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3M™ Single Bond Universal Adhesive

Technical Product Profile



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Product Description

3M™ Single Bond Universal Adhesive is a unique dental adhesive built on a trusted 3M bonding legacy. It is the single-bottle solution for all surfaces and can be used reliably in total-etch, self-etch or selective-etch mode for both direct and indirect restorations. It provides the flexibility for the clinician to choose one adhesive to use independent of their preference of technique. It bonds methacrylate-based restoratives, cement and sealant materials to dentin, enamel, glass ionomer and various indirect restorative substrates (metals, glass ceramics, alumina and zirconia) without an extra primer step. The primary use is with light cured materials—however, when used in conjunction with a separate activation solution, like 3M™ Single Bond Universal DCA Dual Cure Activator, it has the capability to also bond to self- or dual-cure composite and cement materials that rely on self-cure polymerization.

Single Bond Universal adhesive provides a strong bond to seal the dentin if used in the self-etch or total-etch mode and protects the dentin from open tubules and potential sensitivity, or as a method for reducing sensitivity for patients who are already symptomatic.

The Single Bond Universal adhesive vial incorporates a new "flip-top" cap design, which allows the user to open and dispense with one hand. Unlike the standard black, opaque vial used for most adhesives that shields the photoinitiator from all ambient light, the Single Bond Universal adhesive vial has a unique translucent orange color that allows visual inspection of the remaining contents but yet protects the adhesive by shielding the visible light absorbed by the photoinitiator.

Single Bond Universal adhesive has a very unique set of properties that include:

- Combined total-etch and self-etch bonding capability
- Uncompromising and consistent bond strengths
- High moisture tolerance to allow consistent bonding to both moist- and dry-etched dentin
- Virtually no post-op sensitivity in both total-etch and self-etch modes
- Combined primer/adhesive capability to bond to indirect substrates (metals, zirconia, alumina and glass ceramics) without a separate primer
- No refrigeration required—2-year shelf life
- Dual-cure capability with separate dual-cure activation solution

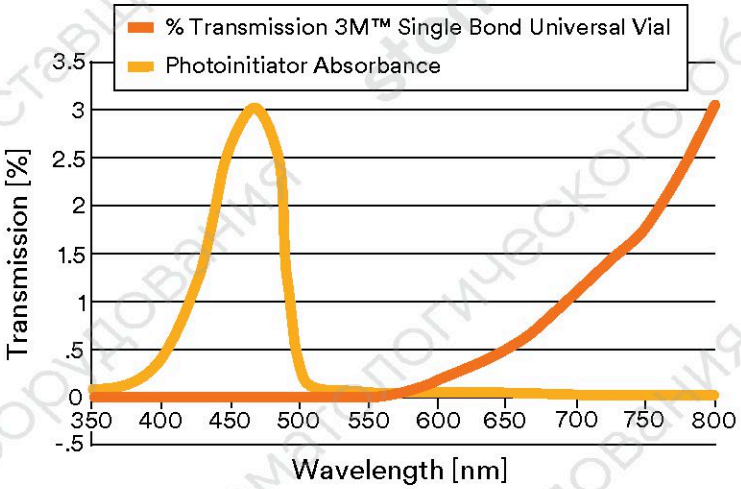


Figure 1: Light absorption of 3M™ Single Bond Universal Adhesive vial.
Source: 3M internal data



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The 3M™ Single Bond Universal Adhesive system offers the 3M™ Single Bond Universal DCA Dual Cure Activator solution as an accessory item. The adhesive can be combined with Single Bond Universal DCA to allow the capability to bond with self- or dual-cure composite, build-up and cement materials that rely on the self-cure mechanism to polymerize the material.

Single Bond Universal adhesive is the adhesive/primer to be used with the 3M™ RelyX™ Ultimate Adhesive Resin Cement. For indirect restorations with RelyX Ultimate cement, the activator is not needed. In contrast to most resin cements, RelyX Ultimate cement is based on an initiator system that incorporates the activator within the cement.

Single Bond Universal adhesive is compatible with conventional phosphoric acid etchants when utilizing the selective-etch or the total-etch bonding mechanism. However, 3M is introducing a new etchant, 3M™ Scotchbond™ Universal Etchant, which can be used when etching dentin or enamel. Scotchbond Universal etchant is 34% phosphoric acid by weight and provides enhanced handling and use features. The viscosity and distinct blue color allow for easy, consistent and controlled placement of the etchant out of the delivery syringe. The blue color also aids in confirmation of complete rinsing of the etchant from the tooth surface

Indications

- All classes of fillings (according to Black) with composite or compomer
- Cementation of veneers when combined with 3M™ RelyX™ Veneer Cement
- Root surface desensitization
- Sealing of cavities prior to cementation of amalgam restorations
- Sealing of cavities and preparations of tooth stumps prior to temporary cementation of indirect restorations
- Protective varnish for glass ionomer fillings
- Bonding of pit and fissure sealants
- Intraoral repair of existing composite, porcelain fused to metal and all ceramic restorations w/o extra primer
- Bonding of dual cure and chemical cure cements, core build-up materials and composites (with activator)
- Bonding of core build-ups made of composite or core build-up materials
- Repair of composite or compomer fillings
- Cementation of indirect restorations (crowns, inlays) of composite or compomer, ceramic and metal when combined with RelyX Ultimate cement

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Composition

The development of 3M™ Single Bond Universal Adhesive is based on trusted existing technologies currently available in 3M™ Adper™ Scotchbond™ Multi-Purpose Adhesive, 3M™ Adper™ Single Bond 2 Adhesive and 3M™ Adper™ Easy One Self-Etch Adhesive. The table below (Figure 2) shows a comparison of the compositions for Adper Single Bond 2, Adper Easy One and Single Bond Universal adhesives.

3M™ Adper™ Single Bond 2 Adhesive	3M™ Adper™ Easy One Self-Etch Adhesive	3M™ Single Bond Universal Adhesive
	MHP Phosphate Monomer	MDP Phosphate Monomer
Dimethacrylate resins	Dimethacrylate resins	Dimethacrylate resins
HEMA	HEMA	HEMA
3M™ Vitrebond™ Copolymer	Vitrebond Copolymer	Vitrebond Copolymer
Filler	Filler	Filler
Ethanol	Ethanol	Ethanol
Water	Water	Water
Initiators	Initiators	Initiators
		Silane

Figure 2: Chemistry composition comparisons.
Source: 3M internal data

Adper Single Bond 2, Adper Easy One and Single Bond Universal adhesives contain 3M™ Vitrebond™ Copolymer. Vitrebond Copolymer was first introduced with Scotchbond Multi-Purpose adhesive. During the development of the Single Bond Multi-Purpose adhesive system, it was noted that the bond strengths of other dental adhesive systems tended to decrease when under varying humidity conditions. Also during this period, it was noted that 3M™ Vitrebond™ Light Cure Glass Ionomer Liner/Base bond strengths did not seem to vary to the same degree. It was determined that incorporating the proprietary copolymer used in Vitrebond liner/base (now termed the Vitrebond Copolymer) into the 3M™ Single Bond Multi-Purpose Primer yielded a system that was very resistant to the detrimental effects of varying humidity (Fundingsland et al, 1992). Since then, Vitrebond Copolymer has also been utilized in 3M™ RelyX™ Luting Plus Cement, 3M™ Vitremer™ Core Buildup/Restorative, Adper Single Bond 2 adhesive, Adper Easy One adhesive and now Single Bond Universal adhesive.

Adper Easy One and Single Bond Universal adhesives differ from Adper Single Bond 2 adhesive primarily in the partial replacement of the methacrylate monomers (UDMA and GDMA) with the phosphorylated methacrylate monomers (MHP or MDP) to allow the acidity for the self-etching capability.

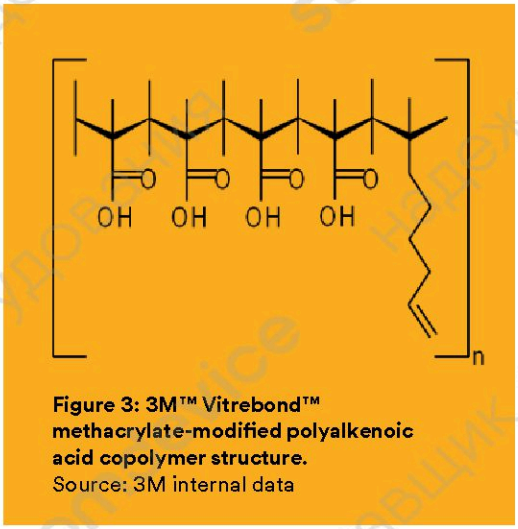


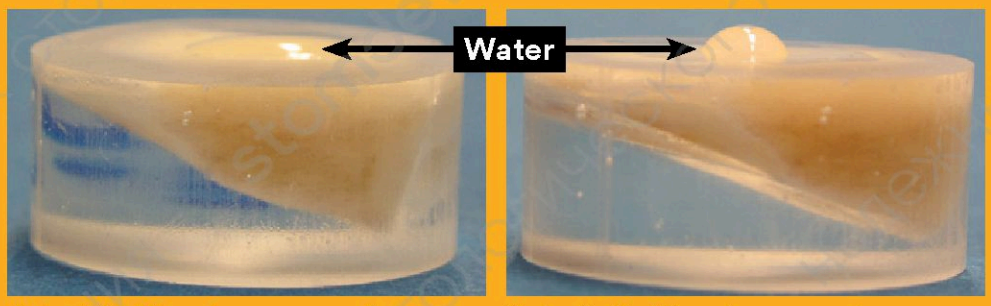
Figure 3: 3M™ Vitrebond™ methacrylate-modified polyalkenoic acid copolymer structure.
Source: 3M internal data

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When 3M™ Adper™ Easy One Self-Etch Adhesive was developed, it was based on the chemistry of the 3M™ Adper™ Single Bond 2 Adhesive formulation and the addition of the phosphorylated monomers to allow for the self-etching properties. The primary difference between the 3M™ Single Bond Universal Adhesive and Adper Easy One adhesive is a change in the phosphorylated monomers used in the two systems and the addition of silane. The Adper Easy One adhesive formulation uses methacryloxyhexyl phosphate (MHP) where Single Bond Universal adhesive uses methacryloxydecyl phosphate (MDP). The MDP allows for better adhesion performance to enamel, greater product stability and adhesion to metal and non-glass ceramic substrates. The addition of the silane allows for adhesion to glass-ceramic surfaces without the need for a separate primer.

The combination of the Single Bond Universal adhesive components provides for a high degree of conversion and more hydrophobic properties upon polymerization. Prior to curing and during application, Single Bond Universal adhesive is hydrophilic for optimum wetting of the tooth structure. After drying and curing, Single Bond Universal adhesive exhibits a high degree of conversion and is hydrophobic for a long-lasting bond. This hydrophilic and hydrophobic nature of Single Bond Universal adhesive is illustrated in Figure 4. One drop of water was placed on an uncured adhesive sample of Single Bond Universal adhesive, as shown in the left photo illustrating the hydrophilic nature of Single Bond Universal adhesive. The photo on the right shows one drop of water on a light cured sample of Single Bond Universal adhesive illustrating the hydrophobic nature after curing.



Hydrophilic: Water drop on uncured 3M™ Single Bond Universal Adhesive.

Hydrophobic: Water drop on cured 3M™ Single Bond Universal Adhesive.

Figure 4: Demonstration of hydrophilic and hydrophobic properties.
Source: 3M internal data

Irrespective of the substrate, Single Bond Universal adhesive exhibits a high degree of conversion at the interface, as shown in a study by Professor Lorenzo Breschi—University of Trieste, Italy (Figure 5).

Adhesive	Substrate	Degree of Conversion (%)
Prime & Bond® NT™	Etched dentin	66a +/-13
3M™ Adper™ Easy One Self-Etch Adhesive	Smear layer	92b +/-10
3M™ Adper™ Easy One Self-Etch Adhesive	Etched dentin	89b +/-8
3M™ Single Bond Universal Adhesive	Smear layer	85b +/-5
3M™ Single Bond Universal Adhesive	Etched dentin	83b +/-4

Figure 5: Dr. Lorenzo Breschi, University of Trieste, Italy. Degree of conversion.

Like Adper Single Bond 2 and Adper Easy One adhesives, Single Bond Universal adhesive contains an ethanol/water-based solvent system. In contrast to acetone, ethanol is less volatile and helps maintain a consistent viscosity and handling while the product is in use. At the same time, the solvent system of Single Bond Universal adhesive, in combination with the rest of the formulation, was optimized to avoid phase separation while the adhesive is applied.

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3M™ Single Bond Universal DCA Dual Cure Activator



The 3M™ Single Bond Universal DCA Dual Cure Activator consists of sodium toluene sulfinate and ethanol. When the activator is mixed with 3M™ Single Bond Universal Adhesive, it allows for bonding to self- and dual-curing core build-up, composite and cement materials that rely on the self-cure mechanism for polymerizing the material.

3M™ Scotchbond™ Universal Etchant

3M™ Scotchbond™ Universal Etchant is available for the selective enamel-etch and total-etch placement modes. Single Bond Universal adhesive etchant superficially demineralizes the enamel and dentin in preparation for bonding. The etchant is 34% phosphoric acid by weight and has a pH of approximately 0.1. The viscosity of the phosphoric acid gel etchant is modified with fumed silica and a water-soluble polymer. Scotchbond Universal etchant has a distinct blue color to assist in complete rinsing away of the etchant in order to avoid remnants of fumed silica or phosphoric acid on the prepared tooth surface.



Summary of 3M™ Single Bond Universal Adhesive—Unique Chemistry Powered by "VMS" Technology

V **3M™ Vitrebond™ Copolymer**

- Provides more consistent bond performance to dentin under varying moisture levels

M **MDP monomer instead of MHP**

- Monomer that provides self-etching properties
- Higher enamel bond strength
- Higher bond strength to zirconia, alumina, metals
- Higher hydrolytic stability—no refrigeration needed

S **Silane**

- Allows the adhesive to chemically bond to glass ceramic surfaces without using a separate ceramic primer

Ethanol/water-based solvent system

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Mechanism of Adhesion

Total-Etch Systems

For total-etch systems (4th and 5th generation), a phosphoric acid etching step is utilized to modify both the dentin and enamel surfaces to allow penetration of the adhesives into the tooth surfaces and achieve a mechanical bond. Phosphoric acid is considered a strong acid with an approximate pH of less than 0.5. It is very effective in dissolving the smear layer and the mineral within the collagen matrix of the dentin and the mineral of the enamel to expose the prismatic crystal structure. On enamel, the phosphoric acid treatment allows for very effective and consistent bonding to both the uncut and cut (prepared) surfaces. Dentists have relied on this high enamel bond integrity to prevent microleakage, marginal degradation and staining. On dentin, the phosphoric acid treatment completely removes the smear layer, leaving the dentin tubules open and exposed. The collagen matrix is also demineralized. In this situation, it is imperative to completely seal the tubules to prevent sensitivity, and, for some systems, the demineralized collagen should be kept moist to prevent the collapse of the collagen fibers and subsequent reduction in bond strength.

Self-Etch Systems

For self-etch systems (6th and 7th generation), the acidity stems from the addition of acidic monomers. Typically, these compounds bear carboxylic or phosphoric acid groups and achieve creation of a mechanical retention pattern by etching the tooth structure and chemical bonding by complex formation with the calcium ions present at the tooth. Their acidity varies considerably and can be significantly less than that of phosphoric acid. When applied onto the tooth surface, the acidic adhesive will demineralize and penetrate into the surface simultaneously. It is not rinsed away to leave the dentin tubules open and exposed. They remain sealed. The adhesive is then air dried and light cured. On dentin, this has clear advantages: the danger of overetching, overdrying of the etched dentin and occurrence of post-operative sensitivity is greatly reduced compared to total-etch adhesives. However, on the enamel surfaces, this reduced acidity can lead to a less pronounced etch pattern compared to phosphoric acid, especially on unprepared or uncut surfaces. Therefore, most self-etch adhesive systems require the incorporation of a separate phosphoric acid etch of these uncut enamel surfaces prior to applying the self-etch adhesives. Self-etch adhesives with a pH < 2 are classified as “strong” self-etch adhesives, whereas those with a pH > 2 are classified as “mild.” Mild self-etch adhesives are preferred over strong ones because they still provide for a strong bond to dentin, however their formulations are less hydrophilic and therefore less prone to undergo hydrolytic degradation, leading to improved shelf life and improved longevity of the restoration.

With the mild self-etch adhesive systems, including 3M™ Adper™ Easy One Self-Etch Adhesive, a “selective” enamel etch technique is often used and recommended on the enamel (cut and uncut) surfaces to maximize the adhesion to the more highly mineralized enamel. The dentin is not etched to take advantage of the self-etch properties on less mineralized dentin, leaving the surface sealed and offering protection from potential sensitivity.

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3M™ Single Bond Universal Adhesive

3M™ Single Bond Universal Adhesive offers the unique advantage that it can be used in a self-etch mode, selective enamel-etch mode or in a total-etch mode for both direct and indirect dental restorative procedures and provides uncompromised and consistent bond strengths. The microscopic images in this section provide insight into the self-etch, selective-etch and total-etch bonding mechanism of Single Bond Universal adhesive.

Self-Etch Mechanism

The Single Bond Universal adhesive chemistry utilizes phosphorylated monomers in an aqueous solution that provide acidity and allow the adhesive bond to dentin and cut enamel without the use of a separate phosphoric acid etching step, which therefore allows it to be considered self-etching. This is the same basic chemistry and process for 3M™ Adper™ Easy One Self-Etch Adhesive. The self-etching simplifies the technique and provides protection to the dentin surface to reduce the potential for post-operative sensitivity. Figure 6 shows the distinct enamel etch patterns of Single Bond Universal adhesive in the self-etch mode. The distinct formation of the hybrid layer and resin tags of Single Bond Universal adhesive in the self-etch mode is apparent in Figures 7 and 8.

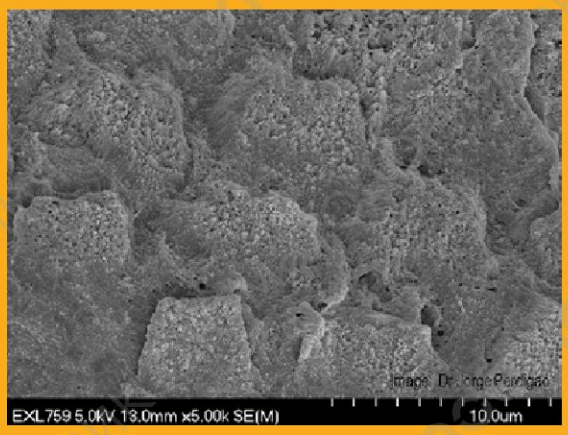


Figure 6: Dr. J. Perdigao, University of Minnesota School of Dentistry. SEM of 3M™ Single Bond Universal Adhesive to cut enamel in self-etch mode.

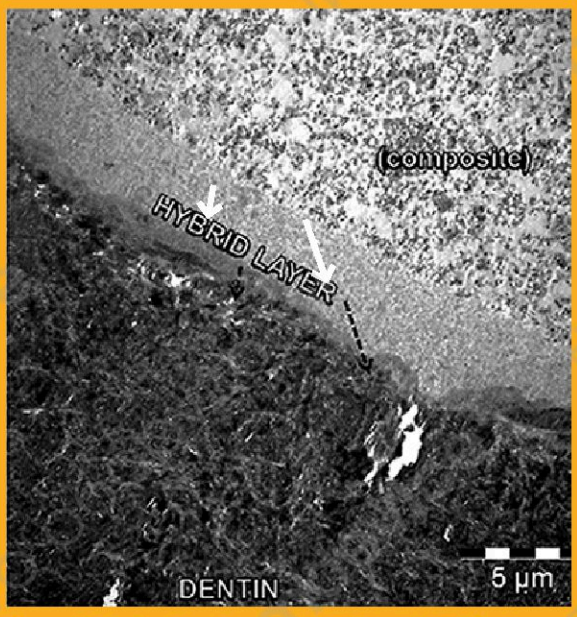


Figure 7: Dr. Bart Van Meerbeek. TEM of 3M™ Single Bond Universal Adhesive to dentin in self-etch mode.

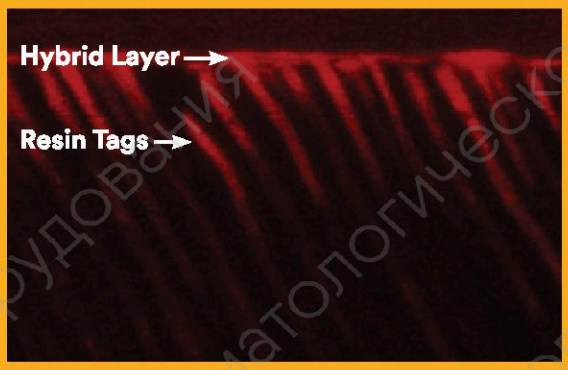


Figure 8: Dr. Mario de Goes, University of Campinas. Confocal Laser Scan image of 3M™ Single Bond Universal Adhesive to dentin in self-etch mode showing hybrid layer and resin tags.

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Selective-Etch Mechanism

The pH of 3M™ Single Bond Universal Adhesive is 2.7 and considered to be a mild self-etch adhesive. With the higher pH of mild self-etch adhesives compared to phosphoric acid, some dentists prefer to still utilize a phosphoric acid etch on the cut and uncut enamel surfaces. This is commonly referred to as "selective" enamel etching, which will be supported and recommended with Single Bond Universal adhesive. When incorporating the "selective enamel etch" with a self-etch adhesive, the etchant is isolated to the enamel, leaving the dentin intact. Therefore, the clinician can maximize the enamel bond strength and take advantage of the low post-op sensitivity feature that the self-etch adhesive provides for on the dentin and still achieve a strong bond to dentin. One concern that a clinician may have with the selective enamel etch is whether they can isolate the etchant to the enamel and not inadvertently etch the dentin in the process. If this occurs, the adhesive must properly infiltrate and wet the etched dentin for thorough sealing and to ensure high bonding and sensitivity prevention. Some self-etch adhesives may have reduced performance when bonding to etched dentin surfaces. The carefully balanced formulas of both 3M™ Adper™ Easy One Self-Etch Adhesive and Single Bond Universal adhesive containing the 3M™ Vitrebond™ Copolymer, HEMA and water allow for high and consistent bonding to etched dentin surfaces, even if the dentin surface is accidentally dried. Numerous adhesion studies have been conducted to support this, as well as SEM/TEM studies showing that there is a uniform hybrid layer with resin on moist or dry etched dentin. Together, with the high moisture tolerance and robustness and its high degree of polymerization at the tooth interface, Single Bond Universal adhesive leads to virtually no post-operative sensitivity in self-etch and total-etch modes.

Total-Etch Mechanism

Some clinicians prefer to bond to the tooth surface with a total-etch approach where both the enamel and dentin surfaces are directly etched with the phosphoric acid. Typically after a 15-second application, the phosphoric acid is then rinsed to remove any residual acid and the dissolved mineral from the enamel and dentin. This leaves a very well-defined etched enamel surface (Figure 9) and also completely removes the smear layer from the dentin surface, as well as mineral within the collagen network on the dentin surface. The total-etch approach allows for a thicker hybrid layer to be formed, which some clinicians prefer. The TEM by Dr. Bart Van Meerbeek (Figure 10) and the Confocal Laser Scan image by Dr. Mario de Goes (Figure 11) illustrate the well-defined hybrid layer and resin tags with Single Bond Universal adhesive to dentin in the total-etch mode.

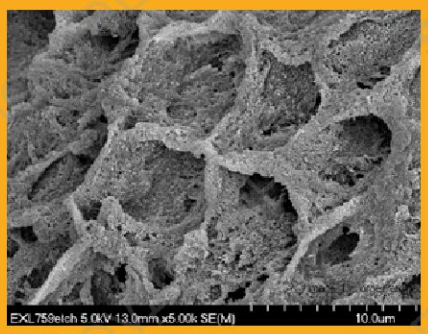


Figure 9: Dr. J. Perdigao, University of Minnesota School of Dentistry. SEM of 3M™ Single Bond Universal Adhesive interface to etched cut enamel.



Figure 10: Dr. Bart Van Meerbeek. SEM of 3M™ Single Bond Universal Adhesive to dentin in total-etch mode showing the adhesive film thickness to be in range of 5–10 microns.

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3M™ Single Bond Universal Adhesive



Figure 11: Dr. Mario de Goes, University of Campinas. Confocal Laser Scan image of 3M™ Single Bond Universal Adhesive to dentin in total-etch mode.

3M™ Adper™ Single Bond 2 Adhesive

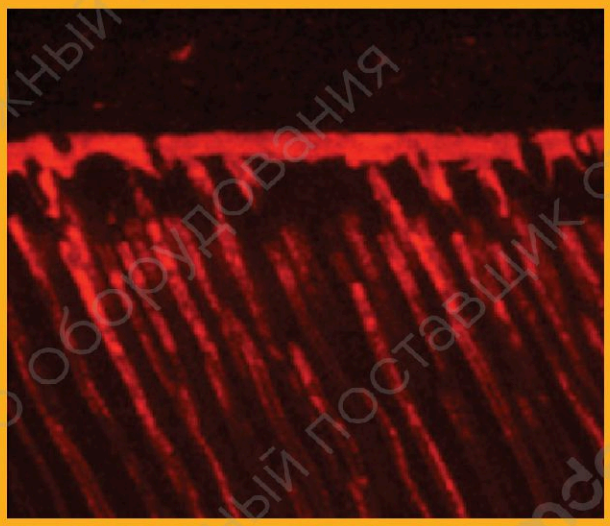


Figure 12: Dr. Mario de Goes, University of Campinas. Confocal Laser Scan image of 3M™ Adper™ Single Bond 2 Adhesive to dentin.

This adhesion method can be technique-sensitive for the 5th-generation adhesives due to the fact the dentin surface must be kept moist after etching to prevent the collapse of the unsupported collagen fiber network. If kept moist, the collagen network will remain intact and the adhesive can be applied or infiltrated to form a well-defined hybrid layer along with resin tags within the tubules. If the dentin surface is dried, the collagen network collapses and does not allow for a proper hybrid layer to be formed with the resin tags and, thus, results in a reduced and compromised bond to the dentin, which can lead to decreased performance and an increase in the potential for sensitivity. The primary reason for the technique sensitivity is that the formulations of the 5th-generation adhesives have limited or no water available to reverse the collapse of the collagen. Water and other components can act to rehydrate the collagen and allow for the formation of a proper hybrid layer if the dentin was dried after etching.

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As mentioned above, the chemistry of 3M™ Single Bond Universal Adhesive that includes water, HEMA and the 3M™ Vitrebond™ Copolymer allows it to provide high and consistent bond performance to etched enamel and dentin in the total-etch technique. The unique chemistry will provide consistent performance to etched dentin whether it is kept moist as recommended or dry. The SEMs of Single Bond Universal adhesive to etched moist dentin (Figure 13) and etched dry dentin (Figure 14) illustrate the distinct formation of the hybrid layer and resin tags. This is a major advantage compared to typical 5th-generation or two-step etch-and-rinse systems that require the dentin surface to be moist or result in reduced bond strength and potential sensitivity if the dentin surface is dried prior to the application of the adhesive.

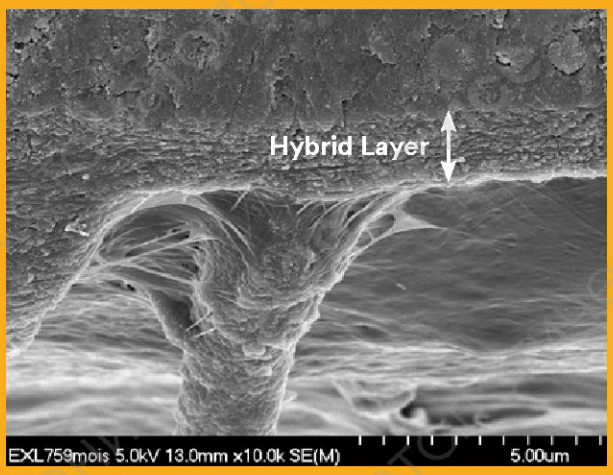


Figure 13: Dr. J. Perdigao, University of Minnesota School of Dentistry. SEM of 3M™ Single Bond Universal Adhesive to etched moist dentin.

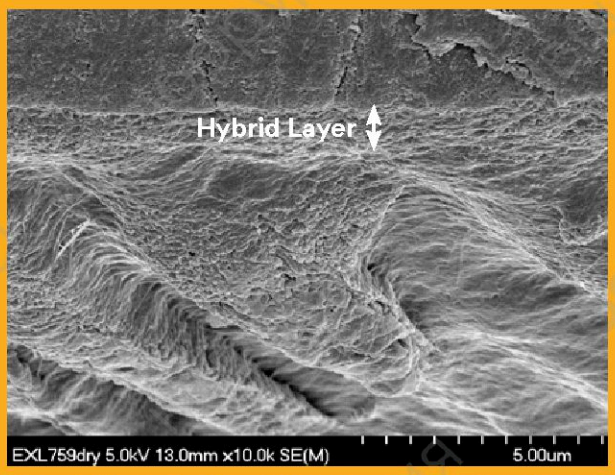


Figure 14: Dr. J. Perdigao, University of Minnesota School of Dentistry. SEM of 3M™ Single Bond Universal Adhesive to etched dry dentin.

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The hybrid layer and resin tag formation of 3M™ Single Bond Universal Adhesive to moist dentin is similar to a typical 5th-generation adhesive, however, when a typical 5th-generation adhesive is applied to a dried dentin surface, the hybrid layer is not visible (Figure 15).

Bonding to Indirect Substrates

Single Bond Universal adhesive utilizes the MDP (methacryloxydecyl phosphate) monomer, as well as incorporates silane into the chemistry. The MDP monomer has been shown to have the ability to bond to zirconia and alumina ceramic surfaces as well as to metals. The silane component allows the adhesive to bond to glass containing ceramic materials used for indirect restorations. These two components will allow the Single Bond Universal adhesive to be used as a bonding agent to these substrates without the need to incorporate a separate ceramic or metal primer prior to the placement of the adhesive. This will simplify the techniques for the intraoral repair of damaged indirect restorations, as well as the priming of indirect restorations prior to cementation.

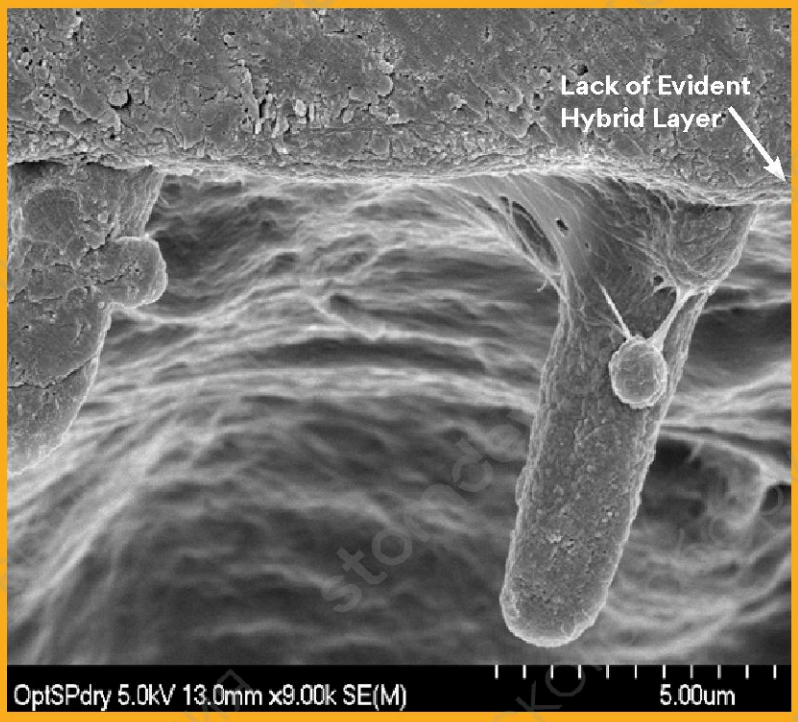


Figure 15: Dr. J. Perdigao, University of Minnesota School of Dentistry. SEM of Optibond Solo Plus Adhesive on etched dry dentin.

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Virtually No Post-Operative Sensitivity

120 dentists from Germany, Great Britain, Italy, France and Switzerland clinically evaluated 3M™ Single Bond Universal Adhesive. During the evaluation, dentists placed 3,467 total-etch restorations, 1,544 selective enamel-etch restorations and 3,495 self-etch restorations. After evaluating, the dentists completed a questionnaire to report their experience with the use of this product.

Out of the 120 dentists, only 5 indicated experiencing sensitivity with some patients during the evaluation. The number of patients experiencing sensitivity for the various treatment types were 14 total-etch, 0 selective-etch and 2 self-etch. Of these 16 cases, the dentists stated that 2 were very close to the pulp, 2 had prior sensitivity and 1 had other issues.

Based on the feedback from this evaluation, the calculated sensitivity rates for each treatment type is as follows: 0.4% for total-etch, 0.0% for selective-etch and 0.06% for self-etch.

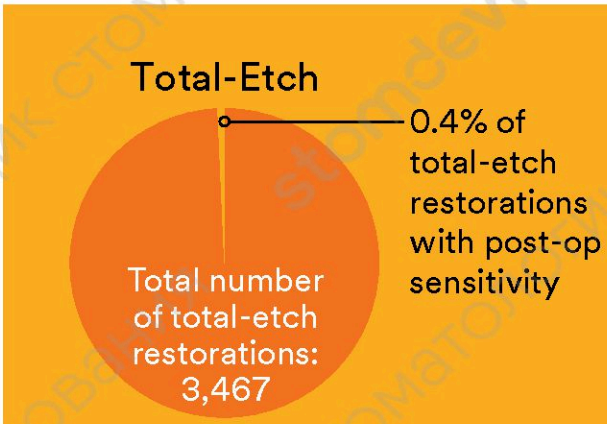


Figure 16: Field evaluation—0.4% post-op sensitivity in total-etch mode.
Source: 3M internal data

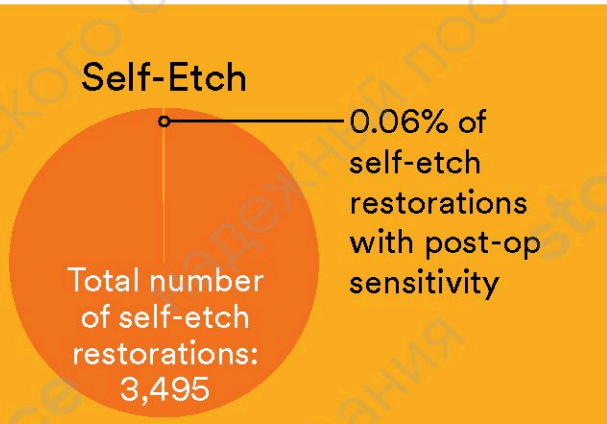


Figure 17: Field evaluation —0.06% post-op sensitivity in self-etch mode.
Source: 3M internal data

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Internal and External In Vitro Studies

3M™ Single Bond Universal Adhesive is a very unique and simple-to-use adhesive that offers the dentist the flexibility to use one single adhesive in a variety of application methods and achieve high and consistent bond strengths. The data in this section will show that Single Bond Universal adhesive bonds to enamel, dentin, glass ceramic, zirconia, noble and non-precious alloys and composites without an additional primer. The data will also show that Single Bond Universal adhesive provides high levels of adhesion to dentin in both the self-etch mode, if the dentin is accidentally or intentionally etched as a result of the selective- or total-etch process, and on dentin that has been etched and left moist or dry. Additionally, the data will show that Single Bond Universal adhesive bonds pit and fissure sealants without etching, that Single Bond Universal adhesive is dual-cure compatible and that Single Bond Universal adhesive can be used to prime restoration surfaces prior to the application of 3M™ RelyX™ Ultimate Adhesive Resin Cement and composite cements

Adhesion to Dentin and Enamel

The adhesion to enamel will be shown in a variety of methods. For self-etching materials, it is important to show the adhesion performance to both the uncut and the instrument-prepared (cut) enamel surfaces. The uncut enamel surfaces are more mineralized and typically require an additional phosphoric acid etching step prior to the placement of the adhesive. The cut or prepared surface has the harder outer surface removed and can be easily treated in the self-etch mode. Alternatively, a “selective” enamel-etch technique is recommended as an option to enhance the enamel bond strength if desired.

The adhesion to dentin surfaces and the ability to seal the dentin is also the mechanism for providing desensitizing properties for the adhesive. This can be done directly on patients who are currently experiencing sensitivity due to open tubules. The adhesive can be applied to bond and seal the exposed tubules, thus reducing, if not eliminating, the sensitivity. This technique also applies for tooth surfaces that have been prepared for amalgam placement and for indirect restorations. The adhesives can be applied to the dentin surfaces to adhere to and seal the surface prior to the impression and temporization process. This prevents a potential sensitivity situation from arising when the patient has the final restoration seated at a later time. The adhesion data and SEM images of the sealed dentin support this indication. Figures 18 and 19 illustrate the performance of Single Bond Universal adhesive compared to products in the 5th- and 7th-generation categories.

Self-Etch Bond Strength—3M™ Single Bond Universal Adhesive vs. Competition

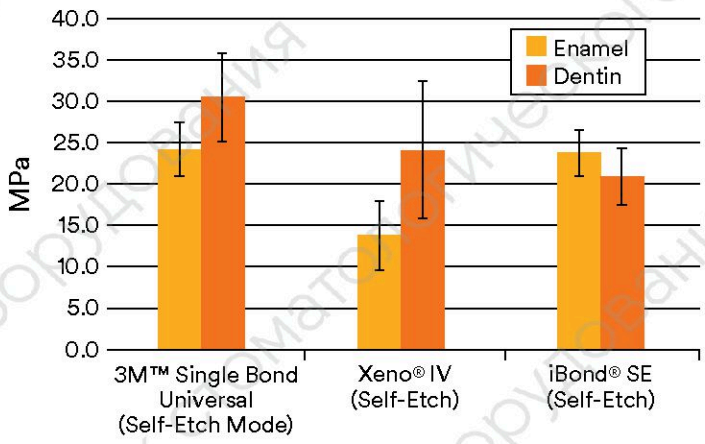


Figure 18: 24-hour shear bond strength data showing adhesion to dentin and cut enamel in the self-etch mode for 3M™ Single Bond Universal Adhesive and two competitors in the 7th-generation or one-bottle self-etch category. Source: 3M internal data

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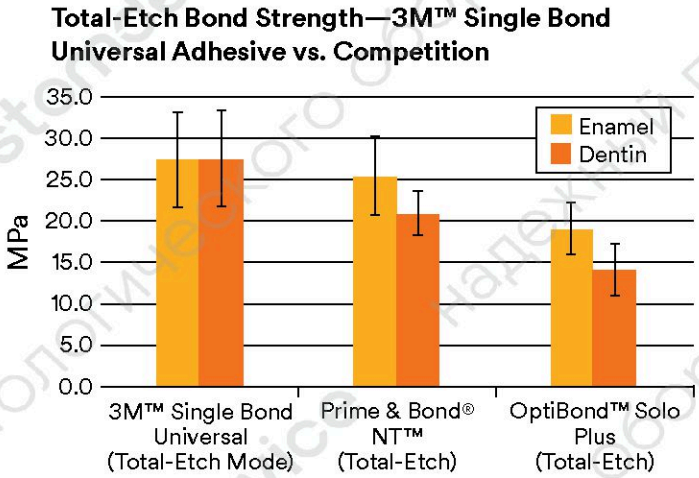


Figure 19: 24-hour shear bond strength data showing adhesion to dentin and cut enamel in the total-etch mode for 3M™ Single Bond Universal Adhesive and two competitors in the 5th-generation or two-step etch-and-rinse category. Source: 3M internal data

The 7th-generation category is also called the one-bottle self-etch category and includes 3M™ Adper™ Easy One Self-Etch Adhesive, iBond SE and Xeno IV. The 5th-generation category is also called the two-step etch-and-rinse category and includes 3M™ Adper™ Single Bond 2 Adhesive, Optibond Solo Plus and Prime & Bond NT. 3M™ Single Bond Universal Adhesive performs equivalently, if not better, than the leading products in those categories.

The bond strength durability of Single Bond Universal adhesive to dentin, cut enamel and uncut enamel is shown in Figure 20.

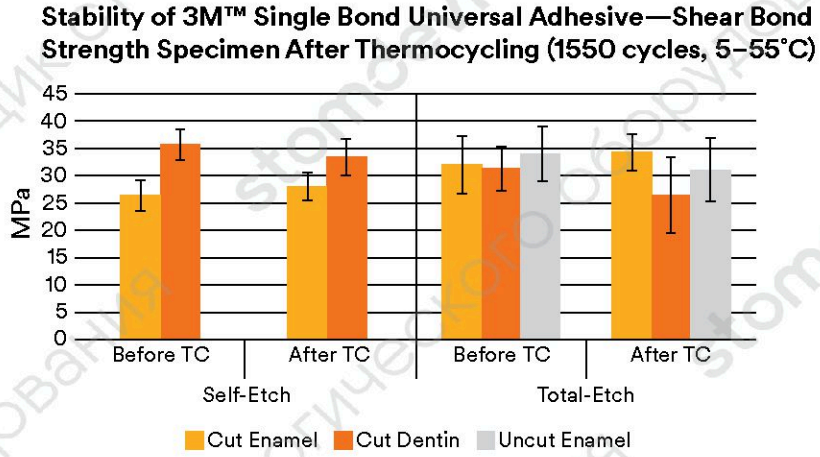


Figure 20: 24-hour and thermocycled shear bond strength data showing stressed adhesion performance to dentin, cut enamel and uncut enamel in both the self-etch and total-etch mode.
Source: 3M internal data

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Figures 21 and 22 show data generated by Dr. John Burgess at the University of Alabama. The charts show shear bond strength at 24 hours. 3M™ Single Bond Universal Adhesive was compared directly to 3M™ Adper™ Easy One Self-Etch Adhesive in the self-etch mode to dentin and cut enamel. Single Bond Universal adhesive was compared to 3M™ Adper™ Single Bond 2 Adhesive in the total-etch mode to cut enamel and dentin.

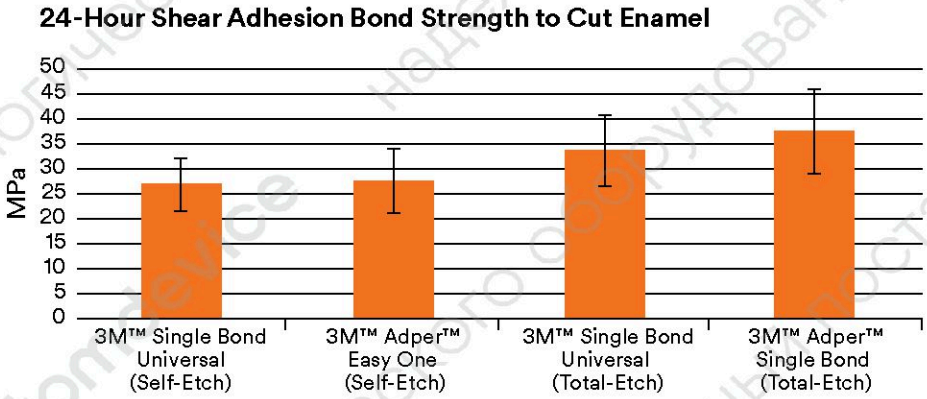


Figure 21: Dr. Burgess, University of Alabama. 24-hour shear bond strength data showing performance to cut enamel in the self-etch mode and the total-etch mode.
Source: 3M internal data

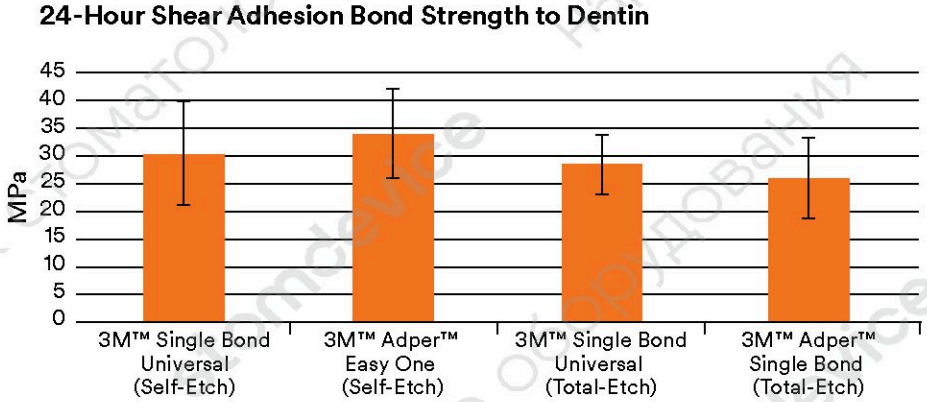


Figure 22: Dr. Burgess, University of Alabama, Birmingham. 24-hour shear bond strength data showing performance to dentin in the self-etch and the total-etch mode.
Source: 3M internal data

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Dr. Mario de Goes, University of Campinas, conducted a study to evaluate the bond strength of one-step self-etching adhesives on pre-etched dentin and interface bond morphology. The dentin pre-etched using phosphoric acid did not affect the bonding strength of one-step self-etching adhesives (Figure 23).

Microtensile Bond Strength of Pre-Etching Dentin for One-Step Self-Etching Adhesives

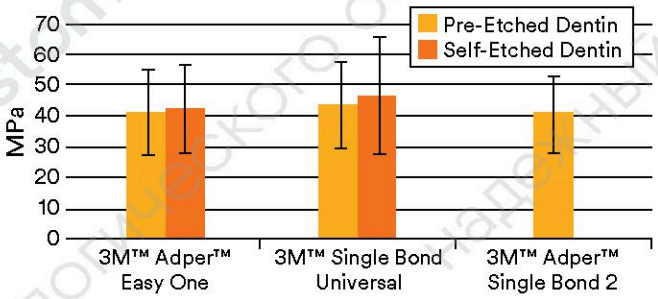


Figure 23: Dr. Mario de Goes, University of Campinas. Microtensile bond strength of pre-etching dentin for one-step self-etching adhesives.
Source: 3M internal data

The results of a study by Dr. Nara, Nippon Dental University (Figures 24 and 25), show that self-etch bond strengths are similar to Clearfil SE and that bond strength to abrasion lesion dentin is similar to that of sound dentin or enamel.

Immediate Tensile Bond Strength to Human Enamel and Dentin

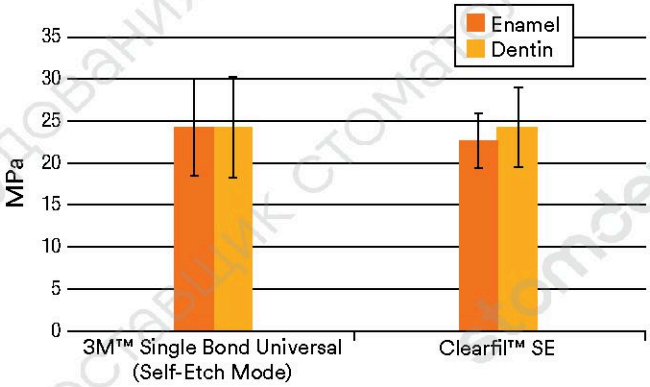


Figure 24: Dr. Nara, Nippon Dental University. Immediate tensile bond strength of 3M™ Single Bond Universal Adhesive to human enamel and dentin.
Source: 3M internal data

Immediate Tensile Bond Strength of 3M™ Single Bond Universal Adhesive Self-Etch to Sound Enamel, Sound Dentin and Abrasion Lesion Dentin

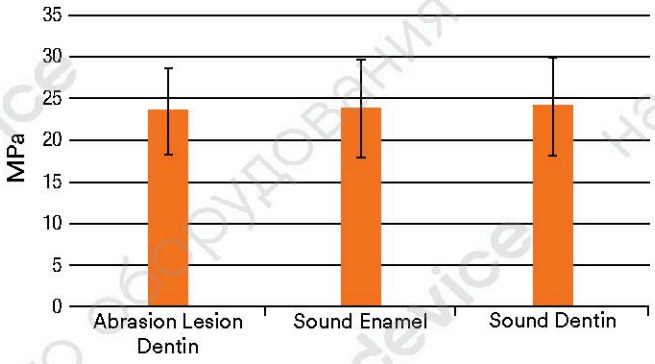


Figure 25: Dr. Nara, Nippon Dental University. Immediate tensile bond strength of 3M™ Single Bond Universal Adhesive in self-etch mode to sound enamel, sound dentin and abrasion lesion dentin.
Source: 3M internal data

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Adhesion to Etched Dentin (Moist and Dry Conditions)

The data will show that 3M™ Single Bond Universal Adhesive performs well on dentin that has been etched and left either moist or dry. This is a major benefit of Single Bond Universal adhesive compared to the traditional 5th-generation total-etch adhesives, which require that the dentin surface be kept moist following etching. If drying occurs and the collagen fibers collapse, there is not sufficient water and hydrating components in the adhesive to overcome the collagen collapse and subsequent poor bond strengths can occur, which often can lead to post-operative sensitivity for the patient. Single Bond Universal adhesive performs well in the self-etch mode, etched/moist mode and etched/dry mode. Figure 26 shows the performance of Single Bond Universal adhesive on dentin and cut enamel in moist and dry conditions using 3M™ Adper™ Single Bond 2 Adhesive as a control.

Shear Bond Strength of Etched Moist and Dry Dentin and Enamel Surfaces

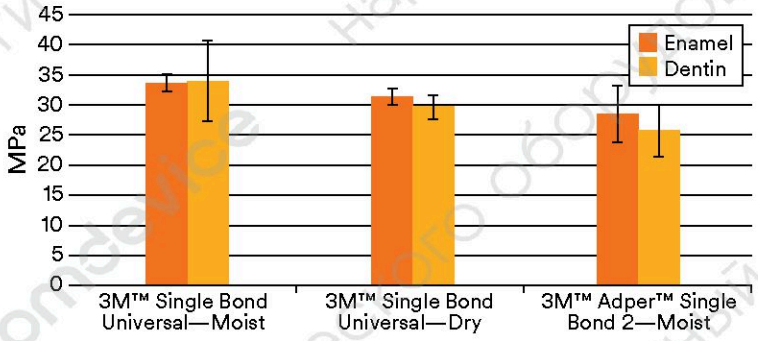


Figure 26: 24-hour shear bond strength data showing performance to dentin and cut enamel in etched moist/dry conditions.
Source: 3M internal data

Figure 27 shows the contribution of 3M™ Vitrebond™ Copolymer on the performance to etched and dry dentin with Single Bond Universal adhesive. Vitrebond Copolymer is a 3M proprietary polyalkenoic acid copolymer that enhances the wetting characteristics of the adhesive onto the dentin surface. It is present in 3M™ Scotchbond™ Multi-Purpose Dental Adhesive, Adper Single Bond 2 adhesive and 3M™ Adper™ Easy One Self-Etch Adhesive, as well as the majority of 3M resin-modified glass ionomer materials. The Single Bond Universal adhesive formulation contains 1 to 5% of the copolymer. This aids in reducing the technique sensitivity, provides for more consistent performance and reduces potential for post-op sensitivity as shown earlier in the "Virtually No Post-Operative Sensitivity" section.

Bond Strength to Dry Etched Dentin: Dependency on 3M™ Vitrebond™ Copolymer Content

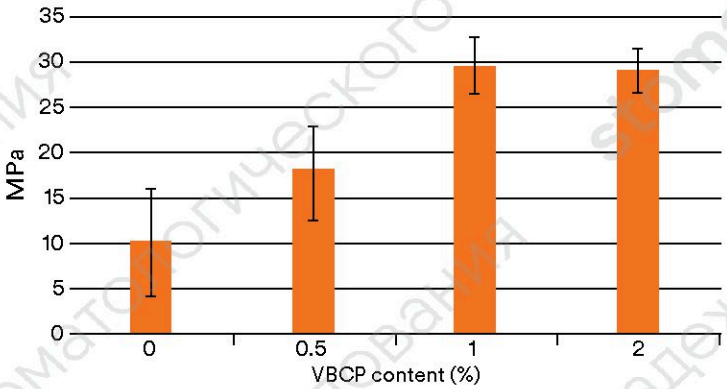


Figure 27: 24-hour shear bond strength data showing the contribution of the 3M™ Vitrebond™ Copolymer to enhance the adhesion performance of 3M™ Single Bond Universal Adhesive to etched and dried dentin.
Source: 3M internal data

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Figures 28 and 29 illustrate the technique versatility of 3M™ Single Bond Universal Adhesive and its ability to bond to etched dentin in both moist and dry conditions. Figure 28 is data generated by Dr. Gerry Kugel at Tufts University and highlights the dentin performance of Single Bond Universal adhesive compared to Prime & Bond NT. Figure 29 is data generated by Dr. J. Perdigao at the University of Minnesota and highlights the performance of Single Bond Universal adhesive compared to dentin in the self-etch mode, and to moist and dry dentin in the total-etch mode.

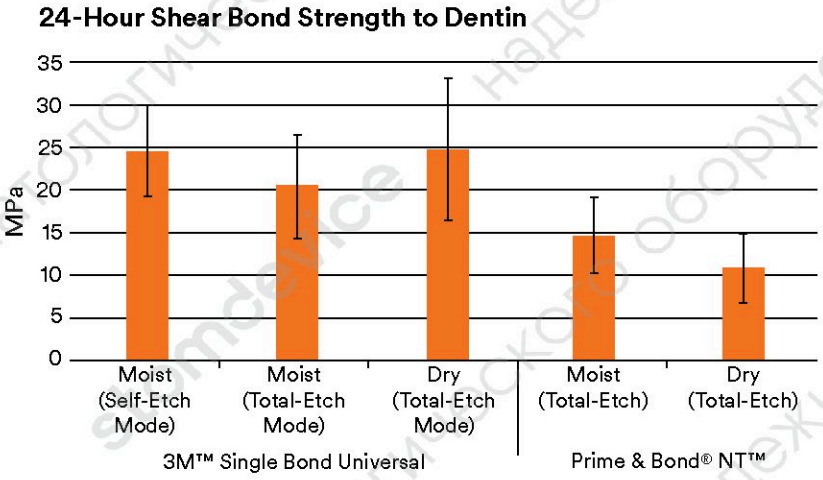


Figure 28: Dr. Kugel, Tufts University. 24-hour shear bond strength to etched moist and dry dentin in comparison to leading total-etch adhesive.
Source: 3M internal data

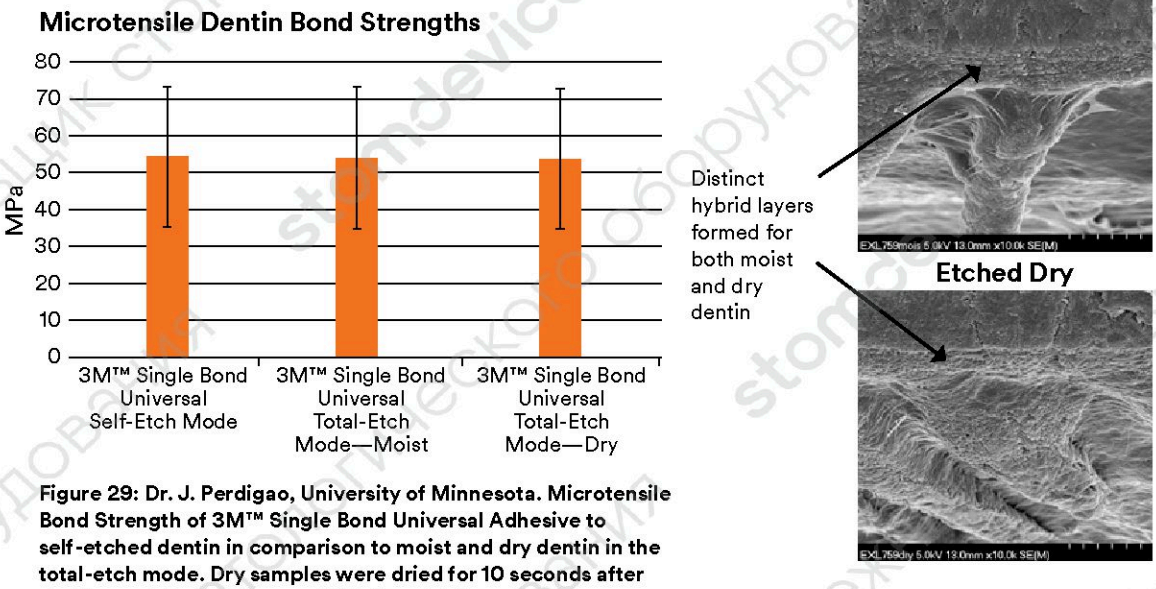


Figure 29: Dr. J. Perdigao, University of Minnesota. Microtensile Bond Strength of 3M™ Single Bond Universal Adhesive to self-etched dentin in comparison to moist and dry dentin in the total-etch mode. Dry samples were dried for 10 seconds after etching and rinsing. Source: 3M internal data

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Adhesion to Saliva-Contaminated Enamel and Dentin

Another common clinical concern is the ability to adequately isolate the prepared tooth surface from saliva contamination. It is very important to try and maintain a clean and isolated bonding surface, however, if the adhesive system could be tolerant to a slight amount of saliva contamination prior to the adhesive placement, that would be very beneficial clinically. 3M™ Single Bond Universal Adhesive is tolerant to slight/moderate saliva contamination prior to adhesive application (Figure 30).

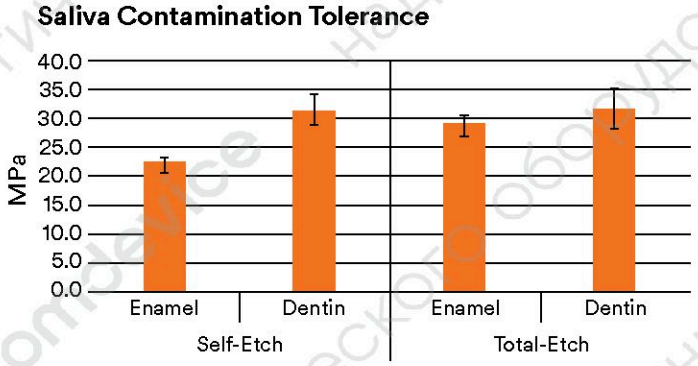


Figure 30: Shear bond strength of 3M™ Single Bond Universal Adhesive. Tooth surface wetted with human saliva immediately before adhesive application. Source: 3M internal data

Adhesion to Various Indirect Substrates

There are a wide range of materials that can be used to fabricate indirect dental restorations, including a variety of metals, composites and ceramic materials.

Metals range from base, non-precious metals to semi-precious and precious. Metal substrate bonding typically relies on a mechanical bond aided by the surface roughening by air abrasion with aluminum oxide. The adhesive will flow in and around the roughened surface and, when cured hard, will provide a mechanical bond to the surface. If additional bond strength is desired, a metal primer may be used to enhance the bond with some additional chemical bond to the surface.

Composite substrate bonding is very straightforward. The surface may be roughened, but when the adhesive is applied, a chemical bond is formed between the methacrylate groups of the composite and the adhesive.

Ceramic materials vary considerably in their composition. From a bonding perspective, they can be grouped into two categories: glass-containing ceramics (i.e., feldspathic porcelain, leucite reinforced glasses and glass-infiltrated alumina and zirconia) and non-glass containing ceramics (polycrystalline zirconia and alumina).

For glass ceramics, the surfaces are typically etched with hydrofluoric acid to etch or dissolve some of the glass to create a microporous surface for mechanical retention. The surfaces are then treated with a ceramic primer/silane primer that will chemically bond to the glass and will also chemically bond to the adhesive, thus creating a chemical bond between the glass surface and the adhesive in addition to the mechanical bond.

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For non-glass ceramics, these surfaces are relatively inert and are typically treated in the same manner as metals. The surfaces are air abraded with aluminum oxide to create a roughened surface for mechanical retention. Recently, new primers have been introduced that can provide an additional chemical bond to the metal oxides. These primers are primarily based on the MDP monomer. This monomer is a part of various cements, primers and adhesives currently in the market and has been shown to provide adhesion to the zirconia, alumina surfaces and metal surfaces. It is important not to pre-treat these surfaces with phosphoric acid, as this will create a strongly bonded phosphate layer that will be detrimental to the bond strength.

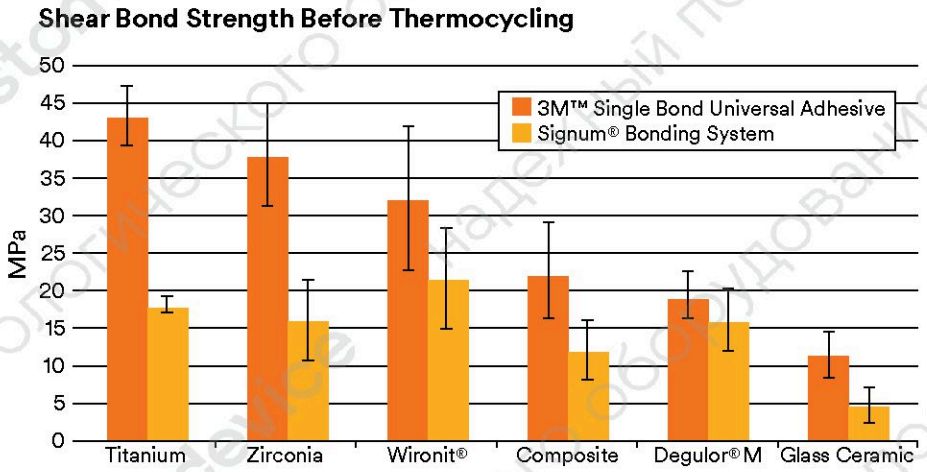


Figure 31: 24-hour shear bond strength of 3M™ Single Bond Universal Adhesive to various indirect substrates compared to the Signum Bonding System.
Source: 3M internal data

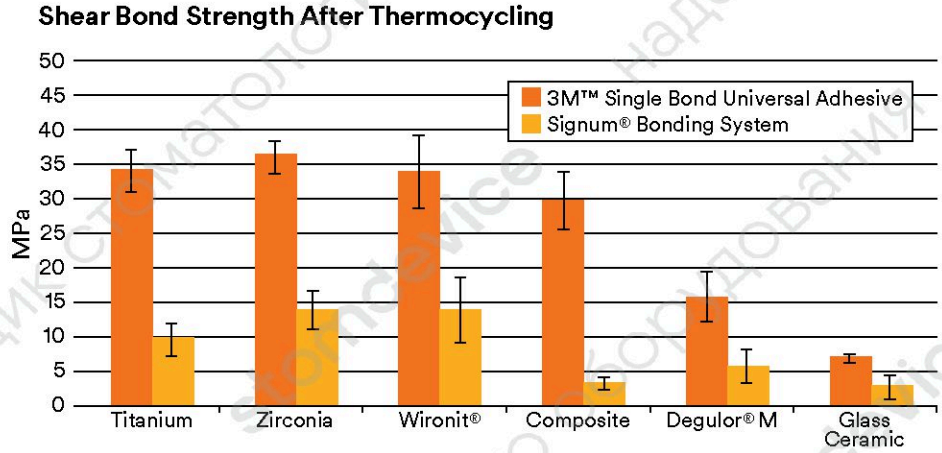


Figure 32: Shear bond strength of 3M™ Single Bond Universal Adhesive to various indirect substrates compared to the Signum Bonding System after thermocycling.
Source: 3M internal data

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Dr. Markus B. Blatz, University of Pennsylvania, conducted a study to look at bonding composite (to simulate a repair situation or indirect bonding situation) to sandblasted zirconia, alumina and glass ceramic surfaces (Figure 33). The blasted surfaces were treated either with 3M™ Single Bond Universal Adhesive or with Z-PRIME Plus primer and adhesive, cured and then composite bonded over that. Samples were subjected to 10,000 thermocycles between 5° and 60°C. Dr. John Burgess, University of Alabama in Birmingham, conducted three indirect shear bond strength studies. The first study (Figure 34) looked at the shear bond strength of Single Bond Universal adhesive to 3M™ Paradigm™ C Glass Ceramic Block [Leucite-reinforced glass ceramic]. The Paradigm C glass ceramic block surfaces were sandblasted and treated with hydrofluoric acid. The two surface treatments were applied, followed by bonding a cylinder of 3M™ Z100™ Restorative on top. The second study looked at bonding of non-glass ceramic (Figure 35). The 3M™ Lava™ Zirconia samples were sandblasted and then treated with the various surface treatments. Z100 restorative was then bonded over the top in a cylinder. The third study (Figure 36) looked at bonding to metal surfaces. The metal samples were sandblasted and then treated with the primer/adhesive or the Single Bond Universal adhesive, followed by bonding a Z100 restorative cylinder on top.

Shear Bond Strength to Indirect Substrates After 10,000 Thermocycles

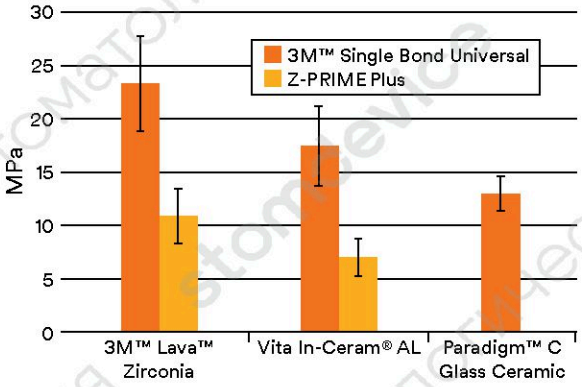


Figure 33: Dr. Markus Blatz, University of Pennsylvania. Shear bond strength of 3M™ Single Bond Universal Adhesive to indirect substrates after thermocycling.
Source: 3M internal data

Shear Bond Strength to 3M™ Paradigm™ C Glass Ceramic

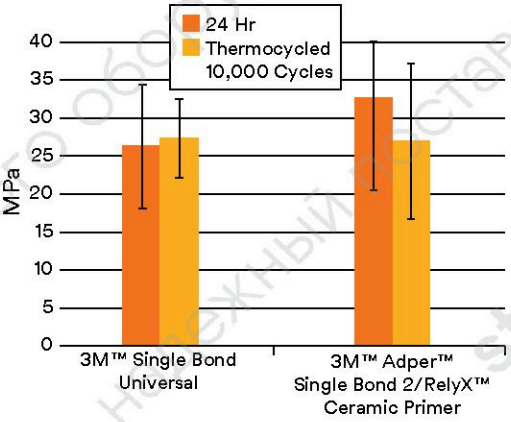


Figure 34: Dr. John Burgess, University of Alabama in Birmingham. Shear bond strength of 3M™ Single Bond Universal Adhesive before and after thermocycling.
Source: 3M internal data

Shear Bond Strength to 3M™ Lava™ Zirconia

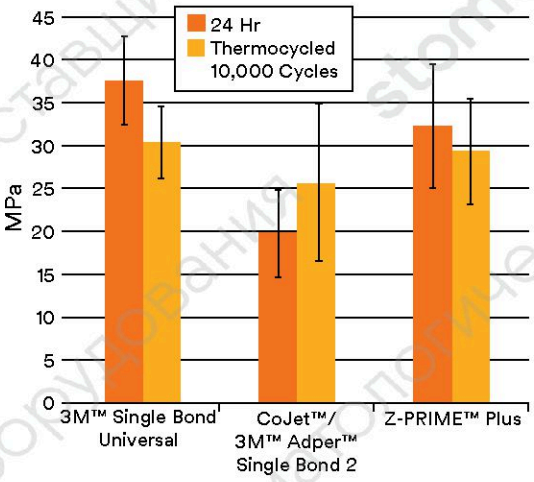


Figure 35: Dr. John Burgess, University of Alabama in Birmingham. Shear bond strength of 3M™ Single Bond Universal Adhesive before and after thermocycling.
Source: 3M internal data

Shear Bond Strength to Metal

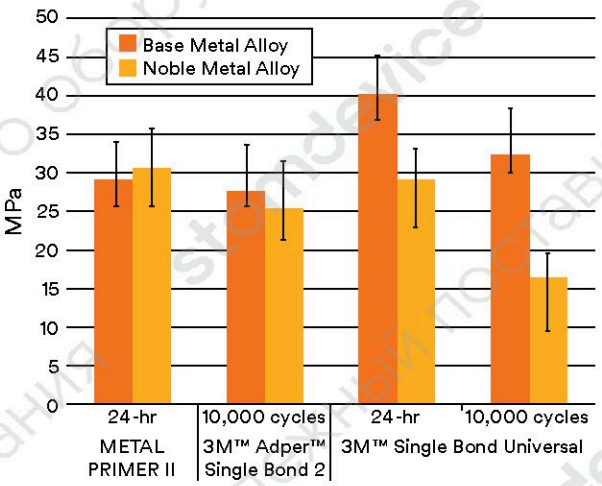


Figure 36: Dr. John Burgess, University of Alabama in Birmingham. Shear bond strength of 3M™ Single Bond Universal Adhesive.
Source: 3M internal data

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Marginal Integrity

An important aspect of bonding is the ability of an adhesive to resist the polymerization forces of the dental composite and maintain a sealed, continuous interface between tooth structure and composite. Dr. Blunck from Berlin, Germany, performed an in vitro study of Class V restorations comparing 3M™ Single Bond Universal Adhesive and other adhesive systems and found the new adhesive to have high percentages of continuous margins in the total-etch and self-etch modes (Figure 37). Figure 38 shows the results of an in vitro study by Dr. Roland Frankenberger from Marburg, Germany, of Class II restorations comparing Single Bond Universal adhesive and other adhesive systems.

In Vitro Marginal Integrity Study—Class V Restoration

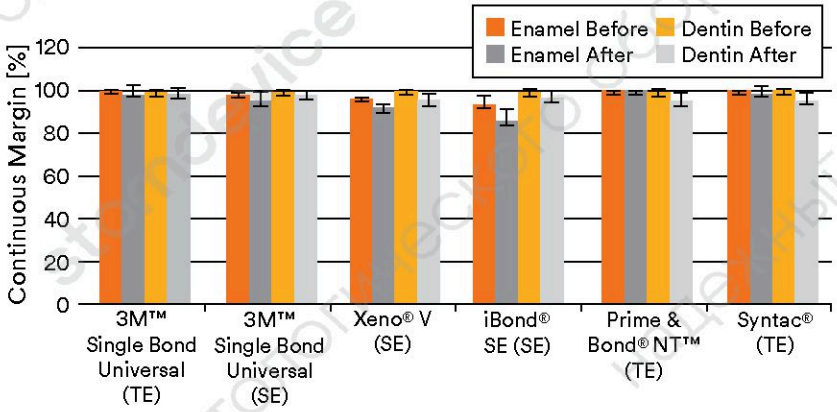


Figure 37: Dr. Blunck, Berlin, Germany. Marginal integrity study, Class V restorations.
Source: 3M internal data

In Vitro Marginal Integrity Study—Class II Restoration

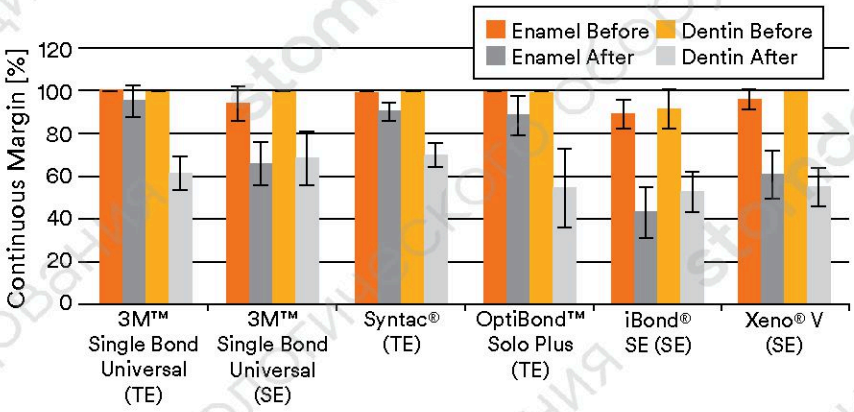


Figure 38: Dr. Frankenberger, Germany. Marginal integrity study—Class II restorations.
Source: 3M internal data

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SEM Images—Dentin Sealing

A proper seal to the dentin is important to be able to provide high adhesion and to prevent sensitivity or to reduce sensitivity if it is present. Dental adhesives have the ability to prevent or reduce sensitivity if they can provide for a high bond strength to both unetched and etched dentin, effectively seal any open tubules and provide a hard cured film that can act as a barrier to the external environment.

The adhesion data presented earlier shows that 3M™ Single Bond Universal Adhesive can provide for high adhesion to dentin in the self-etch mode with the smear layer present, but also to etched moist and dry dentin where the tubules are exposed. The fact is that Single Bond Universal adhesive performs well in both dry and moist conditions to etched dentin, allows for consistent high adhesion and good sealing and removes the technique sensitivity from the clinician.

This ability to seal the dentin allows for low sensitivity potential for direct and indirect procedures. It allows the adhesive to be used for

- cervical root surface desensitization,
- sealing cavity surfaces prior to amalgam placement, and
- sealing tooth surfaces that have been prepared for indirect procedures prior to placement of the temporary restoration.

Based on the results for adhesion testing, SEMs showing the adhesive sealing/bonding capability and the literature study reviews would indicate that the Single Bond Universal adhesive should perform well as a dentin sealing agent.

The SEM images below show how Single Bond Universal adhesive provides an effective seal to the dentin surface. Figure 39 shows how Single Bond Universal adhesive provides a sealed surface over the exposed dentin tubules. The upper half of the image shows the exposed tubules following etching. The lower half shows the surface after placing a single coat of the Single Bond Universal adhesive. The tubules in the lower half are completely sealed. Figure 40 shows a cross-sectional SEM image of the bonding interface to dentin.

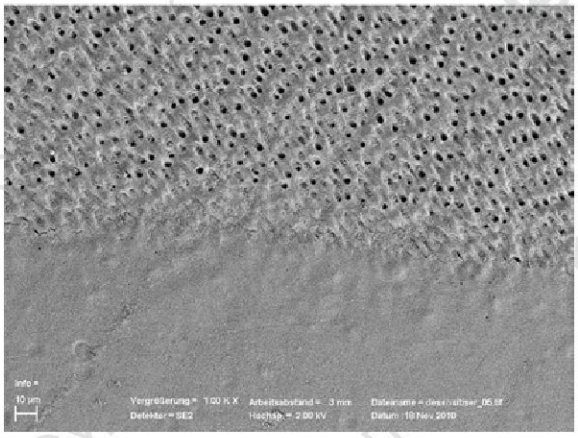


Figure 39: SEM image of etched dentin surface. Upper half shows the exposed dentin tubules. The lower half was treated with 3M™ Single Bond Universal Adhesive to show a complete seal of the dentin surface with no open tubules.
Source: 3M internal data

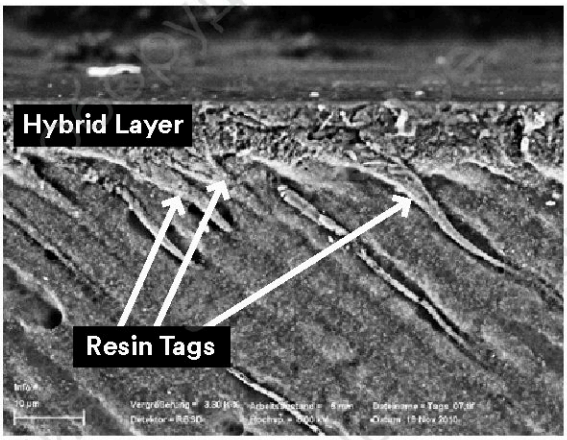


Figure 40: SEM image of cross-section of bonded dentin with 3M™ Single Bond Universal Adhesive. Clear images of the hybrid layer (infiltrated collagen), resin tags in the tubules and sealed layer of adhesive over the surface.
Source: 3M internal data

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Bond Strength and Dye Penetration—Veneers

For glass ceramic bonding, the cementation of veneers was evaluated individually. Due to the highly esthetic demands for porcelain veneers, the bonding and marginal seal were evaluated separately. It is very important to make sure that the veneer is bonded tightly and sealed to prevent any leakage or staining at the margin. For the veneer indication, it is recommended that the enamel surfaces, whether cut or uncut, be phosphoric acid etched prior to the placement of the adhesive. This will provide additional assurance that the restoration will be properly sealed. Figure 41 shows the bond strength comparisons of 3M™ Single Bond Universal Adhesive to 3M™ Adper™ Single Bond 2 Adhesive made with 3M™ RelyX™ Veneer Cement. Glass ceramic wafers were bonded to etched and cut enamel. The bond strengths were statistically the same. Additionally, a dye penetration study was done where veneers were bonded to an etched enamel substrate, subjected to thermocycling and subsequent dye penetration. Figure 42 shows the image of a prepared sample with a tight seal and no dye penetration at the veneer/enamel margin.

Shear Bond Strength—3M™ Adper™ Single Bond 2 Adhesive and 3M™ Single Bond Universal Adhesive With 3M™ RelyX™ Veneer Cement and 3M™ Paradigm™ C Veneer

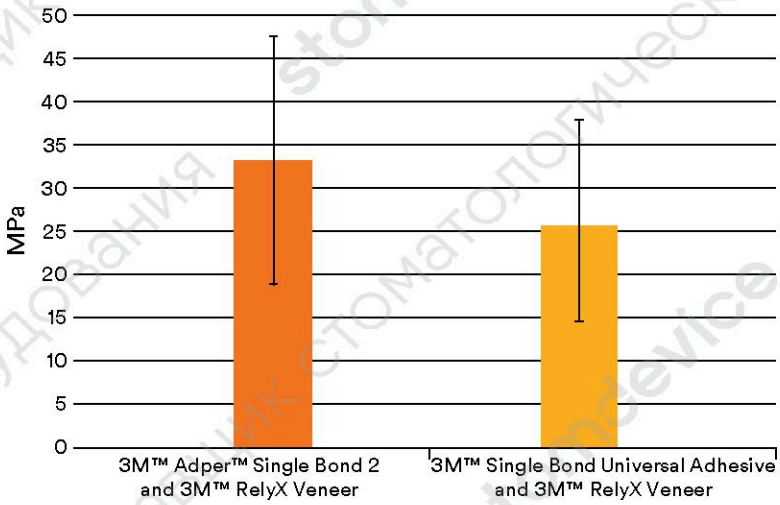


Figure 41: 24-hour shear bond strength of veneers bonded to etched and cut enamel for 3M™ Single Bond Universal Adhesive/3M™ RelyX™ Veneer Cement compared to 3M™ Adper™ Single Bond 2 Adhesive/ 3M™ RelyX™ Veneer cement. Source: 3M internal data

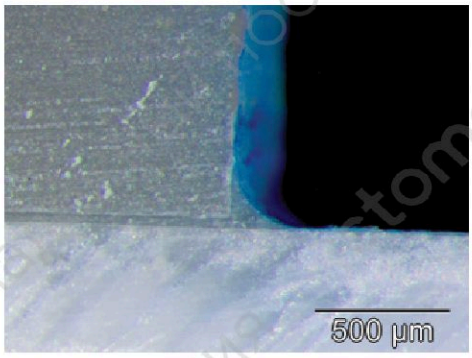


Figure 42: Dye penetration images for bonded veneer using 3M™ Single Bond Universal Adhesive and 3M™ RelyX™ Veneer Cement. No dye penetration seen at the margin interface after 5000 thermocycles (5–55°C, dwell time 30 seconds).
Source: 3M internal data

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Bond Strength and Dye Penetration—Pit and Fissure Sealants

Pit and fissure sealants are used to seal the deep crevices of molars in primary teeth. Historically, the application technique has been to first treat the uncut or unprepared enamel surfaces with phosphoric acid followed by a water rinse and dry. The sealant was then placed over the etched enamel surfaces and allowed to flow down into the fissures. The sealant was then light cured or allowed to self-cure, depending on the type of initiation system. Typically, sealants are applied in a quadrant (3–4 teeth) at one time. This procedure allowed for high bond strengths and good retention of the sealant. The negative effect of this process was that following rinsing of the acid—the young patients would object to the taste of the rinsed acid and for the length of time it required to sufficiently rinse the acid and place the sealant—contamination of the surface with saliva was a concern. With the advent of the self-etch adhesives, the option to replace the phosphoric acid step with a self-etch adhesive used as a primer for the sealant became attractive. 3M™ Adper™ Prompt™ Self-Etch Adhesive is a two-step self-etching adhesive that was investigated thoroughly for use as a self-etching primer for the placement of 3M™ Clinpro™ Sealant and is indicated for the technique.

The pH of phosphoric acid is in the range of 0.5. 3M™ Single Bond Universal Adhesive has a higher pH in the range of 2.7. It is generally not indicated for use on uncut enamel surfaces without a prior phosphoric acid etching step for direct or indirect restorative procedures. However, in contrast to these restorations, the fissures to be sealed are typically not exposed to direct occlusal contact. With the incorporation of the MDP monomer and 3M™ Vitrebond™ Copolymer in the Single Bond Universal adhesive and resulting chemical bonding, investigations were conducted to determine if equivalent performance could be achieved with the Single Bond Universal adhesive and the light cured Clinpro Sealant.

Figure 43 provides 24-hour shear adhesion data for Single Bond Universal adhesive, Adper Prompt adhesive and 3M™ Scotchbond™ Etchant with Clinpro Sealant to uncut enamel. The technique for using the Single Bond Universal adhesive was to apply the adhesive onto the tooth surface and rub or scrub the surface to be sealed for 20 seconds, air dry, apply the sealant and light cure simultaneously.

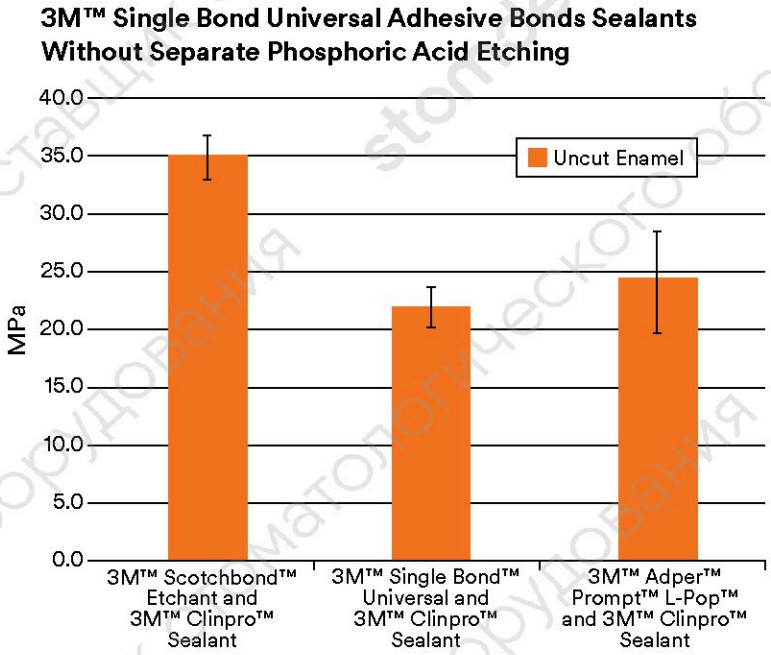


Figure 43: 24-hour shear bond strength of 3M™ Single Bond Universal Adhesive, 3M™ Adper™ Prompt™ L-Pop™ and 3M™ Scotchbond Universal Adhesive Etchant used with 3M™ Clinpro™ Sealant to uncut enamel. Source: 3M internal data

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A second study was conducted to look at the microleakage or dye penetration of extracted molars treated with the 3M™ Single Bond Universal Adhesive and 3M™ Clinpro™ Sealant. Extracted molars were cleaned by treating the surface with polishing paste, rinsed and dried. The Single Bond Universal adhesive was then applied to the tooth surface and rubbed into the surface for 20 seconds. The adhesive was air dried to remove the solvents. Clinpro Sealant was applied in a thin layer. Both materials were then light cured simultaneously for 20 seconds. The samples were then thermocycled for 5000 cycles from 5–55°C. High magnification images were taken of the images prior to immersion into the dye. The teeth were then subjected to the dye. Following the dye immersion, the samples were removed, rinsed and high magnification images were taken to evaluate the margins for any dye penetration or staining. Figure 44 shows the images before and after the dye penetration. No staining of the margins was noted and therefore a strong seal of the margins was present.

Dye Penetration After Thermocycling 5000 Cycles, 5–55°C

Before penetration **After penetration**

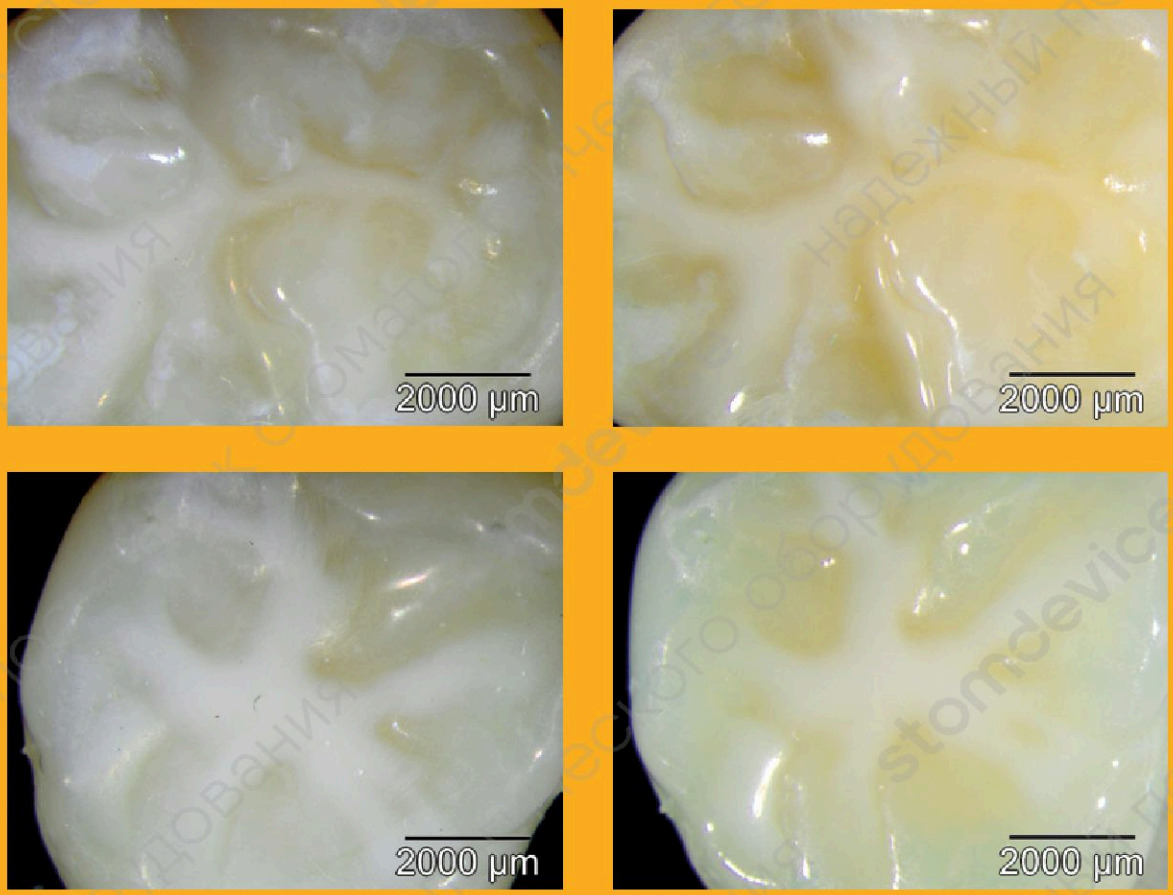


Figure 44: Dye penetration images for molars sealed with 3M™ Single Bond Universal Adhesive and 3M™ Clinpro™ Sealant. No staining or dye penetration is seen at the margins.
Source: 3M internal data

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The following before and after photos (Figures 45, 46 and 47) are from an in vitro 2- and 3-body wear study conducted at the Minnesota Dental Research Center for Biomaterials and Biomechanics (MDRCBB). The study compared three techniques for the application of 3M™ Clinpro Sealant. Photos were taken immediately after preparing samples according to the traditional phosphoric acid etch technique and according to the self-etch techniques of 3M™ Adper™ Prompt™ L-Pop™ Self-Etch Adhesive and 3M™ Single Bond Universal Adhesive. The "after" photos were taken after subjecting the samples to 300K cycles of chewing media, which simulates approximately 1 year of actual chewing.



Figure 45: Dr. Fok, Chen, et al, MDRCBB University of Minnesota. Phosphoric acid etch and 3M™ Clinpro™ Sealant—before (left) and after 300K (right).
Source: 3M internal data



Figure 46: Dr. Fok, Chen, et al, MDRCBB University of Minnesota. 3M™ Adper™ Prompt™ L-Pop™ Self-Etch Adhesive and Clinpro™ Sealant—before (left) and after 300K (right).
Source: 3M internal data



Figure 47: Dr. Fok, Chen, et al, MDRCBB University of Minnesota. 3M™ Single Bond Universal Adhesive and Clinpro™ Sealant—before (left) and after 300K (right).
Source: 3M internal data

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3M™ Single Bond Universal Adhesive as a Protective Coating/Varnish for Glass Ionomer-Based Restorative Materials

Glass ionomer restorative materials have a requirement that after placement they require a protective coating or varnish to be placed over the exposed surfaces to avoid water loss at the surface. The water loss would cause the surface to weaken upon setting and cause surface cracking and weakness in the physical properties of the material at the surface. Therefore, a varnish or protective coating is applied over the exposed surfaces during the curing process. The coating will be cured and act as a barrier to allow the restorative material to cure properly without the water loss. Once cured, the restoration can be finished and polished. If any of the underlying glass ionomer material is exposed, the coating can be reapplied to further protect the surface from water loss and also provide a smoother surface.

The following internal studies show the ability of 3M™ Single Bond Universal Adhesive to provide a hard cured surface over the surface of the glass ionomer restorative and the ability of the Single Bond Universal adhesive to protect the surface from water uptake in the form of a coffee staining test. Figure 48 compares the Vickers surface hardness for 3M™ Ketac™ Molar Glass Ionomer Restorative coated with both the conventional 3M™ Ketac™ Glaze Light-Cured Varnish and then with the Single Bond Universal adhesive. The Fuji IX glass ionomer restorative from GC was also tested with the G-Coat Plus coating.

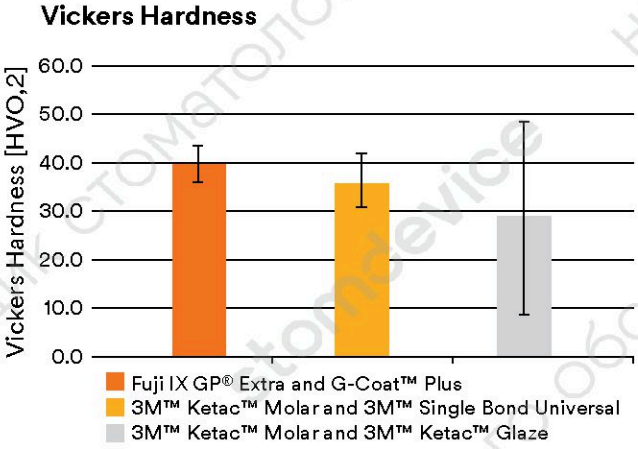


Figure 48: Vickers hardness values for 3M™ Ketac™ Molar Glass Ionomer Restorative coated with 3M™ Ketac™ Glaze Light-Cured Varnish and 3M™ Single Bond Universal Adhesive compared to Fuji IX coated with G-Coat Plus.
Source: 3M internal data

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The second study looked at the ability to protect the cured surface of the glass ionomer restorative from staining with coffee. This would also indicate the ability to protect the surface from water uptake. Samples of 3M™ Ketac™ Molar Glass Ionomer Restorative and 3M™ Ketac™ Fil Plus Aplicap™ Glass Ionomer Restorative were prepared and coated with 3M™ Ketac™ Glaze Light-Cured Varnish and 3M™ Single Bond Universal Adhesive. Fuji IX samples were also prepared and coated with the G-Coat Plus. The samples were immersed in coffee for 24 hours. Figure 49 shows the images of the actual samples that were immersed. The baseline (before) samples are shown on the right side. No distinct color change is visible for any of the sample sets. The samples were measured for color and the changes or Delta E values were calculated for each sample set. Figure 50 shows a graph of the color change or Delta E for the five groups.

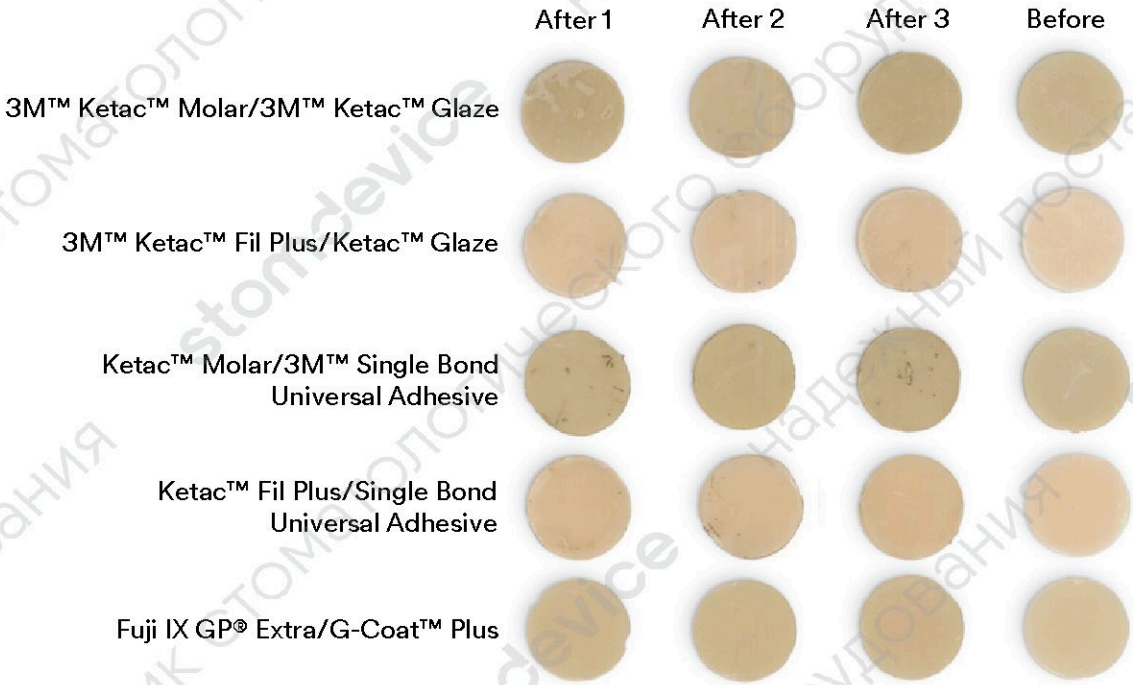


Figure 49: Images of coated samples of 3M™ Ketac™ Molar Glass Ionomer Restorative, 3M™ Ketac™ Fil Plus Aplicap™ Glass Ionomer Restorative with 3M™ Ketac™ Glaze Light-Cured Varnish and 3M™ Single Bond Universal Adhesive compared to Fuji IX coated with G-Coat Plus following immersion in coffee.
Source: 3M internal data

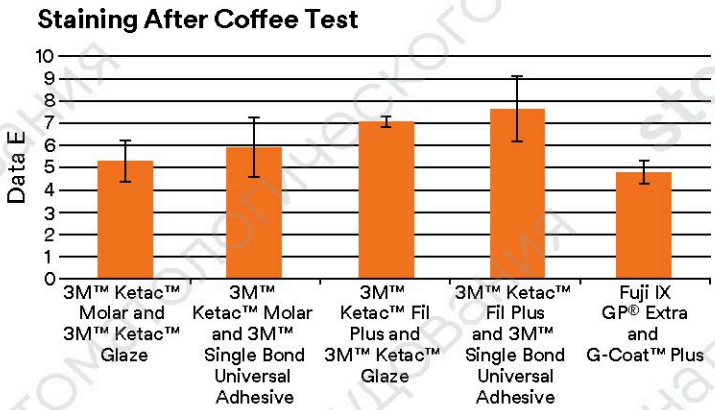


Figure 50: Chart showing Delta E or color change values for the coated glass ionomer samples following immersion in coffee.
Source: 3M internal data

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Bonding Self- or Dual-Cure Composite or Cement Materials with the 3M™ Single Bond Universal DCA Dual Cure Activator

The ability to bond self- and dual-curing composite and cement materials with conventional adhesives has been a challenge. The slightly acidic or acidic nature of the adhesives can protonate the amine component of commonly used peroxide/amine initiator systems and therefore have a retarding effect on the self-curing mechanism of the composite or cement and not allow the interface between the adhesive and the composite/cement to polymerize completely, resulting in low bond strengths. Dual- or self-cure activators are available for some adhesive systems that, when mixed with the adhesive, allow for better polymerization at the interface and subsequent higher bond strengths. 3M™ Single Bond Universal Adhesive has an activator available as part of its system. The activator consists of 2% sodium toluene sulfinate and 98% ethanol. This sulfinate salt, when mixed with the Single Bond Universal adhesive, allows for bonding to these materials. Figure 51 shows bond strength data when Single Bond Universal adhesive was mixed with 3M™ Single Bond Universal DCA Dual Cure Activator, and alloy cylinders were bonded to dentin and enamel with various non-3M cements in both the self-etch and total-etch modes. The bond strengths are all within or above the 20 MPa range and are acceptable. Figures 51 and 52 show the wire loop shear bond strengths of various core build-up materials and self-cure composite materials. Single Bond Universal adhesive was mixed with Single Bond Universal DCA (1 drop of each), applied to the tooth surface and light cured. Cements were used per their instructions for use to cement stainless steel buttons, which were tested in shear mode after 24 hours at 36°C. Core build-up materials were applied in a 5mm increment in order to simulate a worst-case scenario, light cured from the top and tested in shear mode after 24 hours at 36°C.

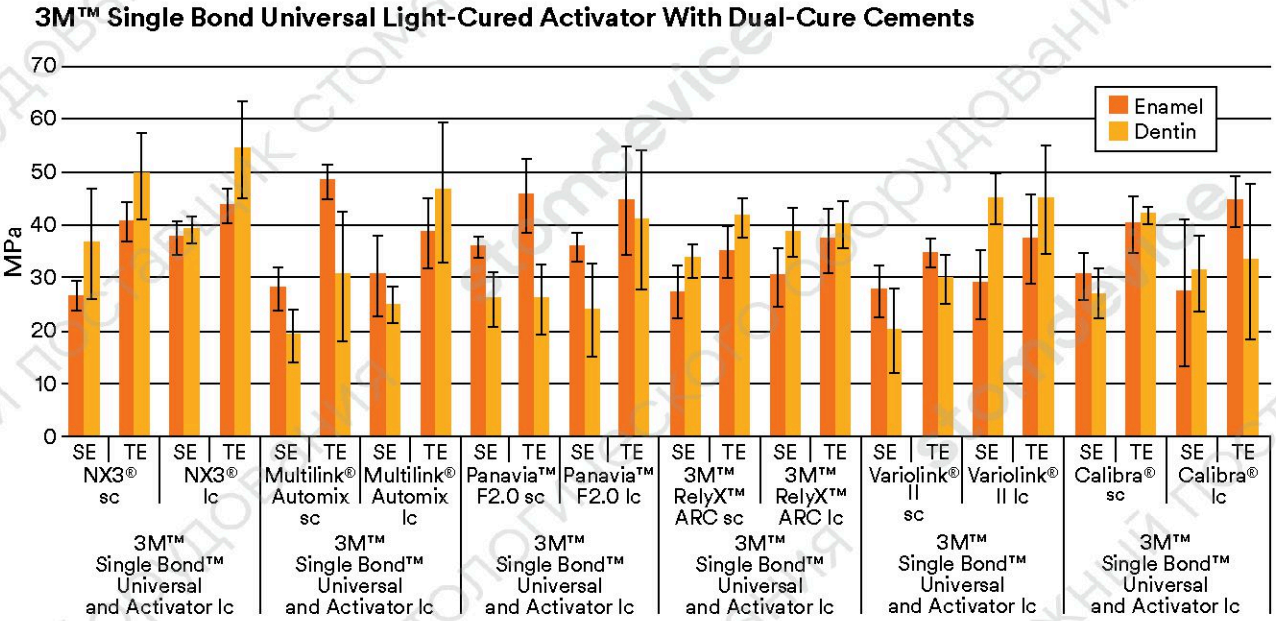


Figure 51: 24-hour shear bond strength of 3M™ Single Bond Universal Adhesive with activator in both the self-etch and total-etch modes with various resin cement systems to enamel and dentin.
Source: 3M internal data

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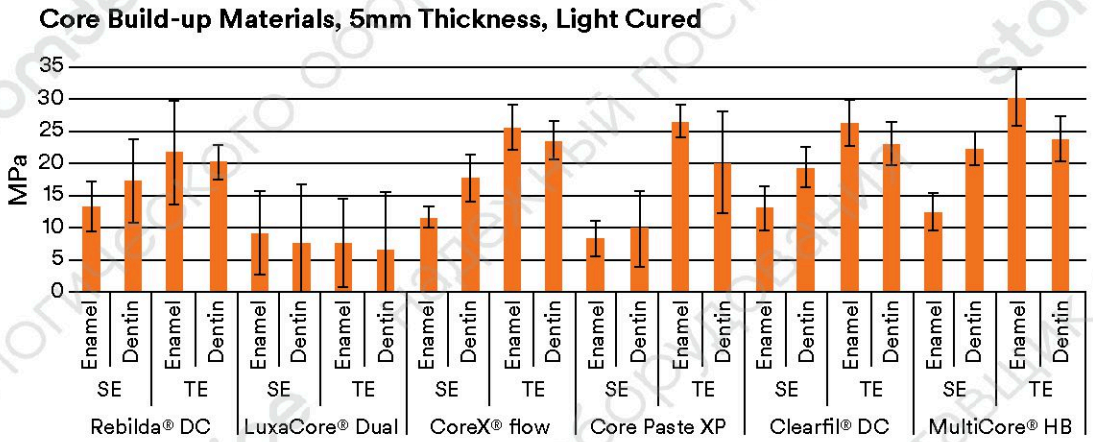


Figure 52: 24-hour shear bond strength of 3M™ Single Bond Universal Adhesive with activator in both the self-etch and total-etch modes with various core build-up systems to enamel and dentin.
Source: 3M internal data

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System Adhesive for 3M™ RelyX™ Ultimate Adhesive Resin Cement

3M™ Single Bond Universal Adhesive is the system adhesive for 3M™ RelyX™ Ultimate Adhesive Resin Cement. Figures 53 and 54 show the enamel and dentin bond strength results of light cured RelyX Ultimate cement bonded with self-cured Single Bond Universal adhesive in comparison to competitive systems according to their recommended pretreatment. The bond strengths of light cured RelyX Ultimate cement to ceramic with self-cured Single Bond Universal adhesive in comparison to competitive systems can be found in Figure 55.

Shear Bond Strength to Enamel of 3M™ RelyX™ Ultimate Adhesive Resin Cement and Other Pretreatment Steps According to IFU

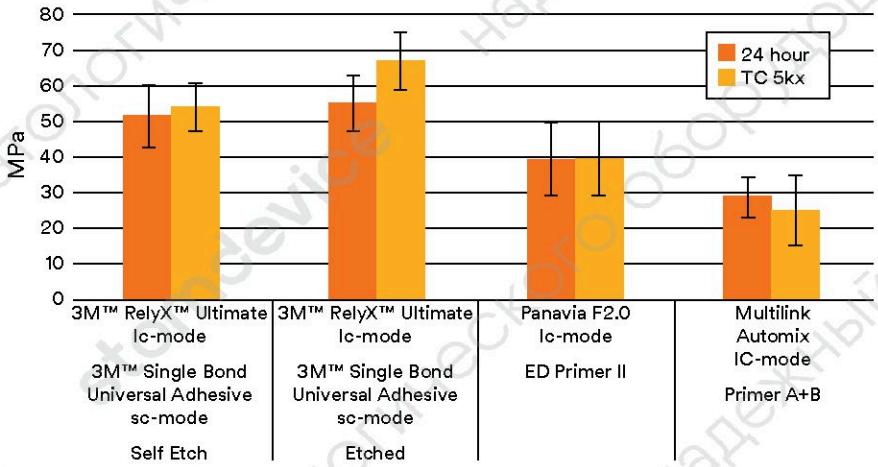


Figure 53: Shear bond strength to enamel—3M™ RelyX™ Ultimate Adhesive Resin Cement with 3M™ Single Bond Universal Adhesive and various pretreatments according to instructions for use before and after thermocycling.
Source: 3M internal data

Shear Bond Strength to Dentin of 3M™ RelyX™ Ultimate Adhesive Resin Cement and Other Pretreatment Steps According to IFU

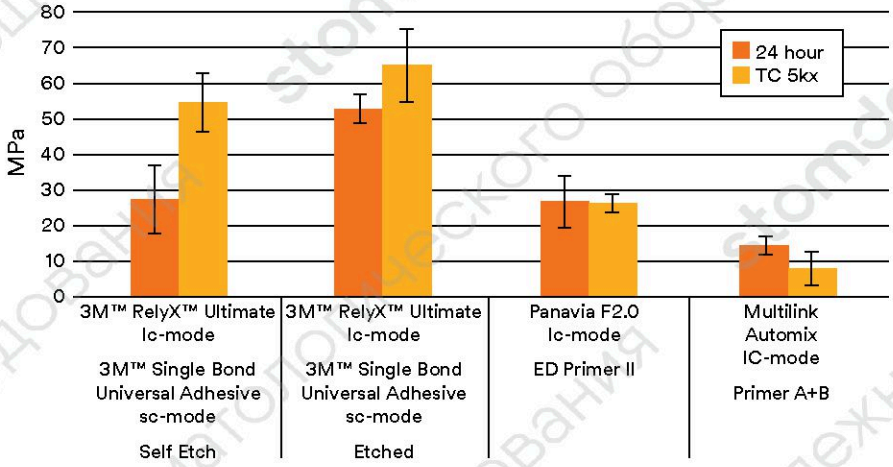


Figure 54: Shear bond strength to dentin—3M™ RelyX™ Ultimate Adhesive Resin Cement with 3M™ Single Bond Universal Adhesive and various pretreatments before and after thermocycling.
Source: 3M internal data

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Shear Bond Strength to Ceramic of 3M™ RelyX™ Ultimate Adhesive Resin Cement with 3M™ Single Bond Universal Adhesive as a System Primer in Comparison to Competitive Systems

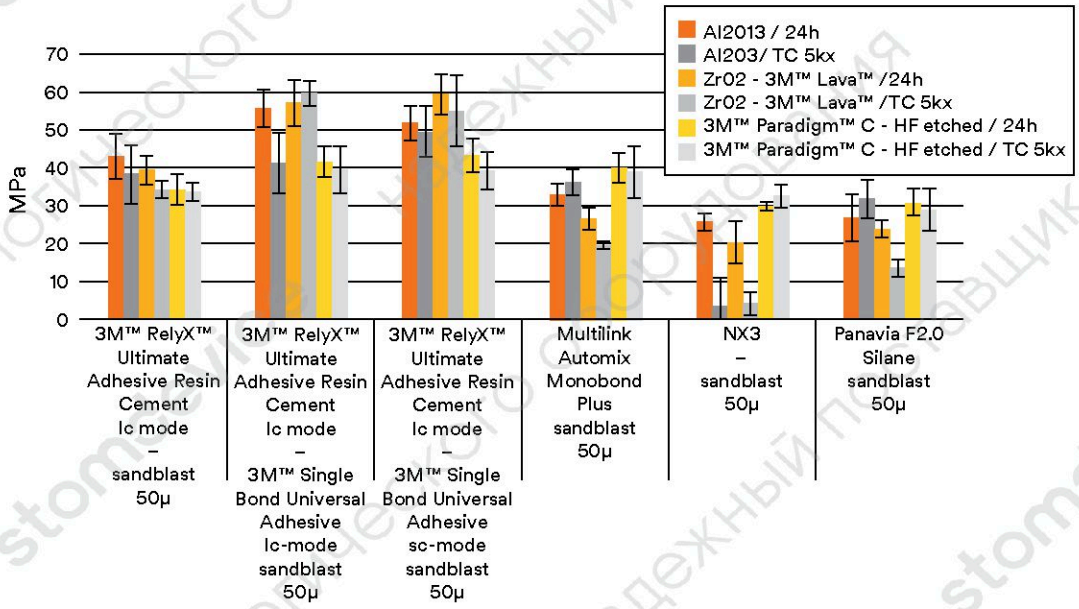


Figure 55: Shear bond strength of light-cured RelyX™ Ultimate Adhesive Resin Cement to ceramic using self-cured Single Bond Universal Adhesive.
Source: 3M internal data

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Customer Feedback

As mentioned earlier, 120 dentists from Germany, Great Britain, Italy, France and Switzerland evaluated 3M™ Single Bond Universal Adhesive. After evaluating, the dentists were asked for their feedback. The following summarizes their responses regarding the improved flip-top vial and their overall satisfaction with Single Bond Universal adhesive.

Improved Vial Delivery

The new and improved flip-top vial is designed for opening, dispensing and closing with one hand (Figure 56). 82% of the evaluators rated the opening and closing of the flip-top vial with one hand as “Easy” or “Very Easy” (Figure 57). The improved vial also has a unique nozzle, which was specifically designed for dispensing control. Cleanliness of the vial after repeated use was rated as “Clean” by 39% and “Very Clean” by 42% of the evaluators (Figure 58).



Figure 56: Vial dispensing.
Source: 3M internal data

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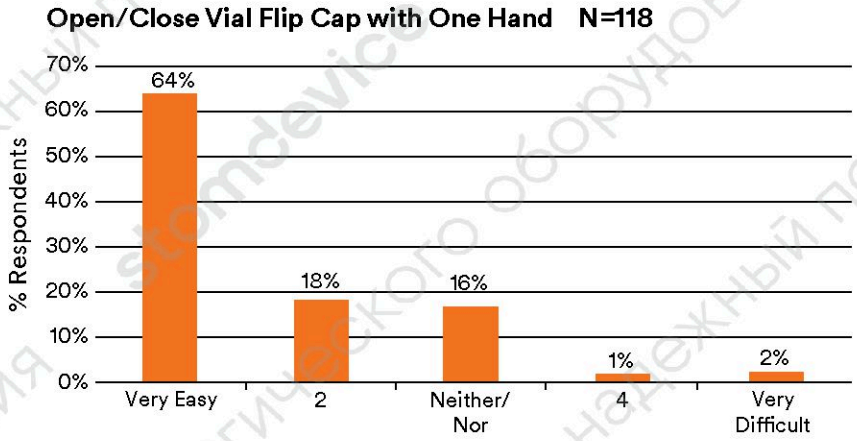


Figure 57: Response to ease of opening and closing vial with one hand.
Source: 3M internal data

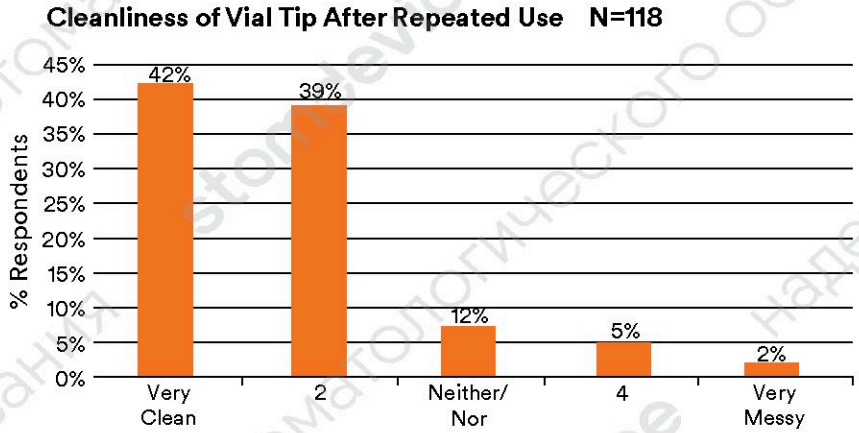


Figure 58: Response to cleanliness of vial tip after repeated use.
Source: 3M internal data

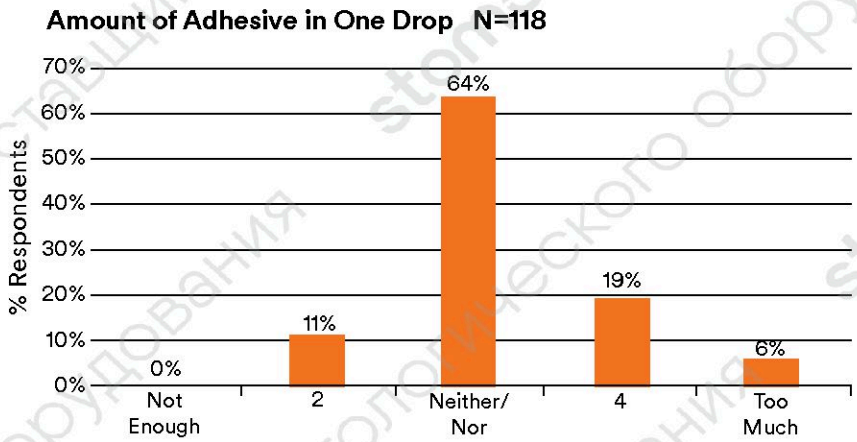


Figure 59: Response to amount of adhesive in one drop of 3M™ Single Bond Universal Adhesive.
Source: 3M internal data

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Overall Satisfaction

Overall, 89% of the evaluators were “Satisfied” or “Very Satisfied” with 3M™ Single Bond Universal Adhesive. 81% responded with “Probably would recommend” or “Definitely would recommend” this new adhesive to their colleagues and 84% “Probably would purchase” or “Definitely would purchase” Single Bond Universal adhesive if price was not an issue.

Please rate your overall satisfaction of 3M™ Single Bond Universal Adhesive: N=120

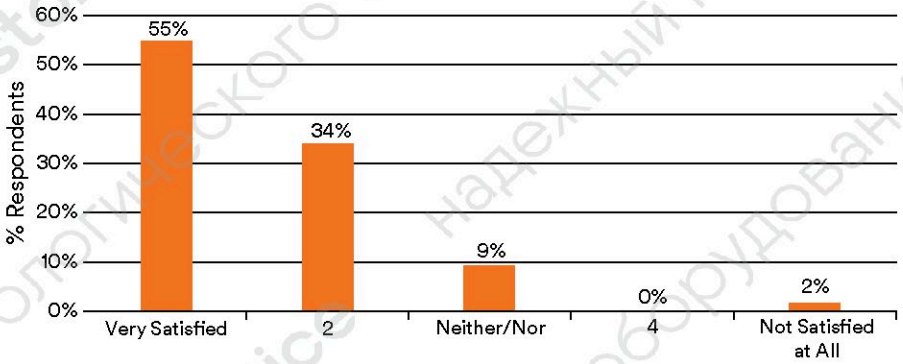


Figure 60: Response—Overall satisfaction with 3M™ Single Bond Universal Adhesive.
Source: 3M internal data

How likely would you recommend 3M™ Single Bond Universal Adhesive to your colleagues, if it was available soon? N=118

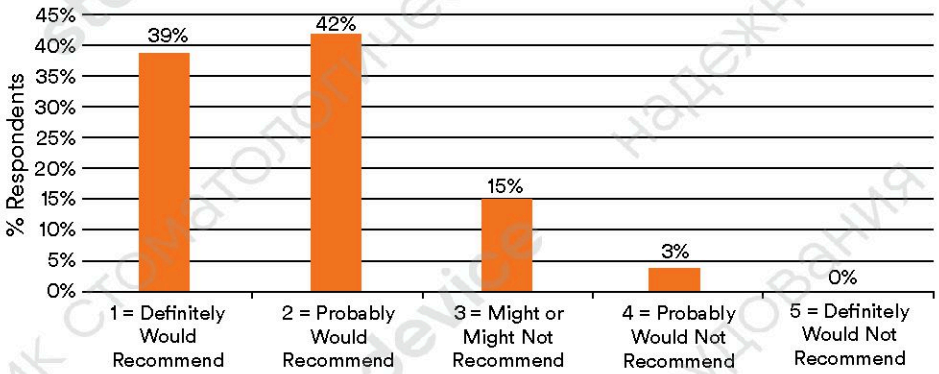


Figure 61: Response—Likelihood to recommend 3M™ Single Bond Universal Adhesive.
Source: 3M internal data

How likely would you be to purchase 3M™ Single Bond Universal Adhesive if it was available and price was not an issue? N=118

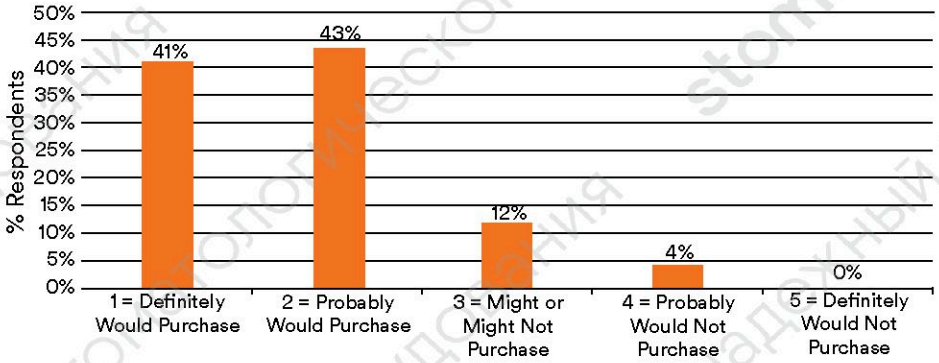


Figure 62: Response—Likelihood to purchase 3M™ Single Bond Universal Adhesive.
Source: 3M internal data

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