



**FACULDADE DE
MEDICINA DENTÁRIA
UNIVERSIDADE DO PORTO**

**UNIVERSAL ADHESIVES: CONTRIBUTION TO THE RESTORATION
LONGEVITY**

**MESTRADO INTEGRADO EM MEDICINA DENTÁRIA
MONOGRAFIA DE REVISÃO**

Susana Daniela Leal Pinto

PORTO 2020



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Aluna do 5º ano do Mestrado Integrado da Faculdade de Medicina Dentária da
Universidade do Porto

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PORTO 2020

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**“Sou o intervalo entre o meu desejo e aquilo que
os desejos dos outros fizeram de mim...”**

by Álvaro de Campos

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Abstract

Introduction: Nowadays, the massive search for the best dental treatment is much noticed. Therefore, there is a vast hunt for the finest materials, including the superlative and most recent adhesive, considering that adhesion performs a huge role in resin composite restorations and consequently in their longevity. Universal adhesives are the latest materials used in adhesive dentistry since they are applied in different and easy protocols, according to each clinical case. Many studies proved that they are the greatest in dental market, excelling their long durability and ability to deliver the best option for a pleasant restoration.

Objectives: Determinate the variables that may affect the longevity of universal adhesives through a current bibliographic review.

Materials and Methods: It was performed an extensive literature search for articles on three databases: PubMed, Scielo and Web of Science, until April 2020. It incorporated laboratorial and clinical studies, clinical and systematic reviews, meta-analysis, including universal adhesives and restorative composite resins, just as titles and abstracts according to the theme, using some inclusion criteria: last 5 years, free full text and English or Portuguese articles.

Development: Multiple variables interfere with the adhesive restoration longevity. Bonding agents, active application, 10-methacryloyloxydecyl dihydrogen-phosphate-containing adhesives, selective etching, ions-releasing dentin-replacement, copper nanoparticles, ethanol-wetting, flow composites, silver diammine fluoride, bur-cut and 4W lased dentin, light intensification and curing, ozonated water and boric acid pre-disinfection, sodium bicarbonate air abrasion and active agitation of HEMA-free multimode adhesives may increase their durability. Nanoleakage, caries, eroded dentin, bleached teeth, thermocycle aging, water storage, pulpal pressure, desensitizing agents and acetone, maleic acid or HEMA-free adhesives are negative effects for their longevity.

Conclusion: Adhesion durability always depends on the materials properties and composition. There is a wide range of adhesives available for each specific case, since this variability allows them to have different performances. 10-Methacryloyloxydidecyl-dihydrogen-phosphate-containing multimode adhesives have proven to be the most favourable for strong and lasting adhesion, and consequently, to the restoration longevity.

Key words: Universal Adhesives, Bonding Longevity, Multi-mode Adhesives, Bond Strength, Bonding Durability, Multipurpose Adhesives.

Resumo

Introdução: Atualmente, a procura massiva pelo melhor tratamento dentário é muito notada. Assim, existe uma vasta pesquisa pelos melhores materiais, incluindo o melhor e mais recente adesivo, já que a adesão desempenha um enorme papel nas restaurações em resina composta e conseqüentemente na sua longevidade. Os adesivos universais são dos materiais mais recentes na dentisteria adesiva, já que são aplicados com protocolos fáceis e distintos, conforme cada caso clínico. Muitos estudos sugerem que são os melhores do mercado, destacando-se pela sua longa durabilidade e capacidade de conceder a melhor opção para uma boa restauração.

Objetivos: Determinar as variáveis que podem condicionar a longevidade dos adesivos universais através de uma revisão bibliográfica atual.

Materiais e Métodos: Realizou-se uma extensa pesquisa bibliográfica de artigos em três bases de dados: PubMed, Scielo e Web of Science, até Abril de 2020. Incluíram-se na pesquisa estudos laboratoriais e clínicos, revisões clínicas e sistemáticas e meta-análises contendo adesivos universais e resinas compostas restauradoras bem como títulos e resumos sobre o tema, utilizando como critérios de inclusão: últimos 5 anos, texto completo e gratuito e artigos em inglês ou português.

Desenvolvimento: Múltiplas variáveis interferem com a longevidade das restaurações adesivas. Agentes de adesão, aplicação ativa, adesivos com 10-metacriloiloxidecil-di-hidrogenofosfato, ataque seletivo, liberação de iões, nanopartículas de cobre, solvente de etanol, compósitos fluídos, fluoreto de diamina de prata, dentina cortada com broca e laser de 4W, intensificação da luz, pré-desinfecção com água ozonizada e ácido bórico, abrasão por ar com bicarbonato de sódio e agitação ativa de adesivos multimodo sem HEMA, podem aumentar a sua durabilidade. Nanoinfiltração, cáries, erosões, branqueamentos, envelhecimento por termociclagem, armazenamento em água, pressão pulpar, dessensibilizantes e adesivos com acetona, ácido maleico ou sem HEMA, têm efeitos negativos na sua longevidade.

Conclusões: A durabilidade da adesão depende sempre das propriedades e composição dos materiais. Existe uma vasta gama de adesivos disponíveis para cada caso específico, já que esta variabilidade lhes permite diferentes modos de atuação. Adesivos universais que contêm 10-metacriloiloxidecil-di-hidrogenofosfato provaram ser os mais favoráveis para uma adesão forte e duradoura.

Palavras-chave: Adesivos universais, Longevidade Adesiva, Adesivos Multimodo, Força de Adesão, Durabilidade Adesiva, Adesivos Multiuso.

Introduction

Nowadays, it is noticed that there is a massive search for aesthetics in many areas, including medical ones; therefore, the field of dentistry has been highly developed. Every clinical decision has to be the superlative solution for the patient and so the hunt for the correct biomaterial is now one of the main concerns.

Operative dentistry has a special role in aesthetics, and so resin restorations even more. To be successful in every restoration, it is mandatory to get the best adhesive, in order to have the strongest bonding tooth-composite and the longest-term application. Adhesives linked to composite resin in order to solve many restorative concerns⁽¹⁾. That is why, currently, this area is trying to get the finest adhesive for every restorative work. The one that can give us the nicest aesthetics and can stand for the most extended time possible. It is where Biomaterials area begins to get the main role by hunting the best adhesive with the best conditions to assure longevity to every restoration.

There are three main types of adhesive application mode: etch-and-rinse, self-etch and universal adhesives (that allows the combination of the other two). The chart below (Chart 1) may expose, in a simple scheme, the direct adhesive protocol of each one.

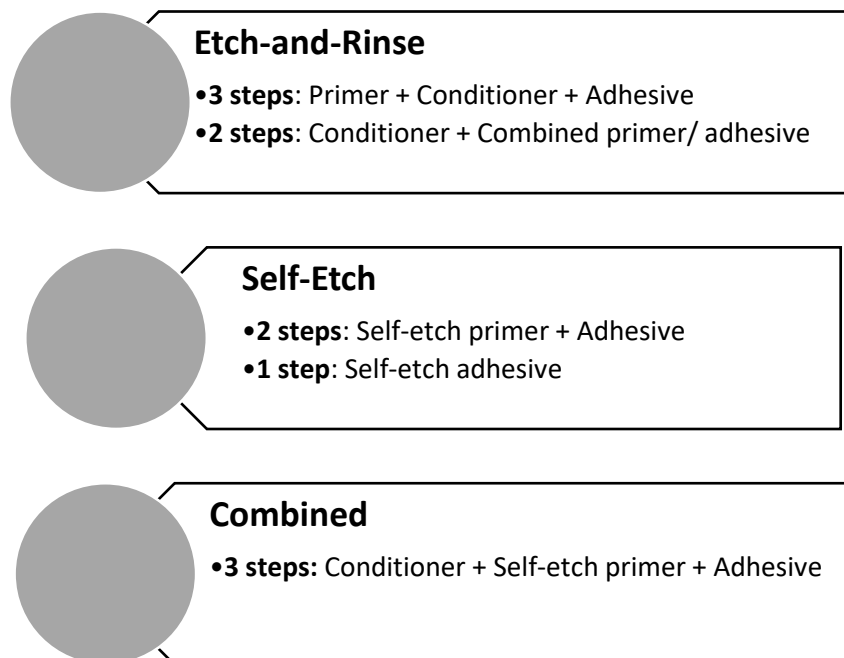


Chart 1 Etching protocols

Starting with the etch-and-rinse technique, essentially, the process of adhesion involves removing minerals of dental substrate, with the help of acid etching, which promotes the

removal of the also called smear layer and creates micro-porosities by opening dentin tubules. Then, the resin monomers are allowed to infiltrate collagen mesh and dentin tubules, forming two defined structures: hybrid layer and resin tags.⁽¹⁾

Thus, an effective bonding does not rely entirely on its thickness, but mainly in the ability of the bonding agent to infiltrate, seal and protect the collagen mesh from any sorts of contamination.⁽¹⁾

As so, the etch-and-rinse strategy involves the prior application of phosphoric acid in enamel and/or dentin. In which, applied to the first, causes the assembly of deep holes in the hydroxyapatite-rich substrate but when used in dentin it demineralises up to a profundity of some micrometres to uncover a mesh dispossessed of hydroxyapatite.⁽²⁾

The presentation of etch-and-rinse method may have two-steps (when the primer and the adhesive are combined in just one bottle) or three-steps (acid, primer and adhesive, all separated), depending on the manufacturer.⁽²⁾

In the self-etch approach, this acid application is completely dispensed, once this adhesive has monomers with acidic functional groups that, in just one single step, can work as primer and acid, at the same time.^(2, 3) These type of adhesives comprehend specific monomers containing carboxylate or phosphate acidic groups that demineralise the dental surface and primer agents that can penetrate the dentin.⁽²⁾

It may have just one-step or two-steps, relying on how the acidic primer and the adhesive are provided by the producer.⁽²⁾ It is known self-etch adhesives are easier and faster to apply comparing to etch-and-rinse type, being less vulnerable to different clinical skills.⁽²⁾

Universal adhesives also called “multimode” or “multipurpose” adhesives are now the most recent solution for that, as they can be used in two different bonding methods: etch-and-rinse or self-etch mode, thanks to their properties.⁽⁴⁾ As the chart above presented (Chart 1), it works by combining the two previous application mode.

The application mode depends on how the materials used in each restoration are provided by the operator as its individual predilection and clinical condition.^(2, 4)

Although the number of steps used in each strategy can be different, when talking about multimode adhesives, the preference is essentially just one-step self-etch protocol.

In other words, universal adhesives do not require acid conditioning unless it is advantageous for adhesion.⁽⁴⁾

Beyond these advantages found in these multimode adhesives, there is the remaining question about the longevity and steadiness of the adhesion itself. Even though many studies showed that these adhesives have a better bond strength on enamel, in the other hand, dentin bonding finds some issues. Furthermore, there are also a few disquiets on terms of efficiency

and durability, as there are some factors that may contribute for a longer or shorter longevity of universal adhesives.⁽⁴⁾

Many factors may affect the efficiency of the adhesives and consequently the restoration longevity but this new trend purposes sustaining bonding durability and decreases the complication of clinical applications.⁽⁵⁾

The present revision work aims to determinate which are the principal factors that can affect the durability and effectiveness of universal adhesives.

Materials and Methods

This review consisted on a search for articles on three electronic databases: PubMed, Scielo and Web of Science.

The keywords used on PubMed are contained on the table below (Table I). The same search method was applied on the other databases.

The reviewer searched for title and abstracts using some filters, which were articles from the last 5 years, free full text and articles written in English or Portuguese.

Table I Search terms

SEARCH TERMS	
No. 1	Universal Adhesives OR Multi-mode Adhesives Or multipurpose adhesives AND free full text AND "last 5 years" AND English OR Portuguese
No. 2	Bond Strength OR Bonding Durability OR Bonding Longevity AND free full text AND "last 5 years" AND English OR Portuguese
No. 3	Search No. 1 AND No. 2

There were achieved 376 articles in PubMed using those search terms connected.

As so, by reading title and abstracts, there was the need to embrace some inclusion criteria as studies on permanent teeth, direct and indirect composite restorations, universal adhesives, bonding durability, human specimens, enamel and dentin. Then it included exclusion criteria, which were: articles about any other type of adhesive that not the universal system, studies with primary tooth, computer-aided design/computer-aided manufacturing, ceramics or nanoceramics, dentures and prosthetics, amalgam restorations, studies with animal teeth, orthodontics and root canal treatments. Finding articles that only included universal adhesives in resin restorations and some of their properties. There were not excluded clinical reviews.

This exclusion resulted in only 27 articles.

There was also the search, with the same criteria and key words in other databases labelled above, excluding duplicated articles. Other articles were captioned by achieving some references of the previous search, reaching 46 significant articles for this review.

Results

After the research referenced above, in materials and methods, it was achieved a result of 46 significant articles. As so, they were organized into a table (Table II), described underneath, where it can be read the name of the authors, the title of the article, year of publish and authors' conclusions about each theme.

Table II Results

Name of the author(s)	Title of the article	Publish year	Authors' Conclusions
Zhou, W. <i>et al.</i>	Modifying Adhesive Materials to Improve the Longevity of Resinous Restorations	2019	In order to increase longevity to modifying adhesives: integration of agents with anti-matrix metalloproteinase, remineralisation, or antibacterial functions into adhesive systems, assigning them specific functions.
Manfroi, F. B. <i>et al.</i>	Bond Strength of a Novel One Bottle Multi-mode Adhesive to Human Dentin After Six Months of Storage	2016	The results of this study validate that the bond strength for different universal adhesives are comparable between each other when added to dentin. When applied in self-etch mode, most adhesives exposed higher bond stability paralleled to the etch-and-rinse mode.
Elkaffas, A. A. <i>et al.</i>	Do Universal Adhesives Promote Bonding to Dentin? A Systematic Review and Meta-analysis	2018	This study provided enough scientific evidence to support the theory that the bonding of universal adhesives to dentin does has no significantly difference depending on application mode used (self-etch or etch-and-rinse).
Takamizawa, T. <i>et al.</i>	Influence of Different Etching Modes on Bond Strength and Fatigue Strength to Dentin Using Universal Adhesive Systems	2015	Some multi-mode adhesives applied to conventional single-step self-etch mode presented significantly better results in this mode compared to etch-and-rinse. However, most of the universal adhesives revealed similar bonding quality to dentin with both etching mode.
Suzuki, T. <i>et al.</i>	Influence of Etching Mode on Enamel Bond Durability of Universal Adhesive Systems	2016	All adhesives in this study presented significantly higher values in etch-and-rinse mode than in self-etch. Thus, etch-and-rinse mode takes a positive effect on the enamel bond stability.

Zhang, Z. <i>et al.</i>	Defying Ageing: An Expectation for Dentine Bonding with Universal adhesives?	2016	This study concluded that the bonding of five of the universal adhesives in the self-etch mode are generally, more durable than in the etch-and-rinse mode. However, bonds produced by these five adhesives are short-lived and are unable of defying ageing.
Loguercio, A. D. <i>et al.</i>	Does Active Application of Universal Adhesives to Enamel in Self-etch Mode Improve Their Performance?	2015	Active application of universal adhesives in self-etch mode to enamel rises the mark of conversion of the adhesive at the interface and as the resin–enamel bond strength of most of the tested adhesives comparing to passive self-etch strategy. The active application of universal adhesives may be a sustainable alternative to selective enamel etching.
Kraczor, K. <i>et al.</i>	Effects of Different Etching Modes on the Nanoleakage of Universal Adhesives: A Systematic Review and Meta-analysis	2018	Nanoleakage may be influenced by the etching mode. Moreover, this study proved that the application method and the additional layer of hydrophobic resin are very important to reduce the nanoleakage.
Nagura, Y. <i>et al.</i>	Effect of Reduced Universal Adhesive Application Time on Enamel Bond Fatigue and Surface Morphology	2018	The results suggested that some universal adhesives could be utilized with reduced application times and they seem to have appropriate enamel bond fatigue strength and surface roughness values at application times, going from 0,1 second to 20 seconds. Still, geometric surface area did not demonstrate any substantial variations with different application times.
Wong, J. <i>et al.</i>	Enamel Etching for Universal Adhesives: Examination of Enamel Etching Protocols for Optimization of Bonding Effectiveness	2018	This study advocated that enamel bond durability with universal adhesives may be different depending on the etching mode and these different etching protocols have impact on enamel surface morphology. In conclusion, the enamel bonding of universal adhesives was better with phosphoric acid etching for reduced etching times from more or less 1 to 15 seconds or with polyacrylic acid etching for 15 seconds.
Nicoloso, G. F. <i>et al.</i>	The Bonding Performance of a Universal Adhesive to Artificially-created Caries-affected Dentin	2017	Universal adhesives can be applied in different modes when bonded to dentin affected by artificially-created caries. Nevertheless, the etch-and-rinse strategy increases the bonding ability of the adhesive when applied in dentin.
Siqueira, F. S. F. <i>et al.</i>	Bonding Performance of Universal Adhesives to Eroded Dentin	2018	Both models of this study reduced the bond strength and amplified the nanoleakage of the composite on the eroded-dentin interface. Multimode adhesives containing 10-Methacryloyloxydecyl dihydrogen phosphate used in etch-and-rinse or self-etch mode presented better bonding results in both sound and eroded dentin compared to universal adhesives without that monomer.

Cuevas-Suárez, C. E. <i>et al.</i>	Bonding Performance of Universal Adhesives: An Updated Systematic Review and Meta-analysis	2019	The study shows that bond strength to dentin of universal adhesives was dependent on their pH. Bonding performance may be improved by applying the selective enamel-etch strategy, in some cases. In dentin, a few universal adhesives appear to afford better stability in both etch-and-rinse and self-etch strategies. Moreover, a relevant decline in the bond strength after aging was detected.
Rosa, W. L. <i>et al.</i>	Bond Strength of Universal Adhesives: A Systematic Review and Meta-analysis	2015	The literature suggests that bond strength is developed while applying previous acid etching, only for enamel. There was no supporting evidence of the same result, while in dentin. In conclusion, selective enamel etching may be deliberated the best method for improving the bond strength of the average of the multipurpose adhesives.
Yamauchi, K. <i>et al.</i>	Etch-and-rinse vs self-etch mode for dentin bonding effectiveness of universal adhesives	2019	Multimode adhesives utilized in etch-and-rinse mode could get an improved bond fatigue resistance because it develops a higher enamel bonding than self-etch mode, while in dentin it makes no substantial differences. The intensification of enamel's bond fatigue resistance in etch-and-rinse mode miscarries an important clinical difference, once dentin's bond fatigue resistance has a greater influence.
Tsujimoto, A. <i>et al.</i>	Influence of surface wetness on bonding effectiveness of universal adhesives in etch-and-rinse mode	2018	The study reveals that surface wetness may or may not influence bonding strength of these type of adhesives in self-etch mode, depending on each clinical case and material used. For that reason, even though multimode adhesives are, in general, less sensible to exterior conditions than other types of adhesives, their properties should be considered before it is applied, in order to reach the best adaptation to each clinical case.
McLean, D. E. <i>et al.</i>	Enamel Bond Strength of New Universal Adhesive Bonding Agents	2015	Universal adhesives showed higher enamel shear bond strength with in addition of selective-etch step. On the other hand, storage time did not interfere with shear bond strength values of any of the materials studied.
Vinagre, A. <i>et al.</i>	Bonding performance of a universal adhesive: effect of hydrophobic resin coating and long-term water storage	2019	The study results showed that water storage stimulated around 50% decrease in dentin bond strength. In addition, adding an extra hydrophobic layer over a multi-mode adhesive did not improve significantly its bond strength, in dentin.
Pires, C. W. <i>et al.</i>	Bonding of universal adhesive system to enamel surrounding real-life carious cavities	2019	This study concludes that bonding strength of universal adhesive in enamel presumably demineralised is lower than in sound enamel. The closeness to carious cavities with few or no enamel preparation can endanger the bonding to enamel. Moreover, bonding strategy does not affect the bond strength of universal adhesives, when applied in enamel.

Sauro, S. <i>et al.</i>	Effects of Ions-Releasing Restorative Materials on the Dentine Bonding Longevity of Modern Universal Adhesives after Load-Cycle and Prolonged Artificial Saliva Aging	2019	<p>The choice of proper materials from a chemical and mechanical perspective can mark a difference on the bonding efficiency of dentine-bonded edges.</p> <p>Undeniably, the use of universal adhesives combined with ion-releasing dentine-replacement materials may enable a better enduring adhesive performance.</p>
Matos, T. P. <i>et al.</i>	18-month clinical evaluation of a copper-containing universal adhesive in non-cariou cervical lesions: A double-blind, randomized controlled trial	2019	<p>Adding nanoparticles of copper to a universal adhesive system at 0.1 wt% is a reasonable method to preserve or even increase cervical restorations in terms of its clinical performance.</p> <p>Conversely, there was only a small development when the universal adhesive was used in the self-etch mode, possibly by the adding copper nanoparticles.</p>
Souza, M. Y. <i>et al.</i>	Influence of ethanol-wet dentin, adhesive mode of application, and aging on bond strength of universal adhesive	2018	<p>The results presented that the ethanol wet bonding technique revealed better average microtensile values, mainly when aging.</p> <p>Combining universal adhesives with the ethanol-wet bonding was approved for possible upcoming clinical indications, due to this search results.</p>
Choi, A. N. <i>et al.</i>	Effect of Dentin Wetness on the Bond Strength of Universal Adhesives	2017	<p>This article concluded that the dentin surface's wetness influences dentin bond strength, depending on the type of multimode adhesive system utilized.</p>
Lima, J. F. M. <i>et al.</i>	Effect of adhesive mode and chlorhexidine on microtensile strength of universal bonding agent to sound and caries-affected dentins	2018	<p>The results presented that the etch-and-rinse mode for the universal adhesives generated the greater bond strength to sound and caries-affected dentins.</p> <p>On the other hand, chlorohexidine decreased bond strength in both dentins independently of the adhesive mode.</p>

Pouyanfar, H. <i>et al.</i>	Microtensile Bond Strength of Composite to Enamel Using Universal Adhesive with/without Acid Etching Compared To Etch and Rinse and Self-Etch Bonding Agents	2018	<p>Previous etching with phosphoric acid of the enamel showed meaningful higher bond strength, although universal adhesives without that prior etching conceded similar bond strength between two-step etch-and-rinse and two-step self-etch bonding agents.</p> <p>Bonding strength with simplified application may provide the ideal efficacy.</p>
Irmak, Ö. <i>et al.</i>	Effect of rubbing force magnitude on bond strength of universal adhesives applied in self-etch mode	2018	<p>Rubbing increased bonding performance of one particular universal adhesive to dentin, but, on the other hand, was unsuccessful to another. Therefore, rubbing force magnitude and simulated aging had no significant values in order to affect multi-mode adhesives bonding strength.</p>
Oz, F. D. <i>et al.</i>	Effect of various bleaching treatments on shear bond strength of different universal adhesives and application modes	2018	<p>This study showed that tested multipurpose adhesives presented better bonding strength in etch and rinse mode than in self-etch mode, either with or without the bleaching treatment.</p>
Shadman, N. <i>et al.</i>	Effect of chlorhexidine on the durability of a new universal adhesive system	2018	<p>The application of chlorhexidine had stopped bond strength decrease in long term, for two of the tested adhesives; on the other hand, it did not show significant values for bonding strength in the other two tested materials.</p>
Steiner, R. <i>et al.</i>	Effect of Dentin Bonding Agents, Various Resin Composites and Curing Modes on Bond Strength to Human Dentin	2019	<p>This article showed that universal adhesives used in multi-step mode are better than one-step ones because of their higher bonding strength to dentin.</p> <p>There were also other interesting results of these study in terms of bonding strength such as: Flow composites demonstrated the highest bond strength results to dentin; Shrinkage-reducing soft-start mode of resin composites polymerization does not improve bonding strength; Adhesives that are acetone-based, HEMA-free and maleic acid-containing should not be used, once their bond strength values in dentin are very low.</p>
Lutgen, P. <i>et al.</i>	Effects of silver diamine fluoride on bond strength of adhesives to sound dentin	2018	<p>Silver diamine fluoride did not presented better bonding results when applied to sound dentin.</p> <p>Rinsing after applying silver diamine fluoride showed some improved results compared to non-rinsing values.</p>

Chowdhury, A. <i>et al.</i>	Variable Smear Layer and Adhesive Application: The Pursuit of Clinical Relevance in Bond Strength Testing	2019	<p>The study concluded that preparation with 180-grit silicon carbide papers or fine-grit diamond bur of dentin surface did not disturb the bond strength of the adhesives systems, which points out that 180-grit silicon carbide papers could be used to prepare better substrate conditions for adhesion to dentin.</p> <p>Besides, the performance of universal adhesives may be increased by duplicating their application time.</p>
Leite, M., <i>et al.</i>	Bond Strength and Cytotoxicity of a Universal Adhesive According to the Hybridization Strategies to Dentin	2018	<p>Applying universal adhesives should not be acclaimed for deep dentin as they present a high toxic potential to pulp cells.</p> <p>However, the dentin wettability did not affect universal adhesive systems performances, although it was prejudiced by using self-etch applying mode.</p>
Araoka, D. <i>et al.</i>	The strategies used for curing universal adhesives affect the micro-bond strength of resin cement used to lute indirect resin composites to human dentin	2018	<p>Light cured universal adhesives utilized on both dentin and indirect composite resin sides showed the upper bond strength results concerning the protocols currently used.</p> <p>When curing method is applied to lute indirect resin composites into dentin, the efficacy depends on materials for any individual bonding system. This may influence the adhesive polymerization.</p> <p>Thermocycle aging reduced micro-tensile bond strength, mainly at the non-light-irradiated surface, although it did not decrease meaningfully the group prepared after the adhesive light-curing on both the dentin- and indirect composite resins.</p>
Akturk, E. <i>et al.</i>	Do Ozonated Water and Boric Acid Affect the Bond Strength to Dentin in Different Adhesive Systems?	2019	<p>Ozonated water and boric acid may be employed for disinfection previously a restoration.</p> <p>Besides, immediate bond strength, curing systems and number of steps characterizing bonding systems are not connected unless by their chemical formulations.</p>
Hirai, K. <i>et al.</i>	Influence of photoirradiation conditions on dentin bond durability and interfacial characteristics of universal adhesives	2017	<p>Light intensification while sustaining energy density, water contact angle and viscosity of universal adhesives were increased thanks to the improved polymerization of these adhesives.</p> <p>Satisfactory light intensity could develop polymerization reaction of the universal adhesive heading to better durability of the adhesive system on dentin.</p> <p>Inversely, universal adhesives photoirradiated at 100mW/cm² showed higher hydrophilicity, getting lower bond durability values.</p> <p>Consequently, the bond durability and interfacial characteristics of universal adhesives massively depend on the light intensity and irradiation time.</p>

Flury, S. <i>et al.</i>	Exposed Dentin: Influence of Cleaning Procedures and Simulated Pulpal Pressure on Bond Strength of a Universal Adhesive System	2017	<p>Pre-treatment did not bring any significant differences on bonding strength of universal adhesives systems.</p> <p>Therefore, air abrasion with erythritol and chlorhexidine or glycine powders conceded parallel dentin bond strength as no pre-treatment at all or polishing with pumice groups.</p> <p>By simulating pulpal pressure while specimen preparation made bond strength reduce only when self-etch adhesive systems were applied in total-etch mode.</p>
Dönmez, N. <i>et al.</i>	Comparison of the micro-tensile bond strengths of four different universal adhesives to caries-affected dentin after ER:YAG laser irradiation	2019	<p>The treatment of carious cavities and multimode adhesives applied in etch-and-rinse and self-etch protocols influenced bonding strength in carie-affected dentin.</p> <p>Once the lesions were exposed to laser, 10-methacryloyloxydecyl dihydrogen phosphate multimode adhesives are preferable bonding systems as they have better bonding strength.</p>
Shadman, N. <i>et al.</i>	Shear Bond Strength of a Multi-Mode Adhesive to Bur-Cut and Er,Cr:YSGG Lased Dentin in Different Output Powers	2019	<p>Bur-cut dentin achieve meaningfully higher shear bond strength results than lased dentin.</p> <p>When applied in etch-and-rinse mode, 4W lased-dentin performed a higher bonding strength than 5W lased-dentin.</p> <p>Bur-cut and 4W lased-dentin, the universal adhesive system had the better shear bond strength values when used in etch-and-rinse mode.</p>
Sutil, B. <i>et al.</i>	Dentin pre-treatment and adhesive temperature as affecting factors on bond strength of a universal adhesive system	2017	<p>Dentin pre-treatment with sodium bicarbonate air abrasion improved bonding strength of universal adhesives in this study, whether using the etch-and-rinse or the self-etch protocols.</p> <p>It was also noticed that dentin treatment utilizing abrasion with aluminium oxide particles might affect adhesion but only on etch-and-rinse mode.</p> <p>Finally, the adhesive previous heating did not influence bonding strength in meaningful levels.</p>
Jayasheel, A. <i>et al.</i>	Comparative Evaluation of shear Bond Strength of universal Dental Adhesives -An in vitro study	2017	<p>A previous etching step before the application of a universal adhesive can increase meaningfully their penetration pattern through dentin even though it does not affect its shear bond strength average values.</p>

Siso, S. H. <i>et al.</i>	The Effect of Calcium Phosphate-containing Desensitizing Agent on the Microtensile Bond Strength of Multimode Adhesive Agent	2016	<p>The desensitizing agent that had calcium phosphate combined with a multimode adhesive delivered inferior bond strength in etch-and-rinse mode but a better marginal seal.</p> <p>To avoid sensitivity after an operation, a multimode adhesive, in self-etch mode, can be applied with a teeth mate desensitizer underneath the cavities.</p>
Geng Vivanco, R. <i>et al.</i>	Effect of thermo-mechanical cycling and chlorhexidine on the bond strength of universal adhesive system to dentin	2020	<p>Self-etch mode group had a better performance than that the etch-and-rinse adhesive system once the pre-treatment with chlorhexidine of dentin surface was applied and then submitted to thermo-mechanical cycling, as well, when controlling the samples and having no thermo-mechanical cycling.</p> <p>This mechanism is one of the steps to get more stability and longevity when the adhesive is applied either on pre-treated dentin surface or no treated with chlorhexidine and even in universal adhesives applied with etch-and-rinse mode under control conditions.</p>
Jang, J. <i>et al.</i>	Effect of various agitation methods on adhesive layer formation of HEMA-free universal dentin adhesive	2019	<p>The study showed that with or without ultrasonic energy, active application increases bonding results of universal adhesives without HEMA in the self-etch mode.</p> <p>Active agitation of dentin adhesive is presumably one of the ways to reduce the entangled blisters inside adhesive layer compared to passive agitation, majorly because of the exclusion of HEMA from its composition.</p>
Surmelioglu, D. <i>et al.</i>	Effect of Surface Flattening and Phototherapy on Shear Bond Strength Immediately after Bleaching with Different Modes of Universal Adhesive	2020	<p>Phototherapy with Er,Cr:YSGG and enamel flattening may be used in order to remove adversative effects of bleaching agents.</p> <p>This study proposes the restoration of bleached teeth straightaway after a bleaching session and therefore decrease clinical appointments.</p> <p>This laser phototherapy delivered to tested bleached teeth a minor improvement in shear bond strength. Moreover, flattening was showed as an economical and easy method for conditioning bleached teeth.</p>

As it was described above, numerous factors may influence multimode adhesive systems, as so many articles can be compared for their studies results, as several of them explore the same factor.

Development

The relevance of this subject to dentistry, particularly to restorative dentistry, justifies the large number of research that has been conducted in recent years in this area. Consequently, the research is directed at the different variables that may condition treatment success.

Etching application mode

As multimode adhesives can be applied in two different etching modes, many authors compared which one is the best for endure bonding agents.

As so, Takamizawa, T. *et al.* started by saying that the self-etch mode provided better results than the etch-and-rinse protocol, once the adhesive used was delivered in a conventional single bottle⁽⁶⁾. Geng Vivanco, R. *et al.*, Manfoi, F. B. *et al.* and Zhang, Z. *et al.* agreed with this statement but the first one added that this only happened once the dentin surface was pre-treated with chlorohexidine⁽⁷⁻⁹⁾.

Cuevas-Suárez, C. E. *et al.* and Suzuki, T. *et al.* disagreed, as the last even referred that etch-and-rinse mode takes a positive effect on enamel bond stability⁽¹⁰⁾. Cuevas-Suárez, C. E. *et al.* also supplemented their study with this conclusion that pH may influence bonding strength⁽⁴⁾.

Besides that conclusion, Kraczor, K. *et al.* and Wong, J. *et al.* complemented that nanoleakage may be influenced by the etching mode^(11, 12). In order to decrease it, a layer of hydrophobic resin may be added⁽¹¹⁾. As when on enamel, phosphoric acid etching is supposed to be applied for a reduced time of 1 to 15 seconds⁽¹²⁾.

In addition, according to Rosa, W. L. *et al.* and Yamauchi, K. *et al.*, when applying the adhesive to enamel, pre-etching causes better results on bonding durability, but on dentin surface, the etching mode do not show significant differences between the two possibilities, which Elkaffas, A. A. *et al.* agreed^(2, 3, 13). Jayasheel, A. *et al.* even adds that the previous etching is an enormous advantage on penetration pattern through dentin⁽¹⁴⁾.

Lastly, according to Lima, J. F. M. *et al.*, when using the etch-and-rinse mode, it improves bonding durability on either sound dentin or caries-affected dentin⁽¹⁵⁾. Furthermore, McLean, D. E. *et al.* and Pouyanfar, H. *et al.* also agreed that the acid does improve bonding strength, adding that enamel selective-etch is a good way to improve the adhesive durability and strength^(16, 17).

Surface wetness

Tsujimoto, A. *et al.* brought a study about water wetness revealing that surface wetness may or may not influence bonding strength of these type of adhesives in self-etch mode and it always depends on the material used ⁽¹⁸⁾.

Then, Souza, M. Y. *et al.*, studied ethanol wetness combined with the multimode adhesives, which resulted in a bonding technique with better average microtensile values, mainly when aging. Revealing that this may be the new clinical trend ⁽¹⁹⁾.

Finally, Choi, A. N. *et al.*, concluded that the wetness of dentin surface affects dentin bond strength, depending on the multimode adhesive type applied ⁽²⁰⁾.

Surface pre-treatment with chlorohexidine

When mentioning chlorohexidine surface pre-treatment, Shadman, N. *et al.* got a despair conclusion in the study made, once different groups of materials came with different results. One group proved that chlorohexidine had stopped bond strength decrease for long time; The other did not show significant values for bonding strength ⁽²¹⁾.

Lima, J. F. M. *et al.* came to a better conclusion, saying that chlorohexidine reduced bond strength in dentin independently of the application mode ⁽¹⁵⁾.

Geng Vivanco, R. *et al.*, mentioned the importance of surface pre-treatment with chlorohexidine, as referred above, once, according to this study, self-etch application mode presented better bonding strength values when compared to etch-and-rinse mode, only when chlorohexidine pre-treatment was applied in dentin surface ⁽⁷⁾.

Application time

Nagura, Y *et al.*, studied the influence of reduced application time in the durability and bonding strength of universal adhesives, concluding that it seems to have proper enamel bond fatigue strength and surface roughness values at a scale of 0,1 second to 20 seconds ⁽²²⁾.

On the other hand, Chowdhury, A. *et al.* concluded that multimode adhesives performance could be improved by duplicating their application time ⁽²³⁾.

Laser application

Dönmez, N. *et al.* brought a different perspective, while using ER:YAG laser irradiation in caries-affected dentin, concluding that treating carious cavities affected bonding strength values, in both etching application mode ⁽²⁴⁾.

Then, Shadman, N. *et al.* studied the influence of bur-cut and ER,CR:YSGG laser in universal adhesives bonding strength, which resulted in a conclusion that bur-cut and 4W lased-dentin presented the better shear bond strength values when used in etch-and-rinse mode, although bur-cut dentin achieve significantly better shear bond strength than lased one⁽²⁵⁾.

Also working with ER,CR:YSGG laser, Surmelioglu, D. *et al.* brought a new perspective of previously bleached teeth treatment. According to this study, phototherapy with Er,Cr:YSGG may be used to remove adversative effects in bonding strength of bleached teeth⁽²⁶⁾.

Bleaching treatments

Surmelioglu, D. *et al.* recently proposed the restoration of bleached teeth right after a bleaching session, in order to decrease clinical appointments and increase bonding strength⁽²⁶⁾.

Oz, F. D. *et al.* studied the effect of bleaching treatments on bonding strength of multimode adhesives, concluding that etch-and-rinse protocol presented better bonding strength than in self-etch, with or without the bleaching treatment⁽²⁷⁾.

10-Methacryloyloxydecyl dihydrogen phosphate

Siqueira, F. S. F. *et al.* proved that 10-Methacryloyloxydecyl dihydrogen phosphate-containing multimode adhesives used in both etching application mode presented better bonding results in both sound and eroded dentin compared to the ones without that monomer⁽²⁸⁾.

Dönmez, N. *et al.* said that when exposed to ER:YAG laser irradiation, 10-methacryloyloxydecyl dihydrogen phosphate-containing multimode adhesives showed better bonding strength values⁽²⁴⁾.

Dentin pre-treatment

Sutil, B. *et al.* experimented two different pre-treatments protocol. The first one with sodium bicarbonate air abrasion, which end up improving the universal adhesives bonding strength⁽²⁹⁾. In the other, dentin was pre-treated with aluminium oxide particles abrasion that affected boding strength but only on etch-and-rinse method⁽²⁹⁾.

Chowdhury, A. *et al.* used 180-grit silicon carbide papers and fine-grit diamond bur to pre-treat the dentin surface but neither of them disturbed the bond strength of the universal adhesives, though 180-grit silicon carbide papers could be used to prepare better substrate conditions for adhesion to dentin⁽²³⁾.

Contrariwise, Flury, S. *et al* said that within the limitations of the study, cleaning procedures as a tooth pre-treatment did not carry any substantial differences on bonding strength of universal adhesives systems ⁽³⁰⁾.

Active application

Loguercio, A. D. *et al.* came to conclusion that active application of multipurpose adhesives may be a favourable choice over selective enamel etching, while bringing a better resin–enamel bond strength comparing to passive self-etch strategy ⁽³¹⁾.

Jang, J. *et al* agreed while adding that active application increases multimode adhesives without HEMA bonding strength in the self-etch mode ⁽³²⁾.

There are still many factors whose reference appears in just one article; therefore, there is no possibility to compare its results. However, their results are described below, singularly.

Adhesive temperature

Sutil, B. *et al.* suggested that previous heating of the multimode adhesives did not affect bonding strength in a significant level ⁽²⁹⁾.

Artificially-created caries

Nicoloso, G. F. *et al.* suggested that both etching modes are applicable to dentin with artificially-created caries, though the etch-and-rinse mode increased the bonding ability of the adhesive ⁽³³⁾.

Real life caries

According to Pires, C. *et al.*, universal adhesives bonding strength in enamel apparently demineralized is lower than in sound enamel and carious cavities with few or no enamel preparation can compromise enamel bonding ⁽³⁴⁾.

In conclusion, the study suggested that etching mode does not affect the bond strength of universal adhesives, when applied in enamel ⁽³⁴⁾.

Eroded dentin

Siqueira, F. S. F. *et al.* tested universal adhesives to eroded dentin interface, which resulted a decreased bond strength and amplified the nanoleakage of the composite ⁽²⁸⁾.

Surface flattening

Surmelioglu, D. *et al.* suggested that flattening a tooth surface was a cheaper and easier method for conditioning bleached teeth and get better bond strength ⁽²⁶⁾.

Ion-releasing restorative materials

Sauro, S. *et al.* concluded that universal adhesives plus ion-releasing restorative materials may enable a better long-lasting adhesion on dentin ⁽³⁵⁾.

Copper-containing adhesives

Matos, T. *et al.* added copper nanoparticles to universal adhesive systems at 0.1 wt% and came to a conclusion that this is a rational technique to preserve or even increase clinical performance in cervical restorations ⁽³⁶⁾.

Water storage

Vinagre, A. *et al.* proved that water storage could decrease in 50% a universal adhesive bonding strength, when applied in dentin ⁽³⁷⁾.

Rubbing force magnitude

Irmak, Ö. *et al.* tested rubbing force magnitude and simulated aging in universal adhesives to dentin, which did not affect significantly multimode adhesives bonding strength ⁽³⁸⁾.

Silver Diamine Fluoride

Lutgen, P. *et al.* experimented applying Silver diamine fluoride to sound dentin but did not present better bonding results when applied to sound dentin, although applying silver diamine fluoride and rinsing showed a better result than non-rinsing method ⁽³⁹⁾.

Ozonated water and Boric acid

Akturk, E. *et al.* proved that ozonated water and boric acid could be used for disinfection before a restoration, in order to improve universal adhesives bonding strength ⁽⁴⁰⁾.

Photoirradiation time and Light intensity

Hirai, K. *et al.* proved that light intensification is directly proportional to bonding durability of the multimode adhesives, which means higher intensification leads to better adhesion durability. In conclusion, the bond durability and interfacial characteristics of universal adhesives massively depend on the light intensity and irradiation time ⁽⁴¹⁾.

Curing and Thermocycle aging

Araoka, D. *et al.* suggested that light curing universal adhesives improves their bonding strength when utilized on both dentin and indirect composite resin surfaces. It was also proved that thermocycle aging decreases microtensile bond strength, mostly non-light-irradiated surfaces ⁽⁴²⁾.

Dentin wettability

Leite, M., *et al.* initially said that universal adhesives should not be applied in deep dentin once they show high toxic potential to pulp cells. On the other hand, dentin wettability did not influence the performance of universal adhesives ⁽⁴³⁾.

Adhesive agitation mode

Jang, J. *et al.* referred that the adhesive active agitation is probably one of the better methods to reduce the entangled blisters inside adhesive layer, especially when compared to passive agitation ⁽³²⁾.

Calcium Phosphate-containing desensitizing

Siso, S. *et al.* revealed that calcium phosphate desensitizing agent combined with a multimode adhesive provided a weaker bond strength in etch-and-rinse mode, but a better marginal seal ⁽⁴⁴⁾.

Also, in order to prevent post operation sensitivity, it can be applied a universal adhesive with a desensitizer underneath the cavities, in self-etch mode ⁽⁴⁴⁾.

Integration of agents with anti-matrix metalloproteinase, remineralisation and antibacterial functions

According to Zhou, W. *et al.* literature search, the integration of agents with anti-matrix metalloproteinase, remineralisation or antibacterial functions may assign specific functions to universal adhesives, which helps to increase longevity to these adhesives⁽⁴⁵⁾.

Air abrasion

Flury, S. *et al.* concluded that air abrasion with erythritol and chlorhexidine or glycine powders provided similar dentin bond strength at no pre-treatment at all or polishing with pumice groups⁽³⁰⁾.

Simulated pulpal pressure

Flury, S. *et al.* simulated pulpal pressure while preparing the specimen groups, which resulted in a reduced bond strength, only when self-etch adhesive systems were applied in total-etch mode⁽³⁰⁾.

Dentin Bonding Agents, Various Resin Composites and Curing Modes

Steiner, R. *et al.* studied multiple factors, while concluding very interesting facts, for example that multi-step bonding agents are better than one-step ones due to their higher bonding strength to dentin⁽⁴⁶⁾.

There were also other curious conclusions in terms of bonding strength such as flow composites establishing the highest bond strength values to dentin⁽⁴⁶⁾.

Then, while testing shrinkage-reducing soft-start mode of resin composites polymerization it was suggested that it does not improve bonding strength of the universal adhesive systems⁽⁴⁶⁾.

Finally, it was proved that acetone-based, HEMA-free and maleic acid-containing multimode adhesives should not be applied due to their very low bond strength values in dentin⁽⁴⁶⁾.

In the adhesive composition, 10-Methacryloyloxydecyl-dihydrogen-phosphate-containing multimode adhesives was proven the best factor to provide longevity to the composite restoration.

Besides that, it is suggested that integration of bonding agents into universal adhesives, active application, selective etching steps, ions-releasing dentin-replacement, copper nanoparticles, ethanol-wet bonding method, utilization of flow composites, rising and applying silver diammine fluoride, bur-cut and 4W lased dentin, light intensification of polymerization, light cured universal adhesives, previous disinfection with ozonated water and boric acid, dentin pre-treatment with sodium bicarbonate air abrasion and active agitation of HEMA-free multimode adhesives may also increase bonding strength, and consequently the durability of these adhesive systems.

On the other hand, nanoleakage, caries either real or artificially created, eroded dentin, bleached teeth, thermocycle aging, water storage, pulpal pressure, desensitizing agents and adhesives that contain acetone, maleic acid or are HEMA-free should be considered negative effects for the endurance of multimode adhesives.

Conclusion

Within the limitations of this literature review, it was possible to conclude some interesting facts about how many factors may contribute or affect negatively the bonding strength and durability of universal adhesives.

In summary, any dental procedure, such as adhesion, entirely relies on each adhesive composition and properties. These provide a vast variability in their utilization and bonding performances. Therefore, the durability of a composite restoration should always depend on those characteristics, in order to choose the best method for each clinical case.

Throughout these study, it was possible to conclude that in terms of the adhesive composition, 10-Methacryloyloxydecyl-dihydrogen-phosphate-containing multimode adhesives was proven the best factor to provide longevity to the composite restoration and that there are many other investigated factors to increase the bonding strength and others to be excluded, those considered negative.

However, there are still some disagreements in terms of etching application mode, which resulted in convergent conclusion of many authors.

Thus, it is recommended more studies about this theme, and obviously many other factors, whose reference appeared in insufficient articles to achieve meaningful and congruent conclusions.

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Attachments

Declaração de autoria

Monografia de Revisão

Declaro que o presente trabalho, no âmbito da Unidade Curricular de Monografia de Investigação/Relatório de Atividade Clínica, integrado no MIMD, da FMDUP, é da minha autoria e todas as fontes foram devidamente referenciadas.

Porto, 01 de julho de 2020

A autora,



(Susana Daniela Leal Pinto)



PARECER DO ORIENTADOR

(Entrega do trabalho final de Monografia)

Informo que o Trabalho de Monografia desenvolvido pelo(a) estudante Susana Daniela Leal Pinto, com o título: "UNIVERSAL ADHESIVES: CONTRIBUTION TO THE RESTORATION LONGEVITY" está de acordo com as regras estipuladas na FMDUP, foi por mim conferido e encontra-se em condições de ser apresentado em provas públicas.

A Orientadora

(Prof. Doutora Ana Isabel Pereira Portela)

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O Co-Orientador



(Prof. Doutor Paulo Melo)