LITERATURE REVIEW: *THE BONDING PERFORMANCE OF UNIVERSAL TWO-STEP SELF-ETCH ADHESIVE MATERIALS*

THESIS

Submitted to Hasanuddin University to Complete One of the Requirements to Achieve a bachelor's degree in Dentistry.

BY:

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DEPARTMENT OF CONSERVATIVE DENTISTRY

FACULTY OF DENTISTRY HASANUDDIN UNIVERSITY

2023

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ABSTRACT

The Bonding Performance of Universal Two-Step Self-Etch Adhesive Materials: Literature Review

Background: Universal adhesives, used as self-etch or etch-and-rinse, vary in bond strength depending on application mode. There in vitro performance is material-dependent, with acid etching increasing bond strength and laser etching providing similar results. Coating with hydrophobic resin enhances bonding performance. One-step universal adhesives have limitations like reduced bond strength and moisture sensitivity, making them unsuitable for extensive restorations. Researchers have developed two-step universal adhesives to improve bond strength, but bonding performance remains scarce**.** **Objective:** The purpose of this literature review was to inform How is the performance of universal two step self –etch adhesive material to tooth structure. **Method:** This research used a Literature Review study design to assessment and evaluation of research studies about The Bonding Performance of Universal Two-Step Self-Etch Adhesive **Results:** Self-etch adhesives in dentistry are popular due to their bond strength, resistance to microleakage, and superior marginal adaptation. Research explores hydrophilic and hydrophobic adhesive systems, either two step or one step with deep etching enhancing bond strength but increasing nano leakage risk. **Conclusion:** Review have shown that Universal two-step self-etching adhesives, a recent dental material development, have demonstrated favorable bonding performance, offering high bond strength, good marginal adaptation, and low microleakage rates, making them a popular choice for dentists.

Keywords: bonding performance, universal adhesive, two step self-etch

بِسْمِ اللَّهِ الرَّحْمَٰنِ الرَّحِيمِ

FOREWORD

The author would like to express his gratitude to the presence of Allah SWT who has given His mercy and grace, blessings and greetings which are always bestowed upon our lord, the Prophet Muhammad SAW, for the completion of the thesis entitled "***THE BONDING PERFORMANCE OF UNIVERSAL TWO-STEP SELF-ETCH ADHESIVE MATERIALS: LITERATURE REVIEW*”** well.

Writing this thesis is intended to fulfil one of the requirements for achieving a Bachelor of Dentistry degree at the Faculty of Dentistry, Hasanuddin University. Apart from that, it is hoped that this thesis will be useful for institutions, readers, and researchers to increase knowledge.

The author realizes that in the process of writing this thesis there were many obstacles that the author faced. However, thanks to the help, guidance and support from various parties, the writing of this thesis was completed well. Therefore, the author would like to express his deepest thanks to:

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2023

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CHAPTER I

INTRODUCTION

1.1 Background

The enamel and dentin tissues have different structures that affect the development of adhesive materials. The conventional total etching technique (also known as etch-and-rinse) and Self-etch adhesive are standard methods that are widely used as adhesives. Adhesive dentistry began in 1955 by Buonocore on the benefits of acid etching. With changing technologies, dental adhesives have evolved from no etch to total-etch (4th and 5th generation) to self-etch (6th, 7th, and 8th generation) systems. Currently, bonding to dental substrates is based on three different strategies: 1) etch-and-rinse, 2) self-etch and 3) resin-modified glass-ionomer approach as possessing the unique properties of self-adherence to the tooth tissue. More recently, a new family of dentin adhesives has been introduced (universal or multi-mode adhesives), which may be used either as etch-and-rinse or as self-etch adhesives (Sauro 2019).

Adhesive systems have progressed from the ineffective systems of the 1970s and early 1980s to the successful total- and self-etching systems of today. The latest players in the adhesive marketplace are the so called “universal adhesives.” In theory, these systems have the potential to significantly simplify and expedite adhesive protocols and may indeed represent the next evolution in adhesive dentistry. Universal adhesives have been described by some manufacturers and opinion leaders as: ideally a single bottle, no-mix, adhesive system that can be used in total-etch, self-etch, or selective-etch mode depending on the specific clinical situation and personal preferences of the operator (Cuevas-Suárez 2019).

In relation to the application mode, self-etch adhesive systems' SE' reduce the possibility of iatrogenic induced clinical mismanipulation during acid conditioning, rinsing, and drying, which may occur when etch-and-rinse systems are used unfortunately, one of the main drawbacks from applying SE adhesives to dentin and enamel is their inability to etch enamel to the same depth that phosphoric acid does, which is likely responsible for the higher rates of marginal discoloration in the enamel margins of cervical restoration due to their lower acidity (Sauro 2019).

The use of universal adhesives, which may be used for both direct and indirect restorations, can speed up processes and reduce waiting times. Bonding process Universal adhesives penetrate the porous tooth by first dissolving calcium and phosphate components in the tooth structure. The advantages of universal adhesives are increased bond strength compatibility with numerous etching methods abilities to adhere to dentin with caries. All light-cure, dual-cure, or self-cure materials are compatible with each other. the capacity to perform both direct and indirect restoration's ability to successfully bind to dentin, regardless of the etch-and-rinse or self-etch modes utilized. By certain methods, it is possible to strengthen the binding between universal adhesives and dentin (Tsujimoto 2017).

Regardless of the adhesive classification, there are similarities in their chemical composition; hydrophilic monomers, with affinity for the organic components of the dental substrate, and hydrophobic monomers, which support bonding with the restorative resin composite placed over the adhesive layer. In addition, there are solvents, photo and/or chemical initiators, in some compositions, a small number of filler particles (Giannini 2015).

Several modifications have been made to the adhesive materials to improve bond strength to the dental substrate, which include chemical composition, bonding mechanism, number of stages, and application technique. One type of universal adhesive, a two-step self-etch universal adhesive with glycerol phosphate methacrylate

(GPDM) monomer, was developed with a primary acidity of 2 higher, to increase the depth of demineralization in dentin, to form a better bond (Cuevas-Suárez 2019).

The in vitro performance of universal adhesives has been reported as material dependent due to the complexity of their chemical composition. All simplified adhesives behave as permeable membranes (either two-step etch and-rinse or one-step self-etch adhesives). As universal adhesives are one-step self-etch adhesives, they behave in the same fashion. As for one-step self-etch adhesives, coating universal adhesives with an extra layer of a hydrophobic resin improves their immediate and long-term bond strengths and degree of conversion, consequently lowering nano leakage. Extra hydrophobic adhesive layer has been proven to improve the bonding performance of one-step selfetch universal adhesives. This is the background to the development of universal two-step self-etch adhesive. However, information about this adhesive system is still not widely known due to its newness. Therefore, the aim of this literature review is to describe the bonding performance of universal 2-steps self-etch adhesive (Hardan 2021).

1.2 Problem Formulation

Based on the description described above, the following problems can be formulated: “How is the bonding performance of universal two-step self-etch adhesive material to tooth structure?”

1.3 Research Objectives

1.1.1 General Purpose

The purpose of this literature review was to inform How is the performance of universal two step self –etch adhesive material to tooth structure.

1.1.2 Special Purpose

To determine the performance of two-step universal and self-etch adhesive material to tooth structure.

1.4 Literature Review Benefits

1.1.3 General Benefits

Knowing the effect of the two-step universal self-etch adhesive material.

1.1.4 Special Benefits

The results of this review are expected to contribute knowledge and information to dentists regarding the performance of the two-step universal self-etch adhesive material to tooth structure, so that it can be used as a reference for further research and treatment option.

CHAPTER II

LITERATURE REVIEW

2.1 History of adhesive

Animal glue became the dominant adhesive used for thousands of years, becoming a major international industry. The history of dental adhesives started as early as 1949, when Dr. Haggard's This product contained an adhesive called glycerol phosphoric acid dimethacrylate, which was polymerized using a sulfinic acid initiator, later known as "Sevitron Cavity Seal". This adhesive relies on acidic monomers capable of etching and interacting on a molecular level with tooth surfaces to for physical/chemical bonds between the restoration and the tooth. Hagger's concept was soon adopted by other investigators and different generations of dental adhesives evolved thereafter; despite the fact it was the first time that bonding to tooth structure became commercially available through the formation of an interface remarkably like what is called today the hybrid layer. That concept is obvious in the development of newer generations of dentin adhesive (Sauro 2019), (Salustio 2022).

Adhesive dentistry has undergone great progress in the last decades. Considering minimal-invasive dentistry, this innovative approach promotes a more conservative cavity design, which relies on the effectiveness of current enamel dentine adhesives. Adhesive dentistry began in 1955 by Buonocore on the benefits of acid etching. With changing technologies, dental adhesives have evolved from noetch to total-etch (4th and 5th generation) to self-etch (6th, 7th, and 8th generation) systems. Currently, bonding to dental substrates is based on three different strategies: 1) etch-and-rinse, 2) self-etch and 3) resin modified glass-ionomer approach as possessing the unique properties of self-adherence to the tooth tissue. More recently, a new family of dentin adhesives has been introduced (universal or multi-mode adhesives), which may be used either as etch-and-rinse or as self-etch adhesives (Eakle 2019).

2.1.1 Generation of adhesive:

The concept of generation was used because of the complexity of bonding agents, the variety of classifications refers to when and in what order this type of adhesive was developed by the dental industry. Adhesive dentistry began in 1955 by Buonocore on the benefits of acid-etching. With changing technologies, dental adhesives have evolved from no-etch to total-etch (4th and 5th generation) to self-etch (6th, 7th, and 8th generation) systems and the details of these are shown. Each generation has attempted to reduce the number of bottles involved in the process, to minimize the number of procedural steps, to provide faster application techniques and to offer improved chemistry to facilitate stronger bonding (Eakle 2019).

a. First generation:

First Generation The first-generation bonding systems were published by Buonocore in 1956, who demonstrated that use of glycerophosphoric acid dimethacrylate (NPG-GMA) containing resin would bond to acid etched dentin These bonding agents were designed for ionic bonding to hydroxyapatite or for covalent bonding (hydrogen bonding) to collagen. However, immersion in water would reduce this bond. After nine years, Bowen used a coupling agent to overcome this problem He addressed this issue using that functioned as NPG-GMA a primer or adhesion promoter between enamel/dentin and resin materials by chelating with surface calcium, where one end would bond to dentin, and other would polymerize with composite resin. Overall, this generation leads to extremely poor clinical results as well as low bond strength in the 1–3 MPa range (Eakle 2019), (Meerbeek 2020).

b. Second generation:

The second generation of dentin bonding agents were introduced in the late 1970s and sought to improve the coupling agents that were utilized in the first generation of adhesives. The second generation of dentin adhesives primarily used polymerizable phosphates added to bis-GMA resins to promote bonding to the calcium in mineralized tooth structure. Bonding mechanism involves formation of ionic bonds between calcium and chlorophosphate groups. This ionic bond would rapidly degrade in water submersion (again analogous to saliva) and even the water within the dentin itself, and cause debonding and/or microleakage. The smear layer was still not removed, and this contributed to the weak and unreliable bond strengths of this second generation. The smear layer is really a smooth layer of inorganic debris that remains on the prepared dentin surface because of tooth preparation with rotary instruments (the drill). This generation of bonding agents is no longer used, due to failed attempts to bond with a loosely bound smear layer. Bond strength: 4–6 Mpa (Eakle 2019).

c. Third generation:

Third Generation In the late 1970s and early 1980s, third generation dentin bonding agents were presented. The thirdgeneration bonding systems introduced a particularly important change: the acid etching of the dentin to modify or partially remove the smear layer. This opened the dentin tubules and allowed a primer to be placed after the acid was completely rinsed away. While this method achieved a greater bond, it was considered controversial in dentistry as the feeling existed that dentin ought not to be etched. After the primer was added, an unfilled resin was placed on both dentin and enamel. The weak link with this generation was the unfilled resins that simply did not penetrate the smear layer effectively according to Tao et al. in 1988 (Eakle 2019), (Meerbeek 2020).

d. fourth generation:

Fourth Generation in 1980s and 1990s, fourth generation dentin bonding agents were introduced. The fourth-generation materials were the first to achieve complete removal of the smear layer and are still considered as the golden standard in dentin bonding. In this generation, the three primary components (etchant, primer, and bonding) are typically packaged in separate containers and applied sequentially. The concept of total-etch technique and moist dentinal hallmarks of the 4th generation systems, where dentin and enamel are etched at the same time with phosphoric acid (H3PO3) for a period of

15–20 s. However, the surface must be left moist "wet bonding", to avoid collagen collapse (Eakle 2019),
(Salustio 2022).

The application of a hydrophilic primer solution can infiltrate the exposed collagen network forming the hybrid layer. The hybrid layer is formed by the resin infiltrated surface layer on dentin and enamel. The goal of ideal hybridization is to give high bond strengths and a dentin seal. Bond strengths for these adhesives were in the low- to mid-20 MPa range and significantly reduced margin leakage compared to earlier systems. This system was very technique sensitive and required an exacting technique of controlled etching with acid on enamel and dentin, followed by two or more components on both enamel and dentin (Salustio 2022).

These systems are highly effective when used correctly, have good long-term clinical track record, and are the most versatile of all the adhesive categories, because they can be used for virtually any bonding protocol (direct, indirect, self-cure, dual-cure, or light-cure). These systems are still the standards by which the newer systems are judged. However, these systems can be very confusing and time consuming with so many bottles and application steps. Because of the complexity of multiple bottles and steps, dentists began requesting a simplified adhesive system (Eakle 2019), (Meerbeek 2020).

e. Fifth generation:

Fifth Generation In the 1990s and in the ongoing decade, the fifth-generation bonding systems sought to simplify the process of fourth generation adhesion by reducing the clinical steps which resulted in reduced working time. These are distinguished by being “one step” or “one bottle” systems. In addition, an improved way was needed to prevent collagen collapse of demineralized dentin and to minimize if not eliminate, postoperative sensitivity. So, the most common method of simplification is “one bottle system” combining the primer and adhesive into one solution to be applied on enamel and dentin simultaneously with 35 to 37% phosphoric acid for 15–20 s. This single bottle, etch-and-rinse adhesive type shows the same mechanical interlocking with etched dentin occurs by means of resin tags, adhesive lateral branches and hybrid layer formation and shows high bond strength values to dentin with marginal seal in enamel. These kinds of adhesives systems may be more susceptible to water degradation over time than the fourth generation. This is because the polymerized primer of the “one bottle system” tends to be hydrophilic in nature. However, when using the fourth generation, the hydrophilic primer is covered by a more hydrophobic resin, making it less susceptible to water sorption (Giannini 2015), (Salustio 2022).

Not all fifth-generation adhesives are compatible with dual and self-cured or core materials. The lower PH of the Oxygeninhibited layer, or the monomers in some simplified products, are too acidic and thereby de-activate the tertiary amine in chemical-cured composites. As well as the same regarding the number of applications (unfilled need more applications), so it is critical to follow the manufacturer’s directions. Several long-term studies indicate that fifth generation dental adhesive achieves high clinical bond strengths. In addition, the resin-dentin bond is prone to water degradation, fifth generation adhesives are more prone to water degradation than fourth generation dental adhesive (Meerbeek 2020).

f. Sixth generation:

Sixth Generation The sixth-generation bonding systems introduced in the latter part of the 1990s and the early 2000s also known as the “self-etching primers”, were a dramatic leap forward in technology. The sixth-generation bonding systems sought to eliminate the etching step, or to include it chemically in one of the other steps: (self-etching primer + adhesive) acidic primer applied to tooth first, followed by adhesive or (self-etching adhesive) two bottles or unit dose containing acidic primer and adhesive; a drop of each liquid is mixed and applied to the tooth. It is recommended that the components are mixed immediately before use. The mixture of hydrophilic and hydrophobic resin components is then applied to the tooth substrate. These bonding systems are characterized by the possibility of achieving a proper bond to enamel and dentin using only one solution. The biggest advantage of the sixth generation is that their efficacy is less dependent on the hydration state of the dentin than the total-etch systems (Eakle 2019).

Unfortunately, the first evaluations of these new systems showed a sufficient bond to conditioned dentin while the bond with enamel was less effective. This may be since the sixth-generation systems are composed of an acidic solution that cannot be kept in place, must be refreshed continuously, and have a pH that is not enough to properly etch enamel. To overcome this problem, it is recommended to etch enamel first with the traditional phosphoric acid prior to using it. However, those utilizing this technique should take care to confine the phosphoric acid solely to the enamel. Additional etching of the dentin with phosphoric acid could create an “over-etch” situation where the demineralization zone is too deep for subsequently placed primers to

completely penetrate. While data indicates that sixth generation adhesives will adhere well to dentin
(41 MPa at 24 hours), the bond to enamel is at least 25% weaker than both the 4th and 5th generation adhesives in pooled data studies. Several respected clinicians have utilized sixth generation adhesives for bonding to dentin after selectively etching the enamel (Hardan 2021).

g. Seventh generation:

Seventh Generation The seventh-generation bonding system was introduced in late 1999 and early 2005. The seventh generation or one-bottle self-etching system represents the latest simplification of adhesive systems. With these systems, all the ingredients required for bonding are placed in and delivered from a single bottle. This simplifies the bonding protocol as the claim was that it could be achieved consistent bond strengths while eliminating the errors that could normally be introduced by the dentist or dental assistant who had to mix the separate components with other more complicated systems (Meerbeek 2020), (Salustio 2022).

However, incorporating and placing all the chemistry required for a viable adhesive system into a single bottle, and having it remain stable over a reasonable period, poses a significant challenge. These inherently acidic systems tend to have a significant amount of water in their formulations and may be prone to hydrolysis and chemical breakdown. Furthermore, once placed, and polymerized, they are more hydrophilic than two-step self-etching systems; this condition makes them more prone to water sorption, limits the depth of resin infiltration into the tooth and creates some voids (Hardan 2021).

The advantage of this generation was not any mixing required and the bond strengths were consistent. However, the seventhgeneration adhesives have proven to have the lowest initial and longterm bond strengths of any adhesive on the market today that may be considered a disadvantage. Seventh generation adhesives involve the application of etch, primer, and adhesive which have already been mixed, followed by light curing the tooth. Seventh generation adhesives are "all-in-one" if there has ever been such a thing. The clinical and scientific data on these adhesives proves that they are hydrophilic and degrade more rapidly. In addition, the chemistry must be acidic, as etch added in this liquid, and this has been shown to adversely react with the composite initiator systems (Eakle 2019).

h. Eight generation (Universal Adhesive):

Eighth Generation In 2010, voco America introduced voco futurabond DC as 8th generation bonding agent, which contains nanosized fillers. In the new agents, the addition of nano-fillers with an average particle size of 12 nm increases the penetration of resin monomers and the hybrid layer thickness, which in turn improves the mechanical properties of the bonding systems. Nano-bonding agents are solutions of nano-fillers, which produce better enamel and dentin bond strength, stress absorption, and longer shelf life. It has been observed that filled bonding agents produced higher in vitro bond strength. These new agents from self-etch generations have an acidic hydrophilic monomer and can be easily used on the etched enamel after contamination with saliva or moisture (Perdigão 2020).

Based on the manufacturer, nanoparticles acting as crosslinks will reduce the dimensional changes. The type of nano-fillers and the method that these particles are incorporated affect the adhesive viscosity and penetration ability of the resin monomers into collagen fibres spaces. Nano-fillers, with dimensions larger than 15–20 nm or a content of more than 1.0 percent by weight, both can increase the viscosity of the adhesives, and may cause accumulation of the fillers over the top of the moisturized surface. These clusters can function as flaws which may induce cracks and cause a decrease in the bond strength (Eakle 2019), (Salustio 2022).

These new products are known as "multi-mode" or "multipurpose" adhesives because they may be used as self-etch (SE) adhesives, etch-and-rinse (ER) adhesives, or as SE adhesives on dentin and ER adhesives on enamel (a technique commonly referred to as "selective enamel etching"). This versatile new adhesion philosophy advocates the use of the simplest option of each strategy, that is, onestep self-etch (SE) or two-step etch-and-rinse (ER) ([77]), using the same single bottle of adhesive solution which is definitely much more challenging to dental substrates of different natures (i.e., sound, carious, sclerotic dentin, as well as enamel). (Giannini 2015).

Beforehand etching enamel with phosphoric acid is often recommended when bonding to unground enamel. Indeed, the priming and bonding components can be separated or combined, resulting in three steps or two steps for etch-and-rinse systems, and two steps or one step for self-etch adhesives. Contemplating these two bonding strategies, adequate bonding to dentin can be completely achieved with either etch-and-rinse or self-etch adhesives; however, at enamel, the etch-and-rinse approach using phosphoric acid remains the preferred choice. In relation to the application mode, self-etch adhesive systems reduce the possibility of iatrogenic induced clinical mis-manipulation during acid conditioning, rinsing, and drying, which may occur when etch-and-rinse systems are used (Pashley,2011).

On the other hand, some drawbacks may be listed for these SE materials. Unfortunately, one of the main drawbacks from applying SE adhesives to dentin and enamel is their inability to etch enamel to the same depth that phosphoric acid does, which is likely responsible for the higher rates of marginal discoloration in the enamel margins of cervical restoration due to their lower acidity. Thereby the degradation of SE was attributed to its acidic content, which increases the hydrophilicity of the adhesive layer and leads to water uptake and plasticization. So, the long-term performance of simplified one-step adhesives is inferior in terms of bond durability, when compared to the gold-standard three-step etch-and-rinse approach. To overcome the weakness of previous generations of single-step self-etch adhesives, universal adhesives have been developed that allow for application of the adhesive with phosphoric acid pre-etching in the total etch or selective-etch approaches to achieve a durable bond to enamel and has been accepted by showing good results *in vitro (*Wagner 2014).

Despite the similarities between adhesives, the composition of universal adhesive differs from the current SE systems by the incorporation of monomers that can produce chemical and micromechanical bond adhesion to the dental substrates. Its composition is an important factor to be taken account, since most of these adhesives contain specific carboxylate and/or phosphate monomers that bond ionically to calcium found in hydroxyapatite (Ca10[PO4]6[OH]2), that could be influence the bonding

effectiveness. This may be important in terms of durability, as water sorption and hydrolytic breakdown of the adhesive interface over time has been implicated as one of the primary causes of bond failure

(Perdigão 2020).

Additionally, the matrix of universal is based on a combination of monomers of hydrophilic (hydroxyethul methacrylate /HEMA) hydrophobic (decandiol dimethacrylite /D3MA) and intermediate (bisGMA) nature. This combination of properties allows universal adhesives to create a bridge over the gap between the hydrophilic tooth substrate and hydrophobic resin restorative, under a variety of surface conditions. Moreover, some universal adhesives may contain silane in their formulation, potentially eliminating the silanization step when bonding to glass ceramics or resin composites, for instance. Nevertheless, it is known that simplified materials are associated with lower *in vitro* bond strength results and poorer *in vivo* longevity of restorations. These findings are probably a result of the complex formulation of simplified adhesives and their high content of solvents, which may impair complete solvent volatilization and consequently lead to poorer adhesive polymerization (Tsujimoto 2017), (Salustio 2022).

This multi-approach capability enables the clinician to apply the adhesive with the so-called selective enamel etching technique that combines the advantages of the etch-and-rinse technique on enamel, with the simplified self-etch approach on dentine with additional chemical bonding on remnant carbonated apatite crystallites in those bonding substrates. Therefore, the universal adhesives have much broader applications than 7th generation systems (Eakle 2019).

Additionally, manufacturers typically state that universal adhesives can be used for the placement of both direct and indirect restorations and are compatible with self-cure, light-cure and dual-cure resin-based cements and bonds to metals, zirconia, porcelain and composite. While the manufacturers of some universal adhesives still recommend the use of separate "activator" and dedicated primers to optimize bond strength to substrates such as porcelain and zirconia. Thus, it appears, at least in certain situations and with some products, that universal adhesives consist of two bottles, or require the use of an additional activator, or have chemistries that must be mixed prior to use, or bond most optimally to porcelain and zirconia with separately applied and dedicated primers or are not compatible with a total-etch protocol (Tsujimoto 2017), (Meerbeek 2020).

Further, there is an advantage in having an adhesive that can operate on these two procedures since it allows the dentist to choose his procedure according to the clinical case to optimize the result. For instance, when the restoration requires strong bonding to enamel or in case of sclerotic dentin, it may be advisable to apply prior etching. The etching step can be modulated according to the length of time the phosphoric acid gel is applied prior to rinsing. On the other hand, it may be preferable to benefit completely from the self-etch pathway, when dealing with cases confronting difficult access, limited time, or poor patient compliance in very young patients (Tsujimoto 2017), (Perdigão 2020).

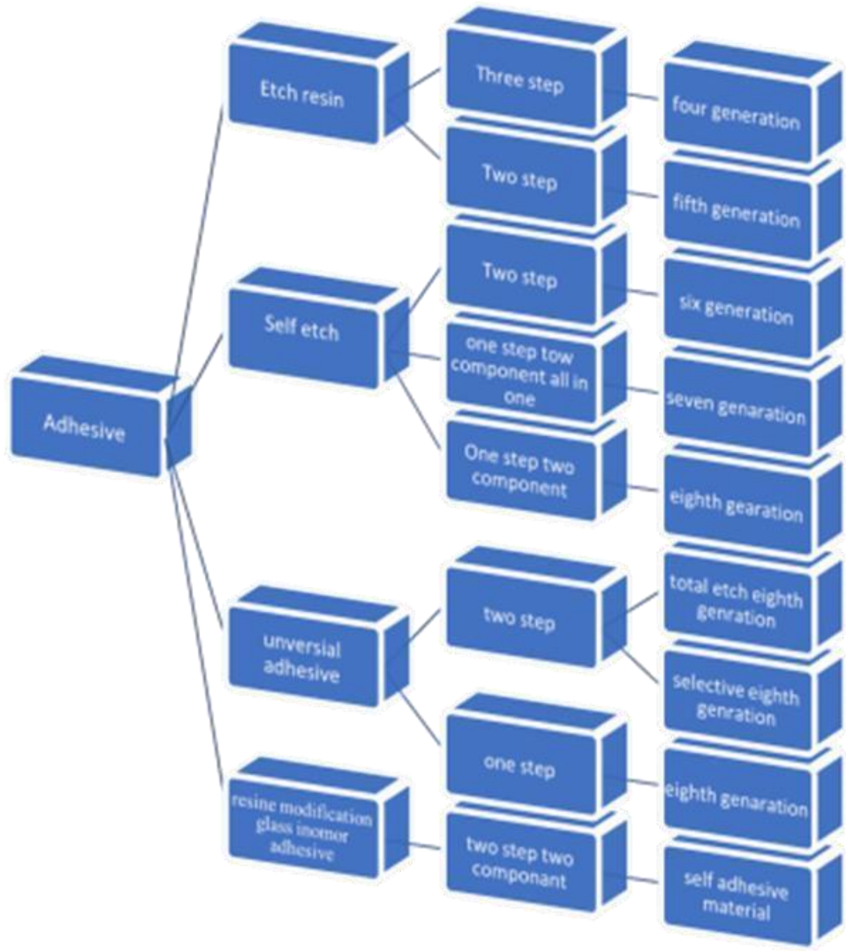


Figure 1.1 (adhesives by generation [22])

Based on stage of application:

2.2.1 Etch - Resin adhesive:

The development of dental adhesives has a lengthy gestation, from the beginnings around 1950, to the latest generation: modern universal adhesives, which were introduced during the 2010s. The foundation for these developments was a deeper understanding of the mechanisms of adhesion to the tooth structure, and to restoration materials. Typically, the performance of an adhesive does not depend on the use of a single ingredient, but on an overall balanced and optimized formulation that contains various components with different roles, such as functional adhesive monomers. Adhesive dentistry has undergone great progress in the last decades. Considering minimalinvasive dentistry, this new approach promotes a more conservative cavity design, which relies on the effectiveness of current enameldentine adhesives (Tang 2023).

Adhesive dentistry began in 1955 by Buonocore on the benefits of acid etching. With changing technologies, dental adhesives have evolved from no etch to total-etch (4th and 5th generation) to self-etch (6th, 7th, and 8th generation) systems. Currently, bonding to dental substrates is based on three different strategies: 1) etch-andrinse, 2) self-etch and 3) resin-modified glass ionomer approach as possessing the unique properties of self-adherence to the tooth tissue. More recently, a new family of dentin adhesives has been introduced (universal or multi-mode adhesives), which may be used either as etchand-rinse or as self-etch adhesives. While a wealth of literature exists on adhesives that have a long and successful clinical history ('gold standards'), some universal adhesives have also accumulated a lot of scientific evidence while offering benefits like ease of use, low technique sensitivity and versatility. (Giannini 2015), (Meerbeek 2020).

To achieve reliable results with a modern adhesive, several tips should be kept in mind regardless of the product, which result in a homogeneous adhesive layer, proper cure, and high bond strength. Resin adhesives are used to enhance retention of both composites and compomers to tooth structure and hence prevent bacterial microleakage (Van Meerbeek et al., 2001). There are a wide range of different formulations, but they consist of the components of RMGICs and composites but with much lower levels of filler to improve fluidity. Preparation of enamel for bonding is straightforward, requiring just partial etching of its hydroxyapatite crystals with 35% phosphoric acid gel for ~30 s followed by rinsing and drying. This produces a microscopically roughened surface into which methacrylate monomers can penetrate and bond by micromechanical retention (Van Landuyt et al., 2007). Successful adhesive bonding depends on the chemistry of the adhesive, on appropriate clinical handling of the material as well as on the knowledge of the morphological changes caused on dental tissue by different bonding procedures (Eakle 2019).

This paper outlines the status of contemporary adhesive systems, with particular emphasis on chemical characteristics and mode of interaction of the adhesives with enamel and dentin tissues Dental adhesives are used for several clinical applications and they can be classified based on the clinical regimen in etch-and-rinse adhesives and self-etch adhesives. Other important considerations concern the different anatomical characteristics of enamel and dentine which participate in the bonding procedures that also have implications for the technique used as well as for the quality of the bond. Adhesive systems have evolved both regarding composition and action mechanisms on dental tissue, and regarding their components and the number of clinical steps necessary for their application. This last aspect enables professionals to achieve lower technical sensitivity and an equivalent performance level on enamel and dentin. Adhesives can then be classified as follows (Hardan 2021), (Salustio 2022).

2.12Three-step adhesives (Total-Etch Systems)

They require acid etching (enamel and dentin), rinse and dry, use of a priming agent and adhesive as steps to follow before placing the composite. Once the tissues are demineralized, primers must transform the hydrophilic dental surface into hydrophobic surface, so that the bonding of adhesive resin is achieved. To do this, agents contain monomers that can be polymerized with hydrophilic properties, dissolved in acetone, water and/or ethanol. These agents carry monomers through the etched tissue. Adhesive systems that have volatile organic compounds such as ethanol and acetone are based on their capacity to remove the remaining water. This makes it possible for the monomers to penetrate the microporosities caused by the acid etching on the enamel, within the open dentinal tubules and through the nano-spaces in the collagen network of the dentin. Hence full tissue infiltration would be achieved if such tissues have been previously wetted. Water-soluble primers have HEMA and polyalkenoic acid (Cuevas-Suárez 2019).

One of the advantages of three-step systems is their capacity to achieve the necessary bond strength to enamel and dentin. However, their main drawback is that the technique is very sensitive given the many clinical steps to follow for their application, and the risk of overwetting or over-drying the dentin during rinsing and drying after the etching acid has been applied. These adhesives have reached bondstrength values of approximately 31 MPa.

1. **Two-step resin adhesive:**

This was the fifth generation developed to simplify the procedures involved in bonding. Therefore, the primer and the bonding agent are present in a single bottle. Components are etchant gel + primer and adhesive Here three components came into being: Primer-it consisted of hydrophilic monomers in ethanol, acetone or water. Primer is a bifunctional molecule having a hydrophilic and a hydrophobic part; the former attaches to the tooth whereas the latter attaches to composite resin. Phosphoric acid etchant (in gel form) Examples: HEMA NTG GMA PENTAThe adhesion mechanism of

these systems is the same as that of their three-step predecessors, but they are more technique-sensitive. These systems require the application of a wet adhesion technique as the priming step does not take place independently (Cuevas-Suárez 2019), (Salustio 2022).

The tissue must remain wet in the case of dentin to prevent the demineralized collagen from collapsing, thus preventing incomplete infiltration of the adhesive. However, it is very difficult for the clinician to reach the optimal degree of moisture, which is why this technique is operator sensitive. These systems have simplified the clinical technique, reducing, to some extent, working time. Two procedures are described:

1. First, the primer and the adhesive come together in one package, and the acid etching agent comes separately. The main drawback of these systems is that the acid must be rinsed with water and then dried. However, the dentin must remain wet after acid etching,

which is difficult to standardize clinically given the lack of stability of the demineralized matrix.

2. Additionally, the primer now has monomers with acid groups that can act as the acid etching agent, and hence prepare the dental tissue for adhesion. The advantages of these systems are that the rinse stage is eliminated, and that the dentin surface is already prepared to receive the adhesive agent.

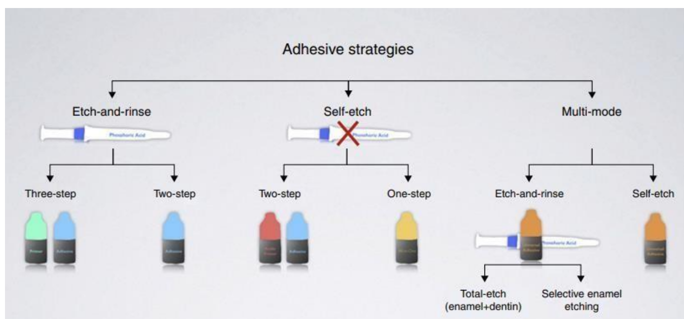


Figure 1.2 (Classification of adhesives by stage of clinical application[18])

2.2.3 Three step resin adhesives:

They require acid etching (enamel and dentin), rinse and dry, use of a priming agent and adhesive as steps to follow before placing the composite. Once the tissues are demineralized, primers must transform the hydrophilic dental surface into hydrophobic surface, so that the bonding of adhesive resin is achieved. To do this, agents contain monomers that can be polymerized with hydrophilic properties, dissolved in acetone, water and/or ethanol. These agents carry monomers through the etched tissue (Wagner 2014).

Adhesive systems that have volatile organic compounds such as ethanol and acetone are based on their capacity to remove the remaining water. This makes it possible for the monomers to penetrate the microporosities caused by the acid etching on the enamel, within the open dentinal tubules and through the nano spaces in the collagen network of the dentin. Hence full tissue infiltration would be achieved if such tissues have been previously wetted. Water-soluble primers mainly have HEMA and polyalkenoic acid. The action mechanism of these materials is since the water evaporates after application and the surface is air dried, thus increasing HEMA concentration (Tang 2023).

The principle of different volatilities of the solvent and the solute is very important. Water has a much higher steam pressure than HEMA. This allows for its retention, as the solvent, water, evaporates at the drying stage. The priming procedure ends with dispersion, using a light airstream to remove the solvent and leave a shiny and homogeneous layer on the surface. In the third step, the hydrophobic bonding agent is applied, which will chemically bond with the composite resin, applied afterwards. One of the advantages of threestep systems is their capacity to achieve the necessary bond strength to enamel and dentin (Wagner 2014).

However, their main drawback is that the technique is very sensitive given the many clinical steps to follow for their application, and the risk of over-wetting or over-drying the dentin during rinsing and drying after the etching acid has been applied. These adhesives have reached bond-strength values of approximately 31 MPa. Threesteps: involving etch, prime and bond. These bonding systems are supplied as three bottles, one each from etchant, primer, and bonding agent. These are the most complicated to use in the clinic but result in highest bond strengths and greatest durability (Eakle 2019) (Salustio 2022).

2.1.4 Self-etch adhesive.

They are defined as "bonding systems which dissolve the smear layer and create porosities in the underlying dental substrates without needing an extra conditioning agent (eg: phosphoric acid) to be applied in a single step. Dental adhesive systems can be classified into two main categories according to different bonding techniques to the dental substrates: the etch-and-rinse and self-etch systems.1, 2 The etch-and-rinse strategy involves the prior application of phosphoric acid, which, at enamel, produces deep etch-pits in the hydroxyapatite rich substrate and, at dentin, demineralizes up to a depth of a few micrometers to expose an HAp-deprived collagen mesh.1, 3 Thus, etchand-rinse adhesives are available for use in three steps (acid etching, primer and adhesive) or two steps (primer and adhesive joined into one single material). For these total etching adhesive systems, hybrid layer formation relies on the demineralization of superficial dentin by inorganic acids, which exposes collagen fibrils that are then infiltrated by hydrophilic monomers.2, 3, 4 although etchand-rinse adhesives are still the gold standard for dental adhesion and the oldest of the marketed adhesives (Giannini 2015).

The current trend is to develop simplified self-etching materials. Current adhesive systems follow either an "etch-and-rinse" or "self-etch" approach, which differ in how they interact with natural tooth structures. Etchand-rinse systems comprise phosphoric acid to pretreat the dental hard tissues before rinsing and subsequent application of an adhesive. Self-etch adhesives contain acidic monomers, which etch and prime the tooth simultaneously. Etchandrinse adhesives are offered as two- or three-step systems, depending on whether primer and bonding are separate or combined in a single bottle. Similarly, self-etch adhesives are available as one- or two-step systems. Both etch-and-rinse and self-etch systems form a hybrid layer because of resins impregnating the porous enamel or dentin. Despite current trends toward fewer and simpler clinical application steps, onestep dentin bonding systems exhibit bonding agent lower bond strengths and seem less predictable than multi-step etch-and-rinse and self-etch systems (Pashley,2011).

The varying evidence available today suggests that the choice between etch and-rinse and self-etch systems is often a matter of personal preference. In general, however, phosphoric acid creates a more pronounced and retentive etching pattern in enamel. Therefore, etch-and-rinse bonding systems are often preferred for indirect restorations and when large areas of enamel are still present. Conversely, self-etch adhesives provide superior and more predictable bond strength to dentin and are, consequently, recommended for direct composite resin restorations, especially when predominantly supported by dentin (Wagner 2014).

2.2 One step self-etch adhesive.

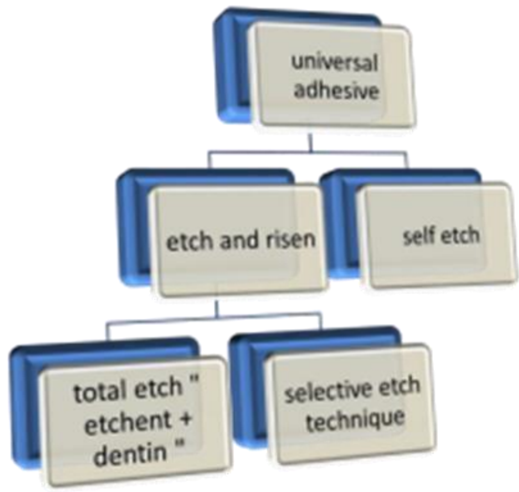
These systems combine the three functions: acid etching, priming and adhesion in one stage. Their main advantage is that they are easy to apply and that it is not necessary to rinse the surface: only drying is necessary to uniformly spread the product before photopolymerization. In these adhesive systems, the technique has been simplified, thus making it possible to keep hydrophilic acidic monomers, organic solvents, and water in one solution. These components are essential to activate the process of dentin demineralization and the operation of the system (Hardan 2021), (Salustio 2022).

Solvents like acetone or alcohol are kept in the solution, but once dispensed, solvent evaporation begins. This evaporation triggers a separation phase, with the formation of multiple droplets and oxygen inhibition. There is also a lower degree of conversion, which promotes hydrolytic degradation, thus affecting the bonding capacity in the adhesive interface. Van Meerbeek et al. report bond-strength values of approximately 20 MPa. One-step: this uses a single bottle containing a formulation that blends a self-etching primer and bonding agent. Clinically, this is the easiest to use, and bond strengths are generally reported to be acceptable, despite the simplicity of bonding operation. Self-etch adhesives do not require a separate etching step because they contain acidic functional monomers that simultaneously etch and prime the tooth substrate for bonding Self-etch adhesives are believed to be user friendly and less technique-sensitive than total-etch adhesives, thereby resulting in reliable clinical performance (Eakle 2019), (Meerbeek 2020).

2.3 Universal adhesive

Indeed, the so-called «cosmetic revolution» in dentistry blossomed in large part due to dramatic advances in adhesive technology. Adhesive systems have progressed from the largely ineffective systems of the 1970s and early 1980s to the relatively successful total- and self-etching systems of today. The latest players in the adhesive marketplace are the so-called «universal adhesives. » In theory, these systems have the potential to significantly simplify and expedite adhesive protocols and may indeed represent the next evolution in adhesive dentistry. The relatively successful total- and self-etching systems of today (Cuevas-Suárez 2019), (Salustio 2022).

These new products are known as "multi-mode" or "multipurpose" adhesives because they may be used as self-etch (SE) adhesives, etch-and-rinse (ER) adhesives, or as SE adhesives on dentin and ER adhesives on enamel (a technique commonly referred to as "selective enamel etching"). This versatile new adhesion philosophy advocates the use of the simplest option of each strategy, that is, one-step self-etch (SE) or two-step etch-and-rinse (ER), using the same single bottle of adhesive solution which is much more challenging to dental substrates of different natures (i.e., sound, carious, sclerotic dentin, as well as enamel (Pashley 2011), (Vaz 2012).



The “Total-etch” or “etch-and-rinse” technique the “total-etch” term refers to the procedure whereby both enamel and dentin are etched before bonding. Total-etch adhesives involve an initial etching step with phosphoric acid which removes the smear layer and conditions the preparation. The totaletch technique is also often referred to synonymously as the “etch-and-rinse" technique. The phosphoric acid is rinsed off together with the smear layer and the exposed dental tissue is carefully dried. Enamel is usually etched for longer than dentin. The “how wet is wet?” discussion refers to the necessity of not over-drying the dentin after etching and rinsing. Dentin should remain moist and slightly glossy in appearance, such that the collagen fibrils do not collapse as this would make the surface less permeable to hydrophilic monomers in the adhesive and create a weak interface, potentially leading to a poor bond and postoperative sensitivity. For this reason, plus the multistep nature of the technique, total-etch adhesives are often referred to as technique-sensitive

(Wagner 2014).

They are however very well established and highly clinically successful. Selective-etch technique: This refers to the conventional etching technique whereby only the enamel edges of a preparation are etched with phosphoric acid and then rinsed. The dentin is then conditioned using an acidic primer step or an all-in-one self-etching adhesive. The smear layer is modified but not removed as surfaces are not rinsed after the primer application. This method (now less common than the total-etch technique) can also be seen as an etch-and rinse method for enamel only. Self-etch technique: Self-etch adhesives are intended for use without a separate etching step. Self-etch systems contain acidic monomers that prime/etch the enamel and dentin. In contrast to total-etch systems there is less danger of excessive demineralization of the dentin because self-etch systems only demineralize dentin as far as the primer penetrates. Thus, all demineralized areas are immediately filled with monomers (Hardan 2021), (Meerbeek 2020).

The potentially technique-sensitive step of drying the dentin to just the right degree after etching is also not required thus the danger of collagen-fiber collapse can be excluded. Each of these factors should reduce the risk of postoperative complaints. The self-etch approach can be further subdivided into a ‘strong’ (pH < 1), an ‘intermediately strong’ (pH≈1.5), a ‘mild’ (pH≈2), and an ‘ultra mild’ (pH≥2.5) selfetch approach depending on the self-etching or demineralization intensity. In relation to the application mode, self-etch adhesive systems reduce the possibility of iatrogenic induced clinical mismanipulation during acid conditioning, rinsing and drying, which may occur when etch-and-rinse systems are used Unfortunately, one of the main drawbacks from applying SE adhesives to dentin and enamel is their inability to etch enamel to the same depth that phosphoric acid does, which is likely responsible for the higher rates of marginal discoloration in the enamel margins of cervical restoration due to their lower acidity (Tsujimoto 2017).

This multi-approach capability enables the clinician to apply the adhesive with the so-called selective enamel etching technique that combines the advantages of the etch-and-rinse technique on enamel, with the simplified self- etch approach on dentine with additional chemical bonding on remnant carbonated apatite crystallites in those bonding substrates. While the manufacturers of some universal adhesives still recommend the use of separate “activator" and dedicated primers to optimize bond strength to substrates such as porcelain and zirconia. The new-generation two-step self-etch adhesive, comprising a universal adhesive-derived primer and a hydrophobic bonding agent, showed superior bond performance to the conventional two-step adhesive systems The shear bond strength to bovine enamel was measured after thermal cycling in both etch-andrinse and self-etch modes (Perdigão 2020).

The bond durability, in terms of fatigue bond strength, of G2Bond Universal bonded to both enamel and dentin was consistently equal to or better than that of other adhesive systems, regardless of the etching mode The key difference among these systems is the hydrophilicity of the adhesive agents; OptiBond FL and G2-Bond Universal are more hydrophobic than Prime&Bond NT and the Scotch bond Universal Plus Adhesive, due to the lack of water in the composition. The enamel fatigue bond strength of G2-Bond Universal (etch-and rinse mode) was significantly higher than those of OptiBond FL, Prime&Bond NT, and the Scotch bond Universal Plus Adhesive (etch-and-rinse mode), while the values for Prime&Bond NT and Scotch bond Universal Plus were significantly greater than that of OptiBond FL (Pashley,2011).

It has been thought that the most important contribution to bond durability between adhesive and etched enamel is from micromechanical interlocking due to the penetration and polymerization of adhesive agents within the honeycomb microstructure of the etched surface. Therefore, the compatibility between the adhesive agents and etched enamel is high, and the adhesive agent can directly penetrate the etched surface without primer application to create a stable bonding interface. On the other hand, the role that thickness of the adhesive layers plays on the dentin fatigue bond strength of the hydrophilic adhesives appears to be large. The adhesive layer in the Scotch bond Universal Plus Adhesive was generally less than 10 µm thick, while that of Prime&Bond NT was three times thicker and 30 µm thick. Clearfil SE Bond 2 and the Scotch bond Universal Plus Adhesive (self-etch mode) were selected for comparison to the bond durability of G2-Bond Universal in self-etch mode (Wagner 2014).

Considering all the results, G2-Bond Universal showed the highest fatigue bond strength to etched enamel (at 24.6 MPa) and to ground dentin (at 27.3 MPa). Although there is limitation in this study, such as the methodology because the testing was not able to fully simulate aging phenomena occurring in the oral cavity in short periods of time and only evaluated the fatigue bond strength with G2Bond Universal and representative adhesives, the use of G2Bond Universal in the selective etching mode may be the best way to secure high fatigue bond strength compared to other representative adhesives. However, one limitation is the dentin tubule orientation relative to the applied load. Some studies have shown that shear bond strength is dependent on tubule orientation. Here, we attempted to keep the dentin tubules vertical, but future research should evaluate the influence of dentin tubule orientation on G2-Bond Universal bond durability (Giannini 2015), (Meerbeek 2020).

Among the tested adhesive systems, the new-generation twostep adhesive GU, which utilize a universal adhesive-derived primer, showed SBS values equal to or higher than the other conventional twostep adhesive systems, regardless of the application mode, etching mode, or bonded specimen storage period. In clinical situations, a thicker adhesive layer at the enamel margin can cause discoloration and gap formation in resin composite restorations. Additionally, it is likely to form the thicker adhesive layer at the corner of cavities. Thus, it is important to limit the thickness of the bonding agent when using a two-step adhesive system (Perdigão 2020).

Type of Dental Adhesive	**Representative Brands**
1-Step Self-Etch Adhesives	- Single Bond Universal - Adper Single Bond 2.0 - Prime&Bond Elect - G-Premio Bond
2-Step Self-Etch Adhesives	- Clearfil SE Bond 2 - OptiBond FL - Adper Scotchbond SE - All-Bond Universal
Total-Etch Adhesives	- Scotchbond Universal Adhesive - OptiBond XTR - Prime&Bond NT - All-Bond 3

Universal Adhesives	- Single Bond Universal - Scotchbond Universal Adhesive - Clearfil Universal Bond - G-Premio Bond
Self-Etch Adhesives	- Clearfil SE Bond 2 - OptiBond FL - Prime&Bond Elect - Adper Single Bond 2.0
Etch-and-Rinse Adhesives	- OptiBond FL - All-Bond 3 - OptiBond XTR - Scotchbond Universal Adhesive

Table 1.1 (Types of dental adhesives and brands)

2.4 Initial bond strength:

The initial bond strength of universal adhesive is typically strong and reliable. Universal adhesives are designed to create a robust and durable bond with dental substrates such as dentin and enamel. They offer an efficient two-step self-etch process, which contributes to their ability to establish a strong initial bond (Tang 2023), (Iwase 2022).

Universal adhesives are known for their versatility, as they can be used in various dental applications, making them a valuable addition to the dental practitioner's toolkit. Their bond strength is typically high, ensuring the success of dental restorations. The initial bond strength of universal two-step self-etches adhesive, and one-step self-etch adhesive varies and depends on several factors. In general, universal two-step self-etch adhesives tend to exhibit superior initial bond strength compared to one-step self-etch adhesives. This enhanced bond strength is attributed to the two-step adhesive's more comprehensive and precise application process (Cuevas-Suárez 2019), (Salustio 2022).

Universal two-step self-etches adhesives involve two separate steps: the etching and the bonding. This approach allows for better interaction with the tooth substrate, resulting in a stronger and more reliable initial bond. One-step self-etch adhesives, while convenient, may not achieve the same level of bond strength due to the combined etching, priming, and bonding steps in a single application. However, it's essential to note that the actual bond strength can vary depending on the specific adhesive product and clinical application techniques used (Tang 2023).

2.5 Strength tensile bonding

The dental market offers a wide range of adhesive systems with different coupling agents for tooth structures and restorative materials. In recent years, the process has been simple Fifield with fewer components and working steps to reduce potential application errors and variations that could lead to bonding failures. Although conventional silica-based ceramics with low fracture strengths require adhesive cementation to achieve longevity, highstrength lithium disilicate ceramic restorations might be used with either conventional or adhesive cementation when an adequate retention of the restorations is provided through full coverage crown restorations (Cuevas-Suárez 2019).

However, restorations with no or minimal retention—such as labial or occlusal veneers, partial crowns, or Maryland-type resinbonded fixed dental prostheses—require adhesive cementation. collagen affects the quality of the dentin-resin bond. Self-etching 1component adhesive systems have been shown to contain a higher concentration of acid derivatives, methacrylated phosphoric acid esters, water, and organic solvents than conventional bonding agents to simultaneously etch and infiltrate the dentin surface in 1 step (Tsujimoto 2017), (Meerbeek 2020).

Due to their hydrophilic nature, these adhesives may act as permeable membranes, absorbing significant amounts of water when polymerize. The low pH (1.5-2.5) of these 1-bottle self-etching adhesive systems makes them hydrolytically unstable because of the methacrylate-based components. Nanometer-sized porosities within the hybrid layer resulting in nanoleak age have also been shown. The amount of nano leak age in the bonded layer may be small however, it may provide a pathway for the movement of water over time. This movement of water within the bonded interface may result in plasticization of the resin matrix and removal of unconverted monomers, leading to a reduction in bond strength. In the present study, although the 1bottle self-etch adhesives exhibited lower MTBS than the 2-bottle self-etch adhesives, there was no significant difference, except for G-Bond, which was significantly lower than

Prime & Bond NT (Wagner 2014).

As a result of the constant and rapid development of adhesives, laboratory screening has become a crucial step to predict their clinical performance, constructed on the principle that the stronger the bond, the better it will withstand functional stress. In this perspective, due to its excellent discriminative capability, standard operating procedure, profound use, and versatility, the micro tensile bond strength (µTBS) test is considered the most suitable laboratory testing tool. Moreover, the μTBS test has been recommended as the most stand-in in vitro assessment of composite resin restoration retention, particularly after subjecting the bonded specimens to a longevity test. Besides the quantitative assessment of adhesion, valuation of the bonded interface's morphologic characteristics achieved with electron microscopic observations adds additional qualitative insights to toothbiomaterial interaction (Vaz 2012).

When applied to dentin, each adhesive creates a hybrid layer that provides a stress-breaking effect when a load is applied. A gradual transition of the structures' mechanical properties across the resindentin interface influences the bond strength by relieving the stresses between the shrinking composite resin and the rigid dentin. Therefore, an appreciation of the interfacial structures' elastic modulus is crucial, commonly gained through the indentation method employing an ultramicrohardness tester. Although a similar trend in results is observed, these findings are not in general agreement with a previous investigation in which the 1-bottle self-etch adhesive bond strengths were significantly lower than those of the 2-bottle self-etch adhesive systems. The results also indicated that the bond strength of the 2bottle selfetch adhesives were not significantly different from the conventional adhesive Prime & Bond NT. This, however, agrees with previous studies, which showed that the bond strengths of the 2-bottle self-etch adhesives are not significantly different from the conventional etch-and-rinse adhesives (Perdigão 2020).

2.6 Bond strength

Bond strength is the amount of adhesion between bonded surfaces measured in terms of the stress required to separate a layer of material from the base to which it is bonded. Bond strength generally involves determining the stress required to rupture a bond formed by an adhesive between two metal blocks. Often, the test involves the measurement of the shear and flexural bond strength of a bonding agent or a comparison of bonding agents under varying environmental conditions. The test may compare the fractured surface produced to failure analysis results within the adhesive inter-phase region (Hardan 2021).

The use of three universal adhesive systems and the evaluation of the bond strength only on molar teeth are the limitations of the present study. Another limitation of this study is that it was an in vitro study. Under different situations and clinical conditions, the optimum air blowing pressure may be affected by several factors including the intensity and application time of the air pressure, the distance of the air spray to the cavity, the adhesive system that is used, cavity depth, shape, and temperature. Bonding agents have moved towards technique simplification throughout the years, as shown by the recent popularity of all-in (Cuevas-Suárez 2019), (Salustio 2022).

one, single-bottle adhesive systems among clinicians, although there is still room for improvement in these products. Moreover, manufacturers and researchers seem to be driven by the current multitasking mentality, as adhesive systems cannot simply bond to enamel and/or dentin anymore, they also must present additional features, such as antibacterial effects, enzymatic inhibition, demineralizing properties, and so on. However, as technological development runs at a fast pace, looking at the past is extremely important to ensure new bonding agents and clinical procedures are strongly based on sound foundations. Otherwise, practitioners might end up with products that promise too much, but only deliver average results (Eakle 2019), (Meerbeek 2020).

2.7 Bonding performance:

The current adhesives can be classified according to their adhesion strategy into etch-and-rinse or self-etch adhesives. Etch-andrinse adhesives are applied after complete phosphoric acid etching of the dental substrates. On the other hand, the acid etching step is eliminated in the self-etching adhesives, as they contain monomers with acidic functional groups that simultaneously etch and prime the dental substrate. Enamel etching in a separate step with phosphoric acid has been recommended prior to application of self-etching adhesives (Vaz 2012).

As universal adhesives are one-step self-etch adhesives, they behave in the same fashion. If the exposed collagen is not fully encapsulated by the polymerized adhesive monomers, demineralized collagen fibrils will be vulnerable to time-dependent hydrolytic degradation by water, leaving voids within the hybrid layer or demineralized nanochannels. As for one-step selfetch adhesives, coating universal adhesives with an extra layer of a hydrophobic resin improves their immediate and long-term bond strengths and degree of conversion, consequently lowering nanoleakage. Furthermore, universal adhesive infiltration is enhanced if active application is used (Tang 2023).

The universal, multipurpose, or multimode adhesives have been introduced for use in any bonding strategy: etch-and-rinse, selfetch, or selective enamel-etch. They are essentially one-step self-etch adhesives that may be associated with phosphoric acid etching. This multi-approach capability enables clinicians to apply the adhesive in any of the bonding strategies described above, depending on the specific clinical situation and the operators' personal preferences. Additionally, one of the major concerns of the previous generation of one-step self-etch or «all-in one» adhesives was related to its increased nanoleakage after any type of aging and limited bond durability. This compromised long-term performance was related to the presence of complex mixtures of hydrophilic and hydrophobic components within single bottle. As universal adhesives represent one type of one-step self-etch adhesives, the durability and stability of bonded interfaces created by these new adhesives continue to be questionable. In contrast, this effect was not evident on dentin with the use of mild universal adhesives. Since the publication of our review,20 researchers have conducted new and more sophisticated studies in this field (Eakle 2019), (Meerbeek 2020).

Bonding to dentin is considered a more challenging scenario, due to the composition on this substrate. The present results showed that the bond strength to dentin was affected by the bonding strategy and the pH of the adhesive used. The etch-and-rinse approach improved the bond strength to dentin of intermediately strong universal adhesives. When an etch-and-rinse approach is used, the acid etching step solubilizes the mineral content of dentin (including the smear layer) to some extent. Subsequent application of the adhesive lets monomers infiltrate into the collagen network and replace the water between the collagen fibrils. After this, in situ polymerization leads to the formation of the hybrid layer, which in combination with the presence of resin tags within the dentinal tubules, provides the composite restoration with micromechanical retention (Cuevas-Suárez 2019), (Salustio 2022).

Irrespective of the bonding strategy used – etch-and rinse or self-etch – the dentin bond strength of intermediately strong universal adhesives was significantly impaired after all aging processes examined here. These lower values are explained by the presence of unpolymerized monomers remaining after light activation, which continue to demineralize the dentin due to their high level of acidity, thus promoting dentin-adhesive interfaces with low hydrolytic stability and low-stability chemical interactions with the collagen. In addition, the dissolved calcium phosphates embedded within the interface are soluble and very unstable, which may weaken the interfacial integrity. Laboratory and clinical data have previously demonstrated the reduced bond durability and restoration longevity when strong self-etch adhesives were used on dentin,9,23,95,117 this being one of the reasons why the literature has recommended that it is better to avoid their use. Regarding the intermediately strong self-etch adhesives analyzed in this review, their inconsistent bonding performance to dentin could be correlated with higher rates of clinical failure; however, the lack of evidence (Iwase 2022).

on the clinical performance of these types of adhesives prevented us from confirming this correlation, so this type of adhesive should be further studied Bonding performance of mild universal adhesives to dentin was not dependent on the bonding strategy used, which suggests that these types of adhesives could be used in a multimode approach. Studies with mild self-etch adhesive have demonstrated that when adhesive is applied, dentin is partially demineralized, leaving a substantial amount of hydroxyapatite crystals around the collagen fibrils. Thus, self-etch adhesives could interact with dentin in two ways: micro mechanically and chemically. The micromechanical interaction occurs due to in situ polymerization of the monomers that infiltrated into the dentin tissue, in a manner like that occurring with conventional etch-and-rinse adhesives. Like that occurring with conventional etch-and-rinse adhesives. Clinically, using the etch-and-rinse approach for bonding to dentin has several disadvantages; it should be considered that the best option for bonding to dentin using mild universal adhesives may be the self-etch strategy (Tsujimoto 2017), (Meerbeek 2020).

It must be mentioned that the generally superior laboratory data of the adhesives currently considered the "gold standard" confirms their excellent clinical performance. Since the main causes of failure of composite restorations are related to the occurrence of fracture and secondary caries, achieving a stable bonding between the bonding effectiveness measured in the laboratory with the clinical effectiveness determined by randomized clinical trials, it must be mentioned that the generally superior laboratory data of the adhesives currently considered the "gold standard" confirms their excellent. Considering the results obtained in this review, the following recommendations to clinicians are made a) when applied to dentin, prior acid etching before the use of intermediately strong and ultra-mild universal adhesives are not recommendable, and b) selective etching of enamel followed by the application of a mild universal adhesive currently appears to be the best choice to effectively achieve a durable bond to tooth tissue. Consequently, the laboratory and clinical performances of two-step and three-step etch, and rinse adhesives were found to be better than their one-step counterparts (Wagner 2014), (Vaz 2012).

CHAPTER 3