divided into two groups (n = 10, each system); a group with stress (S+) and a group without stress (S-). For S+ group, restored specimens were thermocycled (5°C/55°C, 2,000 cycles) and cyclic loaded (12kgf x 105) simultaneously. For S- group, no stress was applied. Dyeing for an hour, microleakage of S+ and S- specimens were evaluated by a graded criterion and analyzed using Kruskal-Wallis and Wilcoxon tests.

# Scotchbond™

## Universal Adhesive

### 4. Bond Durability

#### Sealing Abilities of Latest All-in-one Adhesives Under Thermo-mechanical Cyclic Stress (cont.)

4

**Results:**

There were significant differences in occlusal microleakage between S+ and S- groups in SBU/EXL ( $p < 0.05$ ), EB ( $p < 0.01$ ) and SE ( $p < 0.05$ ), while the differences in gingival leakage was not recognized regardless of the systems. There were no differences in both occlusal and gingival microleakage among the systems regardless of stress mode. The difference in the microleakage of each system between occlusal and gingival walls was not recognized, regardless of stress mode.

**Conclusions:**

Gingival microleakage of all systems was not influenced by the stress, but occlusal leakage increased by the stress. However the sealing ability of EXL was statistically equivalent to those of EB and SE regardless of stress mode and walls.

## 4. Bond Durability

### Self-Assembled Nano-Layering at the Adhesive Interface

**Authors:** Y. Yoshida, K. Yoshihara, N. Nagaoka, S. Hayakawa, Y. Torii, T. Ogawa, A. Osaka, B.V. Meerbeek

**Reference:** Journal of Dental Research. 2012 Apr; 91(4):376–81.  
Epub 2012 Feb 1

**4****Abstract:**

According to the 'Adhesion–Decalcification' concept, specific functional monomers within dental adhesives can ionically interact with hydroxyapatite (HAp). Such ionic bonding has been demonstrated for 10-methacryloyloxydecyl dihydrogen phosphate (MDP) to manifest in the form of self-assembled 'nano-layering'. However, it remained to be explored if such nano-layering also occurs on tooth tissue when commercial MDP-containing adhesives (Clearfil SE Bond, Kuraray; Scotchbond Universal, 3M ESPE) were applied following common clinical application protocols. We therefore characterized adhesive-dentin interfaces chemically, using x-ray diffraction (XRD) and energy-dispersive x-ray spectroscopy (EDS), and ultrastructurally, using (scanning) transmission electron microscopy (TEM/STEM). Both adhesives revealed nano-layering at the adhesive interface, not only within the hybrid layer but also, particularly for Clearfil SE Bond (Kuraray), extending into the adhesive layer. Since such self-assembled nano-layering of two 10-MDP molecules, joined by stable MDP-Ca salt formation, must make the adhesive interface more resistant to biodegradation, it may well explain the documented favorable clinical longevity of bonds produced by 10-MDP-based adhesives.



# Scotchbond™

## Universal Adhesive

### 4. Bond Durability

#### Self-Assembled Nano-Layering at the Adhesive Interface (cont.)

4

##### Results: XrD

Untreated dentin (Fig. 1a, 'dentin') revealed XRD peaks at  $2\theta = 26.0^\circ$ ,  $28.8^\circ$ ,  $31.8^\circ$ ,  $32.2^\circ$  and  $33.0^\circ$ , which must be ascribed to HAp. When dentin was exposed to the MDP:EtOH:H<sub>2</sub>O solution (Figs. 1a, 1b, 'MDP\_dentin'), three characteristic peaks in the range of  $2\theta = 2.52^\circ$  ( $d = 3.50$  nm),  $4.84^\circ$  ( $d = 1.82$  nm) and  $7.16^\circ$  ( $d = 1.23$  nm) appeared and must be assigned to the formation of MDP\_Ca salt (Yoshihara et al., 2011a). The three characteristic peaks have been previously identified as 'nano-layering' of MDP-Ca, more specifically, the structural self-assembly of two MDP molecules joined together by Ca (Fukeygawa et al., 2006; Yoshihara et al., 2010, 2011a). The dentin sample treated with Clearfil SE primer (Kuraray) revealed three characteristic peaks in the range of  $2\theta = 2.53^\circ$  ( $d = 3.49$  nm),  $4.96^\circ$  ( $d = 1.78$  nm) and  $7.36^\circ$  ( $d = 1.20$  nm) (Figs. 1a, 1b, 'C-SE\_dentin'), which were not detected for untreated dentin (Fig. 1a, 'dentin'). Three such peaks at  $2\theta = 2.56^\circ$  ( $d = 3.45$  nm),  $5.04^\circ$  ( $d = 1.75$  nm) and  $7.44^\circ$  ( $d = 1.19$  nm) were also detected when Scotchbond Universal (3M ESPE) was applied to dentin (Figs. 1a, 1b, 'S-U\_dentin').

##### Conclusions:

It is concluded that MDP-containing adhesives do form nano-layering at the adhesive interface. Stable MDP-Ca salt deposition along with nano-layering may explain the high stability of MDP-based bonding, as has been proven previously in laboratory as well as in clinical research.

**4. Bond Durability****Long-term Adhesion and Mechanism of Bonding of Paste-Liquid Resin-Modified Glass-Ionomer**

Authors: S.B. Mitra, C.Y. Lee, H.T. Bui, D. Tantbirojn, R.P. Rusin

Reference: Dental Materials, 2009 Apr;25(4):459–66. Epub 2008 Nov 28

**4 Aim of the Study:**

The contribution of chemical bonding of the polycarboxylic acid in classical powder/liquid conventional glass ionomers (GI) and resin-modified glass-ionomers (RMGI) has been attributed to the excellent long-term bond strengths and clinical retention. RMGIs have been recently introduced as paste/liquid systems for convenience of clinical usage. The objective of this study was to investigate the long-term bond strengths and mechanism of adhesion of paste-liquid RMGI in order to ascertain whether similar characteristics are retained.

**Methods:**

Long-term shear adhesion to dentin and enamel was measured on two paste-liquid RMGIs and one powder/liquid RMGI. Scanning electron microscopy (SEM) Fourier-transformed infrared spectroscopy (FTIR) and X-ray photoelectron spectroscopy (XPS) analyses were carried out on the paste liquid RMGI Vitrebond Plus (VBP) and compared with the classical powder/liquid RMGI Vitrebond (VB).

# Scotchbond™

Universal Adhesive

## 4. Bond Durability

### Long-term Adhesion and Mechanism of Bonding of Paste-Liquid Resin-Modified Glass-Ionomer (cont.)

#### Results:

VBP maintains adhesion to dentin and enamel over long times; its long-term adhesive performance is equivalent to VB. FTIR data confirm that VBP exhibits the carboxylate crosslinking reaction of true glass ionomer. SEM images show evidence of micromechanical bonding at the interface between VBP and the tooth. XPS and FTIR data show that the methacrylated copolyalkenoic acid component present in VB and VBP chemically bonds to the calcium in HAP.

4

#### Conclusions:

The new paste-liquid RMGI liner, VBP, shows equivalent adhesion to its powder-liquid predecessor, VB. The adhesion mechanism was attributed to micromechanical and chemical bonding. This chemical bond is significant factor in the excellent long-term adhesion of these materials.



## Clinical Technique Variables

In both clinical and laboratory settings, application technique variables can affect the bonding performance of an adhesive system.

The previous section showed the consistent performance of Scotchbond™ Universal Adhesive dentin in both the etched and self-etch mode. It also highlighted the consistency based on the moisture or dehydration condition of the dentin after etching.

This section will review studies that have looked at other general type of variables that can be encountered in the clinical environment.

5

A common clinical concern is the ability to adequately isolate the prepared tooth surface from saliva contamination. It is very important to maintain a clean and isolated bonding surface, however if the adhesive system could be tolerant to a slight amount of saliva contamination prior to the adhesive placement, that would be very beneficial clinically. Due to the acidic and aqueous nature of the adhesive, it may be able to maintain the bond strength on a surface that has been slightly contaminated.

Other variables may include the general interpretation of the instructions for use which may reflect the robustness of performance for the adhesive, placing multiple layer of adhesive and utilizing various types of curing light.

The following papers will highlight the consistency of performance for Scotchbond Universal Adhesive under these variable conditions.

**5. Clinical Technique Variables****Saliva Effect on Dentin and Enamel Bond Strength****Authors:** I. Richter and C. Thalacker, 3M ESPE, Seefeld Germany**Reference:** Unpublished**Aim of the Study:**

This study investigated the effects of human saliva contamination on the shear bond strengths (SBS) to dentin and enamel with Scotchbond™ Universal Adhesive.

**5****Method:**

Bovine incisors were embedded in cold-cure acrylic resin. The labial surface of each tooth was ground to expose enamel (E) or dentin (D). Half of the surfaces were contaminated with human saliva. The other half were bonded with no contamination. A cylindrical button of Filtek™ Z250 Universal Restorative A3 (3M ESPE, 2.36mm diameter, 2mm height) was cured on the contaminated and clean tooth surfaces treated with Scotchbond Universal Adhesive (3M ESPE) in SE mode and in TE mode after a 15 second phosphoric acid etch (n = 10). A notched-edge shear method (Ultradent) was used to measure the SBS.

# Scotchbond™

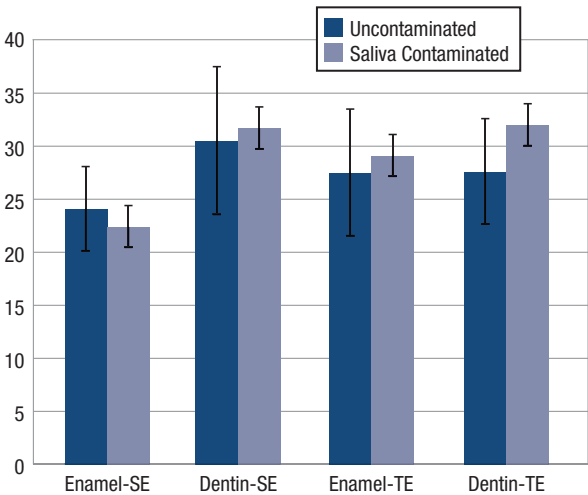
## Universal Adhesive

### 5. Clinical Technique Variables

#### Saliva Effect on Dentin and Enamel Bond Strength (cont.)

##### Results:

The table shows the SBS in MPa. The standard deviations (SD) are given in parenthesis.



##### Conclusions:

There was no negative impact on the bond strength with the saliva contaminated surfaces for both enamel and dentin whether bonded with Scotchbond™ Universal Adhesive in the self-etch or etched mode of application.

## 5. Clinical Technique Variables

### Influence of Curing Units on One-step Self-Etch Adhesives

**Authors:** E. Daudt<sup>1</sup>, G. Marchesi<sup>2</sup>, M. Cadenero<sup>2</sup>, L.N. Baratieri<sup>3</sup> and

L. Breschi<sup>2</sup>, <sup>1</sup>Universidade Federal De Santa Catarina, Curitiba, Brazil,

<sup>2</sup>Department of Medical Sciences, University of Trieste, Trieste, Italy,

<sup>3</sup>Dentistry, Universidade Federal De Santa Catarina, Florianopolis SC, Brazil

**Reference:** AADR 2012, Tampa Bay, USA, Abstract #1303

#### 5 Aim of the Study:

To determine the effect of different curing units on microshear bond strength to enamel using one-step self-etch adhesives. The tested hypothesis was that curing unit type affects the bond strength of adhesives.

#### Method:

One-hundred and eighty human molars were used. Teeth were randomly divided in three main groups, according to the adhesive system used (n = 60): Scotchbond™ Universal Adhesive (3M ESPE); G-BOND (GC Corporation) and MTB-200 (Kuraray). Each adhesive system was applied according to manufacturers' instructions. Each group was divided in three subgroups according to the type of curing unit used (n = 20): Bluephase-LED (Ivoclar Vivadent), VALO-LED (ULTRADENT) and Elipar™ 2500 Halogen Curing Light (3M ESPE). A composite (Filtek™ Z250 Universal Restorative [3M ESPE]) build-up was created on the bonded enamel surface and immediately tested for microshear bond strength testing. Specimens were loaded to failure and data statistically-analyzed by one-way Anova and Tukey's post-hoc test (p < 0.05).



# Scotchbond™

## Universal Adhesive

### 5. Clinical Technique Variables

#### Influence of Curing Units on One-step Self-Etch Adhesives (cont.)

##### Results:

Microshear values are reported in Table 1. G-bond showed lower bond strength than the other adhesives with all the tested curing units. Curing unit type did not affect MTB-200, while Scotchbond Universal polymerized with Bluephase showed the highest values. Same superscript letters indicate no statistical difference ( $p > 0.05$ ).

|                  | Scotchbond Universal             | MTB-200                            | G-BOND                         |
|------------------|----------------------------------|------------------------------------|--------------------------------|
| Bluephase        | 23.2 ( $\pm$ 2.0) <sup>e</sup>   | 19.4 ( $\pm$ 2.9) <sup>b,c,d</sup> | 15.2 ( $\pm$ 2.8) <sup>a</sup> |
| VALO             | 20.4 ( $\pm$ 1.9) <sup>c,d</sup> | 18.5 ( $\pm$ 1.8) <sup>b,c</sup>   | 15.7 ( $\pm$ 2.2) <sup>a</sup> |
| Curing Unit 2500 | 20.6 ( $\pm$ 1.7) <sup>d</sup>   | 18.1 ( $\pm$ 1.9) <sup>b</sup>     | 15.5 ( $\pm$ 1.9) <sup>a</sup> |

##### Conclusions:

The tested hypothesis was partially accepted since microshear bond strength varied according to adhesive type and was affected by curing unit only when Scotchbond™ Universal Adhesive was used.

## 5. Clinical Technique Variables

### Effect of Layers of Bonding System on Dentin Bond Strength

Authors: D. LaFuente, Dept. of Dental Materials, University of Costa Rica, San Pedro, Costa Rica

Reference: AADR 2012, Tampa Bay, USA, Abstract #1304

#### 5 Aim of the Study:

It is known and accepted that using more than two layers of dentin bonding agents increases bond strength. The purpose of this study was to evaluate the effect of additional layers of bonding systems on the bond strength to dentin.

#### Method:

Thirty-six recently extracted caries and restoration free upper premolars, were cut and polished with 600-grit until superficial dentin was exposed. Teeth were divided into three groups to receive dentin bonding systems: ProtecBond (Kuraray), Adper™ Single Bond 2 Adhesive (3M ESPE) and Scotchbond™ Universal Adhesive (3M ESPE). For each bonding system three sub-groups were made (n = 4) to receive 2, 3 and 4 layers of bonding adhesive, all placed according to manufacturer's instructions. Composite Z100™ Restorative was placed over the bonding agent and 1mm<sup>2</sup> sticks were created from all teeth. Twenty randomly selected sticks from each group were selected to be evaluated in microtensile at 0.1cm/min until failure. Data was recorded in MPa and evaluated with a two-way ANOVA. Scheffe's test for comparison among number of layers and bonding systems was also calculated at 0.05 significance level.

# Scotchbond™

## Universal Adhesive

### 5. Clinical Technique Variables

#### Effect of Layers of Bonding System on Dentin Bond Strength (cont.)

##### Results:

Means with standard deviations (in parenthesis) are shown in the table. Scotchbond™ Universal Adhesive was the only one that did not increase its bond strength to dentin with additional layers. ANOVA and Scheffe's test showed a significant difference between the bond strength with two and four layers, for all bonding systems. No difference was found among adhesives.

|          | Scotchbond Universal | Single Bond 2 | Protec Bond |
|----------|----------------------|---------------|-------------|
| 2 Layers | 32.4 (9.0)           | 22.4 (2.4)    | 29.0 (7.1)  |
| 3 Layers | 26.0 (5.8)           | 35.5 (11.7)   | 30.1 (9.5)  |
| 4 Layers | 25.3 (9.5)           | 38.2 (6.6)    | 36.8 (7.6)  |

##### Conclusions:

The use of additional layers affects the bond strength of the system to dentin, but it may be a positive or negative effect depending on the bonding system.

## 5. Clinical Technique Variables

### Bond Strengths Obtained by General Practitioners with a Portable Device

**Authors:** J.C. Farr, A. Rumphorst, I. Richter, A. Bock, M. Wieland and C. Thalacker, 3M ESPE, Seefeld, Germany

**Reference:** IADR DIV/CED 2011, Budapest, Hungary, Abstract #221

#### 5 Aim of the Study:

Very often adhesive bond strengths are evaluated by researchers either from the university or industry. Aim of this study was to compare shear-bond strengths created by a large number of general practitioners with a portable testing device.

#### Method:

Immediate bond strengths were collected for fifteen adhesives and Scotchbond™ Universal Adhesive (SBU, 3M ESPE). Control group: SBM (Scotchbond Multi Purpose), OFL (OptiBond-FL) and SYN (Syntac). Adhesives: AEB-SE (Adper™ Easy Bond Self-Etch Adhesive), AEB-TE (AdperEasyBond, with selective enamel-etch), ADO (AdheseOne), CSE (Clearfil-SE-Bond), FUB (Futurabond), IBO (iBond), OSP (OptiBond-Solo-Plus), PBN (Prime&Bond-NT), SBO (Scotchbond-1XT), XEV (XenoV), EXC (ExciTE), GBO (G-Bond). Data were collected from twenty-seven events with a total of 376 private practitioners. A portable shear-bond tester (Bisco, Ref. T-63010K) was used for debonding of samples prepared by the Ultradent method. Bovine incisors were embedded in cold-cure acrylic resin. The labial surface of each tooth was ground to expose dentin (D). After application of the adhesive a cylindrical composite button (Filtek™ Supreme XTE Universal Restorative, A2, 2.36 diameter, 1–2mm height) was light-cured on the prepared tooth surfaces.

# Scotchbond™

## Universal Adhesive

### 5. Clinical Technique Variables

#### Bond Strengths Obtained by General Practitioners with a Portable Device (cont.)

##### Results:

Shear-bond strengths are reported in MPa (table). All data were analyzed by 1-way ANOVA and multiple comparisons using Fisher's LSD procedure ( $p < 0.05$ ). Means with the same letter are statistically the same.

5

|     |                                 |
|-----|---------------------------------|
| SBU | 25.7 (6.6) <sup>a</sup>         |
| SBM | 28.1 (10.8) <sup>a</sup>        |
| OFL | 17.6 (8.6) <sup>b</sup>         |
| AEB | 16.6 (7.0) <sup>b</sup>         |
| SBO | 15.8 (9.1) <sup>b,c</sup>       |
| ADO | 12.5 (6.2) <sup>c,d</sup>       |
| EXC | 12.4 (3.6) <sup>b,c,d,e,f</sup> |
| SYN | 11.7 (7.0) <sup>d</sup>         |
| CSE | 11.5 (5.5) <sup>d,e</sup>       |
| IBO | 11.4 (4.5) <sup>d,e,f</sup>     |
| XEV | 10.3 (6.8) <sup>d,e,f</sup>     |
| FUB | 9.6 (5.6) <sup>c,d,e,f</sup>    |
| PBN | 8.4 (6.2) <sup>f</sup>          |
| OSP | 8.2 (6.0) <sup>d,e,f</sup>      |
| GBO | 7.5 (5.3) <sup>e,f</sup>        |

##### Conclusions:

Multiple significant differences were found between the different types of adhesives. The highest bond strengths for dentin were found for Scotchbond Multi Purpose and Scotchbond™ Universal Adhesive. Some of the 1-bottle adhesives showed similar or higher bond strengths than the multi-bottle adhesives SYN and CSE.



## Bonding to Indirect Substrates

The unique chemistry of Scotchbond™ Universal Adhesive allows it to achieve chemical adhesion to a variety of indirect restorative substrates. Indirect restorations are fabricated from a wide range of materials including metals, composite, glass-containing ceramics and non-glass ceramics such as aluminum and zirconium oxide.

Historically, conventional methacrylate based adhesives could not provide chemical adhesion to these surfaces alone. Various types of primers or surface treatments were needed to be applied to these surfaces to allow chemical adhesion.

Scotchbond Universal Adhesive contains an active and stable silane. Silanes are bi-functional molecules that will chemically bond to glass and also have a methacrylate functionality that allows the methacrylates in adhesives or cements to bond to the bonded silane. Having the active silane in the adhesive allows the adhesive to be placed directly onto the glass ceramic surface or composite based systems that contain glass fillers and achieve a strong chemical bond without having to use a separate primer.

Scotchbond Universal Adhesive also contains the phosphate monomer, MDP. This monomer is well known for its self-etching capability but also for its ability to chemically bond to the metal oxide layers of zirconia, alumina and metals. By having the monomer as part of its formula, the adhesive can bond to these metal oxide surfaces without incorporating separate priming agents.

Having the ability to chemically bond to these indirect surfaces allows Scotchbond Universal Adhesive to extend its versatility and indications beyond that of a conventional adhesive and simplify the techniques for indirect restoration placement or repair.

The studies in this section highlight the capability of Scotchbond Universal Adhesive to durably bond to these various substrates.

## 6. Bonding to Indirect Substrates

### Bond of a New Self-etch Adhesive to Alumina and Zirconia

**Authors:** M.B. Blatz, C. Zbaeren and F. Mante, Department of Restorative Dentistry, University of Pennsylvania, Philadelphia, PA

**Reference:** AADR 2012, Tampa Bay, USA, Abstract #710

#### Aim of the Study:

This study measured and compared the shear bond strength of resin composite to the high-strength ceramics alumina and zirconia after different surface treatment methods and application of either a new self-etch adhesive or a prominent zirconia primer.

**6**

#### Method:

A total of seventy-two specimens were fabricated from a commercially available zirconium-oxide ceramic (Lava™, 3M ESPE, n = 36, group ZIR) and an aluminum-oxide ceramic (Vita, n = 36, group ALU). Surface treatment protocols consisted of air-particle abrasion (aluminum oxide) followed by application of Scotchbond™ Universal Adhesive (3M ESPE, subgroup SBU) or Z-Prime (Bisco, subgroup ZPR). As a control, a combination of CoJet™ Tribochemical surface treatment, ceramic primer (RelyX™ Ceramic Primer, 3M ESPE) and an adhesive (Adper™ Single Bond Plus Adhesive, 3M ESPE) was applied (subgroup COJ). Bond strength was tested after 10,000 thermal cycles (5 to 600C, dwell time 15 seconds). Data was analyzed with one-way ANOVA ( $p < 0.001$ ) and paired comparisons between groups were done with Tukey test ( $p < 0.05$ ).



# Scotchbond™

## Universal Adhesive

### 6. Bonding to Indirect Substrates

#### Bond of a New Self-etch Adhesive to Alumina and Zirconia (cont.)

##### Results:

The mean bond strength values MPa and standard deviations (SD) are listed in the table.

|                               | Zirconia     | Alumina      |
|-------------------------------|--------------|--------------|
| Scotchbond Universal Adhesive | 23.19 (4.49) | 17.49 (3.67) |
| Z-Primer Plus                 | 10.97 (2.53) | 7.05 (1.64)  |
| CoJet                         | 0.82 (0.49)  | 1.09 (0.81)  |

6

##### Conclusion:

Type of adhesive and surface treatment significantly influences composite-resin bond strengths to zirconia and alumina. Performance of the different bonding protocols was not influenced by the ceramic substrate. The Scotchbond™ Universal Adhesive (SBU) provides superior bond strength to zirconia as well as alumina ceramics.

## 6. Bonding to Indirect Substrates

### Shear Bond Strengths to Restorative Materials and Tooth Structure

Authors: J. Burgess, S. Shah, D. Cakir, P. Bekc and L. Ramp,  
University of Alabama at Birmingham, Birmingham, AL

Reference: AADR 2012, Tampa Bay, USA, Abstract #636

#### Aim of the Study:

1) Measure 24 hour and thermocycled shear bond strength/(SBS) of Scotchbond™ Universal Adhesive/3M ESPE to Paradigm™ C, Lava™ Core, IPS e.max CAD, gold and base metal alloy 2) Measure 24 hours and 10 months SBS of Scotchbond Universal Adhesive to unetched and etched ground human dentin and enamel.

**6**

#### Method:

Paradigm C, e.max CAD, Lava blocks and non-noble metal alloy were sectioned ( $t = 4\text{mm}$ ). Noble metal alloy was received in 2mm thick blocks. Specimens were polished (180-, 320-grit SiC-paper/4 minutes), finished ( $0.5\mu\text{Al}_2\text{O}_3$  slurry/2 minutes) and cleaned (ultrasonic/distilled water/15 seconds). Molars were wet-ground (320-grit) to obtain flat enamel and dentin. Following surface treatments (table) and bonding agent application, Z100™ Restorative/3M ESPE cylinders ( $d = 1.5\text{mm}$ ) were bonded and light-cured (Elipar™ S10 LED Curing Light/3M ESPE/1000mW/cm<sup>2</sup>). Half were debonded after 24 hours storage at 37°C (Instron-1mm/minute). Remainder of ceramic and alloy specimens were debonded after thermocycling (10,000 cycles/6-60°C/15 seconds dwell time). Remaining enamel and dentin specimens were stored for 10 months after thermocycling then debonded. Data analyzed with ANOVA and Tukey/Kramer post-hoc tests ( $p = 0.05$ ).

# Scotchbond™

## Universal Adhesive

### 6. Bonding to Indirect Substrates

#### Shear Bond Strengths to Restorative Materials and Tooth Structure (cont.)

**Results:** MPa/(Mean ± SD) Same letters in same row are not statistically different. Scotchbond™ Universal Adhesive (SBU) and Adper™ Single Bond Plus Adhesive (SBP) are referenced as the adhesives.

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|                    | SBP/Cojet + Silane    | SBP/Al <sub>2</sub> O <sub>3</sub> + Z Prime | SBU/Al <sub>2</sub> O <sub>3</sub> |
|--------------------|-----------------------|--|------------------------------------|
| Lava/24 hour       | 19.8 ± 5 <sup>A</sup> | 32.3 ± 7 <sup>B</sup>                        | 37.5 ± 5 <sup>B</sup>              |
| Lava/10,000 cycles | 25.6 ± 9 <sup>A</sup> | 29.4 ± 6 <sup>A</sup>                        | 30.4 ± 4 <sup>A</sup>              |

|                         | SBP/Silane             | SBP/RelyX-Ceramic Primer | SBU/HF-Etch           |
|-------------------------|------------------------|--------------------------|-----------------------|
| e.maxCAD/24 hour        | 36.8 ± 4 <sup>A</sup>  | 40.6 ± 7 <sup>A</sup>    | 34.2 ± 7 <sup>A</sup> |
| ParadigmC/24 hour       | 44.1 ± 16 <sup>A</sup> | 32.7 ± 12 <sup>A,B</sup> | 26.3 ± 8 <sup>B</sup> |
| e.maxCAD/10,000 cycles  | 28.9 ± 6 <sup>A</sup>  | 32.1 ± 6 <sup>A</sup>    | 15 ± 4 <sup>B</sup>   |
| ParadigmC/10,000 cycles | 38.9 ± 4 <sup>A</sup>  | 27 ± 10 <sup>A</sup>     | 27.4 ± 5 <sup>A</sup> |

|                           | SBP/Al <sub>2</sub> O <sub>3</sub> + Metal Primer | SBU/Al <sub>2</sub> O <sub>3</sub> |
|---------------------------|---|------------------------------------|
| Base-Metal/24 hour        | 29.1 ± 5 <sup>A</sup>                             | 40.2 ± 5 <sup>B</sup>              |
| Noble-Metal/24 hour       | 30.6 ± 5 <sup>A</sup>                             | 29.1 ± 4 <sup>A</sup>              |
| Base-Metal/10,000 cycles  | 27.5 ± 6 <sup>A</sup>                             | 32.3 ± 6 <sup>A</sup>              |
| Noble-Metal/10,000 cycles | 25.4 ± 6 <sup>A</sup>                             | 16.5 ± 3 <sup>A</sup>              |

**Conclusion:** Scotchbond Universal Adhesive is a promising universal adhesive.

## 6. Bonding to Indirect Substrates

### Shear Bond Strength of Various Bonding Systems to Various Substrates

**Authors:** C.J. Kleverlaan, Academic Center for Dentistry Amsterdam (ACTA), Netherlands

**Reference:** Findings to be presented at ACTA Symposium, September, 2012.

#### Aim of the Study:

The aim of the project is to determine the adhesive properties with Scotchbond™ Universal Adhesive for the application to teeth and the repair of indirect restorations. The following materials are selected as substrate: glass ceramic, zirconia, composite, noble metal, and enamel and dentine for comparison. As bonding systems Scotchbond Universal are compared to Scotchbond MP, OptiBond FL, Prime & Bond NT, Clearfil SE Bond, Futurabond DC.

#### Method:

The shear bond strength of Scotchbond Universal, Scotchbond™ MP, OptiBond FL, Prime & Bond NT, Clearfil SE Bond, Futurabond DC to different substrates are determined together with their mode of failure. The substrates were IPS e.max, Lava™ Zirconia, Lava™ Ultimate Restorative, aged Filtek™ Z250 Restorative (Old composite), Carrara PdF (noble metal), Enamel and Dentine (Bovine). The bonding system, e.g. Scotchbond Universal, Scotchbond MP, OptiBond FL, Prime & Bond NT, Clearfil SE Bond or Futurabond DC is applied to the surface according to manufacturer procedures. After applying the bonding to the substrate a neoprene ring with inner diameter of 3.2 mm and a height of 1 mm is filled with Filtek™ Supreme XTE Universal Restorative (Color A2) and light cured (Figure 1). The specimens are stored in water at 37°C for 24 hours.

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## Universal Adhesive

### 6. Bonding to Indirect Substrates

#### Shear Bond Strength of Various Bonding Systems to Various Substrates (cont.)

##### Results:

The table shows the summary of the shear bond strengths and their standard deviations of the 30 different investigated bonding systems bonded to the different substrates.

|               | SBU (TE)      | SBU (SE)      | SBMP           | PB NT         | Futura DC     | SE Bond        | Opti-bond FL   |
|---------------|---------------|---------------|----------------|---------------|---------------|----------------|----------------|
| Enamel        | 22.1<br>(5.9) | —             | 28.5<br>(5.8)  | 18.4<br>(7.5) | 11.0<br>(3.2) | 22.3<br>(6.2)  | 22.1<br>(10.5) |
| Dentin        | 27.4<br>(8.7) | 32.8<br>(6.1) | 22.1<br>(10.5) | 10.7<br>(3.8) | 18.5<br>(4.2) | 24.6<br>(11.2) | 28.2<br>(12.5) |
| Filtek Z250   | 46.0<br>(9.2) | —             | 42.9<br>(7.5)  | 42.2<br>(8.8) | —             | 36.9<br>(9.2)  | —              |
| Gold          | 8.4<br>(3.5)  | —             | 16.8<br>(4.9)  | —             | —             | 10.9<br>(3.7)  | —              |
| e.max         | 12.9<br>(4.1) | —             | 18.6<br>(6.0)  | 13.4<br>(3.1) | —             | 15.9<br>(4.1)  | —              |
| Lava Ultimate | 28.9<br>(5.7) | —             | 19.0<br>(3.9)  | 10.7<br>(4.3) | —             | 17.1<br>(5.0)  | —              |
| Lava Zirconia | 27.5<br>(5.0) | —             | —              | —             | —             | 21.0<br>(5.2)  | —              |

##### Conclusion:

The results show that the initial shear bond strength of Scotchbond Universal is similar to the initial shear bond strength of SE Bond on the substrates enamel, dentine, old composite, gold, E-max CAD, Lava Ultimate, and Lava Zirconia. Furthermore, initial shear bond strength of Scotchbond Universal to enamel and dentine is similar the initial shear bond strength Optibond FL.



## Marginal Integrity

An important aspect of the bonding ability of an adhesive is to resist the polymerization forces of the dental composite and maintain a sealed, continuous interface between tooth structure and composite. In the oral environment the ability to maintain marginal integrity will resist staining and degradation and ultimately, resist secondary decay.

As with adhesion testing, there are a variety of ways to measure marginal integrity. One common method is to conduct a microleakage test. Variables in this study include the staining regimen, sample geometry, and thermal stress. The seal or degree of dye penetration can be evaluated for both the enamel and dentin margins.

Marginal integrity can also be evaluated through utilization of microscopic techniques such as SEM to visually inspect and measure the degree and amount of defects at the marginal interface. These evaluations typically report results as a percentage or degree of continuous margins without defects.

In addition to being able to seal the external margins of the restoration, the adhesive must also be able to adequately seal or penetrate the dentin collagen network. If the etched or demineralized collagen network is not thoroughly infiltrated, open pathways can exist. These open pathways can allow for “nanoleakage” under the restoration. If there is a significant amount of nanoleakage, the dentin bond may degrade over time. Dye infiltration studies can be conducted with microscopic examination to determine degrees or amounts of nanoleakage.

Studies shown earlier in this booklet by Perdigao, et al, reference nanoleakage study results. Additionally, interfacial SEMs and TEMS, shown earlier by Perdigao and Van Meer Beek highlight the dentin/adhesive interface.

In this section, studies showing the ability to maintain marginal integrity are highlighted.

## 7. Marginal Integrity

### Marginal Integrity of Adhesive Systems in Class V Restorations

Authors: U. Blunck, Berlin Germany

Reference: Unpublished

**Aim of the Study:**

To measure the dentin and enamel marginal integrity of Class V composite restorations using self-etch and total-etch adhesive systems. Scotchbond Universal Adhesive will be tested in both the self-etch and total-etch modes.

**7**

**Method:**

Class V cavities were prepared in extracted teeth. The cavities were treated with the adhesive systems with or without acid etching, followed by the composite placement and finishing and polishing. The samples were stored for 21 days and thermocycled for 2,000 cycles. Microscopic analysis was performed to evaluate marginal irregularities and gaps. Data is reported as a percentage of continuous margins.



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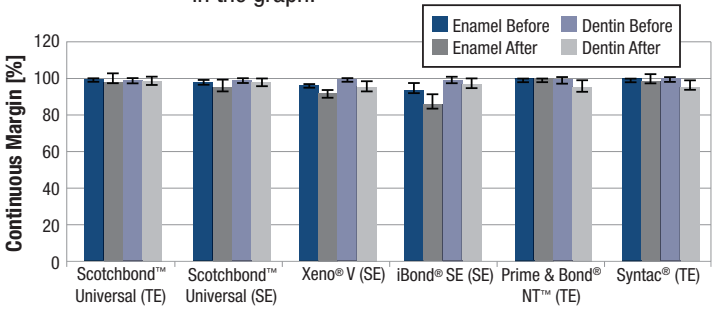
## Universal Adhesive

### 7. Marginal Integrity

#### Marginal Integrity of Adhesive Systems in Class V Restorations (cont.)

##### Results:

Continuous margin percentage for dentin and enamel before and after thermocycling are shown in the graph.



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##### Conclusion:

Scotchbond Universal Adhesive has a high percentage of continuous margins in both the total-etch and self-etch modes to both dentin and enamel.

## 7. Marginal Integrity

### Effect of an Experimental 3M ESPE Adhesive on Marginal Quality of Class II Resin Composite Restorations

Authors: R. Frankenberger, Philipps University, Marburg, Germany

Reference: Unpublished

#### Aim of the Study:

This study evaluated marginal integrity of bonded posterior resin composite fillings to enamel and dentin, before and after thermo-mechanical loading (TML).

#### Method:

48 MOD cavities with one proximal box beneath the CEJ were prepared in extracted human third molars. Direct resin composite restorations (Filtek Z250) were bonded with Scotchbond Universal Adhesive both under etch-and-rinse and self-etch conditions, and with Syntac, OptiBond Solo Plus, iBond Self-Etch and Xeno V. Before and after thermomechanical loading (100,000 x 50N, 2,500 thermocycles between 5 and 55°C), marginal gaps were analyzed using SEM of epoxy resin replicas. Results were analyzed with Kruskal-Wallis and Mann-Whitney U-tests ( $p < 0.05$ ). After thermomechanical loading, specimens were cut longitudinally in order to investigate internal dentin adaptation by epoxy replicas under a SEM (200x magnification).

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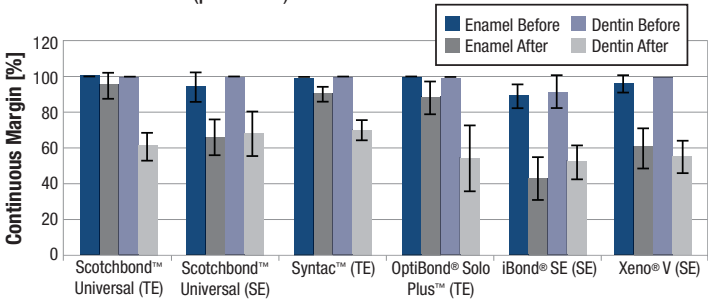
## Universal Adhesive

### 7. Marginal Integrity

## Effect of an Experimental 3M ESPE Adhesive on Marginal Quality of Class II Resin Composite Restorations (cont.)

### Results:

In enamel, high percentages of gap-free margins were initially identified for all adhesives. After TML, Scotchbond Universal Adhesive (etch-and-rinse) and Syntac performed best ( $p < 0.05$ ). Also in dentin, high percentages of gap-free margins were initially identified for all adhesives. After TML, Scotchbond Universal (self-etch) and Syntac performed best ( $p < 0.05$ ).



### Conclusion:

Scotchbond Universal Adhesive showed promising performance in both application modes.

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