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## Reliability of Bond Strength Using Universal Adhesives to Variable Dentin Conditions

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# RELIABILITY OF BOND STRENGTH USING UNIVERSAL ADHESIVES TO VARIABLE DENTIN CONDITIONS

A Thesis Presented

By

MARWA BAWAZIR, D.D.S.

Submitted to the College of Dental Medicine of Nova Southeastern  
University in Partial Fulfillment of the Requirements for the Degree of

MASTER OF SCIENCE IN DENTISTRY

June 2019



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A thesis submitted to the College of Dental Medicine of Nova Southeastern  
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MASTER OF SCIENCE

Department of Operative Dentistry

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## **Dedication**

My deep gratitude goes first to my parents who guided me through my educational path and stood by my side in every step of the way. I want to thank them for believing in me and for their unconditional love and support. I want them to know that without their inspiration and enthusiasm none of my achievements would have happened.

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## **Abstract**

### **RELIABILITY OF BOND STRENGTH USING UNIVERSAL ADHESIVES TO VARIABLE DENTIN CONDITIONS.**

DEGREE DATE: June 2019

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**Brief Background:** Both three-step etch-and-rinse adhesives and universal adhesives have proven their effectiveness to produce successful bond to dentin. However, there are no studies comparing adhesives' bond strength when applied by multiple operators, and to variable dentin conditions.

**Objectives:** To evaluate and compare the bond strength of a universal adhesive when applied by multiple operators, and to variable dentin conditions, in comparison to three-step etch-and-rinse adhesive.

**Methods:** Three hundred extracted human teeth were embedded in resin. Five dentists with at least ten years of experience in general dentistry, and five pre-dental students applied a universal adhesive (Adhese Universal, Ivoclar Vivadent, Amherst, NY) and an etch-and-rinse adhesive (OptiBond FL, Kerr, Orange, CA) on wet, moist and dry dentin surfaces (n=5/group). Subsequently, composite restorations (Tetric EvoCeram Bulk Fill, Ivoclar

Vivadent) were applied using Ultradent shear bond testing jig. After a technique demonstration, same operators repeated the same bonding procedures. Shear bond strength test was conducted using a universal testing machine (Instron, Canton, MA, USA). Failure mode was evaluated by using scanning electron microscopy (SEM).

**Results:** After calculating the descriptive statistics and pairwise comparisons using a Tukey HSD, a significant difference in dentin bond strength by adhesive was found,  $p < 0.001$ . Overall universal adhesives possessed  $7.38\text{MPa} \pm 0.73$  greater dentin bond strength than etch-and-rinse adhesives. Additionally, a significant difference in dentin bond strength by the operator and surface condition was observed. However, there was no significant difference in dentin bond strength by demonstration. While there was no difference between the dentin surface conditions for the universal adhesive, a significant difference was found with etch-and-rinse adhesive between moist and wet (moist  $2.67\text{MPa} \pm 0.89$  greater than wet) ( $p = 0.002$ ), and dry and wet conditions (dry  $3.79\text{MPa} \pm 0.89$  greater than wet) ( $p < 0.001$ ). Further, there was no difference between moist and dry conditions with etch-and-rinse adhesive. Regarding the operators' variability, expert dentists obtained higher bond strength values ( $1.65\text{MPa} \pm 0.73$ ) ( $p = 0.030$ ) than dental students with etch-and-rinse adhesive. However, such a difference was not found with universal adhesive.

**Conclusion:** Universal adhesive showed unaffected to dentin surface condition and operator differences. On the contrary, etch-and-rinse adhesive was influenced by the variability of surface condition and operator's expertise. The tested universal adhesive was found to be more reliable as an adhesive system in comparison to the etch-and-rinse adhesives.

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# **Chapter 1: Introduction**

## **1.1 . Resin Composites and Bonding Agents:**

Since the invention of resin composites by Bowen in 1963<sup>1</sup>, there were continuous attempts by manufacturers to improve the properties of these materials to successfully replace the missing part of the tooth structure. Currently, global resin composite market in dental restorations is expecting a healthy growth over the upcoming five years, with a value of \$536 million by 2024 according to Stratview Research, in 2018.<sup>2</sup> This growth is attributed to the high demand for cosmetic dentistry which urged the need to have a restorative material that can serve as an esthetic alternative to amalgam restorations, in addition to the increase in awareness of the advantages of resin composite restorations by the patients.<sup>3,4</sup>

Resin composite restorations show excellent mechanical properties as well as provide multiple shades that mimic the chromaticity, translucency, and opacity of the natural tooth structure.<sup>5,6</sup> From that aspect, resin composites have revealed a high level of clinical success when used for anterior and posterior direct dental restorations. However, this clinical success is not just related to the mechanical and physical properties but also depends on the intimate adaptation and strong bond of the resin composites to the tooth substrate which is only achieved by using the appropriate dental adhesive system.<sup>7</sup>

Dental adhesives are an integral part of the success of resin composite restorations as they facilitate the integration between the hydrophobic resin composite restoration and the hydrophilic tooth structure. Regarding the bond to tooth structure, dental adhesives bond to two different dental hard tissues, enamel and dentin, through the formation of micro-mechanical interlocking. Enamel is mostly composed of 90% hydroxyapatite minerals. On

the other hand, dentin is composed of dentinal tubules and 50% minerals that surrounded the inter-tubular collagen fibers, in addition to the large amount of organic material and water which make dentin softer and more humid than enamel.<sup>8,9</sup>

Adhesion to enamel is based on the use of an acidic material to remove the minerals and form micro-porosities in the enamel substrate. Then, followed by infiltration and polymerization of a low viscosity resin material. On the other hand, adhesion to dentin is based on two primary principles: first part is complete or partial removal of the smear layer, creating micro-porosities by removing the calcium and phosphate from the dentin substrate, and exposing the dentin collagen fibers. Second part is infiltration followed by polymerization of the low viscosity resin material within the created micro-porosities. This integration between the exposed dentin collagen fibers and the resin results in the formation of the hybrid layer.<sup>10</sup>

The unique biological characteristic of dentin including the high organic contents, the tubular structure, the presence of the dentinal fluid that surrounds the odontoblastic processes, the permeability of dentin, and the existence of smear layer makes the bonding to dentin substrate more challenging than bonding to enamel.<sup>10-12</sup> The dentin permeability and the dentinal fluid amount inside the dentinal tubules are strongly related to the number and diameter of the tubules as well as they are regional dependents. The number of dentinal tubules decreases near the dentino-enamel junction; accordingly, the dentin permeability decreases. Additionally, the diameter of the tubules increases at deep dentin compared to the superficial dentin; thus, the water content is higher near the pulp, which sometimes affects the durability of resin bonding to dentin substrate.<sup>13</sup>

Smear layer is an adherent layer consist of crushed hydroxyapatite, fragmented collagen after cutting the dentin surface with hand or rotary instrument. It is about 1.0  $\mu\text{m}$  in thickness and acts as a physical barrier between the bonding agent and the dentin surface. Additionally, its presence blocks the dentinal tubules and consequently reduces the dentin permeability.<sup>11</sup> Moreover, one of the clinical challenges with dentin bonding is maintaining consistent moist dentin surface to keep the inter-fibrillar spaces of the exposed collagen network. After the acid rinsing step, over-drying of the dentin surface and displacing the water in-between the exposed collagen fibers leads to collapsing of these fibers. Subsequently, it prevents dental adhesive penetration into dentin substrate.<sup>12,14</sup> All of these factors make bonding to dentin more technique sensitive and challenging compared to enamel.

## **1.2 Bonding Agents:**

Dental adhesive systems should contain three essential elements to bond resin composite restorations to tooth substrate: acid, primer, and adhesive resin. The acidic component of the adhesive system is responsible for creating micro-porosities by removing calcium and phosphate from enamel and dentin substrate. It also plays a role in modifying or completely removing the smear layer on the dentin surface. Primer and adhesive resin components are designed to overcome the heterogeneity between the hydrophilic tooth substrate and the hydrophobic resin composite by combining monomers with both hydrophilic and hydrophobic characteristics. The hydrophilic group in primer consists mostly of hydroxyethyl methacrylate (HEMA). This component enhances the wettability of enamel and dentin surfaces. Additionally, in dentin, it facilitates the penetration of the adhesive resin monomer in between the moist dentin collagen fibers. The hydrophobic group in adhesive resin interacts with the resin composite materials and it mainly consists of bisphenol glycidyl

methacrylate (bis-GMA). Solvents such as water, ethanol or acetone are added to the adhesive mixture to decrease its viscosity and increase its diffusion capability into tooth substrate.<sup>15</sup>

In dentin, the dental adhesive infiltrates into dentinal tubules and encapsulate dentin collagen fibers. Resin penetration into tubules can effectively seal the tubules and can contribute to bond strength if the resin bonds to the tubule wall. Further, resin infiltration into exposed dentin collagen fibers after removal of the dentin's minerals by acidic conditioners provides significant opportunities for micro-mechanical retention of the dental adhesive.<sup>16</sup> The ability of the dental adhesive to penetrate and encapsulate the exposed collagen fibers is mainly dependent on the low viscosity and wettability of the adhesive monomers.<sup>12,16</sup> Consequently, the longevity of the resin composite restorations is strongly associated with the success and effectiveness of adhesive systems to overcome the challenges with the bonding to the tooth substrate.<sup>17-</sup>

### **1.2.1 Classification of Bonding Agents:**

History of dental adhesives begun in 1949 when Dr. Hagger introduced the first adhesive material that bonded dentin to chemically cured resin, which was called "Sevriton Cavity Seal".<sup>22</sup> Later in 1954, Buonocore used 85% phosphoric acid to condition the enamel surface for successful bonding.<sup>23</sup> Since then, multiple adhesive systems have been introduced to the market, and their bond strength between resin composites and both enamel and dentin substrates have been improved. Accordingly, there have been several classifications of adhesive systems based on generations, number of clinical steps and adhesive strategy.



### **1.2.1.1 Classification by Generations:**

Classification by generation stands on when and in what order this adhesive system was introduced to the dental market. Each generation evolved to reduce the number of bottles involved in the bonding process as well as the number of clinical steps. Also, each generation was designed to overcome the flaws in the previous generations. The first generation of adhesives utilized glycerophosphoric acid dimethacrylate (NPG-GMA) containing resin as an interface to ionically bond resin composite. This generation produced a weak bond strength to dentin and enamel, which was approximately 1-3 MPa.<sup>24</sup>

The second generation of adhesives incorporated polymerizable phosphates into bisphenol glycidyl methacrylate (bis-GMA) resins to form an ionic bond between phosphate group in adhesive and calcium on dentin and enamel. This addition was an improvement over the first generation. However, these adhesives still provided a weak bond 5-6 MPa to the dentin and enamel substrate. The weak bond strength of previous generation to enamel was due to the lack of enamel etching and formation of micro-mechanical retention. On the other hand, the weak bond strength to dentin was due to bonding to the loose smear layer that was not stable.<sup>25,26</sup>

Acid etching of dentin was first introduced with the third generation adhesives to modify or partially remove the smear layer.<sup>24,27</sup> Yet, this generation also had a weak bond strength of 3-8 MPa since the penetration of the unfilled resin through the smear layer and into dentin was not sufficient.<sup>28</sup>

The fourth generation adhesives consist of three primary components delivered in separate packages, which are 30-40% phosphoric acid, a primer, and a bonding resin. Each of the components contained in a different bottle. In this generation, the acid etching manages to

remove the smear layer entirely to allow the penetration of the bonding agent in between the collagen. This approach provided an adequately strong bond between dentin and resin composites. The bond strength of this adhesive system was around 20 MPa.<sup>24,27</sup>

Fifth generation adhesive systems achieved to reduce the clinical steps down to two steps. This system combined the primer and bonding resin in one solution to be applied after the acid etching. This system produces adequate bond strength to dentin, however, the bond between dentin and resin composite could be prone to degradation over time compared to the fourth generation bonding systems.<sup>24,27</sup>

The sixth generation systems achieved to eliminate the etching step and replace it with a self-etching primer. The acidic primer contains functional monomers that are acidic in nature as well as have a hydrophilic characteristic. These monomers can condition the enamel and dentin surface, and simultaneously prime the tooth substrate.<sup>15</sup> The sixth generation system simplified the clinical procedure by decreasing the sensitivity to humidity in comparison to the previous generations.

The seventh generation or one-bottle self-etch adhesives, characterized by incorporating all of the bonding ingredients in one bottle (acidic monomer and adhesive). This generation significantly shortens the clinical application time, however, chemical stability of this system is questionable.<sup>27</sup>

From that aspect, manufacturers felt the need to develop an adhesive system that can bond strongly to both enamel and dentin, unsusceptible to moisture level, and further minimize the number of clinical steps.

### **1.2.1.2 Classification by Adhesive Strategy:**

This modern classification is based on how the adhesive system treats the smear layer. Etch-and-rinse adhesive strategy (4<sup>th</sup> and 5<sup>th</sup> generation) require the conditioning of dentin with phosphoric acid for complete removal of the smear layer, and a subsequent application of adhesive. On the other hand, the self-etch adhesive strategy (6<sup>th</sup> and 7<sup>th</sup> generation) preserve the smear layer by incorporating it into the adhesive layer. Universal adhesives or multi-mode adhesives can be used following etch-and-rinse strategy or self-etch strategy.<sup>27,29</sup>

## **1.2.2 Challenges with Each Bonding System**

### **1.2.2.1 Etch-and-Rinse Adhesives**

Over the past years, the three-step etch-and-rinse technique (OptiBond FL, Kerr, Orange, CA, USA) was considered the gold standard material and technique for bonding resin composite restorations to both enamel and dentin.<sup>30-32</sup> Yet, it is a more sensitive technique than the self-etch, as it is susceptible to operator error.<sup>10</sup> It is also sensitive to dentin surface moisture level, since over-drying of the dentin after acid conditioning can induce surface tension stresses and collapse of the exposed collagen fiber network, which affects the penetration of the bonding material, and subsequently compromises the bonding success.<sup>31</sup> Moreover, over-drying of dentin surface desiccates the surface and causes an outward flow of dentinal fluid which triggers nerve fibers, and subsequently prompt sensitivity.<sup>33</sup> On the other hand, over-wetting dentin after acid etching can dilute the adhesive and compromise the polymerization process.<sup>34</sup>

### **1.2.2.2 Self-Etch Adhesives**

Self-etch adhesive systems contain acidic monomers that condition and prime the enamel and dentin surfaces simultaneously, which eliminates the need of separate acid etching step.

This approach shortens the clinical bonding process compared to etch-and-rinse adhesives. These self-etch adhesives have been categorized according to their level of acidity as mild ( $\text{pH} \geq 2$ ), intermediate ( $\text{pH} = 1.5$ ) and strong ( $\text{pH} \leq 1$ ). The mild self-etch adhesive systems demineralize the dentin surface superficially and leave the hydroxyapatite crystals free for possible chemical interaction in the hybrid layer, while the strong self-etch adhesives remove all the hydroxyapatite crystals from dentin surface and produce similar morphological features as the etch-and-rinse adhesive systems.<sup>27</sup> Studies showed that self-etch adhesive with weak pH produces a shallow enamel etching with reduced micro-porosities for resin infiltration. In consequence of inadequate enamel etching, deterioration of the resin composite restorations' margins along the enamel surface was observed clinically as marginal staining or marginal leakage.<sup>10,18,31,35</sup> In addition, the one-step self-etch adhesive prone to phase separation between its monomers and solvent components, which reflects the chemical instability of the adhesive formula.<sup>36</sup>

### **1.2.2.3 Universal Adhesives**

Few manufacturers have developed the “universal adhesive” system to shorten the clinical bonding process by incorporating all the adhesive components in one bottle like the one-step self-etch adhesives. Each manufacturer defines the universal adhesive differently according to the capability of their products. Some manufacturers declare that the universal adhesives are compatible with all etching protocols: total-etch, selective-etch, and self-etch.<sup>37-39</sup> Moreover, manufacturers claim that the universal adhesive can overcome the flaws of both self-etch and etch-and-rinse adhesives, as it functions effectively on enamel and dentin surfaces, are chemically stable, tolerate different dentinal moisture level, and overall minimizes the technique sensitivity of the three-step etch-and-rinse bonding technique.<sup>38,39</sup>

Thus, this category of adhesive systems is susceptible to the manufacturer's claims. Accordingly, the clinical efficiency of each universal adhesive is distinctive and limited to the manufacturer's recommendation and indications of use.

Munoz et al., evaluated the bond strength of three universal adhesives in comparison to two self-etch adhesives. According to Munoz, the tested universal adhesives produce a stable bond strength and reduced nanoleakage after six months of water storage.<sup>40</sup> Furthermore, the bond effectiveness of universal adhesive on dentin revealed to be not affected by dentin surface condition (wet or dry) when applied in etch-and-rinse<sup>41</sup> and self-etch mode.<sup>42</sup>

Wagner et al. evaluated the dentin bond strength of three universal adhesives applied in self-etch mode and etch-and-rinse mode. The results revealed that the application of the etching step before the tested universal adhesives improved the adhesive penetration pattern significantly, but did not influence the bond strength to dentin.<sup>43</sup>

Additionally, most universal adhesives incorporate methacryloyloxydecyl dihydrogen phosphate (10-MDP) that chemically bonds with calcium ions of the hydroxyapatite and form stable MDP-calcium salts. The MDP-calcium salts assemble and produce a nano-layered structure at the interface with dentin. Therefore, the universal adhesives not only bond micromechanically, but also chemically to the tooth substrate which subsequently contributes to bond durability.<sup>44,45</sup> Furthermore, some universal adhesives incorporate silane components to prime glass ceramic restorations, and therefore eliminate the need to use separate silanization products.<sup>46</sup>

### **1.3 Test Methodologies to Assess Bond Strength**

The most common method to evaluate the bond performance is measuring the bond strength by either shear bond strength or tensile bond strength tests. However, the shear bond strength test is more accurate and permits efficient testing of adhesive systems.<sup>47</sup> A significant advantage of the shear bond strength test is that the specimen is pre-stressed before testing only by mold removal, while the tensile bond strength test specimen is pre-stressed many times due to specimen sectioning, trimming and shaping that is required for the specimen preparation process.<sup>48</sup>

### **1.4 Operator's Variability**

Studies revealed that operators' variability and experience affect the bond strength of the adhesives to tooth substrate. The variation in operators' performance attributed to how the operators apply the dental adhesives as well as understanding the definitions of different dentin surface conditions (wet, moist and dry).<sup>49-52</sup> Söderholm et al. evaluated the effect of operators' experience on the bond strength of etch-and-rinse adhesive and self-etch adhesive systems, and found that the performance of the experienced operators were better than inexperienced operators.<sup>51</sup> Ünlü et al. reported similar results as higher shear bond strength values were associated with an increased level of operators' experience.<sup>49</sup> Previous studies evaluated the performance of etch-and-rinse and self-etch adhesives when applied by various operators. However, no studies in the current literature reported the effect of operators' variability on dentin bond strength with universal adhesives.

## **1.5 Innovation**

There are no published studies in the literature evaluating the reliability of the universal adhesives in comparison to the three-step etch-and-rinse adhesives. This study evaluated the reliability of the performance of a universal adhesive as a function of consistency of the shear bond strength values, when applied on different dentin surface conditions (wet, dry and moist), and when applied by various operators.

Previous studies evaluated the performance of etch-and-rinse and self-etch adhesives when applied by various operators. However, no studies in the current literature reported the effect of operators' variability on dentin bond strength with universal adhesives. Results of this study provided a better understanding of whether or not universal adhesives are performing reliably under various circumstances, as claimed by the manufacturer. Accordingly, if bond strength of universal adhesives found to be as successful as the current conventional etch-and-rinse adhesives (gold standard), this may improve the efficiency of the daily clinical practice by shortening the process of conditioning the tooth surface, and making the process more predictable and less susceptible to operator error.

## **1.6 Purpose of the Study**

The purpose of this study was to test the reliability of the performance of universal adhesives in comparison to three-step etch-and-rinse adhesives on various dentin surface conditions, as a function of shear bond strength. Failure mode of the fractured specimens were also determined under Scanning Electron Microscopy (SEM).

## **1.7 Specific Aims and Hypotheses:**

### **1.7.1 The Aim:**

The main objective of the study was to evaluate the reliable performance of the universal adhesive in comparison to the three-step etch-and-rinse adhesives as a function of shear bond strength.

### **1.7.2 Hypotheses:**

- 1- Evaluate the reliability of universal adhesives in terms of consistent shear bond strength values, when applied by various operators compared to the etch-and-rinse adhesives as a function of shear bond strength.
- 2- Evaluate if the operators' experience plays a role in the predictable bond success of these adhesive systems as a function of shear bond strength.
- 3- Evaluate if the condition of the dentin surface (wet, dry and moist) will affect the bond strength of the composite for these adhesive systems as a function of shear bond strength.

### **1.7.3 Null Hypothesis:**

- 1- There is no difference in the dentin bond strength of the universal adhesives in comparison to the three-step etch-and-rinse adhesives when applied by various operators.
- 2- The operators' experience and technique demonstration will not affect the dentin bond strength of the universal adhesives in comparison to the three-step etch-and-rinse adhesives.
- 3- There is no difference in the dentin bond strength of the universal adhesives in comparison to the three-step etch-and-rinse adhesives applied on different dentin conditions.



### **1.8 Location of the Study:**

Design, preparation, data collection, and analyses for this study took place at:

Bioscience Research Center, Room 7356

Nova Southeastern University

Health Professional Division

College of Dental Medicine

3200 South University Drive

Fort Lauderdale, Florida 33328-201

## **Chapter 2: Materials and Methods**

### **2.1 Sample Size Calculation**

Based on sample size calculation, given a power of 80%, effect size of 0.80, an alpha of 0.05 and an additional 5% more in the sample number to account for potential loss of specimens, it was determined that the total sample number will be  $n=600$  with  $n=5$  for each study sub-group.

### **2.2 Study Groups and Sample Preparation**

All resin composite placement procedures and the dentin surface conditioning process were performed by a single operator (Dr. Marwa Bawazir) in order to standardize these procedures for standardization and calibration purposes. In this study the independent and dependent variables are described below:

**\* Independent variables:**

A- Adhesive systems (Adhese Universal [Ivoclar Vivadent Amherst, NY, USA], OptiBond FL [Kerr Sybron, Orange, CA, USA]).

B- Dentin surface conditions. (Wet, Moist, Dry).

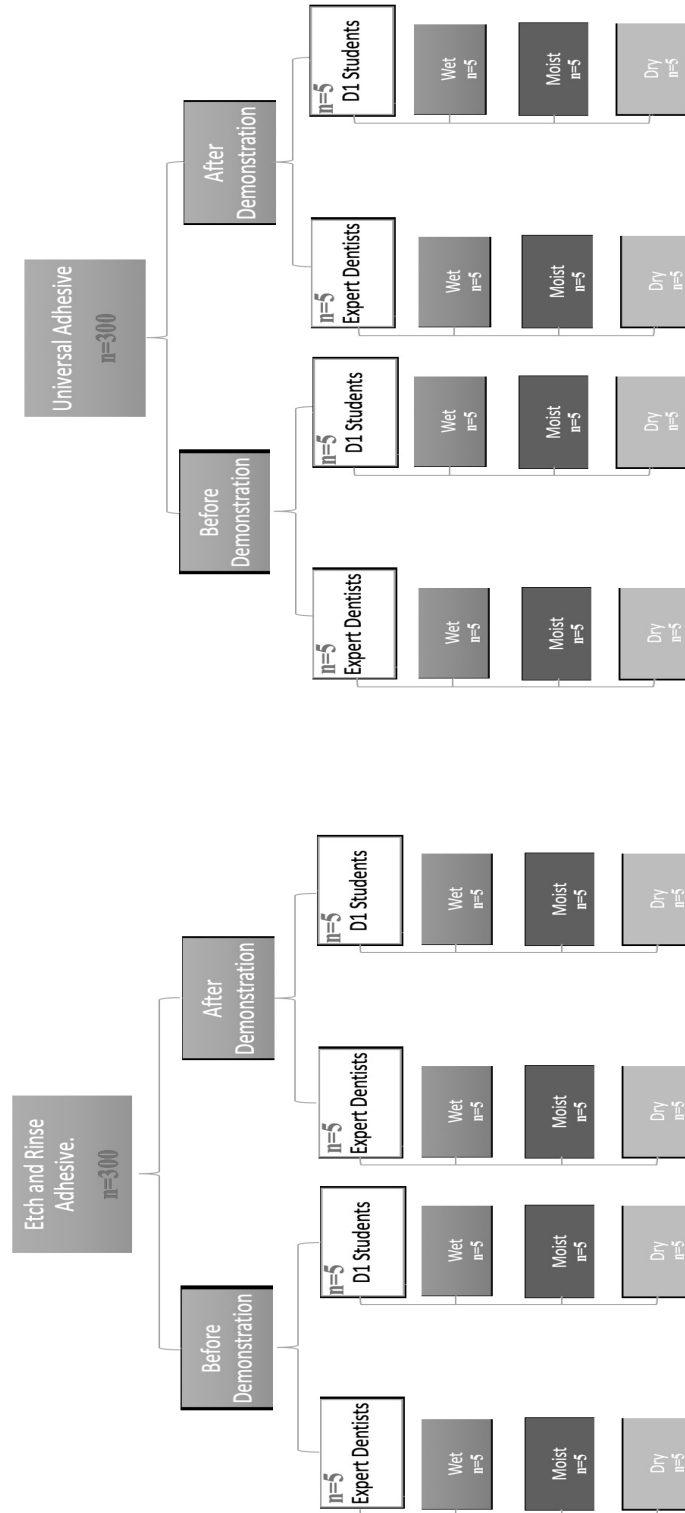
C- Operators (Expert dentist, Student).

D- Technique demonstration (Application before the technique demonstration, Application after the thechnique demonstration)

**\* Dependent variable:** Bond strength of resin composite to dentin.

## Study Groups:

**Flow Chart 1:** Study groups distribution



**Table of the Study Groups Distribution:**

<b>Group Number</b>	<b>Material</b>	<b>Operators</b>	<b>Dentin surface condition</b>
1	Universal Adhesive	Five D1 Students before Demonstration	Wet (n=5)
2	Universal Adhesive	Five D1 Students before Demonstration	Moist (n=5)
3	Universal Adhesive	Five D1 Students before Demonstration	Dry (n=5)
4	Universal Adhesive	Five Expert Dentists before Demonstration	Wet (n=5)
5	Universal Adhesive	Five Expert Dentists before Demonstration	Moist (n=5)
6	Universal Adhesive	Five Expert Dentists before Demonstration	Dry (n=5)
7	Universal Adhesive	Five D1 Students after Demonstration	Wet (n=5)
8	Universal Adhesive	Five D1 Students after Demonstration	Moist (n=5)
9	Universal Adhesive	Five D1 Students after Demonstration	Dry (n=5)
10	Universal Adhesive	Five Expert Dentists after Demonstration	Wet (n=5)
11	Universal Adhesive	Five Expert Dentists after Demonstration	Moist (n=5)
12	Universal Adhesive	Five Expert Dentists after Demonstration	Dry (n=5)
13	Etch-and-Rinse Adhesive.	Five D1 Students before Demonstration	Wet (n=5)
14	Etch-and-Rinse Adhesive.	Five D1 Students before Demonstration	Moist (n=5)
15	Etch-and-Rinse Adhesive.	Five D1 Students before Demonstration	Dry (n=5)

16	Etch-and-Rinse Adhesive.	Five Expert Dentists before Demonstration	Wet (n=5)
17	Etch-and-Rinse Adhesive.	Five Expert Dentists before Demonstration	Moist (n=5)
18	Etch-and-Rinse Adhesive.	Five Expert Dentists before Demonstration	Dry (n=5)
19	Etch-and-Rinse Adhesive.	Five D1 Students after Demonstration	Wet (n=5)
20	Etch-and-Rinse Adhesive.	Five D1 Students after Demonstration	Moist (n=5)
21	Etch-and-Rinse Adhesive.	Five D1 Students after Demonstration	Dry (n=5)
22	Etch-and-Rinse Adhesive.	Five Expert Dentists after Demonstration	Wet (n=5)
23	Etch-and-Rinse Adhesive.	Five Expert Dentists after Demonstration	Moist (n=5)
24	Etch-and-Rinse Adhesive.	Five Expert Dentists after Demonstration	Dry (n=5)

- Predoctoral D1 dental students: They were randomly selected assuring that they do not have any prior dental experience and are willing to participate in the research project.
- Expert dentists: They were randomly selected dentists with more than ten years of clinical experience, and not having any specialty training.

## **2.3 Specimen Preparation:**

### **2.3.1 Tooth Specimen Preparation for Bonding:**

#### **2.3.1.1 Teeth Sectioning:**

Three hundred non-carious unidentified human teeth were collected from the Periodontology and Oral Maxillo-Facial Surgery Departments at Nova Southeastern

University upon IRB approval (IRB #: 2018-428). The teeth were used to obtain dentin substrates for bonding. They were properly cleaned and stored in an aqueous disinfectant solution (Chloramine T, 0.5 wt% at 4 C°) until ready to be used.<sup>30</sup> A slow-speed saw (Buehler Isomet LS Precision Saw, Lake Bluff, IL, USA) with a diamond disk (IsoMet Blade, 15HC, 4in) under water cooling was used to separate the crowns from the roots at the cemento-enamel junction (CEJ) level. The blade was dressed before cutting the teeth to ensure clean, smooth sectioning. From each crown of the posterior teeth, two sections were obtained by making one longitudinal section along the middle of the crown buccolingually. (Figure 1-A and B).

#### **2.3.1.2 Embedding the Teeth:**

The sectioned specimens were embedded in a chemically-polymerized methacrylate (Acratray, Autopolymerizable Custom Tray Material, Henry Schein, FL, USA) using the Ultradent mold (Ultradent, South Jordan, UT, USA) with the dentin surface exposed to fabricate identical cylindrical specimens (Figure 2).

#### **2.3.1.3 Trimming the Specimens:**

Ultradent grinding plate and the grinding mandrel (Ultradent, South Jordan, UT, USA) were stabilized by screw and screw nuts on the trimmer. A level was used to ensure the position and level of the grinding plate (90°) and the precise position of the grinding mandrel. The specimens were rotated clockwise and counter-clockwise using the grinding mandrel during the trimming process. Samples were ground flat to expose the uncontaminated dentin surface. (Figure 3).

For the anterior teeth, the crowns were embedded in the chemically-polymerized

methacrylate (Acratray, Autopolymerizable Costom Tray Material, Henry Schein, FL, USA), then the specimens were ground flat with the model trimmer to expose the facial dentin surface.

Prepared specimens were examined for the presence of caries and cracks under the optical microscope (SZX7, Olympus, Tokyo, Japan). Specimens that showed evidence of caries and cracks were excluded from the study (Figure 4).

#### **2.3.1.4 Finishing Specimens Surfaces:**

Specimen surfaces were slightly refinished with 400 grit size SiC abrasive paper followed by 600 grit size SiC abrasive paper in order to expose fresh dentin using Metaserv 2000 Variable Speed Grinder-Polisher (Lake Bluff, IL, USA) on the speed of 500 rpm. (Figure 5).

#### **2.3.1.5 Ultrasonic Cleaning and Storage:**

Specimens were placed in a container filled with distilled water in the ultrasonic tank and ultrasonically cleaned for 10 min. Then, they were stored immersed in distilled water (100% humidity) in a 37°C incubator for 24 h.

Specimens (n=600) were randomly divided into the study groups with a sample size of five in each sub-group according to the type of adhesive system applied, the operators placing the adhesives and the type of the dentin surface conditions (Flow charts 1 and 2).

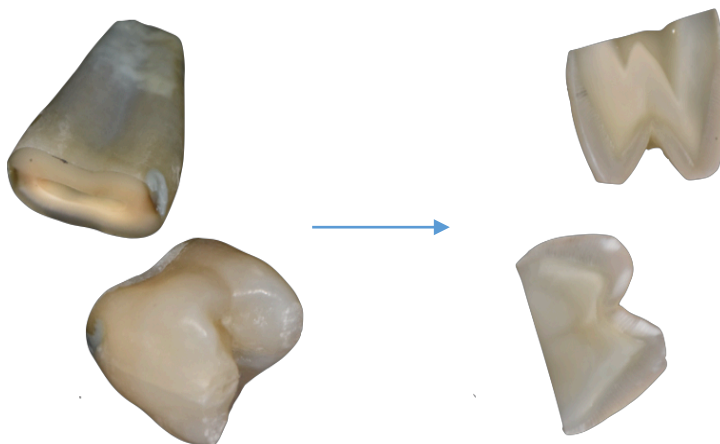
**Figure 1:**

**A- Buehler Isomet LS Precision Saw, Lake bluff, IL, USA**

Specimens were sectioned into 2 longitudinal sections.



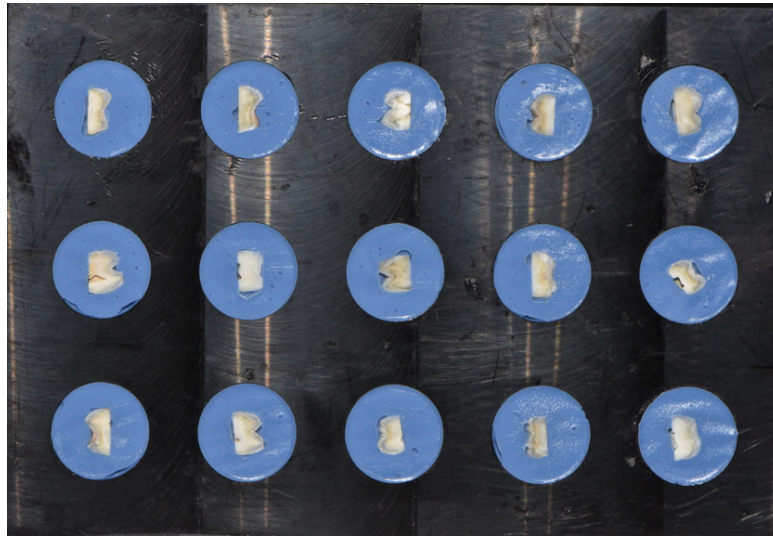
**B- Sectioned tooth into at CEJ then into 2 longitudinal section**





**Figure 2: Ultradent Mold, South Jordan, UT, USA**

Specimens were embedded in the mold



**Figure 3: Ultradent Grinding Plate and Mandrel, South Jordan, UT, USA**

Specimens were grind flat to expose uncontaminated dentinal surface



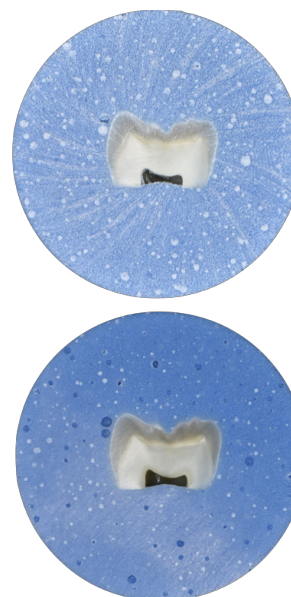
**Figure 4: The Optical Microscope SZX7, Olympus, Tokyo, Japan**

Specimens were examined for caries and cracks.



**Figure 5: Metaserv 2000 Variable Speed Grinder-Polisher, Lake bluff, IL, USA**

Specimens were finished with 400 followed by 600-grit SiC paper.



## **2.4 Bonding Procedures:**

- **Dentin surface conditions without demonstration or showing manufacturers' instructions:**

Five first-year predoctoral dental students (D1), and five expert dentists with more than ten years of clinical experience currently working at Nova Southeastern University started applying the universal adhesive (Adhese Universal, Ivoclar Vivadent, Amherst, NY, USA) and etch-and-rinse adhesive (OptiBond FL, Kerr Sybron, Orange, CA, USA) systems on the specimens after brief directions on the application technique. The operators were asked to apply each of the adhesive systems on three dentin surface conditions (wet, dry and moist) without any further explanation. The calibrated clinician controlled the surface conditioning process, observed, recorded, and took notes on the application technique and timing using a check sheet (See Appendix 1).

- **Dentin surface conditions with demonstration and showing manufacturers' instructions:**

Detailed procedure explanations with demonstrations of the bonding technique for each adhesive system, and the process to achieve each dentin surface condition were provided to the same set of operators after they complete bonding without detailed directions. Manufacturers' instructions were followed. Operators were asked to apply each of the adhesive systems on all three dentin surface conditions (wet, dry and moist). The same calibrated clinician controlled the surface conditioning process, observed, recorded, and took notes on the application technique and timing using a check sheet (See Appendix 1).

- **Manufacturers' instructions for adhesive systems' application techniques:**

Adhese Universal (universal adhesive)	OptiBond FL (etch-and-rinse adhesive)
<ol style="list-style-type: none"> <li>1- <u>Achieving dentin surface conditions (wet, dry and moist):</u> <ol style="list-style-type: none"> <li>1- <u>Wet</u>: One dab with the Kimwipe.</li> <li>2- <u>Moist</u>: Three dabs with the Kimwipe.</li> <li>3- <u>Dry</u>: Three dabs with the Kimwipe followed by 15s air drying.</li> </ol> </li> <li>2. The adhesive was applied to the entire tooth structure and rubbed in for 20 sec.</li> <li>3. The applicator was re-wetted during treatment. Subsequently, a gentle stream of air applied over the liquid until it no longer moved, and the solvent has evaporated completely.</li> <li>4. The adhesive was light-cured for 10 sec using a light emitting diode (LED) curing light with the light intensity of 1,200 mW/cm<sup>2</sup>.</li> </ol>	<ol style="list-style-type: none"> <li>1. The tooth surface was air dried for 10s.</li> <li>2. 37.5% phosphoric acid was applied on dentin for 15 seconds. Rinsed with water for 10s until etchant has been completely removed.</li> <li>3. <u>Achieving dentin surface conditions (wet, dry and moist):</u> <ol style="list-style-type: none"> <li>a. <u>Wet</u>: One dab with the Kimwipe.</li> <li>b. <u>Moist</u>: Three dabs with the Kimwipe.</li> <li>c. <u>Dry</u>: Three dabs with the Kimwipe followed by 15s air drying.</li> </ol> </li> <li>4. The disposable applicator tip was placed into the Prime dispensed into the dappen dish, then was applied on prepared dentin surface with a light scrubbing motion for 15 seconds. The applicator tip was re-wetted with primer. Then, a gentle stream of air applied over the liquid until it no longer moved.</li> <li>5. Another applicator tip was placed into the Adhesive dispensed into the dappen dish. The adhesive was applied to the prepared dentin surfaces with a light scrubbing motion for 15 seconds. A light application of air applied to thin the bonding agent.</li> <li>6. The adhesive was light cured for 10 sec using a light emitting diode (LED) curing light in regular mode with the light intensity of 1,200 mW/cm<sup>2</sup>.</li> </ol>

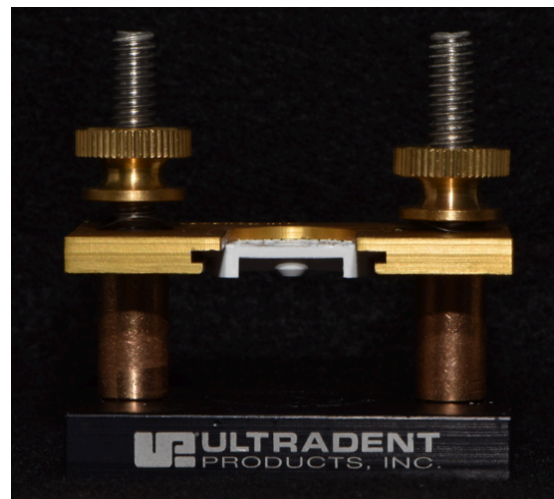
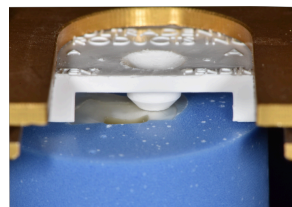
After the adhesive application process, samples were kept in the dark containers in a humid environment until ready for the composite application, immediately following each operator's bonding process.

## **2.5 Resin Composite Application:**

Specimens were placed on a custom fabricated shear bond jig (Ultradent, South Jordan, UT, USA) by the calibrated operator (Figure 6). The Teflon mold was filled with resin composite (Tetric EvoCeram Bulk Fill, Shade IVA, Ivoclar Vivadent, Amherst, NY, USA) in a single increment, no greater than 2 mm, and polymerized for 20 s using a light emitting diode (LED) curing light with the intensity of  $1,200 \text{ mW/cm}^2$ , and a wavelength of 385-515 nm (Bluephase G2, Ivoclar Vivadent, Amherst, NY). The light cure intensity was monitored between samples (with an interval of 10 samples) to maintain the intensity of  $1,200 \text{ mW/cm}^2$  using a radiometer (Bluephase Meter II, Ivoclar Vivadent, Amherst, NY, USA). Immediately after bonding, specimens were stored immersed in distilled water for 24 hours at  $37^\circ\text{C}$  in 100% humidity.

**Figure 6: Ultradent Bonding Clamp and Bonding Mold, South Jordan, UT, USA**

The bonding clamp stabilizes the teeth during the bonding procedure.





## 2.6 Shear Bond Strength (SBS) Testing and Statistical Analysis:

Shear bond strength was determined using a universal testing machine (Instron, Canton, MA, USA) at a cross-head speed of 1 mm/min with a load cell of 1,000 lbs (Figure 7). Specimens were stabilized in an Ultradent testing jig, which is free to move to facilitate positioning under the loading blade (Figure 8). The test base was then positioned so that the notched cross-head was placed precisely against the specimen's bonded surface. The load required to de-bond the specimen was recorded and expressed in megapascals (MPa) by dividing the load by the surface area of the bonded specimen. The mean SBS values per study group were calculated.<sup>53</sup>

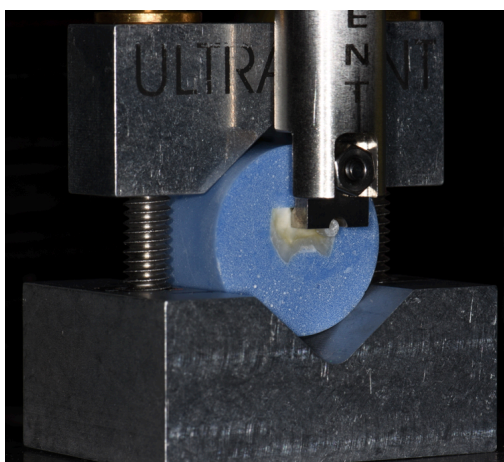
**Figure 7: Ultradent Test Base Clamp, South Jordan, UT, USA**

The test base clamp holds the prepared specimen in place on the Instron universal testing machine during the bond strength testing.



**Figure 8: Instron Universal Testing Machine, Canton, MA, USA**

For measuring the shear bond strength



## 2.7 Failure Analysis:

The interface between the dentin surface and composite was analyzed after the SBS test to determine the pattern of bond failure using optical and scanning electron microscope (SEM) (Figure 9). SEM was used to identify the interfaces between the tooth/bonding and bonding/composite. The energy dispersive spectroscopy (EDS) technology in SEM was utilized to identify the specific elements in order to confirm the failure mode. Failures were classified either as an adhesive failure between the dentin surface/the adhesive layer, or cohesive failure in the resin composite, adhesive or dentin, or mixed failures.

**Figure 9: FEI Quanta 200 Scanning Electron Microscopy, Hillsboro, OR, USA**

To assess surface topography and failure pattern.





## **2.8 Statistical Analysis:**

A three-way analysis of variance (ANOVA) was used to evaluate the effect of material, operator experience, and dentin surface condition on shear bond strength. Pairwise multiple comparison procedures (Tukey test) was used to identify these differences among the individual groups. A significance level of 0.05 was used for all tests.

### **Inclusion criteria:**

- Sound human teeth were collected from Periodontology and Oral Maxillo-Facial Surgery Departments at Nova Southeastern University upon IRB approval.

### **Exclusion criteria:**

- Defective or carious human teeth.
- Materials with flaws or failures.

## Chapter 3: Results

### 3.1 Shear Bond Strength Test:

A random effect, general linear model, was conducted to look at differences in bond strength (MPa). The fixed effects were adhesive systems (etch-and- rinse adhesive vs universal adhesive), dentin surface conditions (wet vs moist vs dry), operators (expert dentist vs student), and technique demonstration (application before the demonstration vs application after the application demonstration). The random effect was dentin specimens. Also, the interaction effect among the independent variables was examined. Results show that 14% of the variance in bond strength was accounted for by the variation subject (operator error). Using a log-worth test, it was found that adhesive was the most critical factor in determining bond strength, followed by surface condition and participant ( $p < 0.05$ ) (Table 1).

Descriptive statistics and pairwise comparisons using a Tukey HSD adjustment were calculated. A significant difference in dentin bond strength by adhesive was found with universal adhesive possessed  $7.38 \pm 0.73$  greater dentin bond strength (MPa) than etch-and-rinse adhesive, regardless to the other variables. As the average bond strength of universal adhesive was 25.18 MPa, while 17.8 MPa was the average bond strength of etch-and-rinse adhesive. Universal adhesive also obtained more consistent results compared to etch-and-rinse adhesive (Figure 10). Moreover, a significant difference in dentin bond strength by the operator was observed with expert dentists possessed  $1.65 \pm 0.73$  greater dentin bond strength (MPa) than students. However, there was no significant difference in dentin bond strength by demonstration (Figure 11). Regarding the surface condition effect

on the bond strength, a significant difference in dentin bond strength by surface condition was identified as follows: dry surface conditions possessed 3.79 +/- 1.01 greater dentin bond strength (MPa) than wet surface conditions. Moist surface conditions possessed 2.67 +/- 1.05 greater dentin bond strength (MPa) than wet surface conditions. On the other hand, no significant difference in bond strength was observed between dry and moist groups. (Table 3)

Precisely, no significant difference in the bond strength between the different surface conditions and multiple operators were found with the universal adhesive. On the other hand, there is a significant difference in the bond strength between groups when etch-and-rinse adhesive was used. (Figure 12 and 13). The expert dentists performed better than students with etch-and-rinse adhesive. Furthermore, etch-and-rinse adhesive obtained high bond strength values with moist and dry surface compared to the wet surface condition. (Table 2)

It was also found that within the students' group, significant differences in the bond strength was observed when etch-and-rinse adhesive was applied on dry surface condition in comparison to the wet surface condition ( $p < 0.05$ ). Such a difference was not observed within the dentists' group.

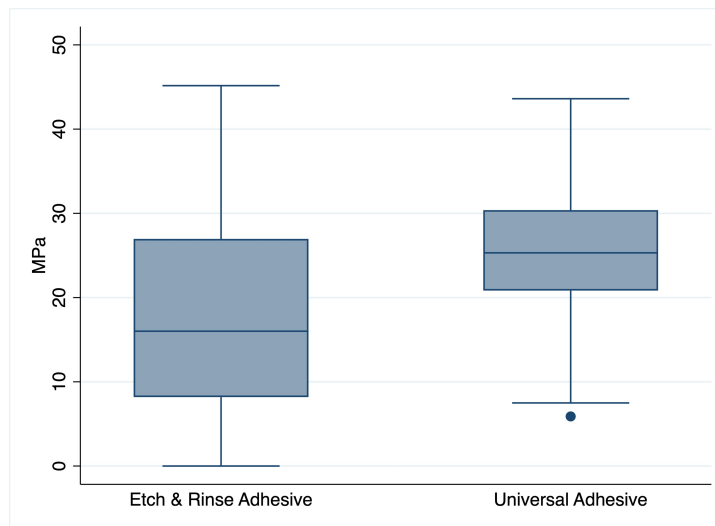
Descriptive statistics were also calculated for failure mode by adhesive systems (etch-and-rinse adhesive vs. universal adhesive), dentin surface conditions (wet vs. moist vs. dry), operators (expert dentist vs student), and technique demonstration (application before the demonstration vs. application after the application demonstration). (Table 4). Most common failure mode with etch-and-rinse adhesive was an adhesive failure (30%) followed by cohesive failure in composite (27%), cohesive failure in bonding agent (24%).

With the universal adhesive the most common type of failure was cohesive failure in composite (47%) followed by mixed cohesive failure (28,7%). The least type of failure in the universal adhesive group was an adhesive failure (6%). The adhesive failure was commonly associated with the wet surface condition for both etch-and-rinse and universal adhesives.

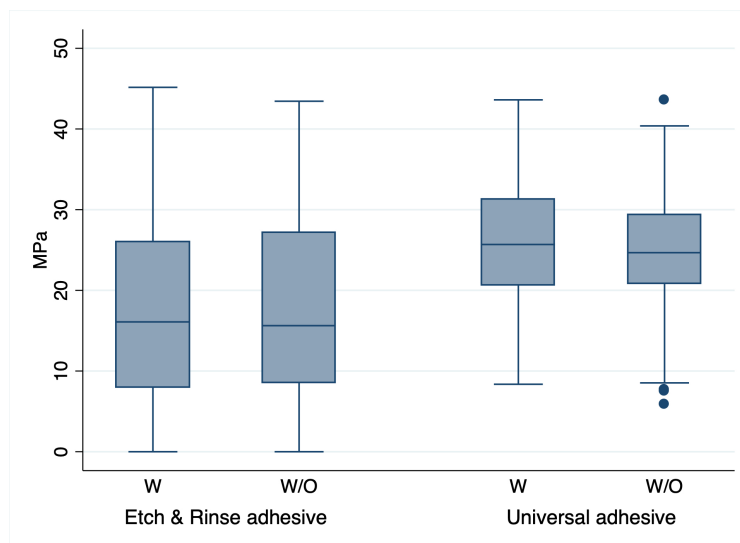
### **3.2 Scanning Electron Microscope (SEM) and Elemental Analysis of the Sample (EDS):**

Representative SEM images of the resin-dentin interfaces for all failure modes were illustrated in Figures 14-18. The EDS elemental mapping for automatic identification of items highlighted calcium (C) and phosphate (P) on the resin/dentin interface of adhesive failure with no presence of silica (Si), aluminum (Al) or ytterbium (Yb). On the contrary, elemental mapping revealed a high concentration of Si and Al on the resin/dentin interface of cohesive failure in composite. The mixed failure specimens displayed a distinct area of concentrated calcium (C) and phosphate (P) that characterize the exposed tooth structure, and an area of focused silica (Si), aluminum (Al) that represent the remnant of resin composite. Elemental mapping was unable to detect ytterbium in resin composite as it was below the detection level in all tested specimens. EDS results of the specimens are detailed below (Figure 19-23).

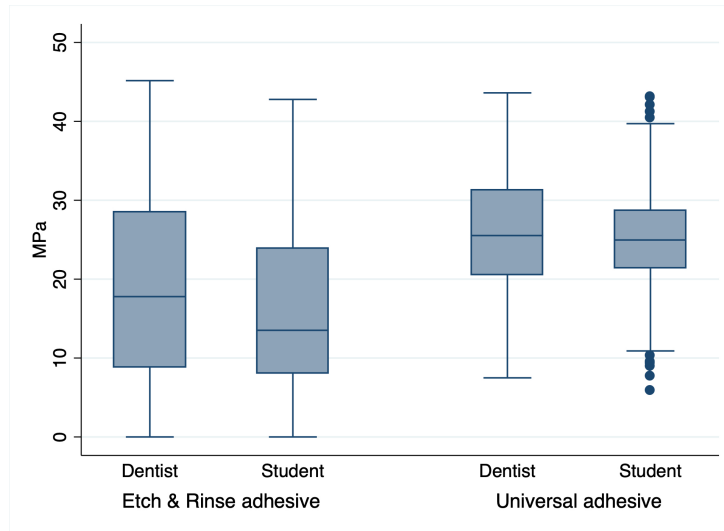
**Figure 10: Box-Plot graph of adhesives showing cumulative shear bond strength results**



**Figure 11: Box-Plot graph of adhesives showing shear bond strength results by demonstration**



**Figure 12: Box-Plot graph of adhesives showing cumulative shear bond strength results  
by operators**



**Figure 13: Box-Plot graph of adhesives showing cumulative shear bond strength results  
by surface condition.**

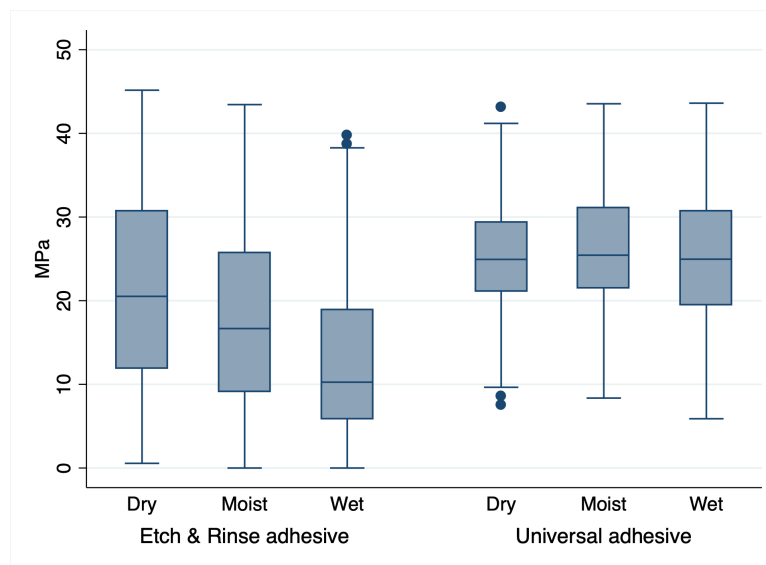


Table 1. Log Worth Test.

Source	Log Worth	P Value
Adhesive	19.96	0.000
Adhesive*Demonstration*Participant	4.24	0.000
Condition	3.73	0.000
Adhesive*Condition	3.58	0.000
Participant	1.52	0.030
Adhesive*Participant	1.09	0.082
Adhesive*Participant*Condition	0.64	0.228
Demonstration*Participant*Condition	0.47	0.339
Adhesive*Demonstration	0.33	0.467
Participant*Condition	0.19	0.654
Demonstration*Participant	0.15	0.716
Demonstration*Condition	0.11	0.770
Adhesive*Demonstration*Participant*Condition	0.09	0.805
Demonstration	0.09	0.812
Adhesive*Demonstration*Condition	0.02	0.949

Table 2. Descriptive Statistics

<b>Adhesive</b>	<b>Demonstration</b>	<b>Subject</b>	<b>Condition</b>	<b>Mean</b>	<b>SE</b>	<b>Lower 95% CI</b>	<b>Upper 95% CI</b>
Etch & Rinse adhesive	W	Dentist	Dry	23.77	1.86	20.10	27.43
Etch & Rinse adhesive	W	Dentist	Moist	22.21	1.86	18.55	25.87
Etch & Rinse adhesive	W	Dentist	Wet	16.38	1.86	12.72	20.05
Etch & Rinse adhesive	W	Student	Dry	18.05	1.86	14.39	21.71
Etch & Rinse adhesive	W	Student	Moist	14.70	1.86	11.04	18.36
Etch & Rinse adhesive	W	Student	Wet	10.58	1.86	6.92	14.24
Etch & Rinse adhesive	W/O	Dentist	Dry	19.71	1.86	16.05	23.37
Etch & Rinse adhesive	W/O	Dentist	Moist	19.17	1.86	15.51	22.83
Etch & Rinse adhesive	W/O	Dentist	Wet	14.50	1.86	10.84	18.17
Etch & Rinse adhesive	W/O	Student	Dry	24.14	1.86	20.48	27.80
Etch & Rinse adhesive	W/O	Student	Moist	16.56	1.86	12.89	20.22
Etch & Rinse adhesive	W/O	Student	Wet	13.84	1.86	10.18	17.50
Universal adhesive	W	Dentist	Dry	24.37	1.86	20.70	28.03
Universal adhesive	W	Dentist	Moist	23.59	1.86	19.92	27.25
Universal adhesive	W	Dentist	Wet	24.97	1.86	21.31	28.63
Universal adhesive	W	Student	Dry	25.34	1.86	21.67	29.00
Universal adhesive	W	Student	Moist	29.26	1.86	25.60	32.92
Universal adhesive	W	Student	Wet	25.77	1.86	22.11	29.43
Universal adhesive	W/O	Dentist	Dry	26.02	1.86	22.36	29.68
Universal adhesive	W/O	Dentist	Moist	27.01	1.86	23.35	30.67
Universal adhesive	W/O	Dentist	Wet	26.11	1.86	22.45	29.77
Universal adhesive	W/O	Student	Dry	23.61	1.86	19.95	27.28
Universal adhesive	W/O	Student	Moist	23.59	1.86	19.93	27.25
Universal adhesive	W/O	Student	Wet	22.53	1.86	18.87	26.19



Table 3. Model Effects

Source	DF	Sum of Squares	F Ratio	Prob > F
Adhesive	1	8169.14	93.99	<.0001
Demonstration	1	4.92	0.06	0.812
Adhesive*Demonstration	1	46.02	0.53	0.467
Participant	1	410.34	4.72	0.030
Adhesive*Participant	1	263.78	3.04	0.082
Demonstration*Participant	1	11.50	0.13	0.716
Adhesive*Demonstration*Participant	1	1428.85	16.44	<.0001
Condition	2	1517.11	8.73	<.0001
Adhesive*Condition	2	1452.43	8.36	<.0001
Demonstration*Condition	2	45.51	0.26	0.770
Adhesive*Demonstration*Condition	2	9.19	0.05	0.949
Participant*Condition	2	73.98	0.43	0.654
Adhesive*Participant*Condition	2	257.42	1.48	0.228
Demonstration*Participant*Condition	2	188.38	1.08	0.339
Adhesive*Demonstration*Participant*Condition	2	37.62	0.22	0.806

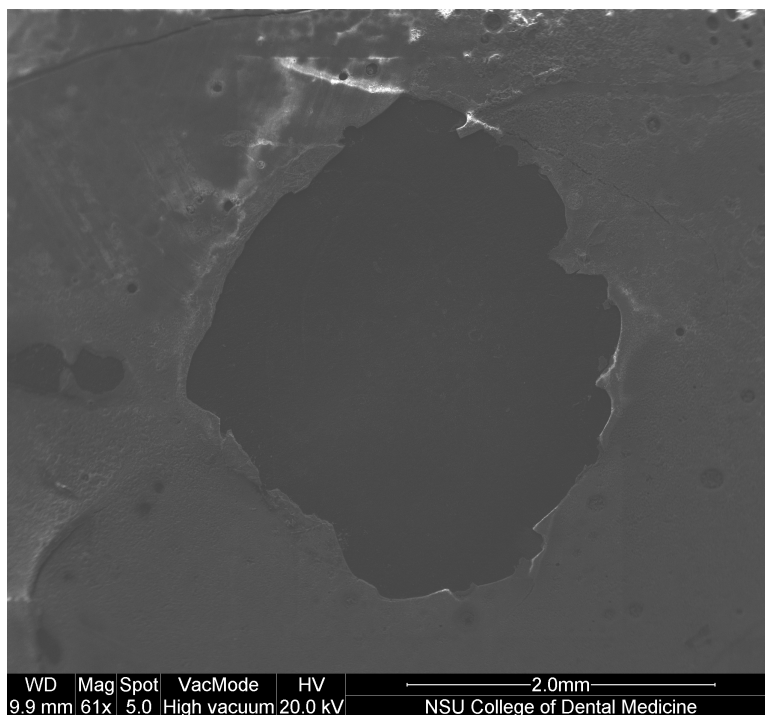
Table 3. Pairwise Comparisons by Main Effects

			Difference	SE	95% Lower CL	95% Upper CL	P-Value
Dentist	Vs.	Student	1.65	0.78	0.13	3.18	0.033
W	Vs.	W/O	0.18	0.73	-1.25	1.62	0.804
Universal adhesive	Vs.	Etch & Rinse adhesive	7.38	0.73	5.94	8.81	<.0001
Dry	Vs.	Wet	3.79	0.89	2.03	5.55	<.0001
Moist	Vs.	Wet	2.67	0.89	0.92	4.43	0.002
Dry	Vs.	Moist	1.12	0.89	-0.64	2.87	0.213

Table 4. Descriptive Statistics from Failure Mode.

		Demonstration W		Demonstration W/O		
		Etch & Rinse adhesive	Universal adhesive	Etch & Rinse adhesive	Universal adhesive	
Dentist	Dry	A	5 (5.00)	2 (2.00)	6 (6.00)	2 (2.00)
		CB	3 (3.00)	3 (3.00)	5 (5.00)	0 (0.00)
		CC	7 (7.00)	13 (13.00)	9 (9.00)	16 (16.00)
		Mix (CC,CT)	8 (8.00)	6 (6.00)	5 (5.00)	6 (6.00)
		CT	2 (2.00)	1 (1.00)	0 (0.00)	1 (1.00)
	Moist	A	6 (6.00)	2 (2.00)	6 (6.00)	0 (0.00)
		CB	4 (4.00)	5 (5.00)	6 (6.00)	1 (1.00)
		CC	6 (6.00)	11 (11.00)	7 (7.00)	13 (13.00)
		Mix (CC,CT)	9 (9.00)	6 (6.00)	4 (4.00)	11 (11.00)
		CT	0 (0.00)	1 (1.00)	2 (2.00)	0 (0.00)
	Wet	A	11 (11.00)	2 (2.00)	10 (10.00)	2 (2.00)
		CB	1 (1.00)	5 (5.00)	5 (5.00)	3 (3.00)
		CC	12 (12.00)	11 (11.00)	4 (4.00)	11 (11.00)
		Mix (CC,CT)	1 (1.00)	6 (6.00)	4 (4.00)	8 (8.00)
		CT	0 (0.00)	1 (1.00)	2 (2.00)	1 (1.00)
Student	Dry	A	8 (8.00)	(0.00)	2 (2.00)	1 (1.00)
		CB	7 (7.00)	4 (4.00)	7 (7.00)	5 (5.00)
		CC	7 (7.00)	8 (8.00)	7 (7.00)	12 (12.00)
		Mix (CC,CT)	3 (3.00)	8 (8.00)	8 (8.00)	5 (5.00)
		CT	0 (0.00)	2 (2.00)	1 (1.00)	4 (4.00)
	Moist	A	6 (6.00)	1 (1.00)	5 (5.00)	4 (4.00)
		CB	12 (12.00)	4 (4.00)	11 (11.00)	5 (5.00)
		CC	7 (7.00)	12 (12.00)	5 (5.00)	11 (11.00)
		Mix (CC,CT)	0 (0.00)	8 (8.00)	3 (3.00)	4 (4.00)
		CT	0 (0.00)	0 (0.00)	1 (1.00)	1 (1.00)
	Wet	A	12 (12.00)	1 (1.00)	13 (13.00)	2 (2.00)
		CB	8 (8.00)	1 (1.00)	3 (3.00)	4 (4.00)
		CC	4 (4.00)	16 (16.00)	6 (6.00)	7 (7.00)
		Mix (CC,CT)	0 (0.00)	6 (6.00)	3 (3.00)	12 (12.00)
		CT	1 (1.00)	1 (1.00)	0 (0.00)	0 (0.00)

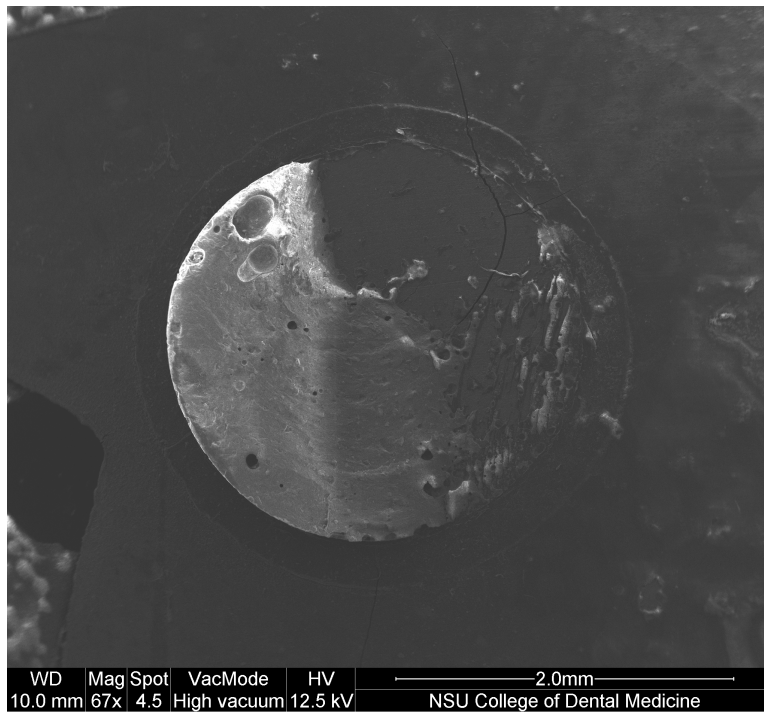
**Figure 14: Example of an adhesive failure between dentin and the bonding agent**



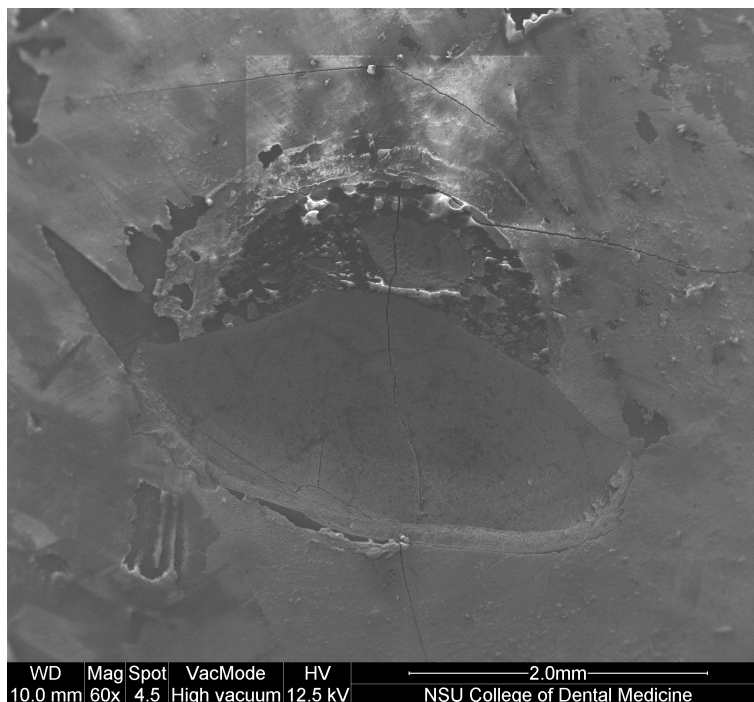
**Figure 15: Example of a cohesive failure in bonding agent**



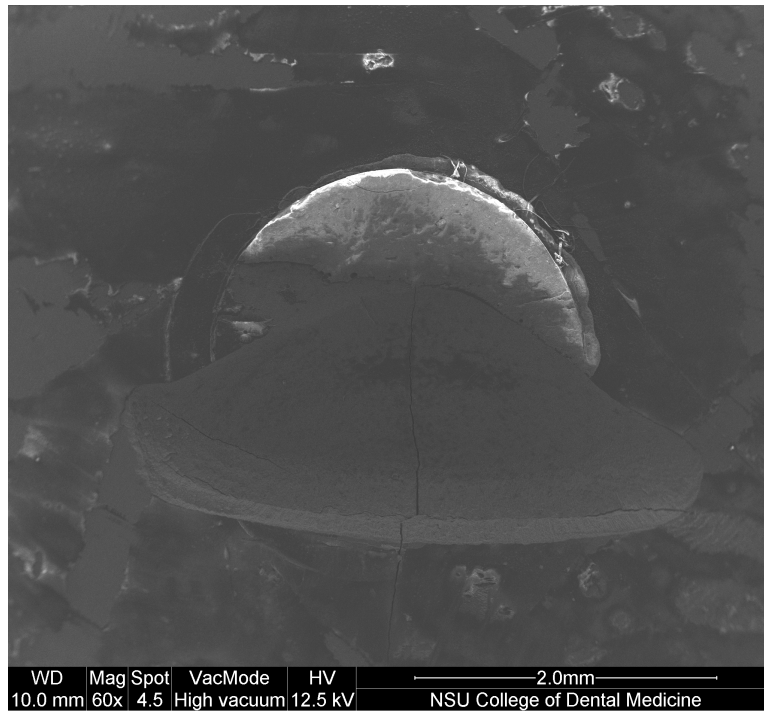
**Figure 16: Example of a cohesive failure in composite**



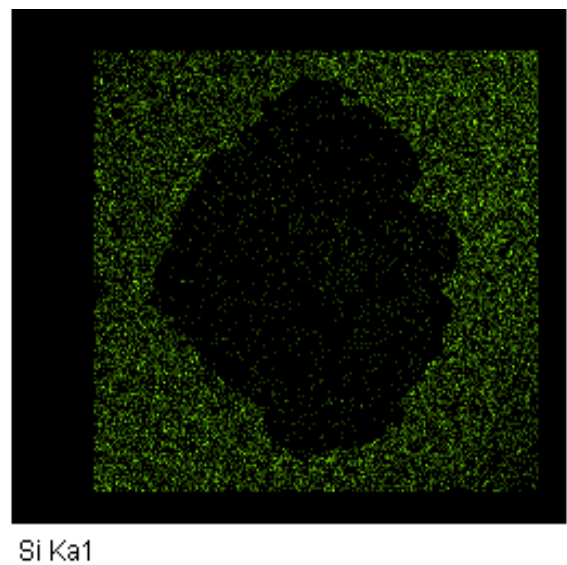
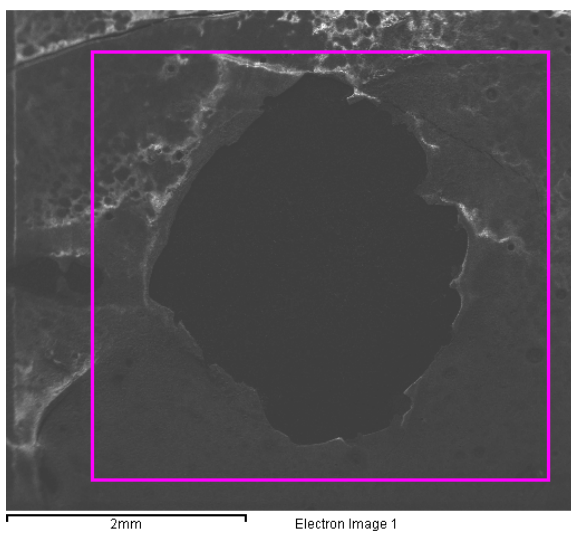
**Figure 17: Example of a cohesive failure in dentin**

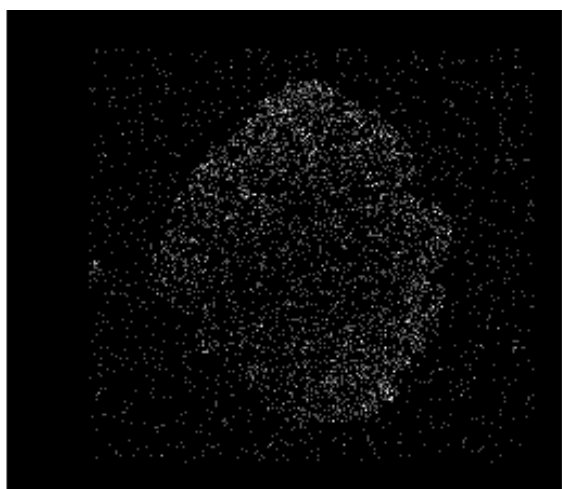


**Figure 18: Example of a mixed failure**

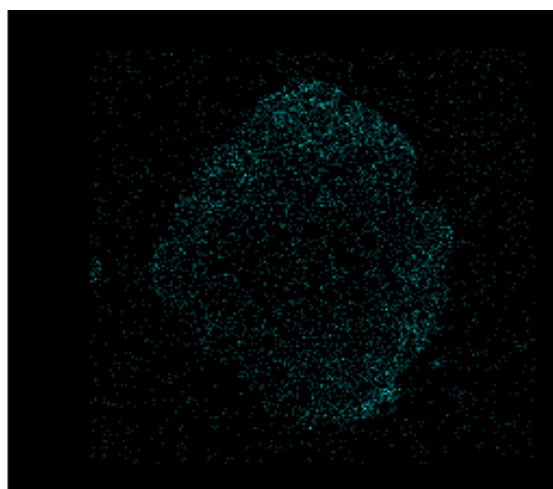


**Figure 19: EDS elemental mapping of an adhesive failure**

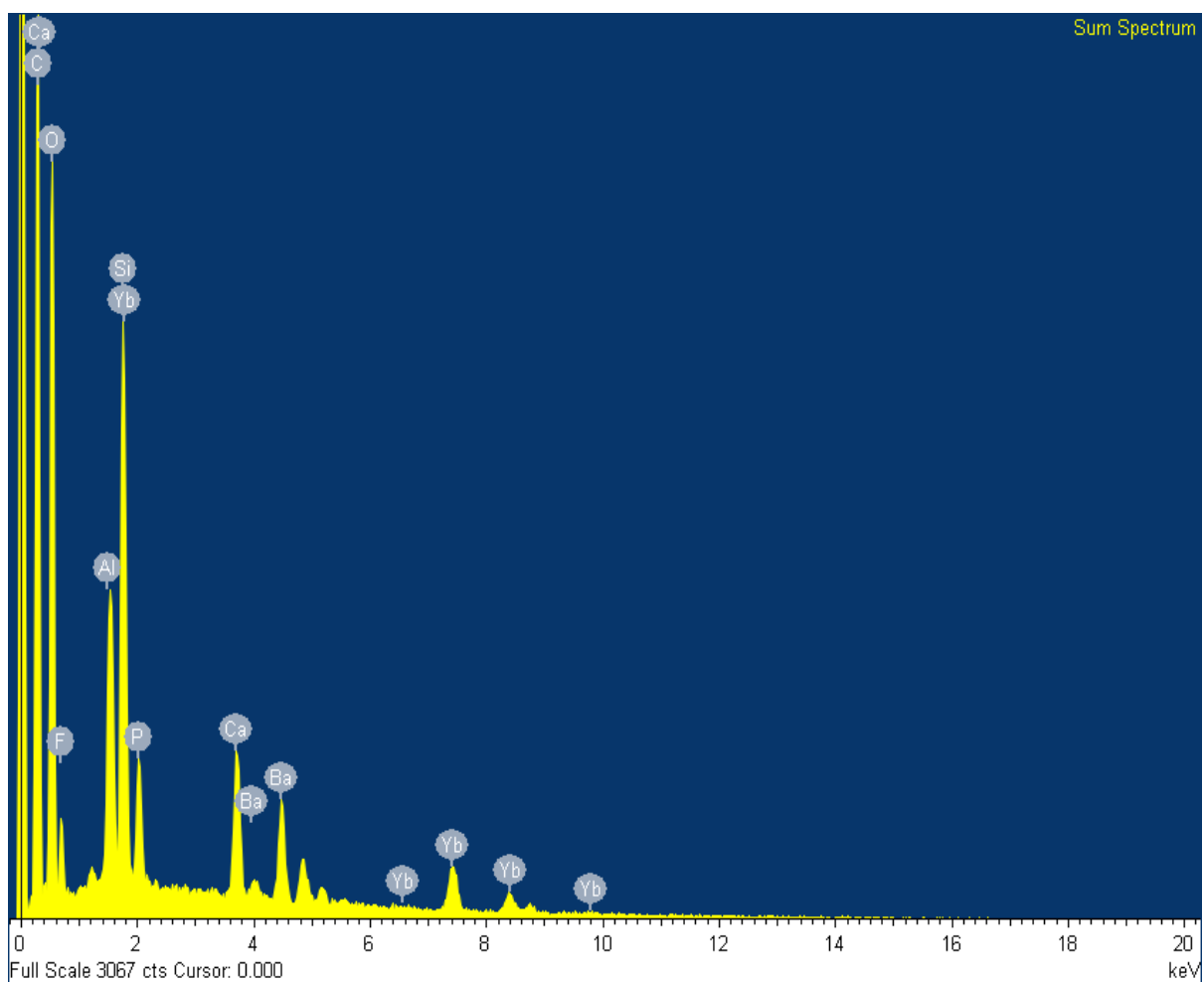




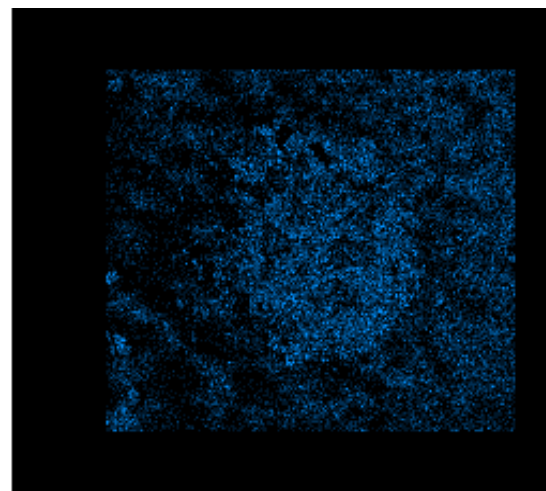
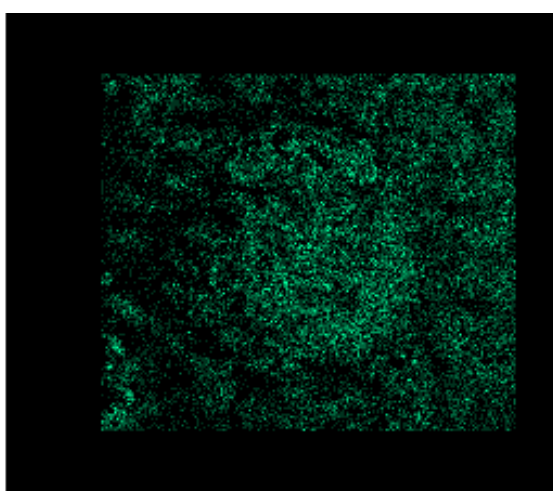
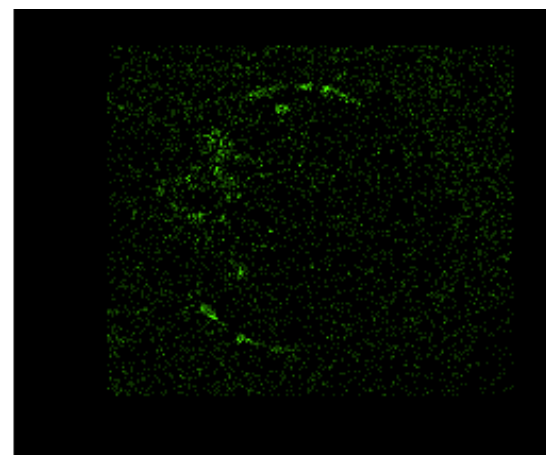
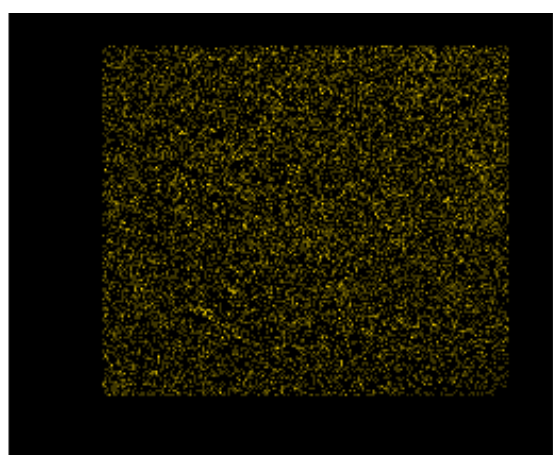
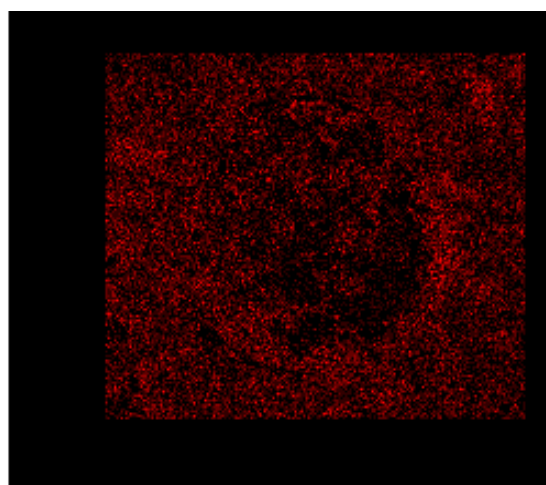
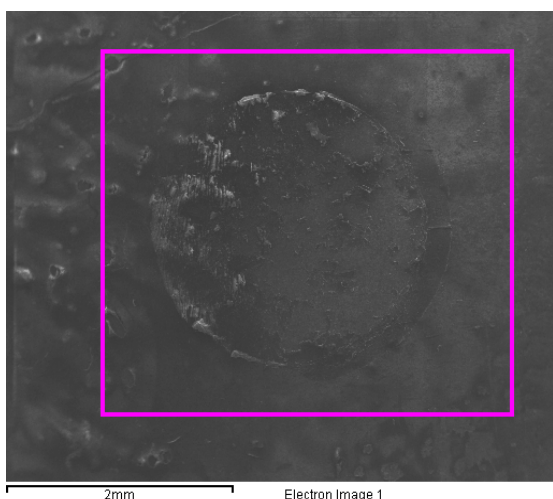
P Ka1

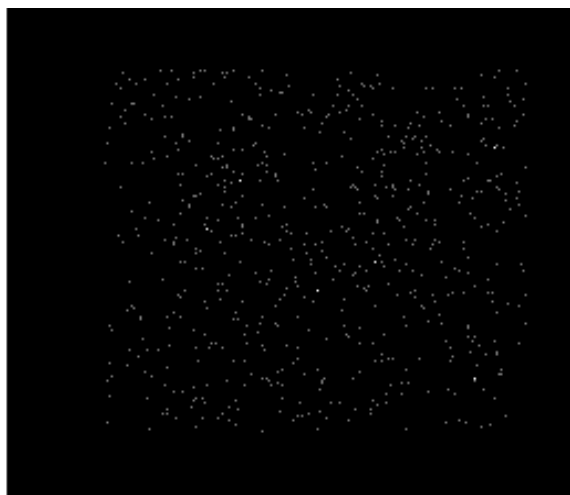


Ca Ka1

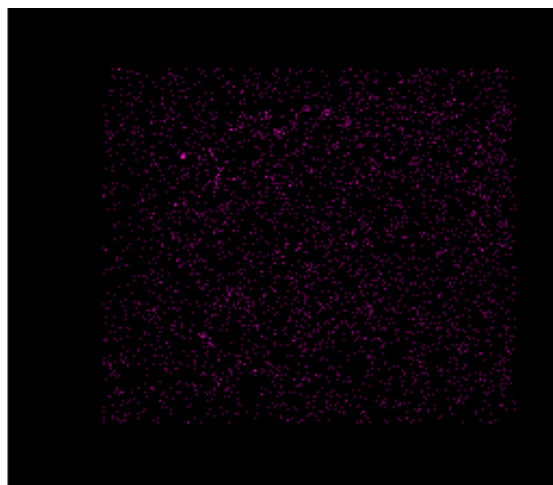


**Figure 20: EDS elemental mapping of a cohesive failure in bonding agent**

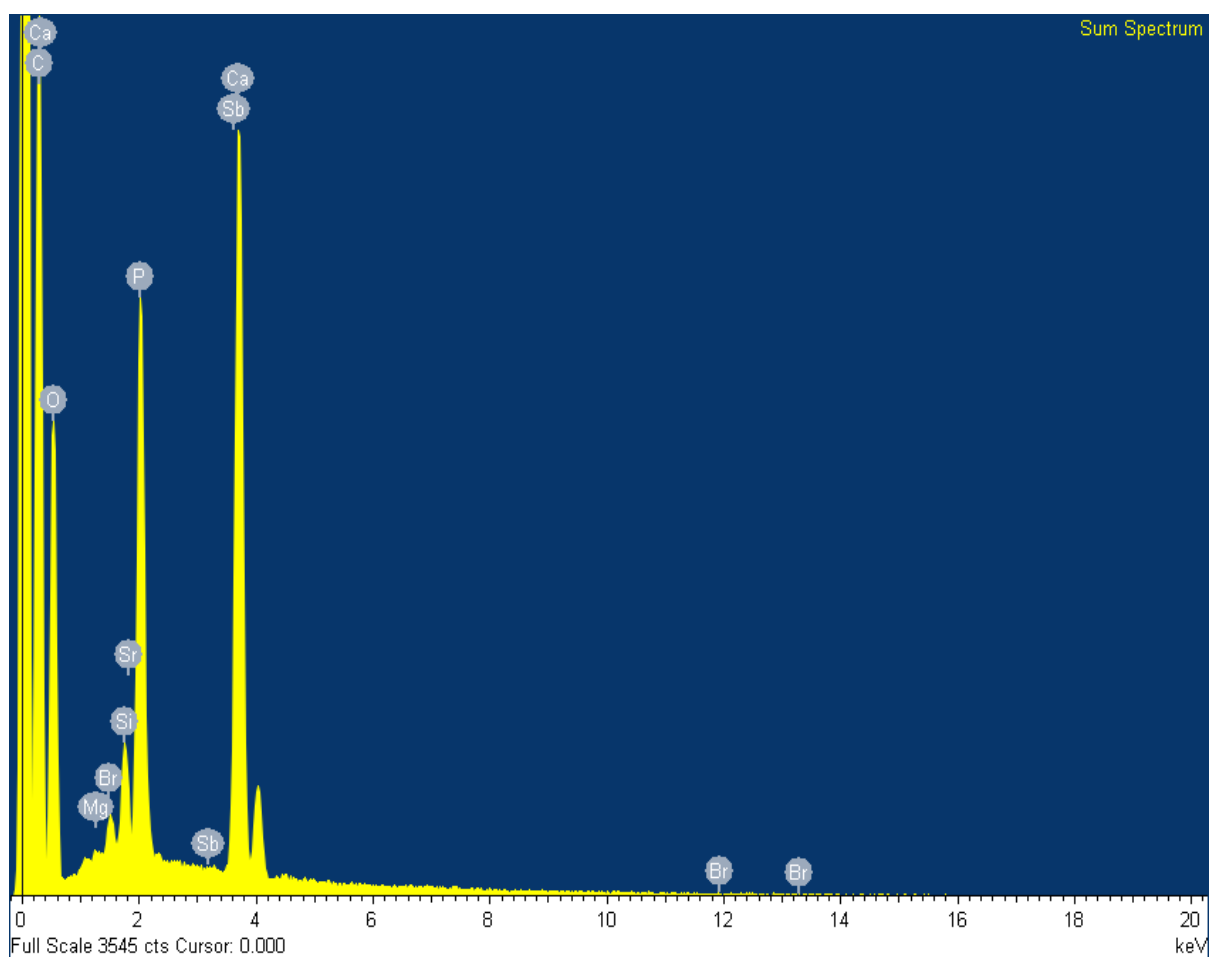




Yb La1

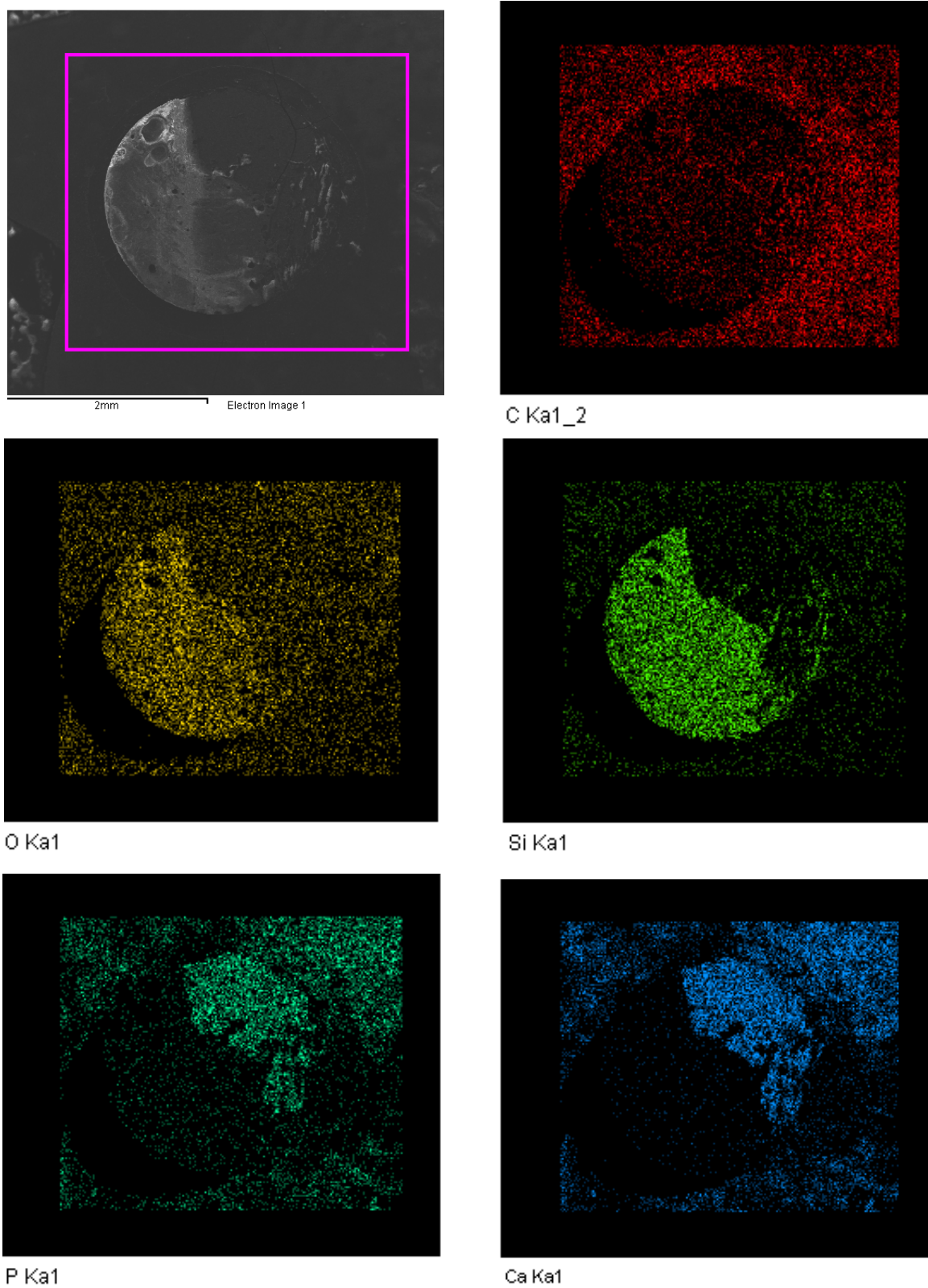


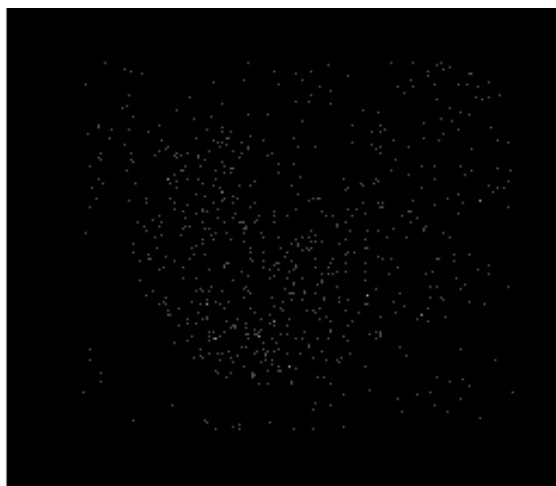
Al Ka1



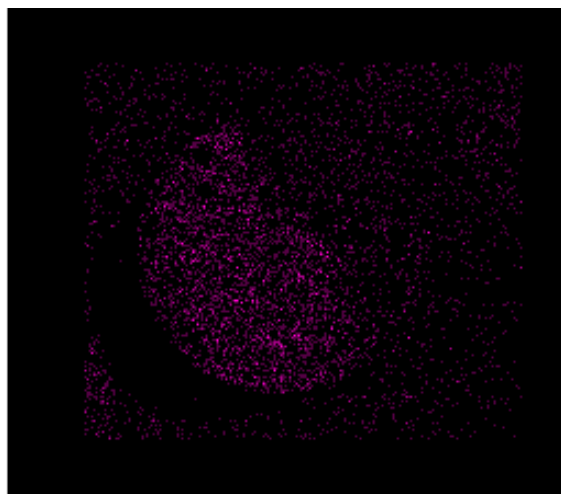


**Figure 21: EDS elemental mapping of a cohesive failure in composite**

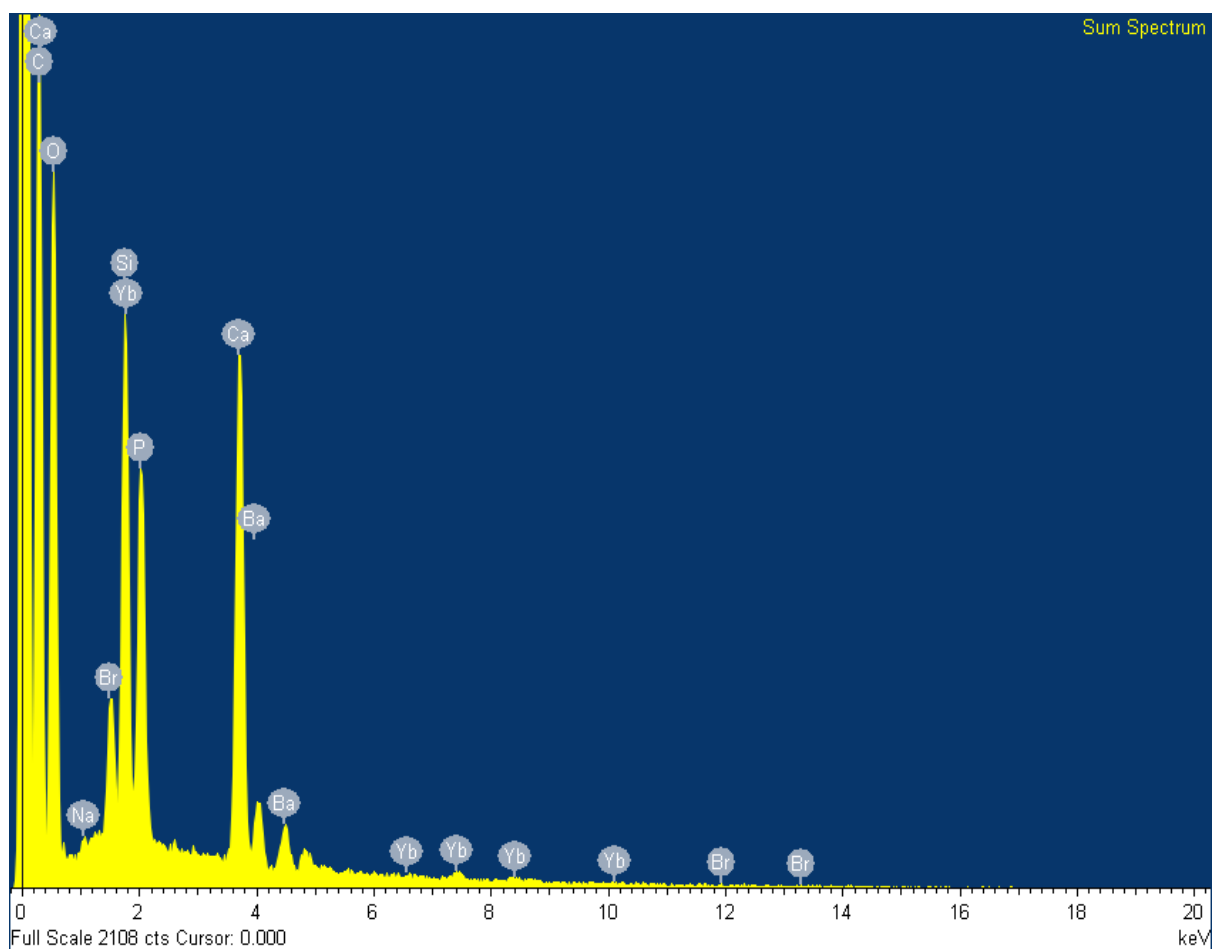




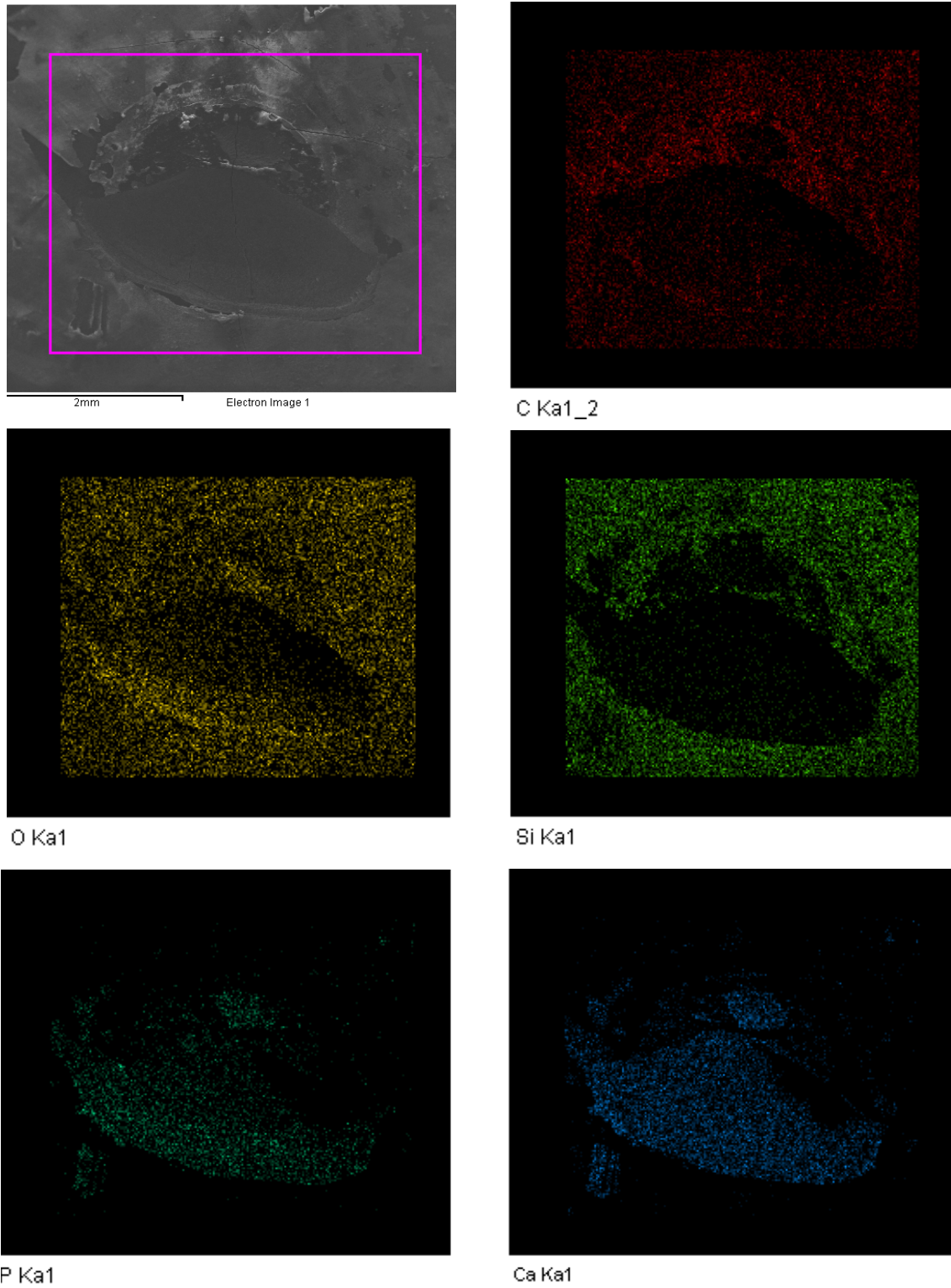
Yb La1

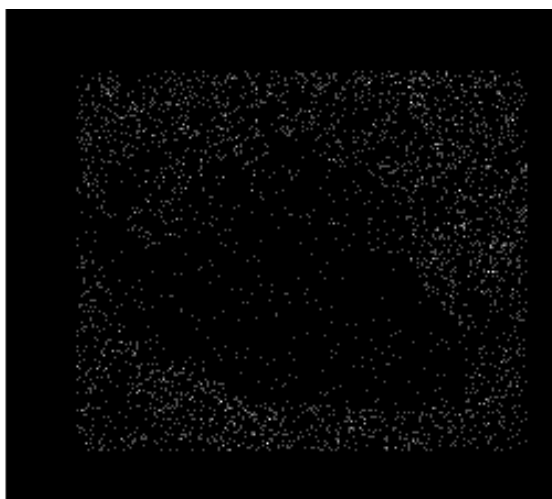


Al Ka1

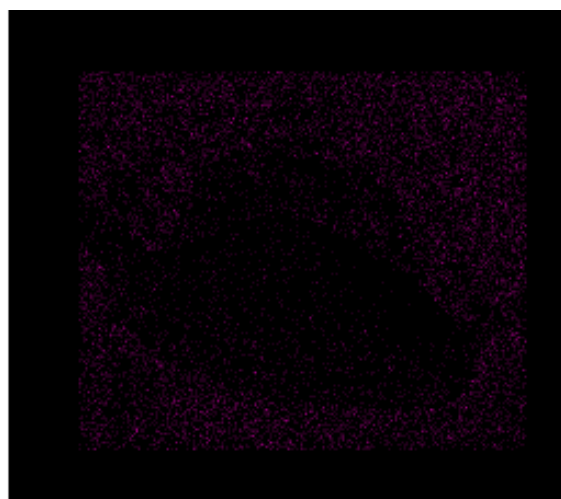


**Figure 22: EDS elemental mapping of cohesive failure in dentin**

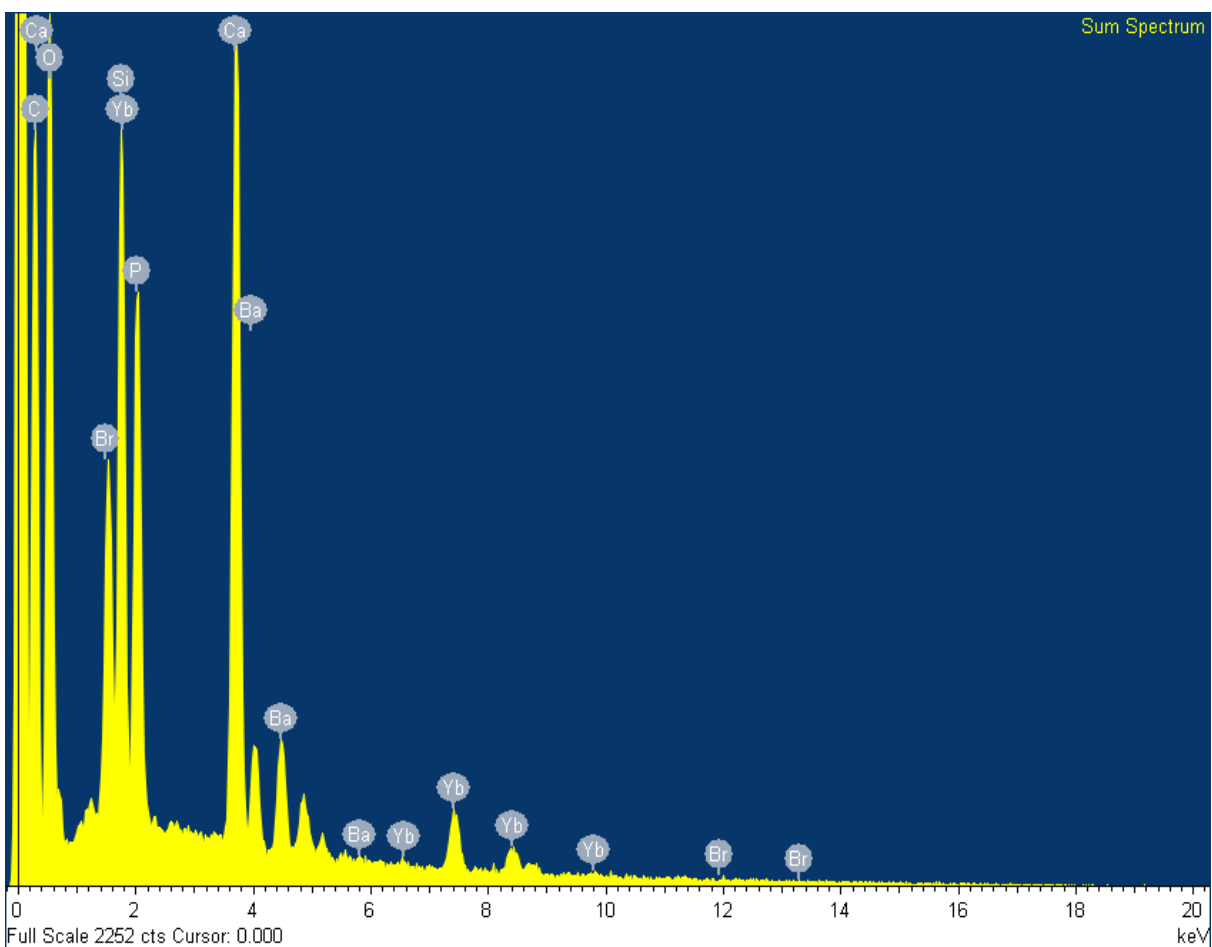




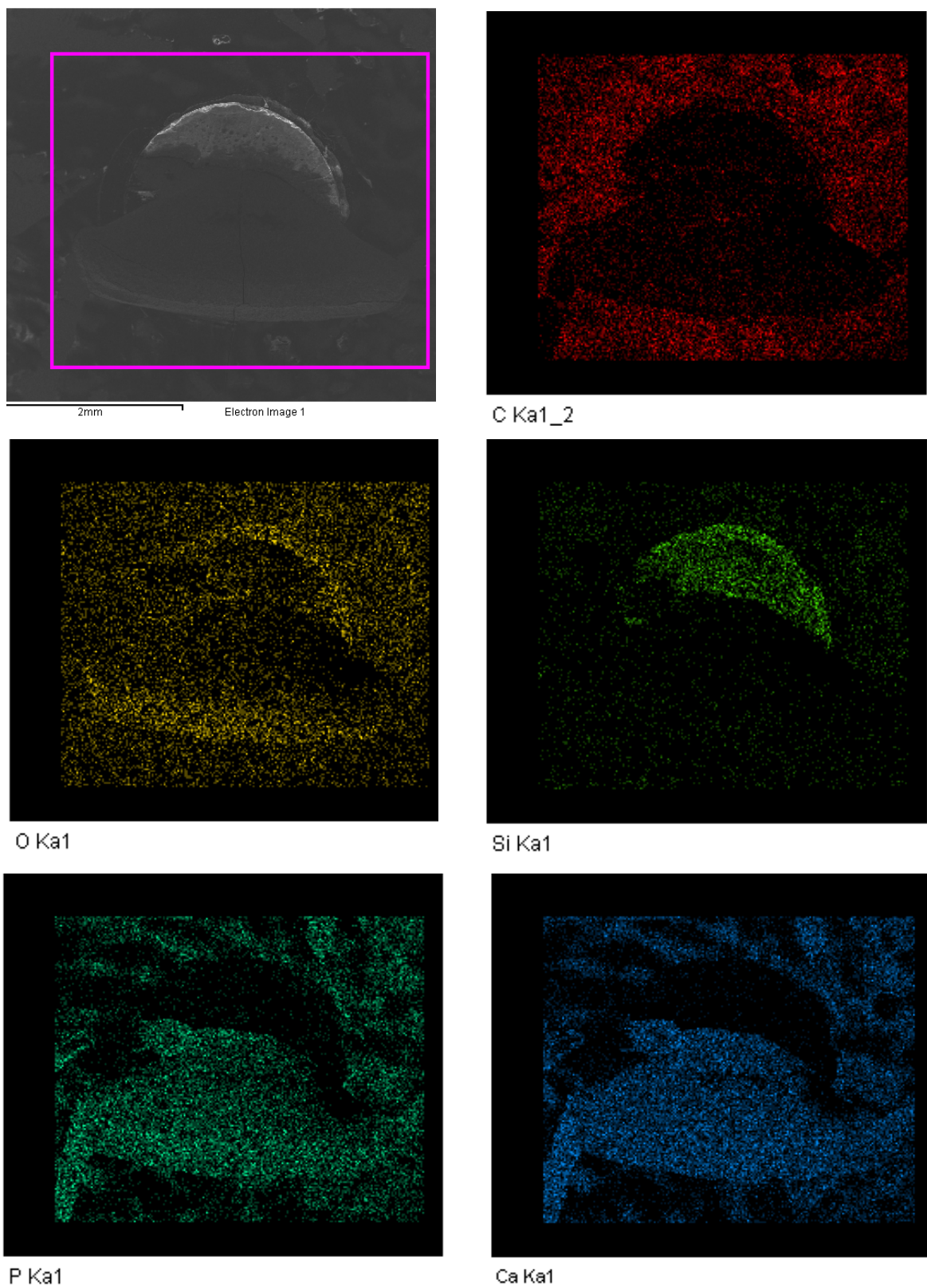
Yb La1

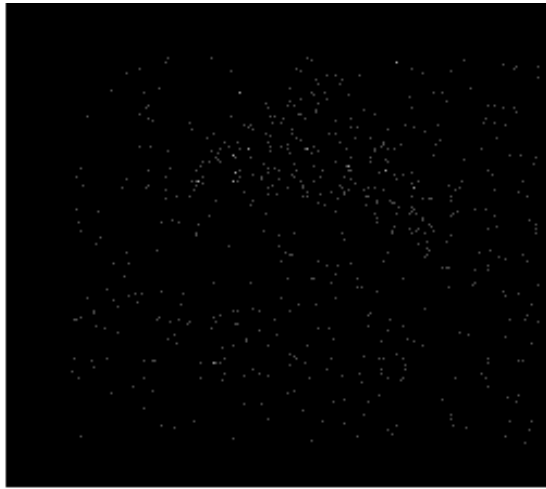


Al Ka1

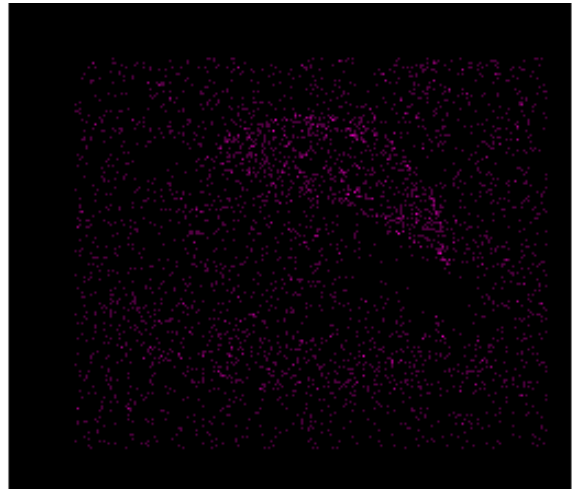


**Figure 23: EDS elemental mapping of a mixed failure**

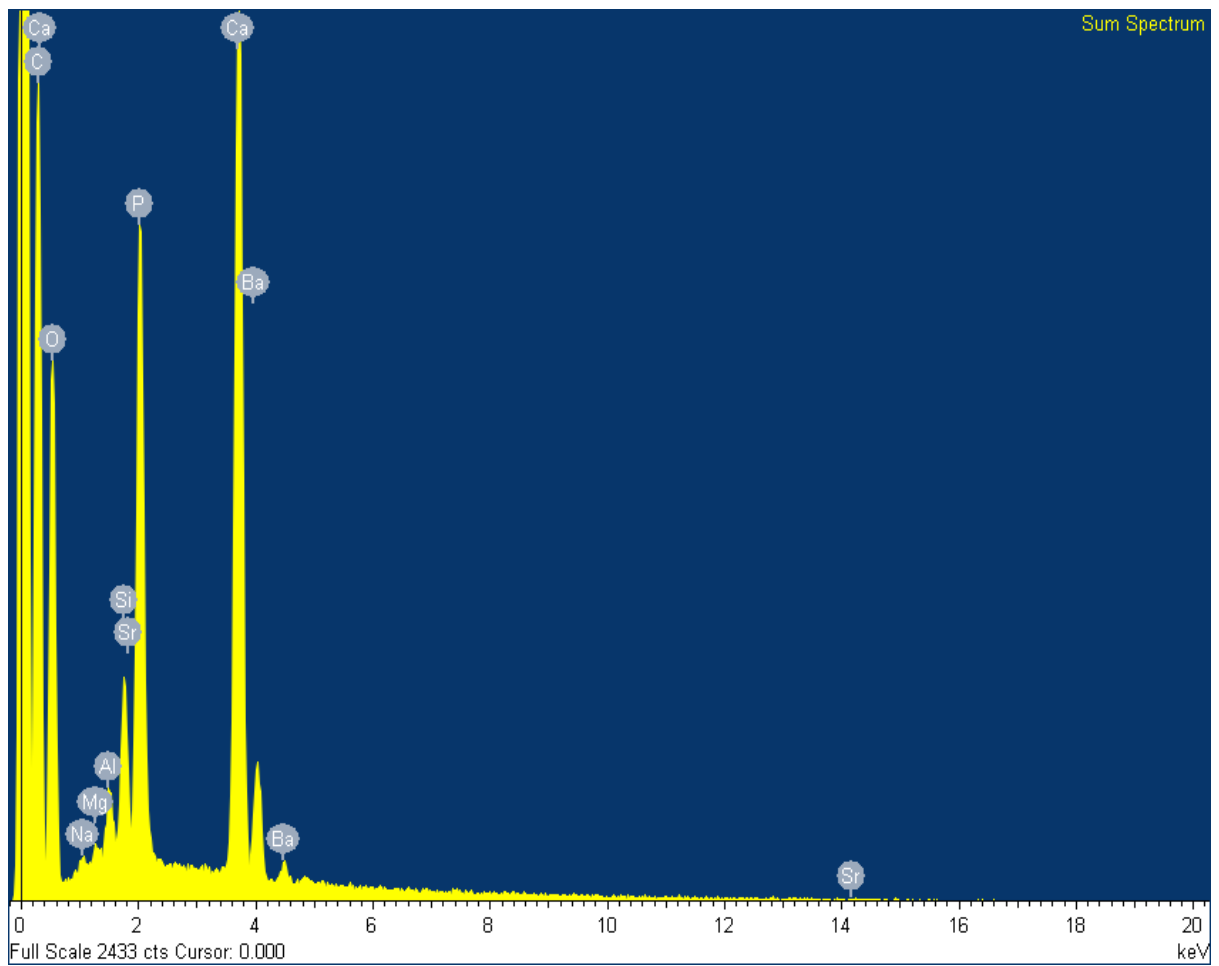




Yb La1



Al Ka1





## Chapter 4: Discussion

The first null hypothesis that there is no difference in the dentin bond strength of the universal adhesives in comparison to the three-step etch-and-rinse adhesives, must be rejected. Universal adhesive obtained significantly higher dentin bond strength than etch-and-rinse adhesives. This result was in agreement with findings of Behdad et al. since she tested the bond strength of universal adhesives in comparison to self-etch and etch-and-rinse adhesives and proved that universal adhesives revealed the highest bond strength values among all other tested adhesives.<sup>54</sup> Reasons for lower dentin bond strength of etch-and-rinse adhesives could be mainly due to the technique sensitivity of the etch-and-rinse procedure that depends on the moisture management of dentin surface as well as the expertise of the operators.

Etch-and-rinse adhesive systems depend on the phosphoric acid as a conditioner to expose dentin collagen fibers, which are consequently infiltrated by the bonding agent, leading to hybrid layer formation and formation of micro-mechanical interlocking.<sup>16</sup> Taking into consideration the moist nature of the exposed dentin collagen fibers, excessive air drying can lead to collapsing of the fibers and compromising the bonding agent's ability to penetrate into dentin substructure, and subsequently failing to form a proper hybrid layer.<sup>14</sup> However, salvaging the over-dried dentin surface with water allows the collapsed fibers to re-expand and facilitate the bonding agent's penetration, and resulting in high bond strength to dentin.<sup>55,56</sup> Multiple in-vitro studies reported a higher bond strength of composite restoration to moist dentin surface compared to the over-dried dentin surface, specifically with acetone or ethanol based adhesive systems.<sup>14,55-57</sup> These results are in disagreement with the results of this study since we found no significant difference in the

bond strength between moist and dry surface conditions. This finding may be explained by the presence of water in the composition of the tested adhesive systems that helps in re-wetting the over-dried dentin surface and provide re-expansion for the collapsed dentin fibers.<sup>58</sup> Van Meerbeek found that the dry-bonded water-based adhesives produce a hybrid layer without ultrastructural evidence of collapsed dentin collagen fibers.<sup>59</sup> Jacobsen and Soderholm's study results also were in agreement with this study, and further confirmed that water-based primers provide comparable bond strength values on dry dentin as on moist dentin in consideration of scrubbing the primer afterward to evaporate the residual water.<sup>60</sup> Also, Dal-Bianco et al. observed that when dentin was air dried for the 30s, water-based adhesives achieved a high bond strength compared to water-free adhesives, and similar bond strength was obtained on moist dentin as long as the remaining water was not entrapped within the hybrid layer.<sup>61</sup>

On the other hand, in the current study, bonding to wet surface condition revealed a significantly lower bonding strength compared to dry and moist groups, which can be probably due to the dilution and compromised polymerization of the bonding agent.<sup>34</sup>

Additional amounts of water to the dentin surface before applying the adhesive system was proven to significantly decrease the bond strength of water/solvent and water-based adhesives.<sup>62</sup>

On the contrary, universal adhesives show insensitivity to variation in dentin moisture as results of this study revealed a consistently high shear bond strength values when applying universal adhesive on all dentin surface conditions, such as moist, wet and dry. The insusceptibility of bonding to a variable dentin substrate maybe related to the advanced



chemical formulation of the universal adhesives. Additionally, they require less variability in the application technique compared to etch-and-rinse adhesives.

The universal adhesive, in this study, contained monomers of methacryloyloxydecyl dihydrogen phosphate (10-MDP), hydrophilic (hydroxyethyl methacrylate/HEMA), hydrophobic (decandiol dimethacrylate/D3MA) and intermediate (bis-GMA) components that facilitate the transition between hydrophilic and hydrophobic sections, in addition to the presence of solvents (ethanol and water). The incorporation of methacryloyloxydecyl dihydrogen phosphate (10-MDP) to universal adhesives enhance the bond quality and durability to dentin via chemical bonding with the calcium ions of the hydroxyapatite and form nano-layered structure along with the interface with dentin.<sup>44,45</sup> Moreover, the presence of water and ethanol in its formula play the main role in overcoming the dentin moisture difference. Water helps to re-expand the collapsed collagen fibers and permit the diffusion of monomer into the collagen network in case of over-dried dentin surface,<sup>58</sup> in addition to its main role in ionizing the acidic functional monomer and starting the self-etching process.<sup>63</sup> In the meantime, ethanol's presence promotes the penetration of the adhesive into exposed collagen fibers. Furthermore, it facilitates the evaporation of the excess water in case of presence of wet dentin surface.<sup>64</sup> Choi et al. evaluated the bond strength of Single-Bond universal adhesive (ethanol/water-based adhesive) on moist, slightly dry (5s air drying) and over-dry (10s air drying) dentin surface conditions. He found that in self-etch mode the tested universal adhesive did not show a significant difference in the bond strength under different moisture conditions.<sup>65</sup> Tsujimoto et al. reported similar results, that ethanol/water and acetone/water-based universal adhesives obtained comparable bond strength values regardless of dentinal surface wetness in etch-

and-rinse mode.<sup>66</sup> On the other hand, universal adhesives that not contain water in its content tend to achieved different bond strength values according to the surface moisture level.<sup>65-67</sup> All of this leads to the conclusion that the insensitivity to dentin surface moisture is conditional and reliant on the adhesive formulation.

Regarding operators' experience, several studies support that operator's variability in the bonding application technique affect the bond strength of etch-and-rinse and self-etch adhesives. This variation in performance was not only related to the operator's understanding of the theory behind the manufacturers' bonding instructions for scrubbing, air drying, and rewetting the bonding agent, but also was related to their previous knowledge, habits, and experience.<sup>49,51,52</sup> Moreover, the variation in performance was also related to the complexity and the multiplicity of adhesive application steps as etch-and-rinse adhesives require three application steps (etching, priming, and adhesive placement) compared to one step application of universal adhesives. Accordingly, fewer application steps lead to less opportunity for error.<sup>49</sup> In this study, expert dentists obtained higher dentin bond strength values than the dental students when they applied etch-and-rinse adhesive while with universal adhesive such a difference was not detected. The influence of the expertise may explain these findings on the bonding performance of participated dentists since they tend to scrub the bonding agent against the dentin surface meticulously. Students were not scrubbing the bonding agent as vigorous as expert dentists. Studies proved that vigorous scrubbing the bonding agent in the priming step against dentin surface increase the bond strength of the etch-and-rinse adhesives since it prevents entrapping of solvents in the hybrid layer and promotes its evaporation.<sup>60,61</sup> Moreover, the majority of expert dentists were applying continuous and strong air stream on the primer. Besides,

some of the expert dentists were waiting for a couple of seconds between primer application and adhesive application steps. These habits believed to enhance solvents' evaporation process and positively impact the bond strength.<sup>68</sup> Difference in the scrubbing and air-drying habits could be attributed to prior training, understanding, and practice of the expert dentists. Results of this study showed that no significant difference in the bond strength between wet and dry surface conditions when expert dentists used etch-and-rinse adhesive. This could be justified by the scrubbing and air-drying habits of the dentists that may facilitate the evaporation of the excess water.

On the contrary, no significant difference was observed in the application technique of universal adhesives between expert dentists and students. All operators were scrubbing universal adhesive around the 20s which was the recommended time by the manufacturer. This action could be related to the fewer application steps so operators were spending more time applying the bonding agent rather than thinking about the following steps. Previous studies found that active application and scrubbing the adhesive against dentin surface increases the bond strength of universal adhesives. Since the scrubbing facilitates the penetration of the adhesive into the smear layer, as well as induce solvent evaporation and creates more nano-layering calcium-salt at the interface with dentin.<sup>69</sup>

The variable of light curing process may also impact the bond strength. In this study, the light cure type, light intensity and exposure time were standardized for all operators. However, the light cure angulation tip and distance were operator-dependent variables. Evidently, the light curing effectiveness decreased when the distance from the light curing tip to polymerizable resinous material increased. In other words, the tip of the curing light must be positioned as close as possible to the polymerizable resinous

material and in a perpendicular position for sufficient polymerization.<sup>70</sup> Comparing the light cure unit handling between expert dentists and students, we noticed that expert dentists hold the light cure unit closer and more perpendicular to the bonded surface than the students. In summary, operators' experience plays a role in the predictable bonding success of etch-and-rinse adhesives. On the other hand, universal adhesive was insusceptible to operator's variability.

Additionally, our results revealed that the precise demonstration of bonding technique to the operators did not affect the bond strength values for both adhesive systems. Generally, after the demonstration, the operators applied both adhesives following manufacturer instructions. However, the difference in bond strength was still significantly high between groups. This result reflects the stronger influence of the adhesive type, surface condition and operators' expertise on the bond strength.

#### **4.1 Failure Analysis:**

Optical microscope and SEM have been used to identify the failure mode after applying the shear bond strength test (SBS). Furthermore, the EDS analysis was used to confirm the findings with SEM and evaluate the quality of the bond. The SBS values were correlated with the results of the failure mode analysis. The adhesive failure was commonly observed with the wet surface condition group for both universal and etch-and-rinse adhesives. The same "wet surface" group was also obtaining the lowest bond strength values with both tested adhesives.

#### **4.1.1 Universal adhesive:**

Almost 50% of universal adhesive's failures were a cohesive failure in composite (n=141/300), followed by 28% of mixed failure (n=86/300). Additionally, only 6% of failures were an adhesive failure (n=19/300) associated with the bonding to wet surface condition. These results reflect the success of universal adhesive to produce a well-defined hybrid layer between adhesive/composite and dentin substrate under any bonding circumstances.

#### **4.1.2 Etch and Rinse Adhesive:**

30% of the etch-and-rinse failures were an adhesive failure (n=90/300) associated with a low bond strength to wet surface condition. The EDS analysis illustrates a clean separation between adhesive and dentin surface with the adhesive failure, which reflects the inability of etch-and-rinse adhesive to penetrate the wet dentin substrate and produce adequate hybrid layer. This finding confirmed that the etch-and-rinse adhesive is susceptible to different surface conditions.

## **Chapter 5: Conclusion**

According to results of this study, there are significant interactions between adhesives, surface conditions, and operator's expertise. In addition, under the present bonding conditions and variability in operators' experience, the tested universal adhesive was found to perform significantly better than the etch-and-rinse adhesive. Universal adhesives showed insusceptibility to dentin surface condition and to operator differences. In contrast, etch-and-rinse adhesive was influenced by variability of surface condition and operator's expertise. In conclusion, the tested universal adhesive was found to be a more reliable adhesive system in comparison to the three-step etch-and-rinse adhesives.

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## Appendix

### Observation check list (Adhese Universal):

Group Number: .....

Surface Condition: W M D

- 1- The adhesive was applied on dentin surface:
  - With scrubbing \_\_\_\_\_
  - Without scrubbing \_\_\_\_\_
- 2- The adhesive was applied on dentin surface and scrubbed in for .....sec.
  - 10 sec
  - 20 sec
  - 30 sec
  - Other, specify ..... sec
- 3- Disposable applicator was rewetted during the process of adhesive application:
  - Yes
  - No
  - If Yes, How many?.....
- 4- Direct stream of air was applied over the adhesive:
  - Yes
  - No
- 5- Characteristic of the stream of air that was applied over the adhesive: (chose one or more)
  - Weak
  - Gentle
  - Strong
  - Continuous
  - Intermittent
- 6- Stream of air that was applied over the adhesive for ....sec
  - 1 sec
  - 5 sec
  - 10 sec
  - Other, specify ..... sec
- 7- Adhesive was light cured for...sec:
  - 10 sec
  - 20 sec
  - 30 sec
  - Other, specify ..... sec

Notes:

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**Observation check list (Optibond FL):**

**Group Number:** .....

**Surface Condition:** .....

- 1- 37.5% phosphoric acid was applied on dentin surface for ... sec
  - 10 sec
  - 15 sec
  - 30 sec
  - Other, specify .... Sec
- 2- After rinsing the phosphoric acid with water, Dentin was air dried for .... Sec
  - 1 sec
  - 5 sec
  - 10 sec
  - Other, specify ..... sec
- 3- Characteristic of the stream of air that was applied over the dentin: (chose one or more)
  - Weak
  - Gentle
  - Strong
  - Continuous
  - Intermittent
- 4- Primer was applied on dentin surface:
  - With scrubbing \_\_\_\_\_
  - Without scrubbing \_\_\_\_\_
- 5- Primer was applied on dentin surface and scrubbed in for .....sec.
  - 10 sec
  - 15 sec
  - 30 sec
  - Other, specify ..... sec
- 6- The disposable applicator was rewetted during the process of primer application:
  - Yes
  - No
  - If Yes, How many times?.....
- 7- Direct stream of air was applied over the primer:
  - Yes
  - No



8- Characteristic of the stream of air that was applied over the primer: (chose one or more)

- Weak
- Gentle
- Strong
- Continuous
- Intermittent

9- Stream of air that was applied over the primer for ....sec

- 1 sec
- 5 sec
- 10 sec
- Other, specify ..... sec

10- Adhesive was applied on dentin surface:

- With scrubbing \_\_\_\_\_
- Without scrubbing \_\_\_\_\_

11- Adhesive was applied on dentin surface and scrubbed in for .....sec.

- 10 sec
- 15 sec
- 30 sec
- Other, specify ..... sec

12- The disposable applicator was rewetted during the process of adhesive application:

- Yes
- No
- If Yes, how many times?.....

13- Adhesive was light cured for...sec:

- 10 sec
- 20 sec
- 30 sec
- Other, specify ..... sec

Notes:

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### Raw Data of Shear Bond Strength Test:

Sample	Adhesive	w or w/o demonstration	S/D participants	D surface condition	SBS in MPa
1	Universal adhesive	W/O	Dentist 1	Wet 1	23.07
2	Universal adhesive	W/O	Dentist 1	Wet 2	17.46
3	Universal adhesive	W/O	Dentist 1	Wet 3	31.78
4	Universal adhesive	W/O	Dentist 1	Wet 4	28.29
5	Universal adhesive	W/O	Dentist 1	Wet 5	20.65
6	Universal adhesive	W/O	Dentist 1	Moist 1	20.46
7	Universal adhesive	W/O	Dentist 1	Moist 2	22.95
8	Universal adhesive	W/O	Dentist 1	Moist 3	21.10
9	Universal adhesive	W/O	Dentist 1	Moist 4	23.13
10	Universal adhesive	W/O	Dentist 1	Moist 5	16.52
11	Universal adhesive	W/O	Dentist 1	Dry 1	24.65
12	Universal adhesive	W/O	Dentist 1	Dry 2	24.39
13	Universal adhesive	W/O	Dentist 1	Dry 3	8.53
14	Universal adhesive	W/O	Dentist 1	Dry 4	25.57
15	Universal adhesive	W/O	Dentist 1	Dry 5	22.98
16	Universal adhesive	W/O	Dentist 2	Wet 1	19.76
17	Universal adhesive	W/O	Dentist 2	Wet 2	26.24
18	Universal adhesive	W/O	Dentist 2	Wet 3	30.04
19	Universal adhesive	W/O	Dentist 2	Wet 4	20.53
20	Universal adhesive	W/O	Dentist 2	Wet 5	25.50
21	Universal adhesive	W/O	Dentist 2	Moist 1	30.40
22	Universal adhesive	W/O	Dentist 2	Moist 2	30.29
23	Universal adhesive	W/O	Dentist 2	Moist 3	28.07
24	Universal adhesive	W/O	Dentist 2	Moist 4	26.95
25	Universal adhesive	W/O	Dentist 2	Moist 5	25.34
26	Universal adhesive	W/O	Dentist 2	Dry 1	24.69
27	Universal adhesive	W/O	Dentist 2	Dry 2	21.73
28	Universal adhesive	W/O	Dentist 2	Dry 3	30.44
29	Universal adhesive	W/O	Dentist 2	Dry 4	21.40
30	Universal adhesive	W/O	Dentist 2	Dry 5	27.43
31	Universal adhesive	W/O	Dentist 3	Wet 1	34.64
32	Universal adhesive	W/O	Dentist 3	Wet 2	30.32
33	Universal adhesive	W/O	Dentist 3	Wet 3	26.82
34	Universal adhesive	W/O	Dentist 3	Wet 4	21.59
35	Universal adhesive	W/O	Dentist 3	Wet 5	38.21
36	Universal adhesive	W/O	Dentist 3	Moist 1	43.54
37	Universal adhesive	W/O	Dentist 3	Moist 2	32.10
38	Universal adhesive	W/O	Dentist 3	Moist 3	38.41
39	Universal adhesive	W/O	Dentist 3	Moist 4	32.47
40	Universal adhesive	W/O	Dentist 3	Moist 5	32.99
41	Universal adhesive	W/O	Dentist 3	Dry 1	31.41
42	Universal adhesive	W/O	Dentist 3	Dry 2	29.56
43	Universal adhesive	W/O	Dentist 3	Dry 3	36.76
44	Universal adhesive	W/O	Dentist 3	Dry 4	7.49
45	Universal adhesive	W/O	Dentist 3	Dry 5	35.71
46	Universal adhesive	W/O	Dentist 4	Wet 1	22.56
47	Universal adhesive	W/O	Dentist 4	Wet 2	34.21
48	Universal adhesive	W/O	Dentist 4	Wet 3	30.59
49	Universal adhesive	W/O	Dentist 4	Wet 4	32.54
50	Universal adhesive	W/O	Dentist 4	Wet 5	30.72

51	Universal adhesive	W/O	Dentist 4	Moist 1	34.47
52	Universal adhesive	W/O	Dentist 4	Moist 2	23.94
53	Universal adhesive	W/O	Dentist 4	Moist 3	21.27
54	Universal adhesive	W/O	Dentist 4	Moist 4	22.36
55	Universal adhesive	W/O	Dentist 4	Moist 5	20.81
56	Universal adhesive	W/O	Dentist 4	Dry 1	28.57
57	Universal adhesive	W/O	Dentist 4	Dry 2	22.45
58	Universal adhesive	W/O	Dentist 4	Dry 3	19.64
59	Universal adhesive	W/O	Dentist 4	Dry 4	23.55
60	Universal adhesive	W/O	Dentist 4	Dry 5	18.76
61	Universal adhesive	W/O	Dentist 5	Wet 1	15.03
62	Universal adhesive	W/O	Dentist 5	Wet 2	27.88
63	Universal adhesive	W/O	Dentist 5	Wet 3	11.81
64	Universal adhesive	W/O	Dentist 5	Wet 4	28.01
65	Universal adhesive	W/O	Dentist 5	Wet 5	24.55
66	Universal adhesive	W/O	Dentist 5	Moist 1	24
67	Universal adhesive	W/O	Dentist 5	Moist 2	16.06
68	Universal adhesive	W/O	Dentist 5	Moist 3	33.03
69	Universal adhesive	W/O	Dentist 5	Moist 4	28.72
70	Universal adhesive	W/O	Dentist 5	Moist 5	25.87
71	Universal adhesive	W/O	Dentist 5	Dry 1	29.32
72	Universal adhesive	W/O	Dentist 5	Dry 2	34.05
73	Universal adhesive	W/O	Dentist 5	Dry 3	36.94
74	Universal adhesive	W/O	Dentist 5	Dry 4	35.86
75	Universal adhesive	W/O	Dentist 5	Dry 5	28.67
76	Universal adhesive	W	Dentist 1	Wet 1	12.75
77	Universal adhesive	W	Dentist 1	Wet 2	20.99
78	Universal adhesive	W	Dentist 1	Wet 3	15.19
79	Universal adhesive	W	Dentist 1	Wet 4	17.99
80	Universal adhesive	W	Dentist 1	Wet 5	12.70
81	Universal adhesive	W	Dentist 1	Moist 1	24.17
82	Universal adhesive	W	Dentist 1	Moist 2	23.92
83	Universal adhesive	W	Dentist 1	Moist 3	23.46
84	Universal adhesive	W	Dentist 1	Moist 4	29.28
85	Universal adhesive	W	Dentist 1	Moist 5	15.84
86	Universal adhesive	W	Dentist 1	Dry 1	11.96
87	Universal adhesive	W	Dentist 1	Dry 2	9.65
88	Universal adhesive	W	Dentist 1	Dry 3	24.21
89	Universal adhesive	W	Dentist 1	Dry 4	16.52
90	Universal adhesive	W	Dentist 1	Dry 5	17.68
91	Universal adhesive	W	Dentist 2	Wet 1	13.99
92	Universal adhesive	W	Dentist 2	Wet 2	21.15
93	Universal adhesive	W	Dentist 2	Wet 3	13.19
94	Universal adhesive	W	Dentist 2	Wet 4	33.26
95	Universal adhesive	W	Dentist 2	Wet 5	20.07
96	Universal adhesive	W	Dentist 2	Moist 1	8.36
97	Universal adhesive	W	Dentist 2	Moist 2	11.40
98	Universal adhesive	W	Dentist 2	Moist 3	14.99
99	Universal adhesive	W	Dentist 2	Moist 4	17.01
100	Universal adhesive	W	Dentist 2	Moist 5	8.75
101	Universal adhesive	W	Dentist 2	Dry 1	25.08
102	Universal adhesive	W	Dentist 2	Dry 2	25.55
103	Universal adhesive	W	Dentist 2	Dry 3	26.40
104	Universal adhesive	W	Dentist 2	Dry 4	24.79
105	Universal adhesive	W	Dentist 2	Dry 5	12.55
106	Universal adhesive	W	Dentist 3	Wet 1	35.57
107	Universal adhesive	W	Dentist 3	Wet 2	37.94

108	Universal adhesive	W	Dentist 3	Wet 3	43.61
109	Universal adhesive	W	Dentist 3	Wet 4	38.06
110	Universal adhesive	W	Dentist 3	Wet 5	36.69
111	Universal adhesive	W	Dentist 3	Moist 1	25.28
112	Universal adhesive	W	Dentist 3	Moist 2	35.41
113	Universal adhesive	W	Dentist 3	Moist 3	32.34
114	Universal adhesive	W	Dentist 3	Moist 4	30.36
115	Universal adhesive	W	Dentist 3	Moist 5	21.33
116	Universal adhesive	W	Dentist 3	Dry 1	27.90
117	Universal adhesive	W	Dentist 3	Dry 2	29.44
118	Universal adhesive	W	Dentist 3	Dry 3	35.73
119	Universal adhesive	W	Dentist 3	Dry 4	39.73
120	Universal adhesive	W	Dentist 3	Dry 5	32.76
121	Universal adhesive	W	Dentist 4	Wet 1	12.89
122	Universal adhesive	W	Dentist 4	Wet 2	32.72
123	Universal adhesive	W	Dentist 4	Wet 3	40.09
124	Universal adhesive	W	Dentist 4	Wet 4	30.33
125	Universal adhesive	W	Dentist 4	Wet 5	33.07
126	Universal adhesive	W	Dentist 4	Moist 1	41.71
127	Universal adhesive	W	Dentist 4	Moist 2	30.89
128	Universal adhesive	W	Dentist 4	Moist 3	12.83
129	Universal adhesive	W	Dentist 4	Moist 4	23.90
130	Universal adhesive	W	Dentist 4	Moist 5	35.47
131	Universal adhesive	W	Dentist 4	Dry 1	28.03
132	Universal adhesive	W	Dentist 4	Dry 2	15.11
133	Universal adhesive	W	Dentist 4	Dry 3	32.37
134	Universal adhesive	W	Dentist 4	Dry 4	30.74
135	Universal adhesive	W	Dentist 4	Dry 5	30.33
136	Universal adhesive	W	Dentist 5	Wet 1	16.84
137	Universal adhesive	W	Dentist 5	Wet 2	12.14
138	Universal adhesive	W	Dentist 5	Wet 3	25.56
139	Universal adhesive	W	Dentist 5	Wet 4	21.47
140	Universal adhesive	W	Dentist 5	Wet 5	25.96
141	Universal adhesive	W	Dentist 5	Moist 1	26.85
142	Universal adhesive	W	Dentist 5	Moist 2	31.25
143	Universal adhesive	W	Dentist 5	Moist 3	31.27
144	Universal adhesive	W	Dentist 5	Moist 4	23.81
145	Universal adhesive	W	Dentist 5	Moist 5	9.78
146	Universal adhesive	W	Dentist 5	Dry 1	31.53
147	Universal adhesive	W	Dentist 5	Dry 2	20.90
148	Universal adhesive	W	Dentist 5	Dry 3	17.62
149	Universal adhesive	W	Dentist 5	Dry 4	28.85
150	Universal adhesive	W	Dentist 5	Dry 5	13.70
151	Universal adhesive	W/O	Student 1	Wet 1	15.35
152	Universal adhesive	W/O	Student 1	Wet 2	28.60
153	Universal adhesive	W/O	Student 1	Wet 3	19.32
154	Universal adhesive	W/O	Student 1	Wet 4	13.43
155	Universal adhesive	W/O	Student 1	Wet 5	10.90
156	Universal adhesive	W/O	Student 1	Moist 1	9.53
157	Universal adhesive	W/O	Student 1	Moist 2	21.73
158	Universal adhesive	W/O	Student 1	Moist 3	20.59
159	Universal adhesive	W/O	Student 1	Moist 4	32.32
160	Universal adhesive	W/O	Student 1	Moist 5	8.90
161	Universal adhesive	W/O	Student 1	Dry 1	15.96
162	Universal adhesive	W/O	Student 1	Dry 2	24.45
163	Universal adhesive	W/O	Student 1	Dry 3	23.17
164	Universal adhesive	W/O	Student 1	Dry 4	18.26

165	Universal adhesive	W/O	Student 1	Dry 5	27.55
166	Universal adhesive	W/O	Student 2	Wet 1	25
167	Universal adhesive	W/O	Student 2	Wet 2	31.81
168	Universal adhesive	W/O	Student 2	Wet 3	20.14
169	Universal adhesive	W/O	Student 2	Wet 4	19.66
170	Universal adhesive	W/O	Student 2	Wet 5	27.29
171	Universal adhesive	W/O	Student 2	Moist 1	25.22
172	Universal adhesive	W/O	Student 2	Moist 2	19.18
173	Universal adhesive	W/O	Student 2	Moist 3	25.38
174	Universal adhesive	W/O	Student 2	Moist 4	25.50
175	Universal adhesive	W/O	Student 2	Moist 5	39.71
176	Universal adhesive	W/O	Student 2	Dry 1	26.35
177	Universal adhesive	W/O	Student 2	Dry 2	26.52
178	Universal adhesive	W/O	Student 2	Dry 3	15.88
179	Universal adhesive	W/O	Student 2	Dry 4	27.05
180	Universal adhesive	W/O	Student 2	Dry 5	29.35
181	Universal adhesive	W/O	Student 3	Wet 1	7.70
182	Universal adhesive	W/O	Student 3	Wet 2	34.04
183	Universal adhesive	W/O	Student 3	Wet 3	22.11
184	Universal adhesive	W/O	Student 3	Wet 4	27.38
185	Universal adhesive	W/O	Student 3	Wet 5	18.76
186	Universal adhesive	W/O	Student 3	Moist 1	20.48
187	Universal adhesive	W/O	Student 3	Moist 2	22.78
188	Universal adhesive	W/O	Student 3	Moist 3	27.30
189	Universal adhesive	W/O	Student 3	Moist 4	19.68
190	Universal adhesive	W/O	Student 3	Moist 5	23
191	Universal adhesive	W/O	Student 3	Dry 1	25.58
192	Universal adhesive	W/O	Student 3	Dry 2	23.17
193	Universal adhesive	W/O	Student 3	Dry 3	22.76
194	Universal adhesive	W/O	Student 3	Dry 4	22.09
195	Universal adhesive	W/O	Student 3	Dry 5	20.86
196	Universal adhesive	W/O	Student 4	Wet 1	23.86
197	Universal adhesive	W/O	Student 4	Wet 2	32.63
198	Universal adhesive	W/O	Student 4	Wet 3	5.89
199	Universal adhesive	W/O	Student 4	Wet 4	23.27
200	Universal adhesive	W/O	Student 4	Wet 5	28.06
201	Universal adhesive	W/O	Student 4	Moist 1	28.45
202	Universal adhesive	W/O	Student 4	Moist 2	30.92
203	Universal adhesive	W/O	Student 4	Moist 3	37.70
204	Universal adhesive	W/O	Student 4	Moist 4	23.47
205	Universal adhesive	W/O	Student 4	Moist 5	21.80
206	Universal adhesive	W/O	Student 4	Dry 1	27.67
207	Universal adhesive	W/O	Student 4	Dry 2	30.16
208	Universal adhesive	W/O	Student 4	Dry 3	17.88
209	Universal adhesive	W/O	Student 4	Dry 4	29.54
210	Universal adhesive	W/O	Student 4	Dry 5	20.51
211	Universal adhesive	W/O	Student 5	Wet 1	25.78
212	Universal adhesive	W/O	Student 5	Wet 2	14.20
213	Universal adhesive	W/O	Student 5	Wet 3	23.87
214	Universal adhesive	W/O	Student 5	Wet 4	23.79
215	Universal adhesive	W/O	Student 5	Wet 5	40.38
216	Universal adhesive	W/O	Student 5	Moist 1	9.29
217	Universal adhesive	W/O	Student 5	Moist 2	28.23
218	Universal adhesive	W/O	Student 5	Moist 3	23.90
219	Universal adhesive	W/O	Student 5	Moist 4	21.21
220	Universal adhesive	W/O	Student 5	Moist 5	23.47
221	Universal adhesive	W/O	Student 5	Dry 1	27.47

222	Universal adhesive	W/O	Student 5	Dry 2	13.49
223	Universal adhesive	W/O	Student 5	Dry 3	26.37
224	Universal adhesive	W/O	Student 5	Dry 4	22.31
225	Universal adhesive	W/O	Student 5	Dry 5	25.94
226	Universal adhesive	W	Student 1	Wet 1	16.41
227	Universal adhesive	W	Student 1	Wet 2	32.50
228	Universal adhesive	W	Student 1	Wet 3	24.47
229	Universal adhesive	W	Student 1	Wet 4	28.48
230	Universal adhesive	W	Student 1	Wet 5	28.50
231	Universal adhesive	W	Student 1	Moist 1	23.12
232	Universal adhesive	W	Student 1	Moist 2	26.64
233	Universal adhesive	W	Student 1	Moist 3	22.46
234	Universal adhesive	W	Student 1	Moist 4	30.87
235	Universal adhesive	W	Student 1	Moist 5	28.29
236	Universal adhesive	W	Student 1	Dry 1	21.41
237	Universal adhesive	W	Student 1	Dry 2	13.44
238	Universal adhesive	W	Student 1	Dry 3	21.52
239	Universal adhesive	W	Student 1	Dry 4	31.86
240	Universal adhesive	W	Student 1	Dry 5	22.12
241	Universal adhesive	W	Student 2	Wet 1	13.15
242	Universal adhesive	W	Student 2	Wet 2	21.81
243	Universal adhesive	W	Student 2	Wet 3	27.39
244	Universal adhesive	W	Student 2	Wet 4	37.44
245	Universal adhesive	W	Student 2	Wet 5	30.72
246	Universal adhesive	W	Student 2	Moist 1	27.50
247	Universal adhesive	W	Student 2	Moist 2	32.19
248	Universal adhesive	W	Student 2	Moist 3	36.69
249	Universal adhesive	W	Student 2	Moist 4	42.08
250	Universal adhesive	W	Student 2	Moist 5	32.10
251	Universal adhesive	W	Student 2	Dry 1	24.35
252	Universal adhesive	W	Student 2	Dry 2	41.19
253	Universal adhesive	W	Student 2	Dry 3	30.23
254	Universal adhesive	W	Student 2	Dry 4	29.89
255	Universal adhesive	W	Student 2	Dry 5	20.60
256	Universal adhesive	W	Student 3	Wet 1	24.92
257	Universal adhesive	W	Student 3	Wet 2	24.75
258	Universal adhesive	W	Student 3	Wet 3	10.29
259	Universal adhesive	W	Student 3	Wet 4	16.87
260	Universal adhesive	W	Student 3	Wet 5	12.65
261	Universal adhesive	W	Student 3	Moist 1	25.76
262	Universal adhesive	W	Student 3	Moist 2	21.97
263	Universal adhesive	W	Student 3	Moist 3	30.70
264	Universal adhesive	W	Student 3	Moist 4	12.63
265	Universal adhesive	W	Student 3	Moist 5	34.98
266	Universal adhesive	W	Student 3	Dry 1	23.24
267	Universal adhesive	W	Student 3	Dry 2	23.39
268	Universal adhesive	W	Student 3	Dry 3	43.06
269	Universal adhesive	W	Student 3	Dry 4	27.75
270	Universal adhesive	W	Student 3	Dry 5	14.95
271	Universal adhesive	W	Student 4	Wet 1	29.17
272	Universal adhesive	W	Student 4	Wet 2	28.73
273	Universal adhesive	W	Student 4	Wet 3	33.80
274	Universal adhesive	W	Student 4	Wet 4	38.25
275	Universal adhesive	W	Student 4	Wet 5	33.92
276	Universal adhesive	W	Student 4	Moist 1	36.24
277	Universal adhesive	W	Student 4	Moist 2	33.88
278	Universal adhesive	W	Student 4	Moist 3	30.99

279	Universal adhesive	W	Student 4	Moist 4	42.98
280	Universal adhesive	W	Student 4	Moist 5	27.92
281	Universal adhesive	W	Student 4	Dry 1	25.76
282	Universal adhesive	W	Student 4	Dry 2	25.61
283	Universal adhesive	W	Student 4	Dry 3	32.21
284	Universal adhesive	W	Student 4	Dry 4	23.74
285	Universal adhesive	W	Student 4	Dry 5	19.76
286	Universal adhesive	W	Student 5	Wet 1	32.56
287	Universal adhesive	W	Student 5	Wet 2	22.78
288	Universal adhesive	W	Student 5	Wet 3	21.63
289	Universal adhesive	W	Student 5	Wet 4	24.92
290	Universal adhesive	W	Student 5	Wet 5	28.16
291	Universal adhesive	W	Student 5	Moist 1	23.48
292	Universal adhesive	W	Student 5	Moist 2	26.70
293	Universal adhesive	W	Student 5	Moist 3	19.63
294	Universal adhesive	W	Student 5	Moist 4	27.96
295	Universal adhesive	W	Student 5	Moist 5	33.71
296	Universal adhesive	W	Student 5	Dry 1	23.69
297	Universal adhesive	W	Student 5	Dry 2	16.26
298	Universal adhesive	W	Student 5	Dry 3	25.87
299	Universal adhesive	W	Student 5	Dry 4	23.91
300	Universal adhesive	W	Student 5	Dry 5	27.58
301	Etch & Rinse adhesive	W/O	Dentist 1	Wet 1	23.66
302	Etch & Rinse adhesive	W/O	Dentist 1	Wet 2	11.03
303	Etch & Rinse adhesive	W/O	Dentist 1	Wet 3	4.59
304	Etch & Rinse adhesive	W/O	Dentist 1	Wet 4	3.72
305	Etch & Rinse adhesive	W/O	Dentist 1	Wet 5	8.87
306	Etch & Rinse adhesive	W/O	Dentist 1	Moist 1	4.93
307	Etch & Rinse adhesive	W/O	Dentist 1	Moist 2	13.86
308	Etch & Rinse adhesive	W/O	Dentist 1	Moist 3	28.16
309	Etch & Rinse adhesive	W/O	Dentist 1	Moist 4	27.54
310	Etch & Rinse adhesive	W/O	Dentist 1	Moist 5	5.88
311	Etch & Rinse adhesive	W/O	Dentist 1	Dry 1	1.75
312	Etch & Rinse adhesive	W/O	Dentist 1	Dry 2	3.47
313	Etch & Rinse adhesive	W/O	Dentist 1	Dry 3	0.56
314	Etch & Rinse adhesive	W/O	Dentist 1	Dry 4	14.74
315	Etch & Rinse adhesive	W/O	Dentist 1	Dry 5	11.72
316	Etch & Rinse adhesive	W/O	Dentist 2	Wet 1	13.89
317	Etch & Rinse adhesive	W/O	Dentist 2	Wet 2	38.27
318	Etch & Rinse adhesive	W/O	Dentist 2	Wet 3	38.70

319	Etch & Rinse adhesive	W/O	Dentist 2	Wet 4	20.84
320	Etch & Rinse adhesive	W/O	Dentist 2	Wet 5	36.62
321	Etch & Rinse adhesive	W/O	Dentist 2	Moist 1	34.51
322	Etch & Rinse adhesive	W/O	Dentist 2	Moist 2	27.16
323	Etch & Rinse adhesive	W/O	Dentist 2	Moist 3	20.97
324	Etch & Rinse adhesive	W/O	Dentist 2	Moist 4	43.44
325	Etch & Rinse adhesive	W/O	Dentist 2	Moist 5	30.98
326	Etch & Rinse adhesive	W/O	Dentist 2	Dry 1	8.52
327	Etch & Rinse adhesive	W/O	Dentist 2	Dry 2	27.52
328	Etch & Rinse adhesive	W/O	Dentist 2	Dry 3	32.55
329	Etch & Rinse adhesive	W/O	Dentist 2	Dry 4	19.99
330	Etch & Rinse adhesive	W/O	Dentist 2	Dry 5	36.07
331	Etch & Rinse adhesive	W/O	Dentist 3	Wet 1	12.99
332	Etch & Rinse adhesive	W/O	Dentist 3	Wet 2	6.63
333	Etch & Rinse adhesive	W/O	Dentist 3	Wet 3	0.12
334	Etch & Rinse adhesive	W/O	Dentist 3	Wet 4	17.80
335	Etch & Rinse adhesive	W/O	Dentist 3	Wet 5	13.08
336	Etch & Rinse adhesive	W/O	Dentist 3	Moist 1	22.53
337	Etch & Rinse adhesive	W/O	Dentist 3	Moist 2	34.22
338	Etch & Rinse adhesive	W/O	Dentist 3	Moist 3	1.02
339	Etch & Rinse adhesive	W/O	Dentist 3	Moist 4	25.12
340	Etch & Rinse adhesive	W/O	Dentist 3	Moist 5	38.85
341	Etch & Rinse adhesive	W/O	Dentist 3	Dry 1	17.77
342	Etch & Rinse adhesive	W/O	Dentist 3	Dry 2	12.74
343	Etch & Rinse adhesive	W/O	Dentist 3	Dry 3	36.34
344	Etch & Rinse adhesive	W/O	Dentist 3	Dry 4	37.42
345	Etch & Rinse adhesive	W/O	Dentist 3	Dry 5	34.24
346	Etch & Rinse adhesive	W/O	Dentist 4	Wet 1	28.50
347	Etch & Rinse adhesive	W/O	Dentist 4	Wet 2	10.24
348	Etch & Rinse	W/O	Dentist 4	Wet 3	4.76



	adhesive				
349	Etch & Rinse adhesive	W/O	Dentist 4	Wet 4	5.65
350	Etch & Rinse adhesive	W/O	Dentist 4	Wet 5	3.51
351	Etch & Rinse adhesive	W/O	Dentist 4	Moist 1	0
352	Etch & Rinse adhesive	W/O	Dentist 4	Moist 2	6.97
353	Etch & Rinse adhesive	W/O	Dentist 4	Moist 3	10.74
354	Etch & Rinse adhesive	W/O	Dentist 4	Moist 4	11.45
355	Etch & Rinse adhesive	W/O	Dentist 4	Moist 5	24.77
356	Etch & Rinse adhesive	W/O	Dentist 4	Dry 1	12.03
357	Etch & Rinse adhesive	W/O	Dentist 4	Dry 2	17.40
358	Etch & Rinse adhesive	W/O	Dentist 4	Dry 3	17.57
359	Etch & Rinse adhesive	W/O	Dentist 4	Dry 4	15.60
360	Etch & Rinse adhesive	W/O	Dentist 4	Dry 5	28.45
361	Etch & Rinse adhesive	W/O	Dentist 5	Wet 1	6.31
362	Etch & Rinse adhesive	W/O	Dentist 5	Wet 2	10.90
363	Etch & Rinse adhesive	W/O	Dentist 5	Wet 3	13.36
364	Etch & Rinse adhesive	W/O	Dentist 5	Wet 4	11.62
365	Etch & Rinse adhesive	W/O	Dentist 5	Wet 5	16.96
366	Etch & Rinse adhesive	W/O	Dentist 5	Moist 1	12.08
367	Etch & Rinse adhesive	W/O	Dentist 5	Moist 2	8.08
368	Etch & Rinse adhesive	W/O	Dentist 5	Moist 3	10.91
369	Etch & Rinse adhesive	W/O	Dentist 5	Moist 4	21.93
370	Etch & Rinse adhesive	W/O	Dentist 5	Moist 5	13.14
371	Etch & Rinse adhesive	W/O	Dentist 5	Dry 1	9.19
372	Etch & Rinse adhesive	W/O	Dentist 5	Dry 2	37.96
373	Etch & Rinse adhesive	W/O	Dentist 5	Dry 3	3.09
374	Etch & Rinse adhesive	W/O	Dentist 5	Dry 4	36.70
375	Etch & Rinse adhesive	W/O	Dentist 5	Dry 5	19.39
376	Etch & Rinse adhesive	W	Dentist 1	Wet 1	4.42
377	Etch & Rinse adhesive	W	Dentist 1	Wet 2	7.32

378	Etch & Rinse adhesive	W	Dentist 1	Wet 3	4.19
379	Etch & Rinse adhesive	W	Dentist 1	Wet 4	5.90
380	Etch & Rinse adhesive	W	Dentist 1	Wet 5	4.94
381	Etch & Rinse adhesive	W	Dentist 1	Moist 1	10.78
382	Etch & Rinse adhesive	W	Dentist 1	Moist 2	7.66
383	Etch & Rinse adhesive	W	Dentist 1	Moist 3	25.48
384	Etch & Rinse adhesive	W	Dentist 1	Moist 4	25.98
385	Etch & Rinse adhesive	W	Dentist 1	Moist 5	3.68
386	Etch & Rinse adhesive	W	Dentist 1	Dry 1	6.96
387	Etch & Rinse adhesive	W	Dentist 1	Dry 2	6.24
388	Etch & Rinse adhesive	W	Dentist 1	Dry 3	7.27
389	Etch & Rinse adhesive	W	Dentist 1	Dry 4	6.18
390	Etch & Rinse adhesive	W	Dentist 1	Dry 5	18.55
391	Etch & Rinse adhesive	W	Dentist 2	Wet 1	32.30
392	Etch & Rinse adhesive	W	Dentist 2	Wet 2	39.75
393	Etch & Rinse adhesive	W	Dentist 2	Wet 3	9.99
394	Etch & Rinse adhesive	W	Dentist 2	Wet 4	2.51
395	Etch & Rinse adhesive	W	Dentist 2	Wet 5	1.44
396	Etch & Rinse adhesive	W	Dentist 2	Moist 1	18.34
397	Etch & Rinse adhesive	W	Dentist 2	Moist 2	16.32
398	Etch & Rinse adhesive	W	Dentist 2	Moist 3	24.29
399	Etch & Rinse adhesive	W	Dentist 2	Moist 4	25.42
400	Etch & Rinse adhesive	W	Dentist 2	Moist 5	6.32
401	Etch & Rinse adhesive	W	Dentist 2	Dry 1	26.02
402	Etch & Rinse adhesive	W	Dentist 2	Dry 2	13.37
403	Etch & Rinse adhesive	W	Dentist 2	Dry 3	33.66
404	Etch & Rinse adhesive	W	Dentist 2	Dry 4	20.95
405	Etch & Rinse adhesive	W	Dentist 2	Dry 5	22.61
406	Etch & Rinse adhesive	W	Dentist 3	Wet 1	17.57
407	Etch & Rinse	W	Dentist 3	Wet 2	27.50

	adhesive				
408	Etch & Rinse adhesive	W	Dentist 3	Wet 3	21.55
409	Etch & Rinse adhesive	W	Dentist 3	Wet 4	33.35
410	Etch & Rinse adhesive	W	Dentist 3	Wet 5	17.51
411	Etch & Rinse adhesive	W	Dentist 3	Moist 1	41.28
412	Etch & Rinse adhesive	W	Dentist 3	Moist 2	22.50
413	Etch & Rinse adhesive	W	Dentist 3	Moist 3	36.91
414	Etch & Rinse adhesive	W	Dentist 3	Moist 4	38.53
415	Etch & Rinse adhesive	W	Dentist 3	Moist 5	38.14
416	Etch & Rinse adhesive	W	Dentist 3	Dry 1	37.95
417	Etch & Rinse adhesive	W	Dentist 3	Dry 2	36.67
418	Etch & Rinse adhesive	W	Dentist 3	Dry 3	29.20
419	Etch & Rinse adhesive	W	Dentist 3	Dry 4	34.40
420	Etch & Rinse adhesive	W	Dentist 3	Dry 5	22.47
421	Etch & Rinse adhesive	W	Dentist 4	Wet 1	8.89
422	Etch & Rinse adhesive	W	Dentist 4	Wet 2	8.81
423	Etch & Rinse adhesive	W	Dentist 4	Wet 3	36
424	Etch & Rinse adhesive	W	Dentist 4	Wet 4	25.51
425	Etch & Rinse adhesive	W	Dentist 4	Wet 5	16.10
426	Etch & Rinse adhesive	W	Dentist 4	Moist 1	4.41
427	Etch & Rinse adhesive	W	Dentist 4	Moist 2	18.02
428	Etch & Rinse adhesive	W	Dentist 4	Moist 3	6.43
429	Etch & Rinse adhesive	W	Dentist 4	Moist 4	20.93
430	Etch & Rinse adhesive	W	Dentist 4	Moist 5	13.52
431	Etch & Rinse adhesive	W	Dentist 4	Dry 1	15.93
432	Etch & Rinse adhesive	W	Dentist 4	Dry 2	20.33
433	Etch & Rinse adhesive	W	Dentist 4	Dry 3	20.33
434	Etch & Rinse adhesive	W	Dentist 4	Dry 4	14.18
435	Etch & Rinse adhesive	W	Dentist 4	Dry 5	26.41
436	Etch & Rinse adhesive	W	Dentist 5	Wet 1	0

437	Etch & Rinse adhesive	W	Dentist 5	Wet 2	18.38
438	Etch & Rinse adhesive	W	Dentist 5	Wet 3	10.23
439	Etch & Rinse adhesive	W	Dentist 5	Wet 4	17.18
440	Etch & Rinse adhesive	W	Dentist 5	Wet 5	38.25
441	Etch & Rinse adhesive	W	Dentist 5	Moist 1	33.43
442	Etch & Rinse adhesive	W	Dentist 5	Moist 2	27.85
443	Etch & Rinse adhesive	W	Dentist 5	Moist 3	32.51
444	Etch & Rinse adhesive	W	Dentist 5	Moist 4	28.62
445	Etch & Rinse adhesive	W	Dentist 5	Moist 5	27.84
446	Etch & Rinse adhesive	W	Dentist 5	Dry 1	30.59
447	Etch & Rinse adhesive	W	Dentist 5	Dry 2	45.16
448	Etch & Rinse adhesive	W	Dentist 5	Dry 3	39.50
449	Etch & Rinse adhesive	W	Dentist 5	Dry 4	29.23
450	Etch & Rinse adhesive	W	Dentist 5	Dry 5	29.98
451	Etch & Rinse adhesive	W/O	Student 1	Wet 1	28.94
452	Etch & Rinse adhesive	W/O	Student 1	Wet 2	17.94
453	Etch & Rinse adhesive	W/O	Student 1	Wet 3	19.20
454	Etch & Rinse adhesive	W/O	Student 1	Wet 4	9.35
455	Etch & Rinse adhesive	W/O	Student 1	Wet 5	33.65
456	Etch & Rinse adhesive	W/O	Student 1	Moist 1	24.63
457	Etch & Rinse adhesive	W/O	Student 1	Moist 2	26.90
458	Etch & Rinse adhesive	W/O	Student 1	Moist 3	6.51
459	Etch & Rinse adhesive	W/O	Student 1	Moist 4	27.19
460	Etch & Rinse adhesive	W/O	Student 1	Moist 5	23.88
461	Etch & Rinse adhesive	W/O	Student 1	Dry 1	26.81
462	Etch & Rinse adhesive	W/O	Student 1	Dry 2	36.79
463	Etch & Rinse adhesive	W/O	Student 1	Dry 3	30.87
464	Etch & Rinse adhesive	W/O	Student 1	Dry 4	20.87
465	Etch & Rinse adhesive	W/O	Student 1	Dry 5	18.83
466	Etch & Rinse	W/O	Student 2	Wet 1	0

	adhesive				
467	Etch & Rinse adhesive	W/O	Student 2	Wet 2	6.07
468	Etch & Rinse adhesive	W/O	Student 2	Wet 3	3.41
469	Etch & Rinse adhesive	W/O	Student 2	Wet 4	0.26
470	Etch & Rinse adhesive	W/O	Student 2	Wet 5	4.56
471	Etch & Rinse adhesive	W/O	Student 2	Moist 1	19.83
472	Etch & Rinse adhesive	W/O	Student 2	Moist 2	7.51
473	Etch & Rinse adhesive	W/O	Student 2	Moist 3	0
474	Etch & Rinse adhesive	W/O	Student 2	Moist 4	5.23
475	Etch & Rinse adhesive	W/O	Student 2	Moist 5	6.85
476	Etch & Rinse adhesive	W/O	Student 2	Dry 1	32.08
477	Etch & Rinse adhesive	W/O	Student 2	Dry 2	29.84
478	Etch & Rinse adhesive	W/O	Student 2	Dry 3	37.42
479	Etch & Rinse adhesive	W/O	Student 2	Dry 4	34.79
480	Etch & Rinse adhesive	W/O	Student 2	Dry 5	30.06
481	Etch & Rinse adhesive	W/O	Student 3	Wet 1	30.11
482	Etch & Rinse adhesive	W/O	Student 3	Wet 2	12.43
483	Etch & Rinse adhesive	W/O	Student 3	Wet 3	8.41
484	Etch & Rinse adhesive	W/O	Student 3	Wet 4	23.20
485	Etch & Rinse adhesive	W/O	Student 3	Wet 5	8.36
486	Etch & Rinse adhesive	W/O	Student 3	Moist 1	15.65
487	Etch & Rinse adhesive	W/O	Student 3	Moist 2	12.95
488	Etch & Rinse adhesive	W/O	Student 3	Moist 3	13.41
489	Etch & Rinse adhesive	W/O	Student 3	Moist 4	8.97
490	Etch & Rinse adhesive	W/O	Student 3	Moist 5	11.62
491	Etch & Rinse adhesive	W/O	Student 3	Dry 1	36.38
492	Etch & Rinse adhesive	W/O	Student 3	Dry 2	26.74
493	Etch & Rinse adhesive	W/O	Student 3	Dry 3	19.34
494	Etch & Rinse adhesive	W/O	Student 3	Dry 4	28.41
495	Etch & Rinse adhesive	W/O	Student 3	Dry 5	21.91

496	Etch & Rinse adhesive	W/O	Student 4	Wet 1	8.08
497	Etch & Rinse adhesive	W/O	Student 4	Wet 2	20.42
498	Etch & Rinse adhesive	W/O	Student 4	Wet 3	14.21
499	Etch & Rinse adhesive	W/O	Student 4	Wet 4	7.45
500	Etch & Rinse adhesive	W/O	Student 4	Wet 5	22.93
501	Etch & Rinse adhesive	W/O	Student 4	Moist 1	23.72
502	Etch & Rinse adhesive	W/O	Student 4	Moist 2	40.27
503	Etch & Rinse adhesive	W/O	Student 4	Moist 3	26.71
504	Etch & Rinse adhesive	W/O	Student 4	Moist 4	32.16
505	Etch & Rinse adhesive	W/O	Student 4	Moist 5	9.20
506	Etch & Rinse adhesive	W/O	Student 4	Dry 1	15.05
507	Etch & Rinse adhesive	W/O	Student 4	Dry 2	41.51
508	Etch & Rinse adhesive	W/O	Student 4	Dry 3	14.46
509	Etch & Rinse adhesive	W/O	Student 4	Dry 4	13.85
510	Etch & Rinse adhesive	W/O	Student 4	Dry 5	7.10
511	Etch & Rinse adhesive	W/O	Student 5	Wet 1	25.22
512	Etch & Rinse adhesive	W/O	Student 5	Wet 2	30.19
513	Etch & Rinse adhesive	W/O	Student 5	Wet 3	7.79
514	Etch & Rinse adhesive	W/O	Student 5	Wet 4	3.80
515	Etch & Rinse adhesive	W/O	Student 5	Wet 5	0
516	Etch & Rinse adhesive	W/O	Student 5	Moist 1	11.36
517	Etch & Rinse adhesive	W/O	Student 5	Moist 2	19.96
518	Etch & Rinse adhesive	W/O	Student 5	Moist 3	16.86
519	Etch & Rinse adhesive	W/O	Student 5	Moist 4	10.46
520	Etch & Rinse adhesive	W/O	Student 5	Moist 5	12.06
521	Etch & Rinse adhesive	W/O	Student 5	Dry 1	12.76
522	Etch & Rinse adhesive	W/O	Student 5	Dry 2	4.34
523	Etch & Rinse adhesive	W/O	Student 5	Dry 3	19.76
524	Etch & Rinse adhesive	W/O	Student 5	Dry 4	28.22
525	Etch & Rinse	W/O	Student 5	Dry 5	15.32

	adhesive				
526	Etch & Rinse adhesive	W	Student 1	Wet 1	8.08
527	Etch & Rinse adhesive	W	Student 1	Wet 2	34.02
528	Etch & Rinse adhesive	W	Student 1	Wet 3	9.69
529	Etch & Rinse adhesive	W	Student 1	Wet 4	10.53
530	Etch & Rinse adhesive	W	Student 1	Wet 5	28.51
531	Etch & Rinse adhesive	W	Student 1	Moist 1	38.34
532	Etch & Rinse adhesive	W	Student 1	Moist 2	7.06
533	Etch & Rinse adhesive	W	Student 1	Moist 3	23.46
534	Etch & Rinse adhesive	W	Student 1	Moist 4	29.10
535	Etch & Rinse adhesive	W	Student 1	Moist 5	18.66
536	Etch & Rinse adhesive	W	Student 1	Dry 1	31.77
537	Etch & Rinse adhesive	W	Student 1	Dry 2	13.62
538	Etch & Rinse adhesive	W	Student 1	Dry 3	28.60
539	Etch & Rinse adhesive	W	Student 1	Dry 4	42.78
540	Etch & Rinse adhesive	W	Student 1	Dry 5	33.59
541	Etch & Rinse adhesive	W	Student 2	Wet 1	6.98
542	Etch & Rinse adhesive	W	Student 2	Wet 2	5.41
543	Etch & Rinse adhesive	W	Student 2	Wet 3	7.70
544	Etch & Rinse adhesive	W	Student 2	Wet 4	5.77
545	Etch & Rinse adhesive	W	Student 2	Wet 5	5.30
546	Etch & Rinse adhesive	W	Student 2	Moist 1	8.48
547	Etch & Rinse adhesive	W	Student 2	Moist 2	19.86
548	Etch & Rinse adhesive	W	Student 2	Moist 3	10.07
549	Etch & Rinse adhesive	W	Student 2	Moist 4	16.08
550	Etch & Rinse adhesive	W	Student 2	Moist 5	11.94
551	Etch & Rinse adhesive	W	Student 2	Dry 1	20.80
552	Etch & Rinse adhesive	W	Student 2	Dry 2	24.45
553	Etch & Rinse adhesive	W	Student 2	Dry 3	20.70
554	Etch & Rinse adhesive	W	Student 2	Dry 4	3.89

555	Etch & Rinse adhesive	W	Student 2	Dry 5	5.81
556	Etch & Rinse adhesive	W	Student 3	Wet 1	8.07
557	Etch & Rinse adhesive	W	Student 3	Wet 2	10.28
558	Etch & Rinse adhesive	W	Student 3	Wet 3	4.68
559	Etch & Rinse adhesive	W	Student 3	Wet 4	3.83
560	Etch & Rinse adhesive	W	Student 3	Wet 5	6.04
561	Etch & Rinse adhesive	W	Student 3	Moist 1	10.37
562	Etch & Rinse adhesive	W	Student 3	Moist 2	8.97
563	Etch & Rinse adhesive	W	Student 3	Moist 3	23.87
564	Etch & Rinse adhesive	W	Student 3	Moist 4	4.88
565	Etch & Rinse adhesive	W	Student 3	Moist 5	7.11
566	Etch & Rinse adhesive	W	Student 3	Dry 1	7.58
567	Etch & Rinse adhesive	W	Student 3	Dry 2	5.81
568	Etch & Rinse adhesive	W	Student 3	Dry 3	10.65
569	Etch & Rinse adhesive	W	Student 3	Dry 4	4.31
570	Etch & Rinse adhesive	W	Student 3	Dry 5	8.29
571	Etch & Rinse adhesive	W	Student 4	Wet 1	5.08
572	Etch & Rinse adhesive	W	Student 4	Wet 2	18.52
573	Etch & Rinse adhesive	W	Student 4	Wet 3	14.82
574	Etch & Rinse adhesive	W	Student 4	Wet 4	1.19
575	Etch & Rinse adhesive	W	Student 4	Wet 5	10.89
576	Etch & Rinse adhesive	W	Student 4	Moist 1	8.66
577	Etch & Rinse adhesive	W	Student 4	Moist 2	9.63
578	Etch & Rinse adhesive	W	Student 4	Moist 3	17.34
579	Etch & Rinse adhesive	W	Student 4	Moist 4	10.62
580	Etch & Rinse adhesive	W	Student 4	Moist 5	16.48
581	Etch & Rinse adhesive	W	Student 4	Dry 1	34.29
582	Etch & Rinse adhesive	W	Student 4	Dry 2	16.94
583	Etch & Rinse adhesive	W	Student 4	Dry 3	11.55
584	Etch & Rinse	W	Student 4	Dry 4	24.14



	adhesive				
585	Etch & Rinse adhesive	W	Student 4	Dry 5	35.41
586	Etch & Rinse adhesive	W	Student 5	Wet 1	7.42
587	Etch & Rinse adhesive	W	Student 5	Wet 2	9.08
588	Etch & Rinse adhesive	W	Student 5	Wet 3	14.58
589	Etch & Rinse adhesive	W	Student 5	Wet 4	10.37
590	Etch & Rinse adhesive	W	Student 5	Wet 5	17.61
591	Etch & Rinse adhesive	W	Student 5	Moist 1	8.77
592	Etch & Rinse adhesive	W	Student 5	Moist 2	4.23
593	Etch & Rinse adhesive	W	Student 5	Moist 3	21.02
594	Etch & Rinse adhesive	W	Student 5	Moist 4	19.20
595	Etch & Rinse adhesive	W	Student 5	Moist 5	13.26
596	Etch & Rinse adhesive	W	Student 5	Dry 1	10.89
597	Etch & Rinse adhesive	W	Student 5	Dry 2	8.01
598	Etch & Rinse adhesive	W	Student 5	Dry 3	27.03
599	Etch & Rinse adhesive	W	Student 5	Dry 4	9.63
600	Etch & Rinse adhesive	W	Student 5	Dry 5	10.72