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**Ismael Alejandro Guerrero Rodriguez**  
Master's in Sciences Student,  
Universidad Autonoma de Nuevo  
Leon, Facultad de Odontologia,  
Monterrey, Nuevo Leon, 64460 ZIP,  
Mexico

**Osvelia Esmeralda Rodriguez Luis**  
Professor, Universidad Autonoma de  
Nuevo Leon, Facultad de  
Odontologia, Monterrey, Nuevo Leon,  
64460 ZIP, Mexico

**Laura Elena Villarreal Garcia**  
Professor, Universidad Autonoma de  
Nuevo Leon, Facultad de  
Odontologia, Monterrey, Nuevo Leon,  
64460 ZIP, Mexico

**Sonia Martha Lopez Villarreal**  
Professor, Universidad Autonoma de  
Nuevo Leon, Facultad de  
Odontologia, Monterrey, Nuevo Leon,  
64460 ZIP, Mexico

**Fatima del Muro Casas**  
Professor, Universidad Autonoma  
de Zacatecas, Unidad Academica de  
Odontologia, Zacatecas,  
98000 ZIP, Mexico

**Nelly Alejandra Rodriguez Guajardo**  
Professor, Universidad Autonoma  
de Zacatecas, Unidad Academica de  
Odontologia, Zacatecas,  
98000 ZIP, Mexico

**Andrea Elisa Delgado Alcala**  
Dentistry Student, Universidad  
Autonoma de Nuevo Leon, Facultad  
de Odontologia, Monterrey, Nuevo  
Leon, 64460 ZIP, Mexico

**Juan Manuel Solis Soto**  
Professor, Universidad Autonoma de  
Nuevo Leon, Facultad de  
Odontologia, Monterrey, Nuevo Leon,  
64460 ZIP, Mexico

**Corresponding Author:**  
**Juan Manuel Solis Soto**  
Professor, Universidad Autonoma de  
Nuevo Leon, Facultad de  
Odontologia, Monterrey, Nuevo Leon,  
64460 ZIP, Mexico

### Factors influencing adhesion quality in universal adhesive systems

**Ismael Alejandro Guerrero Rodriguez, Osvelia Esmeralda Rodriguez Luis, Laura Elena Villarreal Garcia, Sonia Martha Lopez Villarreal, Fatima del Muro Casas, Nelly Alejandra Rodriguez Guajardo, Andrea Elisa Delgado Alcala and Juan Manuel Solis Soto**

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#### Abstract

**Introduction:** There are many ways to influence the adhesive properties of the various adhesive systems available. These systems have been launched on the dental market to simplify the use of this dental biomaterial in the clinic.

**Objective:** To present the current information about the various factors influencing the quality of adhesion in universal adhesive systems, including the double adhesive layer, acid etching vs self-etching, steps added to the adhesive technique, enamel adhesion vs dentin adhesion and performance against to various aging tests.

**Methodology:** A search was carried out in the PubMed electronic database using as keywords "universal adhesive", "double layer application", "enamel bond strength", "dentin bond strength", "artificial aging".

**Results:** Using a double adhesive layer will increase our adhesion quality in universal adhesive systems, giving us a more stable layer. The difference between the resulting adhesive quality using an acid etching technique versus a self-etching technique could merely be related to the universal adhesive used, however, there does not appear to be a statistically significant difference between both adhesive techniques. We can add steps to our adhesion protocol to result in improvements in our adhesion quality, such as placing silane before placing the adhesive layer, or having our dentin surface wet in an acid etching technique. Adhesion to enamel is more predictable than to dentin, however, it is believed that by inhibiting the oxygen layer, adhesion to dentin is favored. The aging tests influence the adhesive results obtained in in vitro studies, which try to imitate the conditions that we might find in the mouth.

**Conclusion:** Universal adhesive systems offer the advantage of handling this material with various techniques, being for this reason a versatile material that could be used in various clinical procedures that involve dental bonding.

**Keywords:** Universal adhesive, double layer application, enamel bond strength, dentin bond strength, artificial aging

#### 1. Introduction

There are currently many ways to influence the adhesive properties of the various adhesive systems available, regardless of the adhesive technique used. The current demand of the clinical operator is the simplification of the procedures, decreasing the number of steps and the time invested in them, however, the substantial improvement of the adhesive strength obtained with the technique that is decided to be used is also sought<sup>[1]</sup>. Throughout the era of adhesive dentistry, different adaptations have been developed regarding the dental adhesive technique. One of the first observations that were considered to improve adhesive properties was the implementation of an "acid etching" technique, described by Buonocore in 1955<sup>[2]</sup>. From this point on, more complex mechanisms were developed to achieve dental adhesion<sup>[3]</sup>, which has established a new way of thinking and acting in restorative and preventive dentistry. The composition of a dental adhesive is given by a solution of hydrophobic and hydrophilic resin monomers that allow a stable resin-substrate relationship to exist<sup>[4]</sup>.

Adequate knowledge on the part of the clinical operator about the variety of dental adhesive systems is of great importance since they are part of the daily clinical work, and it would be a

great advantage to customize the use of each system knowing its most appropriate indication for each clinical situation presented<sup>[5]</sup>. Therefore, it is crucial to expose the advantages as well as the limitations of the new universal adhesive systems in different application techniques and their placement on different substrates<sup>[6]</sup>.

Universal adhesive systems have been launched in the dental market to simplify the use of this dental biomaterial in the clinic, being able to adhere to different materials<sup>[7]</sup> with different adhesive techniques, either with acid etching or self-etching, giving the possibility to make a series of adjustments in the technique<sup>[8]</sup> to favor the resulting adhesive strength between substrate-restoration. It is of great relevance to expose the different methods that could influence their performance to improve it, as well as to show what durability they present in front of different aging tests. Therefore, the objective of this literature review is to expose the current information about the different factors that influence the adhesion quality of universal adhesive systems, including the double adhesive layer, acid etching vs self-etching, added steps to the adhesive technique, adhesion to enamel vs adhesion to dentin and their performance against different aging tests.

## 2. Materials and methods

Articles on the subject published through the Pubmed, SCOPUS and Google Scholar databases were analyzed, with emphasis on the last 5 years. The quality of the articles was evaluated using PRISMA guidelines, i.e., identification review, choice, and inclusion. The quality of the reviews was assessed using the measurement tool for evaluating systematic reviews.

The search was performed using Boolean logical operators AND, OR, and NOT. It was realized with the words Universal adhesive systems, acid etching, adhesion to enamel, adhesion to dentin and adhesive techniques. The keywords were used individually, as well as each of them related to each other. Initially, the titles of all the articles were selected, the abstract of each one was evaluated, and the articles were chosen for a complete reading review.

## 3. Results & Discussion

### 3.1 Double adhesive layer

Using the double-layer adhesive protocol has been shown to increase the adhesive shear strength compared to using a single layer of adhesive, as well as improving the adhesive fatigue strength<sup>[9]</sup>. One of the advantages of universal adhesive systems is the practicality of their use, and the freedom it gives the operator to use them with the bonding protocol with which he feels most comfortable, making it possible to use an acid etching protocol, or alternatively, to use a self-etching protocol. Being able to apply here the philosophy of placing double layers of adhesive makes us transform the self-etching protocol into a two-step protocol, where the first layer could be considered as a primer, thus increasing the benefits of this technique<sup>[10]</sup>. Similarly, it has been reported that placing the first layer of adhesive and light-curing it before placing the second adhesive layer increases the long-term bond strength resistance<sup>[11]</sup>. Additionally, it has been evidenced that dental pieces with bonded restorations that are exposed to ionizing radiation with a single-layer bonding protocol using a universal adhesive system lose bond strength due to radiation, however, in the double-layer protocol this loss of bonding is avoided to be substantial, maintaining acceptable values of bond strength<sup>[12]</sup>. The

reason why using a two-layer bonding technique in universal adhesive systems will improve our bonding quality compared to the conventional one-layer technique is because a much more uniform adhesive layer is produced and because the second layer would compensate for possible defects that may exist in the first layer<sup>[13, 14]</sup>.

Contrasting with the benefits of the technique, there is a report that this two-layer bonding protocol can be severely affected by applying aging tests, thus decreasing the bond strength, specifically in a long-term water aging process<sup>[15]</sup>. Similarly, studies have focused on determining the duration of the resulting adhesive layer over time, however, aging methods have been shown to have a great impact on the adhesive properties of universal adhesive systems, even using the dual-layer protocol. Nevertheless, depending on the adhesive technique used, these values can be improved, as was observed with an acid etch, wash and subsequent adhesive application technique, as compared to a self-etch technique<sup>[16]</sup>. Many *in vitro* studies have been performed that have indeed demonstrated the higher adhesive quality resulting from placing an extra adhesive layer, yet there is currently not enough clinical evidence to corroborate the findings found in the *in vitro* studies<sup>[17]</sup>. It has been reported that the effectiveness of using universal adhesives with a double bonding layer protocol has generated immediate bond strength in dentin, but this effect is not reflected after subjecting the specimens to aging procedures<sup>[18]</sup>.

Using a double adhesive layer will increase our bonding quality in universal adhesive systems, regardless of the technique used, giving us a more uniform and stable layer, however, there is a need to prove its benefits with the support of more clinical studies.

### 3.2 Acid Etching vs. Self-Etching

When making the decision to use an acid etching technique with a universal adhesive system, variations within the same technique can be considered by varying the acids used. Using phosphoric acid as an enamel etchant for less than 15 seconds and polyacrylic acid for exactly 15 seconds significantly increased the adhesive fatigue strength<sup>[19]</sup>. Regarding a self-etch technique, using Scotch bond Universal (3M ESPE) it has been shown that there is a higher adhesive resistance to micro-leak than when using this same product with an acid etch and wash technique<sup>[20]</sup>, likewise it has been found that the adhesive strength values with Scotch bond Universal with the self-etch technique are comparable with sixth generation adhesives, which are two-step self-etch<sup>[21]</sup>.

It should be noted that the stability of the adhesive layer is strongly influenced by the degree of conversion of the adhesive system during light curing, which can be influenced by the power of the curing light, the way it is placed and the location in the mouth of the area to be cured<sup>[1]</sup>.

There are studies that compared the differences in adhesion values obtained on dentin when using an acid etch and wash technique versus a self-etch technique with universal adhesives and found that there was no significant statistical difference in the levels of adhesive fatigue strength between the two adhesive techniques<sup>[22]</sup>. Another study evaluated the adhesive shear strength in adhesive techniques such as self-etch with one application followed immediately by air-spreading of the adhesive, self-etch with prolonged active application and traditional acid-etch with rinsing, and found that some universal adhesives benefit from increasing their active application time on the tooth surface, thus increasing their bond strength as in Adhese Universal and Scotch bond

Universal irrespective of the adhesive technique used [23]. Another study proved something similar, by increasing the active application times of the universal adhesive, regardless of the adhesive technique used, in which adhesive shear strength values were higher than in bonded surfaces where there was no active application of the adhesive, due to the inefficient penetration of the resin tags on the tooth surface without active application [24].

The difference between the adhesive quality resulting from using an acid etching technique versus a self-etching technique could be merely related to the universal adhesive used, however, there does not seem to be a significant statistical difference between both adhesive techniques, leaving it to the preference of the clinical operator, and the given clinical situation, to choose which technique to use.

### 3.3 Steps added to the adhesive technique

There is evidence in the literature that there are universal adhesives where a change in application time has no effect on adhesive shear strength and immediate adhesive fatigue strength, such as Clearfil Universal Bond Quick and G-Premio Bond universal adhesives. Unlike Adhese Universal and Scotch bond Universal Adhesive, where a difference in adhesive values can be seen. Similarly, a rougher enamel surface was observed with increasing application time for Adhese Universal and Scotch bond Universal Adhesive [25]. Adding extra steps to the adhesive technique in the use of universal adhesives can result in an improvement in the bond strengths obtained, an example of this is seen by adding a silane layer before the adhesive layer is placed, resulting in a higher micro-shear adhesive strength [26]. Sometimes the adhesive technique is also used in favor of being able to repair some type of restoration, as was demonstrated in composite resin restorations fabricated with the CAD-CAM system, helping us with an extra step to improve our adhesion, using a sandblasting technique with abrasive particles of aluminum oxide, which was reported as the best surface treatment to take into account when making any repair in composite resin restorations with the help of a universal adhesive system [27].

If we talk about having a wet surface when using a universal adhesive in dentin, some studies mention that with the acid etching and rinsing technique, we could find that the resin tags formed are longer than those formed on a dry surface in dentin, concluding that the wet surface in dentin is a significant factor for adhesion in this tissue using a universal adhesive system [28, 29].

There are universal adhesives that are marketed under the "quick bonding" technique such as Clearfil Universal Bond Quick, which offers the option of placing it either in a self-etch or etch-and-wash technique, and immediately light curing the adhesive, i.e. without performing an active application of the adhesive on the surface to be bonded, which seems to show promising tensile bond strength values, still it is worth mentioning that the adhesive values were significantly affected when using aging methods [30].

We can add steps to our bonding protocol to have as a result, improvement in our bonding quality, such as placing silane before placing the adhesive layer, as well as, in case we are in an acid etching technique, that our dentin surface is wet for a better formation of the resin tags, thus improving the micro-retention of our adhesive layer in this tissue.

### 3.4 Bonding on Enamel Vs. Bonding on Dentine

Within the adhesive effectiveness related to enamel, it has been found that the early shear bond strength, when using a double-layer bonding protocol using a universal adhesive

system, is favored in this tissue, maintaining reassuring bond strength values for the clinician [31]. The bond strength with the universal adhesive system is particularly increased on enamel when it is conditioned with acid etchant and the enamel surface is eroded, however the same is not true for dentin [32]. Attempts have also been made to improve the bond strength in dentin by using 8% arginine product additives to eliminate matrix metalloproteinases, but it was found that using this alternative with universal adhesives has been counterproductive, affecting the immediate and long-term bond strength [33]. However, there is evidence that laser irradiation pretreatment with neodymium-doped yttrium aluminum garnet on dentin improves both short- and long-term bond strength in universal adhesives with an acid etch and wash technique [34].

If we would like to compare in enamel the adhesive fatigue durability with universal adhesive systems versus two-step self-etch adhesive systems, we can see that the former system shows lower adhesive strength values than in sixth generation adhesives regardless of the type of adhesive brand used [35].

It is important to mention that there is record that the bonding capacity of fiberglass posts bonded to root canals using a universal adhesive system is comparable to that of a sixth-generation adhesive system, and the adhesive strengths were also increased by the use of diamond rotary instruments [36].

In dentin, studies measuring the fatigue of universal adhesives using a total dentin etch versus a self-etch technique have been performed and the results were found to be highly dependent on the adhesive material to be used. For example, in Prime & Bond elect significantly higher adhesive values were found in a total etch mode as opposed to a self-etch mode, however in Clearfil Bond SE ONE adhesive significantly lower adhesive values were found in an acid etch and wash mode as opposed to a self-etch mode, where the adhesive values obtained were better [37]. Other studies mention that to improve the adhesive properties of universal adhesives on dentin, the oxygen inhibition layer is placed, which improves the adhesive shear strength and fatigue resistance values by the simple fact of using it, regardless of the adhesive technique to be used [38].

There is controversy on adhesion issues on dentin due to its composition. Bonding on enamel is more predictable and is thought to be better if an acid etching technique is used. It is believed that by inhibiting the oxygen layer of the adhesive, dentin bonding values are favored, helping us with this alternative to have a more predictable bond.

### 3.5 Aging Tests

Within the in vitro studies where the adhesion strength of universal adhesive systems is evaluated, there are a large number of applicable tests to obtain measurable values. Among the tests that significantly affect the adhesion strength in enamel, there is the thermocycling (20,000 and 30,000 cycles), this in a self-etching technique. However, there are other tests that show higher adhesion values, such as the method that involves storing the samples in NaOCl [39]. One of the simplest and most commonly used tests in dental adhesion studies is storage in water for 24 hours [40]. Studies that have evaluated the adhesion of universal adhesive systems have placed samples to aging tests such as water storage for two years and thermocycling tests, however, have not shown significant reductions in enamel bond strength [41].

Water storage testing is reported to severely affect the adhesive strengths at micro bleaching irrespective of the adhesive technique used. Although it is important to mention



that in a double-layer adhesive technique the values of micro-shear bond strengths and hardness at the dentin-resin interface are significantly increased, due to this extra layer of hydrophobic resin that is added<sup>[11]</sup>.

Aging tests influence the adhesive levels obtained in in vitro studies, where they try to mimic the conditions that we might encounter in the mouth. Water storage tests for different periods of time is a valid and simple aging test used in most in vitro studies.

#### 4. Conclusions

Universal adhesive systems offer the clinical operator the advantage of handling this material with various adhesive techniques, being for this reason a friendly and versatile material that could be used in various clinical procedures that will involve dental bonding. It depends a lot on the universal adhesive available in the office to know which adhesive technique will favor the bonding levels, as well as where the bonding will be done (dentin or enamel) to know which additional steps to the technique could improve its performance.

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